THE BUILDING EDUCATOR

A COMPREHENSIVE, PRACTICAL AND AUTHORITATIVE GUIDE FOR ALL ENGAGED IN THE BUILDING INDUSTRY

Edited by RICHARD GREENHALGH, A.I.Struct.E.

ASSISTED BY A LARGE NUMBER OF SPECIALIST CONTRIBUTORS

VOLUME I

FULLY ILLUSTRATED WITH MANY PHOTOGRAPHS AND DIAGRAMS

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By courtesy of the R.I.B.A.

ATHENS: THE PARTHENON, FROM THE EAST

From the Drawing by R. Phené Spiers, Esq., F.R.I.B.A., F.S.A.

(5461)

FOREWORD

THIS treatise is believed to be the most comprehensive work on building hitherto published, and deals with modern building in its three aspects—design, construction, and cost.

During the past twenty or thirty years, building design and construction have grown enormously in complexity, largely as the result of the demand for greater comfort and taste in our houses and of efficiency in industrial and business premises. Formerly, four or five trades were employed; but to-day on any large building a score or more specialist trades are represented. The architect's activities, too, have grown so wide that he has to avail himself of specialist assistance, such as in quantity surveying, structural steel and concrete, perspectives, electrical fitting, heating and ventilation, lifts, lighting, etc.

With this growing complexity and specialization, the average textbook has become somewhat inadequate. For two reasons. No ordinary textbook can cover the wide field of an architect's or builder's activities, not even on the constructional side alone: the work is now too elaborate, and the details too numerous. But perhaps an even more serious failing of the average textbook is that it is a one-man production—and no one man can be an expert in all branches of modern building. The BUILDING EDUCATOR is the result of the combined efforts of upwards of 40 specialists, each contributor being an expert eminent in his particular subject.

It is not intended that this work will replace in any way a proper course of training at technical colleges or schools of architecture, but that it will prove a useful adjunct to the recognized courses of instruction. It covers all the usual trade and professional subjects, and it will be equally valuable to both the professional man and the craftsman.

One of the chief lines of advance during the last few years has been in structural steel and concrete, and these subjects will be found to be treated adequately and in accordance with the latest practice. The commercial and administrative sides of building work have been sadly neglected in the past, but the quantity surveyor, estimator, builder's clerk, manager, clerk of works, and foreman will find these aspects fully dealt with in this work.

It is hoped that pupils and apprentices will find in this treatise a clear and comprehensive textbook, and that builders and architects will find it useful as a work of reference. Students preparing for the various examinations—such as the Royal Institute of British Architects, the Surveyors' Institution, the Institution of Structural Engineers, the Institute of Builders, the Royal Sanitary Institute, the City and Guilds, and other examining bodies—will find the BUILDING EDUCATOR of invaluable assistance.

THE EDITOR.

HOW TO USE THE EDUCATOR

By reading such articles as *Training and Opportunities*, readers will be able to select for themselves the sections and articles that are most suitable for them, but usually the following subjects will be of most use to the various classes of readers.

Architects and Pupils

will find about three-fourths of the EDUCATOR of direct value, but stress should be laid on the following subjects—

- ARCHITECTURAL DRAWING, by Walter M. Keesey, A.R.C.A., A.R.I.B.A.
- HISTORY OF ARCHITECTURE, by Thomas E. Scott, A.R.I.B.A.
- ARCHITECTURAL DESIGN, by T. P. Bennett, F.R.I.B.A. and Thomas E. Scott, A.R.I.B.A.
- ARCHITECT'S OFFICE AND ROUTINE, by Herbert J. Axten, A.R.I.B.A.
- LAND SURVEYING, by Professor Henry Adams, M.Inst.C.E., F.S.I.
- SPECIFICATIONS AND QUANTITIES, by Wilfrid L. Evershed, F.S.I.
- BUILDING LAW, by Horace W. Cubitt, A.R.I.B.A.

A sound knowledge is required of all the constructional sections, but particularly *Joinery*, *Carpentry*, *Brickwork*, *Masonry*, *Drainage and Sanitation*, and *Structural Engineering*. The various special articles by eminent architects will be found of great value.

Surveyors

should choose the sections most suitable to their particular requirements. These vary greatly, but the following subjects will be of direct value. In addition, most of the constructional sections should be studied.

- LAND SURVEYING, by Professor Henry Adams, M.Inst.C.E., F.S.I.
- SPECIFICATIONS AND QUANTITIES, by Wilfrid L. Evershed, F.S.I.
- ESTIMATING, by Henry A. Mackmin, F.S.I., M.I.Struct.E.
- BUILDING LAW, by Horace W. Cubitt, A.R.I.B.A.
- VALUATION TABLES, by Henry A. Mackmin, F.S.I., M.I.Struct.E.

Civil and Municipal Engineers

will find most of the EDUCATOR of service, but particularly the following sections—

- CIVIL ENGINEERING, by Professor F. C. LEA, D.Sc., M.Inst.C.E.
- STRUCTURAL ENGINEERING, by W. Arnold Green, M.A., B.Sc., A.M.Inst.C.E.
- PLAIN AND REINFORCED CONCRETE, by H. Kempton Dyson, M.I.Struct.E.
- LAND SURVEYING, by Professor Henry Adams, M.Inst.C.E., F.S.I.
- DRAINAGE AND SANITATION, by Henry C. Adams, M.Inst.C.E.
- BUILDING LAW, by Horace W. Cubitt, A.R.I.B.A.
- FIRE-RESISTING CONSTRUCTION, by Walter R. Jaggard, F.R.I.B.A.

Builders and Supervisors.

The requirements of Master Builders, Managers, Foremen, Clerks of Works, Estimators, Builders' Clerks, are somewhat similar. All the constructional sections and one or more of the following will be found useful.

- SUPERINTENDENCE, by P. J. Luxton
- BUILDER'S OFFICE AND ROUTINE, by R. F. Galbraith, B.Sc.
- BUILDERS' ACCOUNTS AND COSTS, by Robert E. Legge
- SPECIFICATIONS AND QUANTITIES, by Wilfrid L. Evershed, F.S.I.
- ESTIMATING, by Henry A. Mackmin, F.S.I.

Craftsmen

in all trades will find their particular craft fully dealt with. In addition, the ambitious craftsman, according to his particular needs, will study other sections, as *Superintendence* or *Drainage and Sanitation*. The following subjects will be indispensable—

- BUILDERS' GEOMETRY, by Richard Greenhalgh, A.I.Struct.E.
- CALCULATIONS, by T. Corkhill, M.I.Struct.E.
- BUILDING SCIENCE, by Raymond R. Butler, M.Sc., A.I.C., F.C.S.

Specialists

of all kinds will find their requirements met in such sections as

- HEATING AND VENTILATION, by C. Faber, A.C.G.I.
- GAS-FITTING, by R. J. Rogers
- STRUCTURAL ENGINEERING, by W. Arnold Green, M.A., B.Sc., A.M.Inst.C.E.
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- FIRE-RESISTING CONSTRUCTION, by Walter R. Jaggard, F.R.I.B.A.

Professional Examinations.

Practically all examinations, both professional and craft, will be found to be covered by the EDUCATOR, and particulars regarding them will be found in *Training and Opportunities* and other articles.

Reference Work.

A copious index will be found at the end of the EDUCATOR and, as this work is probably unique in its comprehensive treatment of Architecture and Building, it should form a valuable work of reference for builders and architects.

BUILDING EDUCATOR

CRAFTSMANSHIP IN BUILDING

By Sir Banister Fletcher, F.R.I.B.A., F.S.I.

INTRODUCTION *

Architecture may be described as art expressed in terms of building, and it is carried out by means of various crafts which together produce the required structure. If there is an absence of any recognized style or standard in architecture, then the building fails as a work of art; if there is an absence of sound and skilled craftsmanship, then the building fails as a structure for utility. Thus we realize the importance of the combination of the trained taste and judgment of the architect and the trained hand of the craftsman. Any building to-day, for whatever purpose it is erected, is the product, not of one craft but of many crafts, which are all interdependent one on the other for the production of the finished article, whether it be a cathedral or a cottage. In the building world it is not merely a question of the best and latest type of machinery, but of the best and keenest type of workers, of craftsmen, if our building is to be pronounced good.

Sir Banister Fletcher, F.R.I.B.A., F.S.I

The crafts which are employed in the various departments of building have a technical and traditional history, reaching far back into the life of civilized man, and have materially contributed to the evidences we see around us of past human activities.

These crafts, extended in application, and losing nothing of their vitality, are in demand to-day just as much as ever.

The building industry is of national importance: firstly, because of the vast amount of necessary work which it produces; secondly, because of the insistent and varied needs of the community for which it caters; and, thirdly, because of the considerable population actually engaged in it. It is, therefore, essential that the architects, builders and craftsmen, who act in a working partnership in rearing our public buildings and domestic dwellings, should be thoroughly equipped for the execution of their respective tasks, which, all taken together, constitute the finished edifice.

The shortage of killed craftsmen has produced grave problems in late years, and the reduction in numbers employed has resulted in a great national loss, both economic and social. Many buildings have been delayed in or during their erection for lack of qualified operatives. This problem is in need of early solution, which can only be found in the training of a larger number of craftsmen.

The aspect of craftsmanship which chiefly concerns the architect is the part it plays in relation to his design for the complete structure. The craftsman of to-day cannot be allowed the same liberties of design in the work he executes as his predecessor in the Middle Ages, for he has lost the common guiding tradition which in those days ensured that his work, however much the creation of his own spirit, was still in conformity with the general style of the work in hand. Nowadays, the work of all contributors to a large building can be brought into uniformity only by subordinating them to the master-mind of the architect under whose directions they work, and thus it is not possible under present conditions to revive the mediaeval ideal of free play for each craftsman. The architect may therefore be likened to the conductor of an orchestra, under whom each player, though to some extent expressing his individuality, is brought into line with the other players and into a common harmony. Yet there are still occasions where the craftsman may have a freer hand to work out in his own manner the general idea which an architect gives him; in any case the actual execution is in his hands, and its success depends largely on his loyalty to, and sympathy with, the requirements of the complete work in the production of which he has his assigned part.

These introductory remarks are directed to emphasize the necessity for studying and appraising the technical difficulties of craftsmanship, as well as the purely architectural principles of building, so that the painstaking labour and enthusiasm of the craftsman may be appreciated. Different crafts will be briefly reviewed, partly from an historical and partly from a technical standpoint.

BRICKWORK

As clay forms the soil in many vast tracts of low-lying land, it has been used for the making of bricks for buildings of many types, from Babylonian times down to our own day. In our country, thin Roman bricks were followed by the slightly thicker mediaeval bricks, and then by the Tudor brick of rich hues and rugged texture, which give character to many buildings. In the Renaissance period a brick more like the modern type was in use, and has influenced domestic architecture down to the present day.

With the improved facilities of transport in modern times, greater possibilities for producing picturesqueness and colour in buildings have been afforded by the variety of bricks obtainable from various parts of the country, including machine-made bricks, which, however, have not the texture of the old hand-made types. The well-known Fletton and the London yellow stock have done good service for cheaper and internal work; while for facing bricks many kinds are available, including the mottled varieties of grey, brown, red and orange hues, and other sand-faced bricks, Blue Staffordshires for withstanding pressure, and glazed bricks of various kinds for hygienic and ornamental purposes. The arrangement of bricks, known as "bond," has in its different forms given interest to brickwork. A variegated effect is sometimes produced by the use of headers and stretchers, and "flared" or black headers form a conspicuous pattern in much Georgian work, while criss-cross patterns were similarly formed in Tudor times.

Much depends upon the manner of laying the bricks, as well as upon their composition, and the effect of the best bricks can be spoilt by slovenly workmanship. Mortar joints, indeed, play an important part, for a neat joint, either weather-struck or flat, sets off the texture of a brick wall to its best advantage. By the use of rubbed, carved and moulded brickwork, as used by Sir Christopher Wren, rich and varied effects of design have been produced, and terra-cotta can be carefully manipulated to give point and finish to a building.

The work of the tiler and slater must not be overlooked, and much of the character of English domestic buildings is due to the texture and delightful hues of roof coverings, toned down by time, such as hand-made sand-faced tiles and the beautiful Westmorland green slates.

MASONRY

Stone, marble and granite, have been the staple building materials in many countries from the earliest times, and the history of architecture may almost be said to be the history of stonework. In the earliest days, stone or granite was worked into gigantic monuments; in Egypt it was used for pyramids and temples; in Greece, marble was used to produce some of the noblest architecture and sculpture the world has seen—and so on to the Middle Ages, when stone was made the expression of religious devotion, and in the Renaissance period great dignity and symmetry were obtained by the use of the same material.

Much variety can be gained from stone, not only from the differences in texture, but from the methods of cutting and laying—whether as random rubble or polygonal masonry, or quarried in rectangular blocks, and laid irregularly or in straight courses. Again, the face can be left " rock-faced " or hammer-dressed. Ashlar for important buildings, accurately cut, and with its surface or margins dressed smooth, entails much skilled labour. Rustication to add emphasis, obtained by chanelling joints or working a rough surface, has again been much resorted to in recent years. Many processes are entailed in cutting stone for building, and stereotomy is now in general use for determining the accurate jointing and surfaces in arches and other structural features.

PLASTERING

Many buildings when erected needed finishing with a smooth continuous coat, and so plaster, plain and ornamental, came into use for interior domestic work. The timber ceilings of Tudor times were followed in the Elizabethan period and afterwards by elaborate plaster ceilings in small panels ; in the later Renaissance, larger and more deeply recessed panels were produced, giving way again to delicate patterns in the Adam period. Externally also, plaster and stucco were needed from early times, for the Greeks made a stucco from marble-dust to cover coarse-grained stone, as in Sicily, and to produce the effect of marble. In our country stucco has been used with good effect in plaques, and even for whole façades. Decorative pargeting forms a familiar feature in some rural districts, while in modern times, delightful effects are provided by rough-cast over buildings requiring weather protection. Stippled and daubed textures have been evolved, which, enhanced by their gleaming white and cream hues, have relieved many other featureless elevations.

WOODWORK

Buildings also required internal finishings and fittings of a rigid yet workable material, and wood supplied this need—worked by carpenters for structural features like roofs and floors, and by joiners for stairs, doors and windows. In primitive architecture, in many countries, wood framing seems to have been much used. In this country timber was employed in framing up walls on the post-and-beam principle, with brick filling, especially in districts such as Shropshire and Cheshire, where forests abounded. Wood was also wrought into open timber roofs of great ingenuity and beauty, from the simple tie-beam roof to the trussed rafter, arch-braced and hammer-beam types. It has been utilized in all its possibilities for church fittings of great beauty. Doors were first boards nailed together, panelled and moulded types afterwards being evolved, while the window-casement of earlier times was largely superseded by the Georgian sash-window, but is now returning to favour. Much depends here, as in other crafts, upon the execution. Mediaeval work was usually hewn out of the solid, the posts being secured by oak pegs, while carving was done vigorously, but in accord with the nature of the material.

In Renaissance times also, much fine woodwork was carried out, of which the spacious balustraded staircases of Elizabethan, Jacobean, and Georgian times are noteworthy, and carving of great skill and excellence was done, especially in the style of Grinling Gibbons, whose remarkable simulations of natural forms have enriched many city churches and private houses.

PAINTING

Thus substantially completed, buildings needed a protective and decorative layer inside and sometimes out, and painting thus became an important craft. In ancient Egypt vast temple walls were often painted in bright colours ; the refined details of Greek temples were once picked out with painted ornament ; and many mediaeval buildings were enlivened internally by a layer of gold and colours, fittings and furniture often being coloured in the same way. The plaster and cement of later times have been brightened by the same process, and colour schemes for internal decoration have received much attention. The treatment of woodwork has also called forth the processes of graining and varnishing. The great number of oil and water paints, distempers and enamels, and the graded tints in which these are produced, give ample facilities for the colour design of modern buildings. The application of washable distemper to walls, which has in many cases superseded wallpaper for small houses, has altered the character of interiors.

The art of glass painting has entered much into architecture, especially ecclesiastical. The stained glass of the early mediaeval period, actually coloured in the making, and formed chiefly in lead patterns, and the painted glass of the Renaissance period which replaced it, both offer suggestions for original work at the present day, while conventional treatment of the " cames " for domestic buildings has reached a high standard of design.

PLUMBING

The structure thus built up, within and without, needed provision for the supply of water and the carrying away of refuse matter, and the craft of the plumber has satisfied both these requirements by the use of pipes of lead and other materials, which have necessitated skilled handiwork in bends, joints, welding, and other processes. Again, he has worked hand in hand with the tiler and slater in that most important work, the drainage of roofs, with his ridges, valleys, gutters, and flashings, rendering our buildings secure against the elements. Indeed, from early mediaeval times the plumber has often supplanted the tiler, and given us the immense advantage of a flat roof with maximum of headroom beneath, covering large areas with his lead sheets joined by carefully worked "rolls." The leadworker has also used his material decoratively, such as in the lead cisterns, of which eighteenth century examples are familiar, and fine rain-water heads, with their ornamental devices.

SMITHING

The ironworker's craft is an equally necessary contribution to the perfect working of a building. Bronze and iron were used by early nations for clamps in stonework, doors, and other features, and in Western Europe, iron was worked into window frames, while in the Middle Ages, the ironworkers played a great part in the making of doors, with their long strap and crescent hinges. It was worked into internal fittings, such as the fine Spanish "rejas" or screens, pulpits, and other features. In Renaissance times, wrought-iron gates of much elaboration, as seen at Hampton Court, added much dignity to mansions and public buildings, while cast iron also was put to good use internally in fire-backs, grates, and hearth furniture. Iron balconies and fanlights are characteristic features of the Georgian period. In modern times, cast iron has proved a useful auxiliary to lead for rain-water heads and other features.

TECHNICAL INSTRUCTION

From the foregoing summary of the part played by the crafts in contributing their respective shares to the utility and beauty of buildings as a whole, it will be clearly seen that much training, perseverance and experience are necessary to produce the skilled craftsman. The system of apprenticeship was, and is undoubtedly, the best method of familiarizing the would-be craftsman with the practical details of the work at first hand, and it is commonly felt that it should be extended sufficiently to ensure an adequate supply of skilled craftsmen in the future.

This daily practice can and should, however, be supplemented by technical training and instruction, so that the student may develop a capacity for more advanced and varied work than he is already doing in the limited scope of his daily routine, and this need is supplied by many technical evening schools all over the country. In our Capital City such training is provided by the London County Council, including their School of Building, and by the Polytechnics, while the Carpenters' and other City Companies have for years given highly specialized technical instruction in their Trades Training Schools (Great Titchfield Street, W.1), where the instructors are skilled men of long experience. It is of the utmost importance that there should be no lack of qualified operatives for the erection of buildings in the future. The efficient and extended training provided for architects in the schools of architecture can only be used to good advantage if the various classes of craftsmen employed in building have the necessary craft-skill and keen interest in their work. It is largely with the object of giving prominence to this aspect of building requirements that this publication has been undertaken.

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HISTORY OF ARCHITECTURE

By Thomas E. Scott, A.R.I.B.A.

LESSON I

INTRODUCTION

There is nothing more fascinating than the study of architecture. It is almost the study of human life, for buildings, more than anything else, have placed on record the history of peoples and their customs.

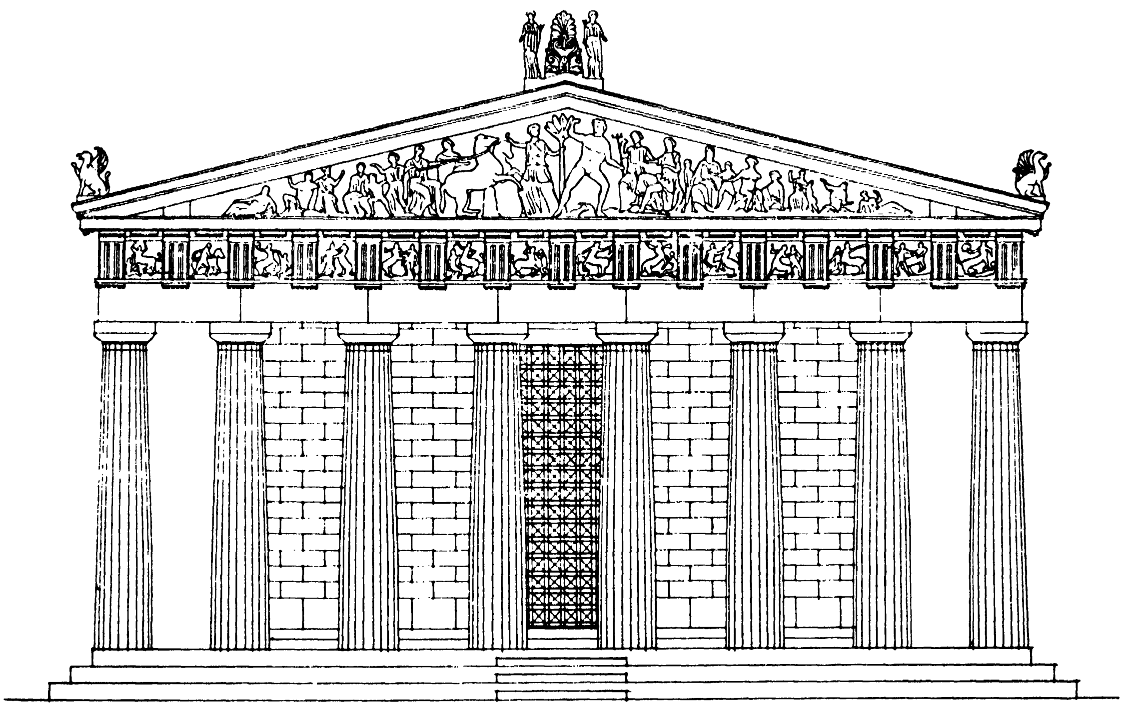


Fig. 1. The Parthenon, Athens

A knowledge of terms and dates, and an understanding of the peculiarities and characteristics of the so-called "styles," are useful to the student, but they do not constitute the true story of architecture. The real meaning of the works of the past can only be appreciated when they are intelligently studied as the reasoned outcome of the social and economic conditions which produced them. Students of architecture, and casual readers alike, should do more than survey the superficial characteristics of buildings and their ornament; it is essential to visualize the requirements of the people, the difficulties of labour and material which confronted the builders, and the social conditions under which they worked; the changing ideas through social intercourse and movements between nations; and, above all, the sentiments, ideals, and aspirations of the people, which are expressed in their buildings.

In all ages, buildings have been created to satisfy the needs of human beings—their shelter, work, religions, and pleasures. It will usually be found that the outlook of the people is evidenced in the care bestowed upon the buildings most important to their civilization.

The importance of religion and power of the priesthood accounts for the great number of temples built by the Egyptians, while their anticipation of the return of the soul to its

FIG. 2. THE NORMAN NAVE, NORWICH CATHEDRAL

FIG. 3. HENRY VII'S CHAPEL, WESTMINSTER ABBEY

former body some 3,000 years after death explains the massive, eternal nature of their tombs. The Greeks, with their simple customs, and desire for the ideal for its own sake rather than the pretentious, had few material requirements, and were content to concentrate on the perfection of an accepted form of temple. The Romans, however, appear to have possessed a national temperament akin to that of nations of the present day: ambitious, commercial, and with a love of grandeur and pleasure, it is obvious that they required a great variety of buildings for their work and amusement. How natural that such a nation should have little time for religion! Roman temples, although

FIG. 4. TEMPLE OF HORUS, EDFU

probably plentiful in the days when Rome was in its prime, were not nearly as magnificent as the public and other buildings. And later, when Christianity had spread over Western Europe, it is found that the influence and power of the Church resulted in a great enthusiasm for church building to the exclusion of almost all other works. In the past, as well as the present, the very essence of the life of a nation is expressed in its architecture.

It is most useful and interesting, in the study of historic architecture, to investigate the relationship between *structure* and *architectural form*; to observe, in the early buildings in the two great styles—CLASSIC and GOTHIC—the limitations of constructibility controlling the creation of buildings, and later, through added knowledge and experience, the subservience of construction to the expression of ideals. In the examination of Greek work, it will be found that buildings were almost standardized in general form owing to the limitations of the lintel, or beam, form of construction, and that later, the introduction of the arch and the use of concrete by the Romans permitted an almost infinite variety in architectural form; in many cases, in fact, the art of construction was so mastered, that it was hidden in the provision of the enrichment so adored by the Romans. The development of architecture from the twelfth to the fifteenth century, both in England and the rest of Western Europe, is an excellent illustration of the evolution of a style in which construction and decoration progressed side by side, the form of the various features being invariably determined by structural necessity, subsequent enrichment beautifying them, but never hiding the constructional function. It will be interesting to compare the heaviness and timidity of the early Norman work (Fig. 2) with the decision and delicacy of the later Gothic period (Fig. 3). By the comparison of such examples, and by the careful analysis of the buildings of the past, it is possible to appreciate the magnitude of the many constructional problems which confronted their builders.

It is not within the scope of this section to consider in detail the development of the various features which have been used in the architecture of the past, but it is essential to their logical application to the design of modern buildings that their structural origin is understood.

The influences of climate will be evident as the various styles are dealt with; however commonplace these influences may seem, they are important factors which must not be overlooked.

Although these more material considerations of utility, construction, and climate have affected the general form of buildings, it was the constant striving after effect that gave character to the architecture of the past. It was the infusion of a nation's temperament into its buildings that imbued them with a character which history shows to be the crystallization of contemporary civilization: the mystery and expression of eternity in Egyptian temples and monuments (Fig. 4); the refinement and simplicity of Greek work (Fig. 1); the grandeur and power of the Roman baths, Basilicas, and other great buildings (Fig. 5); and so, as the great epochs of the past are reviewed, the temperament of the people is found to be indelibly written in their buildings.

Although, for convenience, the history of the architecture of the past is subdivided into *periods*, or *styles*, it is necessary to remember that evolution has been continuous; changes occurring, not as a result of the passing fancies of the builders, but as the outcome of the constant advance and spread of civilization through the various national and social happenings in the world's history.

There were periods of transition when architecture was of a hybrid nature; when buildings,

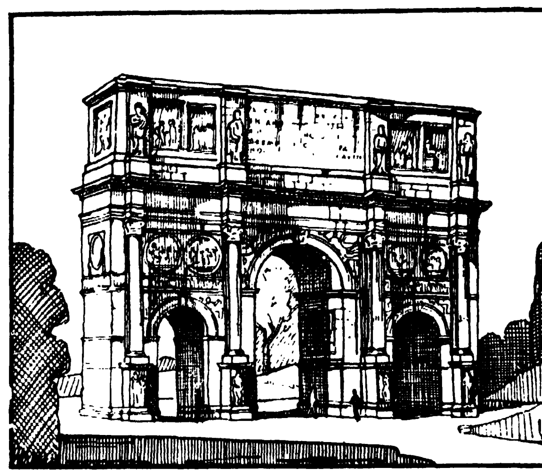


FIG. 5. THE ARCH OF CONSTANTINE, ROME

while retaining the essence of a decadent style, possessed certain minor features, usually decorative, culled from some fresh source which travel or literature had opened up. Subsequently, the better understanding of these new ideas led to their development into a style expressive of local ideals and requirements, and modified to suit local materials and labour. And so the evolution of architecture proceeded throughout the ages, reflecting always the great events which have brought nations together in peace and war, and the great social, industrial, and religious movements which have produced civilization as it is to-day.

To appreciate architecture to the full, it is necessary to recreate mentally the conditions which produced it: to visualize the life and customs which existed when the buildings of the past were in their full glory, for it is only when its human quality is appreciated that architecture becomes a real part of civilization, instead of a mass of technicalities.

LAND SURVEYING AND LEVELLING

By Professor Henry Adams, M.Inst.C.E., F.R.I.B.A., F.S.I., etc.

LESSON I

INTRODUCTION

Geometry—Triangle the Basis of Land Surveying—Linear and Square Measure—Areas

Application of Practical Geometry. Many books on land surveying commence with a series of problems in practical geometry. The advantage of this is that a surveyor first learns how to set up a true perpendicular by the aid of compasses only, instead of relying upon tee and set-squares, which may be untrue. It also shows him the true methods of copying angles and plotting triangles, and the method of reducing irregular figures to simple triangles. We can only find room here for a few of these.

1. From a given point in a straight line to erect a perpendicular (see Fig. 1). All verbal description can be saved by observing that the given lines are shown thin, the construction lines dotted, and the lines found by construction thick. They are also lettered in the order of construction, the given parts with capital letters and the construction lines with small letters, so that what may be called the "life history" of the problem is presented at a glance, and does not really require any further description to enable anyone to work it out.

2. To let fall a perpendicular from a given point on to a given straight line (see Fig. 2).

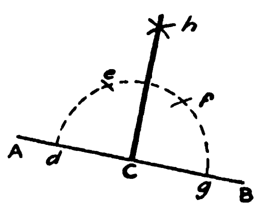


Fig. 1. To Erect a Perpendicular from a Given Point in a Straight Line

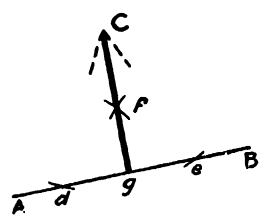


Fig. 2. To Let Fall a Perpendicular from a Given Point on to a Given Straight Line

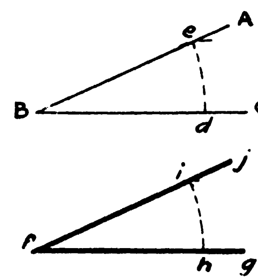


Fig. 3. To Copy a Given Angle

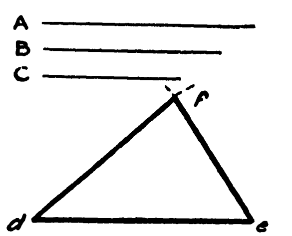


Fig. 4. To Construct a Triangle having Sides equal to Three Given Straight Lines

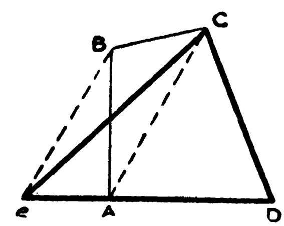


Fig. 5. To Make a Triangle equal to a given Trapezium

3. To copy a given angle (see Fig. 3).

4. To construct a triangle whose sides shall be equal to three given straight lines, any two of which must be greater than the third (see Fig. 4).

5. To make a triangle equal to a given trapezium (see Fig. 5). The given trapezium is shown at *ABCD*. The object is attained by converting two of the sides into two other sides which shall give an equal area and form with the remainder of the figure a single triangle. Let these two sides be *AB*, *BC*. Join their extremities by dotted line *AC*, and parallel to

this through B draw Be meeting DA produced in e. We know by Euclid that " triangles upon the same base and between the same parallels are equal," therefore triangle AeB is equal to triangle ABC, and the remainder of the figure being unaltered we have the triangle DeC equal to the irregular four-sided figure or trapezium $ABCD$.

Basis of Land Surveying. In land surveying the triangle is the basis upon which all work is carried out, and, generally speaking, the longest side should be treated as a base line upon which the remainder of the work is built up. The measurements taken on the land are recorded in a field book, and from these notes the work is " plotted," or transferred to paper, to produce a plan or map. If the land alone is concerned, whether for acreage or mapping, a 66-ft. chain divided into 100 links is used ; but where building or constructional work of any kind is to be carried out, the 100-foot chain is preferable divided into 100 links, each 1 foot long. When a chain is spoken of, the 66-foot chain is usually intended.

Units of Measurement.

LINEAR MEASURE

7·92 in.[1]	=	1 link	12 in.	=	1 ft.
25 links	=	1 pole	3 ft.	=	1 yd.
4 poles	=	1 chain	5½ yd.	=	1 pole
80 chains	=	1 mile	1760 yd.		1 mile

[1] 66 ft. divided by 100 = 7·92

SQUARE MEASURE

625 sq. links	=	1 perch	9 sq. ft.	=	1 sq. yd.
16 perches	=	1 sq. chain	30¼ sq. yd.	=	1 perch
40 perches		1 rood	43560 sq. ft.	=	1 acre
40 roods	=	1 acre	4840 sq. yd.	=	1 acre
10 sq. chains		1 acre	640 acres	=	1 sq. mile

Every opportunity should be taken to test one's natural stride on the level, and up or down hill. Some can pace out a long distance in yards with great accuracy, but it is too long a stride for ordinary walking. The author prefers normal pacing. His standard is exactly 25 paces to the chain of 66 feet = 31·68 inches each pace = 2,000 paces to the mile.

The origin of the mile is said to be 1,000 double paces, which agrees with above ; a league, or three miles, was the distance one could walk comfortably in an hour. The yard is the British standard of length, it is subdivided into feet and inches and multiplied into chains (66 ft.), furlongs and miles. Short distances may be given in feet and inches, or chains and links ; long distances preferably in miles and furlongs or miles and chains.

The square measure used by land surveyors consists of acres, roods and perches, any small amount over being put as a fraction of a perch, ¼, ½, or ¾, whichever is nearest. The usual limit of accuracy in practice is 1 perch per acre, so that any decimal points would be out of place.

Principles of Mensuration. A little explanation of the principles of mensuration must be given before we can pass on to practical work. The area of any rectangular figure is found by multiplying the length by the breadth. Suppose we have a rectangular plot of ground 6 chains long and 2 chains wide, we find the acres, roods, and perches, thus—

6
2
1,2   *Ans.*, 1 a., 0 r., 32 p.
4
,8
40
32,0

As 10 square chains make 1 acre we divide the first multiplication by 10, or, in other words, mark off 1 figure ; then multiply the remainder by 4 to bring it to roods, which leaves nothing on the left of the decimal point and shows no roods ; then multiply the remainder by 40 to bring it to perches, and we find it leaves 32. The area of a triangle when base and perpendicular are given is found by multiplying base and perpendicular together and dividing by 2. Suppose a triangular field with a base of 9 chains and a perpendicular from the opposite angle 4 chains long.

Then—

9
4
2 | 36
1,8
4
3,2   *Ans.*, 1 a., 3 r., 8 p.
40
8,0

When the three sides only of a triangle are given, the rule is somewhat complicated, but very important to be remembered. It is : *From half the sum of the three sides subtract each side severally, then multiply it and the three remainders together and take the square root for*

(*Continued on page* 15)

ARCHITECTURAL DESIGN

By T. P. Bennett, F.R.I.B.A. and T. E. Scott, A.R.I.B.A.

LESSON I

THE NATURE OF ARCHITECTURE

Introduction. The study of architectural design falls into two general divisions.

Firstly, the *scientific*, in which are considered the utilitarian and economic conditions; and, secondly, the *artistic*, in which these material conditions are resolved into an orderly and beautiful building.

In all buildings, scientific and artistic qualities are present; they are inseparable, but since there are so many varying types of buildings, it necessarily follows that they do not always occur in the same degree. Nor will the artistic qualities find expression in the same manner.

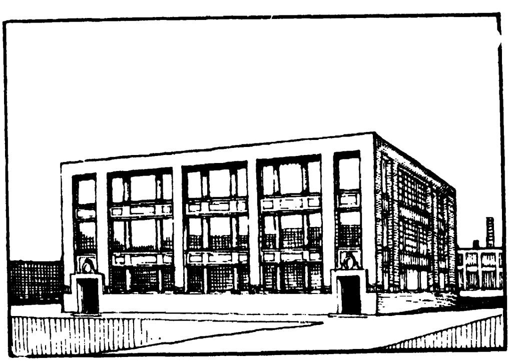


Fig. 1. A Factory Building

For example, the factory, at the one extreme, is the strictly utilitarian structure, designed to give the utmost efficiency. The building illustrated in Fig. 1 shows the structural elements left bare, with the spaces completely filled with windows to provide the maximum amount of daylight. It is also more than a mere feat of structural engineering; the emphasis of certain structural members gives an interest and variety which would be absent if all of the stanchions and girders were merely cased in the smallest possible amount of protective material.

At the other extreme is the sculptured monument (Fig. 2), an edifice designed solely to make an emotional appeal. There, the only scientific requirements are the technicalities of the casting and erection of the bronze statue and the base.

Both of these, however, together with all of the multitudinous types of buildings between, are known as architecture, the relative degrees of the scientific and artistic qualities varying in almost every case.

The stores building in Fig. 3 clearly illustrates the presence of both qualities, the provision of ample lighting and display space by means of windows and the wide, unobstructed shop-front, while the application of architectural embellishments to the bare structural necessities produces a building which is not only useful but beautiful.

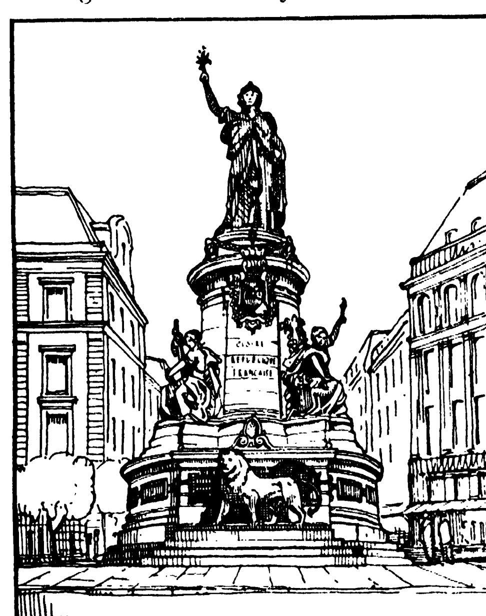


Fig. 2. Statue de la République, Paris

Architectural design is a matter of compromise and adjustment. All features must be given their proper value in the composition, and be perfect of their kind; but constant care is necessary, lest the excellence of any feature is obtained at the expense of another, thereby sacrificing the perfection of the whole for that of one part of it.

The perfect solution of an architectural problem must be at once scientifically correct, characteristic of its purpose, in harmony with the surroundings, and economically sound, both in first cost and in subsequent upkeep and administration.

Design is the outcome of the study of the attendant conditions in a problem. The knowledge required by an architect to enable him to solve the problem is very extensive and varied. An artistic ability of the first order is essential; the power to draw as rapidly and faithfully as the mind conceives; to visualize the building and to give it good proportion and pleasing detail. It is necessary to have a knowledge of the works of the past in order that inspiration may be drawn from them, not only in detail and ornament, but in spirit and character, which are the real essence of architecture.

The architect must have a thorough understanding of the general requirements of modern civilization, so that buildings may not only be good to look upon, but efficient in service.

A sound knowledge of all methods of construction and their relative costs and qualities is essential, for not only must stability be assured in all buildings, but their costs must always be consistent with their economic values.

An appreciation of legal matters is always necessary, in order that clients may be advised upon the many problems connected with the purchase and leasing of land, and the framing of contracts, while an acquaintance with the various Building Acts and by-laws, both legally and technically, is indispensable.

Finally, an architect must possess sound business acumen, both for the organization of his practice, and in the interests of clients, on whose behalf large sums of money may be handled; these must be spent with adequate regard for their earning capacity, and in proportion to the function of the works they are to provide.

An analysis of buildings will show that the determining factors in architectural design may be classified as follows: *programme, site, climate, cost, construction, beauty.*

These factors are by no means disconnected; their influences are inter-related in a most complex manner as soon as an architectural problem is considered, although for purposes of study, such an analysis is necessary.

Programme. By this is meant the collection of conditions and requirements of utility of a proposed building. It is the prime reason for the building, and, as such, must always be uppermost in the mind of the designer. The requirements of various types of buildings will be dealt with in detail later, but it is well to consider this factor of the programme from another point of view. Tradition and custom have given a marked character to some types of buildings. This is clearly the case with buildings of a religious nature in England, while in America, banking premises have acquired a character of their own, suggesting, in their architectural modelling, the stability and security of the concern doing business within their walls. This character, or expression of function, is certainly something to be aimed at, not only for its aesthetic value, but also because of its

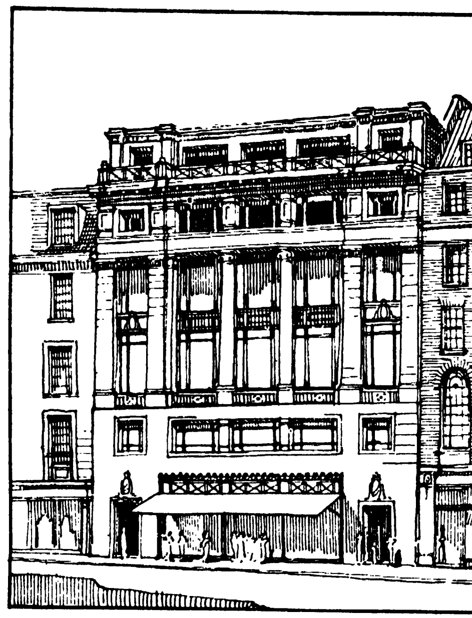


FIG. 3. A STORES BUILDING

real economic value to business and other concerns. Such expression must be anticipated, and manifested in the architectural development of the elevations from the plan which grows out of the problem. The elements in a plan must always be designed in proportion to their function or service, and never be made mere decorative units to produce a pretty pattern of rooms and corridors. At the same time, no opportunity of providing a pleasant grouping should be lost, for it will be found later that pleasant plans usually permit pleasant elevations. Although the plan is usually the chief subject of utilitarian consideration, there are cases where the section is of vital importance; for example, the sight and projection lines in a cinema must determine the various dispositions of the seating accommodation, the orchestra, the screen, and the projection room.

The programme of an architectural design should always be dissected at the very beginning, and the fundamental requirement, when determined, must be constantly remembered when working out the scheme.

The Site. Next to the requirements of utility, the nature of the site is the most rigid condition imposed in a problem. The size, shape, and contouring of the site will immediately influence the size and shape of the building, while the aspect and prospect will determine the direction in which various parts will have to face.

The site and its influence on the building will be dealt with more fully in a later lesson.

Climate. The influence of climate on architecture is dual. In the first place, there is the need for ample lighting and ventilation ; and secondly, the need for the protection, both of the structure and of its occupants from the weather. It will be found in the study of historic architectural elements that climate has exercised a greater influence on them than may be at first apparent.

In England, with its temperate climate, the light is not strong, and the cold in winter is more severe than the heat in the summer. It will be appreciated, then, that although thick walls would appear a necessary protection against cold, the large windows essential for the ample lighting of rooms would neutralize the advantages so gained. In modern architectural practice, therefore, a compromise is effected by providing adequate windows for lighting, and using artificial means of warming the building.

Cost. The limitations which the cost sets upon design are obvious. Not only must the prime cost of a building be carefully considered, but also the subsequent cost of maintenance and administration.

Construction. It is not in the scope of this section to consider in detail the construction of buildings, but the importance of construction in architectural design cannot be exaggerated. Since architecture has for its object the production of beautiful buildings, it follows that all designs must be buildable. Architecture has been produced not only as a fine art, but out of and because of the need for buildings. While it is true that knowledge permits even the most ambitious architectural conceptions to be constructed, it must be constantly remembered that the perfect building is the one in which the architecture grows out of the rational construction of the required accommodation. The study of the refined works of the Greeks, the magnificent buildings of the Romans, and the inspired cathedrals of mediaeval builders, will show that the essential structural elements provided the basis for the architectural decoration, each being given beautiful proportion and shape within the structural limits of the material used.

Traditional forms and motives have, in the majority of cases, developed from structure, which is the fundamental basis of architecture.

In design, the material and artistic requirements of the programme must be logically constructable, subsequent enrichment beautifying the structural nucleus but never hiding it.

Beauty. Although the satisfaction of material needs is the primary object of buildings, it is the satisfaction of the artistic emotions which characterizes them as architecture.

Beauty is not merely a matter of style and decoration, or ingenious construction and fine craftsmanship.

Those works which are accepted as architectural masterpieces are of all styles and periods. It may be asked, " What is it then, that makes a Gothic cathedral as acceptable as an Italian palace ? "

Careful analysis reveals certain qualities common to the best work of all ages. These will be considered in the next lesson.

MASONRY

By E. G. Warland
Instructor in Masonry at the L.C.C. School of Building, Brixton

LESSON I

BUILDING STONES

Introduction. In studying the methods of preparing blocks of stone and their combination in a building to secure the maximum stability of the structure, while satisfying its requirements from an architectural aspect, it is necessary for the student to become acquainted with some of the various processes involved in converting the huge blocks of stone, from the time they are removed from the stratum in the quarry, until they finally rest in their predetermined position in one of the large buildings in the main thoroughfares of our cities.

The demand for stone, together with the speed with which buildings are now being erected, calls for well-organized systems of production and the introduction of up-to-date appliances and machinery. Masonry, like other branches of industry, has advanced during recent years, but old methods of production are still in use in various parts of the country. This is chiefly because the local demand for the material has not warranted any revision of methods, and in some districts the material is more readily worked by hand labour than by machine. Machinery is only introduced to cheapen the cost and to accelerate production. The overhead charges incurred through the installation of machinery would not warrant its introduction in these districts.

It is not sufficient for the craftsman to know only how to shape a piece of rough stone to the required moulds or templates. He should become acquainted with the material upon which he operates, including its formation and general characteristics, the districts having quarries, and the suitability of any particular stone for building purposes.

Although the craftsman is not expected to be a geologist, a certain knowledge bearing upon the various stones used in building is necessary. He should be able to tell a good weathering stone from a bad one, and state the reasons for his selection. Knowledge is gained naturally by the practical use of the various stones and by a careful study of each, but it is essential to combine this knowledge with the study of the geology of building stones. The young craftsman cannot fully appreciate the material upon which he operates until he has acquainted himself with the geology of stones, and has studied for himself the various books on the subject. The following list of books will be found useful to the student—

Geology of Building Stones, by J. Allan Howe.

Stones and Quarries, by J. Allan Howe.

Building and Ornamental Stones, by E. Hull.

Building Stones, by J. Watson.

It is an engrossing subject, and once the student begins drawing from this well of knowledge, his store of information will become a great asset to him, combined with the knowledge obtained by the practical use of the material. It is not intended in these notes to deal fully with the classification of building stones, but to guide the student in a brief survey of the subject, and leave him to seek for himself by studying the books mentioned, and if possible, by visiting some of the quarries from which well-known building stones are taken.

Choice of Building Stones. It is not left to the craftsman to select the stone for a proposed building. The architect decides what stone is to be used, and the mason has to execute the work in the particular stone specified. From this point the architect depends upon the integrity of the mason in the choice of the blocks and their selection for the various positions in the building, especially in regard to placing them in their correct position relative to their natural planes of cleavage.

In the selection of a building stone the student is advised to study the various buildings in the neighbourhood, and see for himself the condition of the stones and how they have weathered.

The chief points to notice are—

1. Situation of the building.
2. The aspect of the building.
3. Appearance and colour.

FIG. 1. GENERAL VIEW OF THE MASONRY WORKS OF THE BATH AND PORTLAND STONE FIRMS, AT PORTLAND

Showing railway running direct into the masons' shops, which are in the background

By kind permission of The Bath and Portland Stone Firms, Ltd., Bath

FIG. 2. DIAMOND SAW AND LATHE AT WORK AT PORTLAND MASONRY WORKS

The lathe is capable of turning stones up to 8 ft. diameter or 4 ft. 6 in. diameter, 12 ft. long

By kind permission of The Bath and Portland Stone Firms, Ltd., Bath

4. Possible supply of blocks of similar stone from the quarry.

5. Facility of working.

6. General characteristics.

7. Whether the stones are placed with their beds of cleavage correct in the building.

Situation of Building. This is very important in regard to the life of a stone. Some stones are known to weather well in an inland town atmosphere, but suffer severely when exposed to sea air. This applies especially to limestones. The chemical constituent of rain water from the sea and the salt bearing winds blowing from the sea, attack the carbonate of lime. Limestones are attacked more readily in towns than in country districts, due to the air in towns containing more sulphuric acid. But by a careful choice of a limestone this can be minimized. Even after every effort has been made to ensure that the choice has been correctly made, a great deal depends upon the selection of the individual stones by the mason.

Aspect. Elevations exposed to the frequent changes in temperature, such as due to the heat of the sun and the prevailing wet winds (chiefly south-west) suffer severely.

Colour and Appearance. The style of architecture and the various purposes for which the stone is to be used should be studied when choosing a stone. If for engineering purposes, where strength and stability should be the chief concern, the colour and appearance do not matter to any great extent; but for commercial buildings in our cities, churches and country residences, colour is a very important factor, and by a judicious choice of the various stones, pleasing effects can be obtained, though this is sometimes at the expense of the durability of the building.

Possible Supply of Blocks from the Quarries. It is important when choosing the stone to ascertain whether quantities of block-stone of sizes suitable for the requirements of the proposed building are available. It would be fatal to commence building operations and then to discover that blocks of the size required were not obtainable.

Facility of Working. There are several stones that would pass tests quite well as suitable for building purposes, but owing to the hardness and density of these stones they would not justify the installation of the machinery necessary for their production at the rate required.

LAND SURVEYING AND LEVELLING

(*Continued from page* 9)

the area. Putting it down as a formula, we have—

$$\text{Area} = \sqrt{S(S-a)(S-b)(S-c)}$$

where a, b, and c, are the three sides respectively, and S is half their sum, or $S = \frac{a+b+c}{2}$. Suppose the sides of the triangle to be 5, 4, and 3 chains long respectively, then—

$5 + 4 \quad = 6 \qquad 6 - 5 = 1 \quad 6 \times 1 \times 2 \times 3$
$6 - 4 = 2 \qquad = 36$
$6 - 3 = 3 \quad \sqrt{36} = 6.$

6,
4
2,4
40 *Ans.*, 0 a., 2 r., 16 p.
16,0

In a four-sided figure with two sides parallel and perpendicular to the base, add together the parallel sides, multiply by the base and divide by 2. Suppose a field with two parallel sides $2\frac{1}{2}$ and 4 chains long respectively, and 6 chains apart, we have —

$4 + 2\frac{1}{2} = 6\frac{1}{2}, 6\frac{1}{2} \times 6 = 39, \frac{39}{2} = 19{\cdot}5$

1,9·5
4
3,80
40
Ans., 1 a., 3 r., 32 p. 32,00

Irregular four-sided figures are divided up into two triangles by drawing either diagonal, and then each triangle is calculated by one or other of the two methods given. All field measurements of lines should consist of not fewer than three figures such as 3·25, 1·17, 025, 004, with or without the decimal point, the last two figures always standing for links and the remainder for chains. Offsets are marked only by the necessary figures and all in links.

JOINERY

By T. Corkhill, F.B.I.C.C., M.I.Struct.E., *Double Medallist*

LESSON I

INTRODUCTION

This section, together with the sections on "Carpentry," Staircasing," and "Geometry," is intended to give the joiner an insight into the intricacies of his craft. He will find all that he requires to make him competent to face the problems with which he may have to contend. The problems are not new; they have always been associated with the working of wood; but the increasing use of machinery has given many of them a new aspect. There are very few materials which give so much pleasure and satisfaction to the craftsman as timber. An artistic and well finished piece of woodwork is an abiding joy to the maker; and nearly everyone who strives patiently can attain the satisfaction of producing the very best results. Most boys, whilst still at school, are filled with a desire for woodworking; but only a few of those who eventually follow the craft remain sufficiently enthusiastic to equip themselves thoroughly and efficiently with knowledge as well as with tools.

It is often contended that the joiner of to-day is not so capable as those of previous generations. Certainly many of them have not the same opportunities of learning their craft whilst at work, but there are many joiners of to-day as capable as any in the past. This is however, not sufficient; *every* joiner should strive to make himself competent. Some men will always excel, but everyone has the ability and power to improve himself by careful study. If the student conscientiously works through the lessons he will feel better equipped and more confident to face the various problems met with in the course of his work.

The first thing the joiner requires is a knowledge of the tools and materials used in his work.

TOOLS

Purchase and Care of Tools. With regard to the tools, the joiner is entirely responsible and it behoves him to make a very careful selection. The finish of a job depends nearly as much on the tools as upon the craftsmanship. Good quality tools are essential; inferior tools are dear at any price. It is not the quantity but the quality of the tools which tell in the production of good work. The beginner should buy from a reputable firm, and should seek the advice of an experienced joiner when purchasing. H should avoid combination tools as a general rule; "one tool one job," is a good maxim. When he has obtained the tools, he should take a pride in them and keep them in good condition, clean and sharp. He is then on the highway towards making a good job.

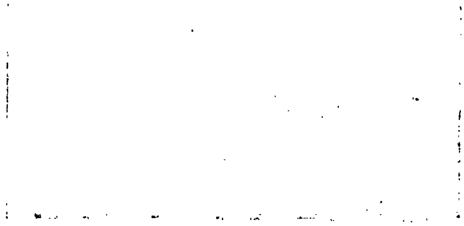
The tools shown have been illustrated from the catalogues of R. Melhuish, Fetter Lane, E.C.4., and S. Tyzack & Son, Old Street, Shoreditch, E.C.

WOODEN PLANES

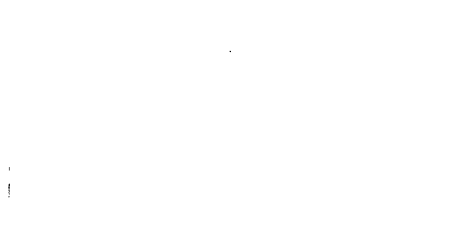
The planes are the most important and expensive part of the equipment, but it is not necessary to have a large assortment at the beginning. It is essential to have what are usually called the *bench planes*, that is, the *jack plane*, *smoothing plane*, *try plane*, and *rebate plane*; the others are added as the occasion requires them. The usual types of wooden planes are shown in Figs. 1 to 12; they are all made of best quality beech wood.

Jack Plane. This is used in rough work for *planing up* the stuff as it comes from the saw, and for planing off large quantities to reduce the size or straighten the surface. It is very convenient to handle, the body or *stock*, being about 17 in. by 3 in. by 3 in. The handle is glued into a slot in the body of the plane. The wedge *w*, Fig. 2, fixes the *irons c*, and the *mouth* and *throat m* allow the shavings to escape. The *sole b* of the body should be at right angles to the medullary rays to give the best resistance to wear.

Plane Irons. A longitudinal section through the mouth of the plane is shown in Fig. 13, with an inverted plan of the sole *b*. The *irons*, *C*, consist of two parts, the *cutting iron*, or blade, and the *back iron*. The cutting iron is shown in Fig. 14, and the back iron in Fig. 15. The

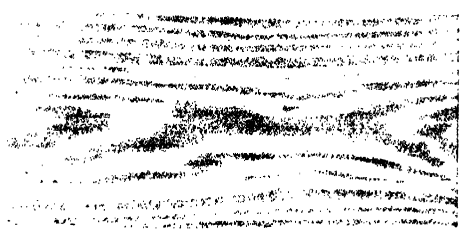


Nº 1 SPRUCE

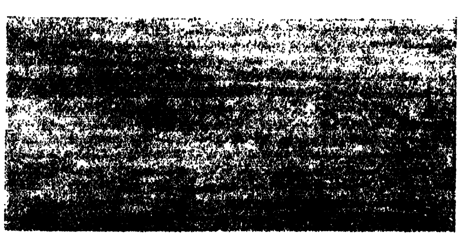


Nº 2 YELLOW DEAL

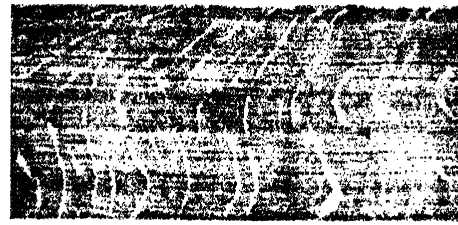
Nº 3 YELLOW PINE



Nº 4 PITCH PINE

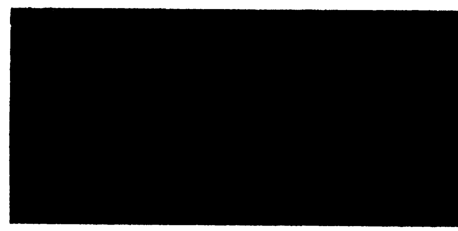


Nº 5 AMERICAN WHITEWOOD

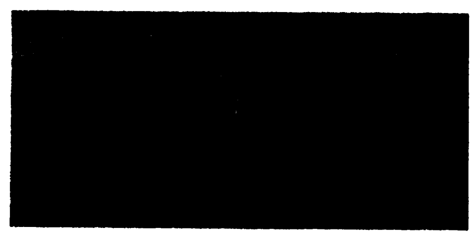


Nº 6 OAK

Nº 7 HONDURAS MAHOGANY



Nº 8 CUBAN CURL



Nº 9 WALNUT

Nº 10 TEAK

COMMON TIMBERS IN USE IN BUILDING

The specimens have been photographed one third actual size

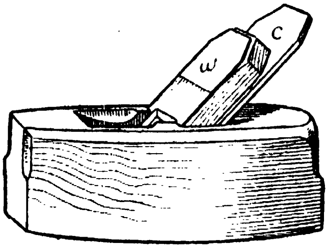


FIG. 1. SMOOTHING PLANE

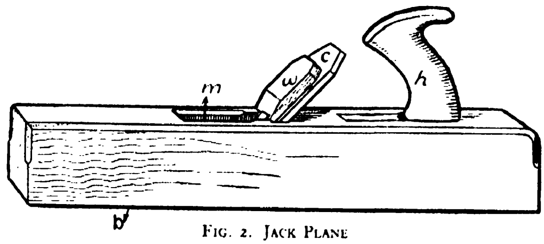


FIG. 2. JACK PLANE

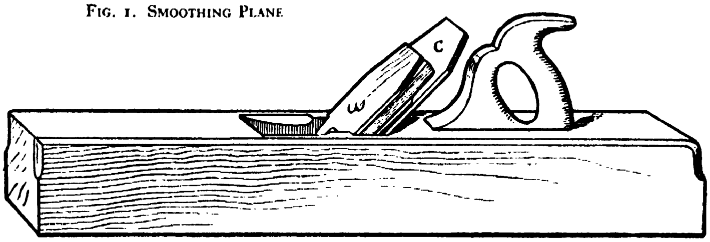


FIG. 3. TRYING PLANE

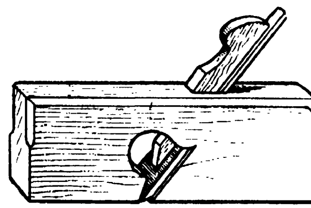


FIG. 4. REBATE PLANE

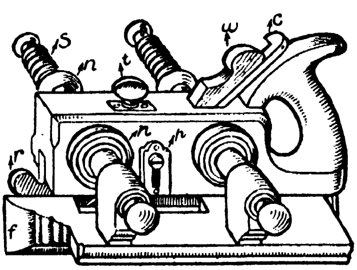


FIG. 5. PLOUGH

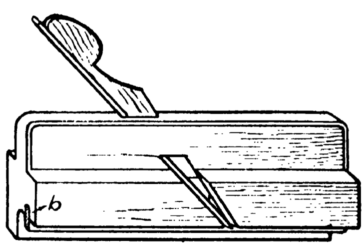


FIG. 6. BEAD PLANE

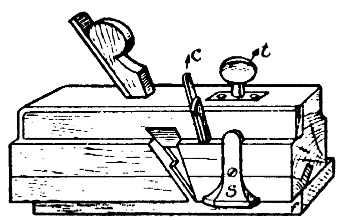


FIG. 7. FILLISTER PLANE

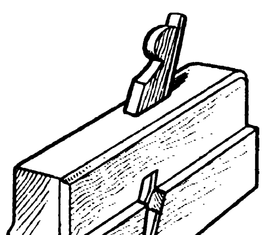


FIG. 8. HOLLOW PLANE

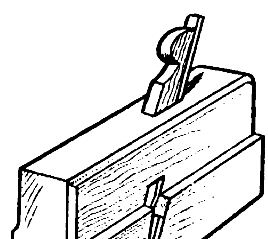


FIG. 9. ROUND PLANE

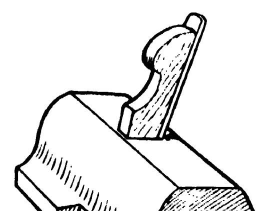


FIG. 10. ROUTER PLANE

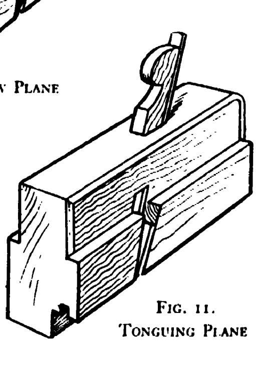


FIG. 11. TONGUING PLANE

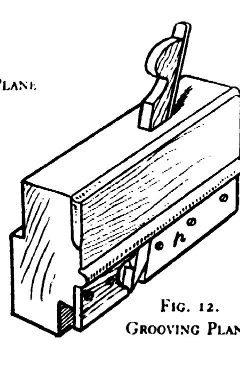


FIG. 12. GROOVING PLANE

former is made of iron with a steel facing *a*; this makes the blade easy to grind and sharpen. The grinding angle *g* is about 25 degrees and the sharpening angles about 35 degrees; but both angles depend upon the nature of the work,

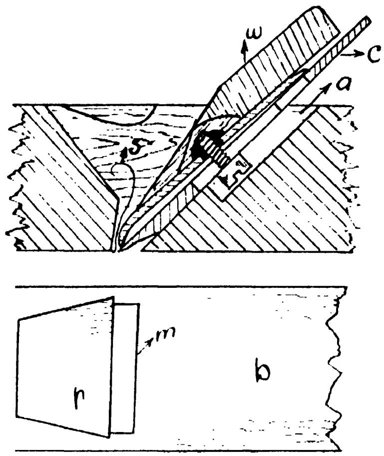


Fig. 13. Section of Plane

as will be explained later. It is usual to sharpen the jack plane iron slightly round as shown at *b*, because of the thick shavings which it has to remove. For the smoothing and try plane irons the edge should be straight, with the corners sharpened off to prevent *plane marks* being left on the stuff.

The *back*, *cap*, or *cover*, iron is made of steel; the brass nut *a* is fixed to the steel and receives the screw *b*. Fig. 13 shows the two irons in position. For the smoothing and try planes the back iron is *set* back from the cutting edge about $\frac{1}{16}$ in., and for the jack plane, about $\frac{1}{8}$ in. For hardwood or cross grain these distances should be halved. The action of the back iron is to *break* the shaving *s* as it is cut and to bend it over, thus preventing the fibres from splitting along the grain in front of the cutting edge. To assist the action of the back iron it is necessary that the mouth *m*, Fig. 13, should not be too open in front of the cutting edge. When the plane is new the mouth is often too close, but it soon wears more open, and eventually it has to be closed by letting a boxwood mouthpiece *p* into the sole. The plane irons are usually $2\frac{1}{4}$ in. wide. The cutting iron generally tapers in thickness, but a *parallel* iron is preferable because it does not require refitting after repeated sharpening, and does not open the mouth when worn down.

Successful planing depends upon a sharp edge, well-fitted irons, and a straight sole. It is generally the second feature which gives trouble. It is impossible to give too much attention to the fitting of the irons, both in the body, and one to the other. Badly fitted irons cause *chattering*, or vibration, and *choking*. The irons should be *set fine* for hardwood, that is, the back iron should be close to the cutting edge; and there should not be much *hook* on the plane, that is, the plane should remove thin shavings.

Smoothing Plane. This plane, Fig. 1, is used for *finishing off* the surface preparatory to scraping or sandpapering. It is about 8 in. long, and made from a piece of 3 in. by 3 in. beech. A metal front, Fig. 16, is usually fitted to the smoothing plane when the mouth is too open. The front *s* is let into the sole of the plane, and carries a slot to receive a small nut *n*. A screw *a* passes through the nose of the plane and engages with the nut to fix the plate *s*. The screw head rests in a cup *c*.

Trying Plane. The trying plane, Fig. 3, is the largest of the bench planes. It is similar to the jack plane except for the closed handle, and is used for straightening surfaces. The body is about 23 in. long, and it is usually about $3\frac{1}{4}$ in., square, with a $2\frac{1}{2}$ in. iron. A *jointing plane* is similar to the trying plane but longer; it is used for making long joints, but very few joiners possess one.

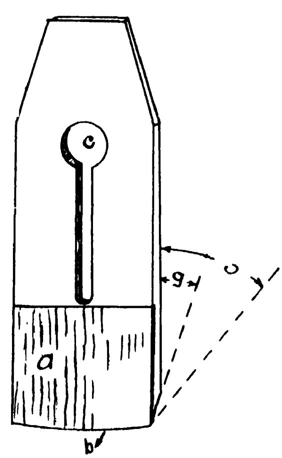


Fig. 14
Cutting Iron

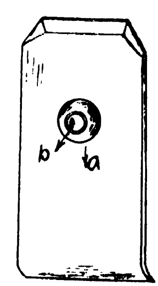


Fig 15
Back Iron

Care of Planes. All the wooden planes should be well soaked in raw linseed oil before being used. This lengthens the life of the plane, reduces the friction on the sole, and adds to the appearance. They should be wiped occasionally with an oily rag for the same reasons. Some joiners mix a little burnt ochre with the oil for wiping the surface, this gives a darker and more mature appearance to the planes. The wedges should be *eased* and the irons *knocked back* when the planes are not in use.

Rebate Plane. The rebate, or *rabbet*, plane, Fig. 4, is intended for planing in corners; hence the iron, which is a single iron, is the same width as the body. The iron is placed on the *skew* to give a shearing cut and clearance for the shavings. The usual thickness is $1\frac{1}{2}$ in., but they may be obtained in various thicknesses up to 2 in.

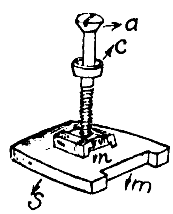


FIG. 16
METAL FRONT

The *badger* is similar to a jack plane in size and shape, but the irons are arranged as a rebate plane on the off side of the stock.

The Stanley rebate plane is about 2 in. wide, and fitted with double irons like the smoothing plane. It is easily adjusted and makes a good finish.

Plough. The plough, Fig. 5, is used for making grooves. The fence *f* is adjusted to the required distance by the wooden nuts *n*, which run on the two spindles *s*. The depth of the groove is regulated by the stop *p*, which is adjusted by the thumb-screw *t*. The metal runner *r* is screwed to the body. There are usually about eight bits, or irons, *c*, of different sizes supplied with the plane. The bits have a projection at the top for adjusting for " hook," they are fixed in position by the wedge *w*. The plough may be obtained with or without handle.

Fillister. This is a rebate plane with an adjustable fence *f*, Fig. 7. The fence is slotted and is fixed in position by two screws underneath. The depth of the rebate is regulated by the stop *s*, which is adjusted by the thumb-screw *t*. A side cutter *c* marks out the rebate in front of the cutting iron.

The *sash fillister* is like a plough in shape, and cuts the rebate on the back edge of the stuff whilst working from the face side. The fillisters are seldom used because rebates are conveniently made by the plough and rebate plane, even where no machines or circular saws are available.

Bead Planes. Fig. 6 illustrates a bead plane; it is so often required that nearly every joiner possesses two or three different sizes. The most common sizes are $\frac{1}{4}$ in., $\frac{3}{8}$ in., and $\frac{1}{2}$ in., but they may be obtained much larger. The strip *b* is made of boxwood to prevent wear.

Hollows and Rounds. These planes are shown in Figs. 8 and 9; they are used to plane up convex and concave surfaces. They may be obtained in various sizes and are usually sold in pairs. A complete set consists of eighteen pairs.

Match Planes. Matching planes, or tonguing and grooving planes, are shown in Figs. 11 and 12. They are sold in pairs and are used to form the tongues and grooves on match-boarding, etc. The grooving plane, Fig. 12, has a metal plate *p* to run in the groove; the iron is not adjustable, so that the groove is always the same distance from the face side.

Other Moulding Planes. There are many other forms of moulding planes, such as *ovolo, lamb's tongue, ogee, reed, torus*, etc., but they are not so often used as formerly, because of the increased use of machinery. It was customary twenty years ago for every joiner to have thirty or more moulding planes of different descriptions; but to-day very few joiners possess more than one or two beads, ovolos, and hollows and rounds.

Old Woman's Tooth. Fig. 10 shows the router, or old woman's tooth. It is used for cleaning out trenches to the required depth. A *trenching plane* is in the form of a rebate plane, but it has two side cutters because it is intended for grooving across the grain.

Spokeshave. This is shown in Fig. 17; it is

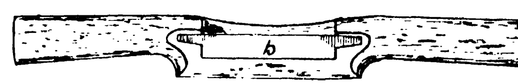


FIG. 17. WOODEN SPOKESHAVE

used for planing small circular work. The blade *b* is fixed in position by two tapered tangs, cast on the blade, which pass through the body. It is adjusted by tapping the blade for less " hook," or the ends of the tangs for more " hook." The body is made of beech or boxwood.

Other Wooden Planes. There are many other forms of wooden planes, but generally they have been superseded by metal planes. *Thumb* planes, however, are usually of wood. They are very small planes of various shapes and are mostly used for wreathed handrailing and *circle-on-circle* work.

BRICKWORK

By William Blaber
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LESSON I

INTRODUCTION

It is not the writer's intention in this section to enter at any length into the history of the craft. Suffice it to say that ancient it is, dating back, according to Biblical history, to the building of the Tower of Babel and the city walls of Babylon. It is recorded in the pre-Christian era by the important structures of ancient Greece and Rome, and was eventually introduced into this country about A.D. 44.

Its existence appears to have been spasmodic up to the year 866, and no real progress was made until the thirteenth century. From that time to the end of the seventeenth century some of the finest examples of brickwork in history were produced. The beauty of line and form in many of the brick buildings of the fifteenth and sixteenth centuries shows a skilful and masterly appreciation of art. Especially is this noticeable in the beautiful examples of the Renaissance buildings.

I believe an appreciation of the beauties of a craft to be essential to the making of a good craftsman, and feels compelled to consider the association of art with this particular craft, instead of immediately introducing the subject with the usual definitions of brickwork, bond, etc. I would rather appeal, first of all, to the artist in the student.

Many fine examples of the use of brickwork as an ornamental feature are still in existence. In these, the artistry of the craftsman is made apparent by the well-balanced lines and curves of his work, as distinct from the designer's efforts.

Art is inseparable from knowledge, and cannot be possessed in ignorance. The imagination is seldom free from intellectual and practical elements, and these, if cultivated, will enable the craftsman to give tangible expression to his ideas. There can be no artistry in bad craftsmanship, and a revival of this ancient art can come only with a revival of that spirit and ambition possessed by the brick builders of the sixteenth and seventeenth centuries, and exemplified in some of the ancient buildings still in existence. These stand pre-eminent as specimens of a workmanship of which the principles have altered little with the passing of the years, and remind one of Kipling's "The Truthful Song."

> The Bricklayer:
> "I tell this tale which is strictly true,
> Just by way of convincing you
> How very little since things were made,
> Things have altered in the building trade."

The student, therefore, should endeavour to obtain a good knowledge of the materials of his craft, and the possibilities and limitations of their application. The latter may more readily be observed by frequent visits to some of the existing brick masterpieces. Among these are St. James's and Hampton Court Palaces, the old palace at Richmond, Esher Water-tower, and the cloisters of Windsor Castle. Deserving of particular attention is the Temple, as the entrance to the Middle Temple is executed in rubbed brickwork. Kew Palace, built 1613, is an interesting example of craftsmanship. The quaint columns and the pilasters over the front entrance are particularly worthy of notice; also the Orangery at Kensington Palace. Excellent examples of modern craftsmanship may be seen in and around London: St. Paul's Schools, Kensington, the City and Guilds Technical Institute, Exhibition Road, South Kensington, and the Midland Hotel, St. Pancras Station, being among the finest. Various private residences in Cadogan Square, Belgravia, and Fitz-John's Avenue, Hampstead, are fine specimens of modern brickwork. A fine instance for the use of various coloured bricks for ornamental purposes is given by the old Philological School in Marylebone Road. This building was erected about the end of the eighteenth century.

The foregoing are merely cited as examples, and the student would be well advised to visit any modern specimens of the bricklayer's art which are within his own knowledge.

The trade presents unlimited scope for the craftsman possessing expert knowledge, by reason of a general shortage of men in the trade and a serious dearth of really capable mechanics. Many parents have, in the past, objected to their boys entering this trade, principally on account of the supposed dirty nature of the work, and the impression that it was largely seasonal, and therefore precarious. There may have been reason for the latter impression many years ago, although the writer's experience of between thirty and forty years has been very favourable in this respect. Employers generally appreciate the services of a reliable man, and he loses very little time unless the severity of the weather is such as to make work practically impossible. Of late years these conditions have been rare. Much is also being done to eliminate loss of time due to stress of weather by providing temporary coverings to buildings in the course of erection. The rates of pay and the conditions of employment have improved so much of late years as to make the trade, in the opinion of the writer, a desirable one; particularly when the possibilities for many years to come are fully considered.

Apprenticeship. This period ranges from three to five years, with rates of pay varying from ·2 of current rates during the first year to ·7 during the last. The current rate of pay in London and many of the provinces is, at the time of writing, 1s. 9½d. per hour.

Possibilities open to the earnest student are various. The post of foreman bricklayer carries with it an advance of from 1d. to 2d. per hour on current rates, while the positions of general foreman and clerk of works produce from £5 to £8 per week.

Many important positions in the educational world are being filled by men who were at one time employed in the craft. There is also the prospect of becoming an employer to be considered.

It is therefore apparent that the advantages of the trade far outweigh its disadvantages, especially when presented to the young artisan, who, not content with mere manipulative skill, is prepared fully to extend his mental faculties.

It is the writer's intention to deal with the indispensable rudiments of the trade as thoroughly as possible in the space available, and to simplify the more complex matters by processes which are the outcome of his own difficulties in the school of experience.

BRICKS

Manufacture. Bricks are manufactured from clay or loamy earth, the suitability of which is determined by practical trials and chemical analyses. The method generally used is to manufacture, by the ordinary processes, a test brick from the selected earth. If this proves unsatisfactory, chemical analyses will generally suggest additions of an improving nature. Brick earths are seldom found ready for use without special preparations, and the constituents of various earths differ to a great extent.

Processes of manufacture vary considerably throughout the country, and even in adjacent brickyards, but the following are general—

1. Preparation of the earth;
2. Moulding;
3. Drying; and
4. Burning.

The finished articles may be classified thus—

1. Hand-moulded bricks (clamp burned);
2. Machine-made wire-cuts (kiln burned); and
3. Machine-made pressed bricks (kiln burned).

In the first process of manufacture, clay-getting takes place in the autumn. The top spit of earth, containing vegetable matter, is removed, the clay being dug and then heaped up on a level piece of ground, when all stones are carefully removed by hand.

The earth is spread in layers, with intermediate layers of coke breeze and liquid chalk to a thickness of four or five feet. This pile is left during the winter, the action of frost and snow disintegrating the mass. If a superior brick is required, the earth and chalk are mixed in wash-mills, passed through sieves into settling pits, and the excess water drained off. When fairly firm, the sediment is covered with a layer of ashes, and the whole left to disintegrate as before.

In the spring, the mass is ground in a pug-mill. This machine has a stationary cylinder, with revolving knives, which cut and knead the clay into a plastic state, fit for the moulder.

BUILDER'S GEOMETRY

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LESSON I

DRAWING INSTRUMENTS AND MATERIALS

Introduction. Geometry might be defined as the scientific basis of technical drawing; in fact, practical geometry and technical drawing are often used as interchangeable terms. It is indispensable to the architect who designs the building and to the craftsmen who construct the the building. An architect might be able to draw a tracery window without a knowledge of geometry, but he would only do so slowly and

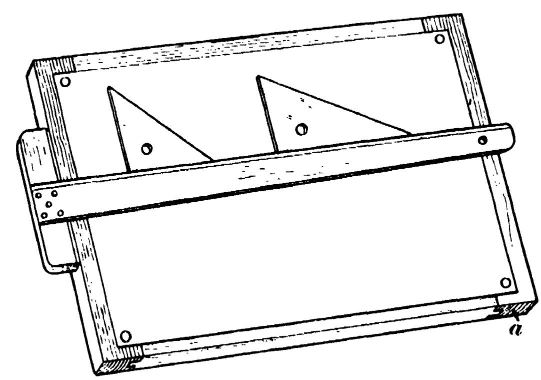


Fig. 1. Small Board, T-square, and Set-squares

inefficiently; so, likewise, a carpenter could cut his roof bevels by trial and error, or by various practical makeshifts, but he would take longer and make a poorer job than if he had a knowledge of geometry. And the same remarks apply to innumerable details and aspects of building construction.

In studying this subject, the student is advised that reading is of little use in itself; the various examples should be drawn out. In this way he will not only better understand the methods given, but he will gain skill and facility with his drawing instruments, and the various principles will be impressed on his mind.

Geometry is often divided into two branches—*plane* geometry and *solid* geometry. Plane geometry treats of geometrical figures, and not with solid objects; it is often termed *geometrical drawing*.

The most difficult part of geometry is solid geometry, which deals with the drawing of objects requiring the use of three dimensions in space. Such branches of building as handrailing, skew arches, and circle-on-circle work require a sound knowledge of solid geometry if they are to be understood thoroughly.

Many craftsmen are somewhat afraid of solid geometry, and look upon it as something very difficult and even mysterious. It is nothing of the kind. In fact, there is hardly another subject in which mere common sense and a little imagination will carry the student so far. But visual imagination, that is, the faculty of picturing the objects in the mind's eye, is a great asset. The ability to draw out a certain problem is of little use unless the student knows *why* it is done. But when only even a few principles in solid geometry have been thoroughly grasped, the student can apply them with facility to many practical building problems.

The following lessons have been arranged to explain in a progressive manner the principles of geometry most useful to builders and architects. After describing the instruments required and their use, simple geometrical constructions are explained, followed by more difficult applications, chiefly in solid geometry. Other particular applications belonging more strictly to one or other of the various trades are dealt with in their special sections.

Drawing Boards. All drawing boards should be made of soft wood, usually yellow pine, so that the drawing pins can be easily inserted and withdrawn. The size required will vary according to circumstances. For technical school work it is usual to have a board 23 in. by 16 in.; this size will take half imperial paper (22 in. by 15 in.) and leave a margin of half-inch all round. For office work, a larger board, 31 in. by 23 in., to take imperial paper, or a board 42 in. by 29 in., to take double elephant paper, 40 in. by $26\frac{3}{4}$ in., is generally used.

Small boards, say up to half imperial size, may be made of 1 in. pine boards, glued together to give the necessary width; two battens, *a*, about $2\frac{1}{2}$ in. wide, as shown in Fig. 1, are tongued and grooved or mortised and tenoned to the ends to prevent warping. Three-ply boards are much used, and these consist of three pine layers, the grain of the centre layer running at right angles to the top and bottom layers to prevent twisting.

For large boards, the best construction is shown in Fig. 2, which shows the back of the board. Here, the pine boards are glued up to the required width, and two battens, *a*, about 3 in. by 1 in., are then screwed to the back to prevent warping. The screws pass through slots in the battens, the slots having slotted washers sunk into the battens; this allows the board to expand and contract, but at the same time keeps it flat. The back of the board is usually grooved at about 3 in. intervals to nearly half its thickness, so that the screws can easily bend the wood and hold the back of the board tightly to the battens.

One edge (the left-hand edge) of the board is often grooved and fitted with a slightly projecting slip, *b*, of ebony, the strip being sawn through at intervals to allow for contraction of the board. This strip forms a good edge for the stock of the T-square to run against, and it can be easily planed if it gets dented or becomes crooked.

A good drawing board has two chief characteristics: a smooth, *straight* edge for the T-square to slide against, and a reasonably flat surface. It is not essential that the board should be dead square; a draughtsman only uses his T-square against the left-hand edge; vertical lines are drawn with a set-square. If, however, the working edge of the board is not straight, it is impossible to draw parallel horizontal lines.

Drawing Paper. There are many varieties of drawing paper, but for ordinary drawings or students' work "cartridge" is generally used. It may be obtained in either rolls or sheets, the chief sizes of the latter having already been given. The rolls are usually 30 yd. long and 30 in. or more in width. Cartridge paper can be obtained in various thicknesses and qualities.

For important work, or where the drawings have to be coloured, a *hand-made paper* is advisable; *Whatman's* is perhaps the best known, but there are many other makes. Hand-made paper is also made in various thicknesses, and with either a "smooth" or a "rough" surface, the latter being the better for coloured drawings.

Bank Detail Paper is a thin, semi-transparent paper; it can be used for drawing large-scale detail views or as a substitute for tracing paper.

Tracing Paper is used chiefly for copying drawings in ink, but it is also employed for large details. *Tracing cloth* has the characteristics of tracing paper, but is more durable and not easily torn; one side is dull and the other glossy, the dull side being used for drawing upon.

Squared paper is sometimes found useful for making sketches, and can be obtained with various sizes of squares, usually $\frac{1}{8}$ in. and $\frac{1}{10}$ in.

Drawing paper is dealt with in more detail in the section on "Architectural Drawing."

Drawing Pins. Four pins are generally required, one for each corner of the sheet, but for large drawings eight pins are often used. The pins should have a thin and slightly curved head,

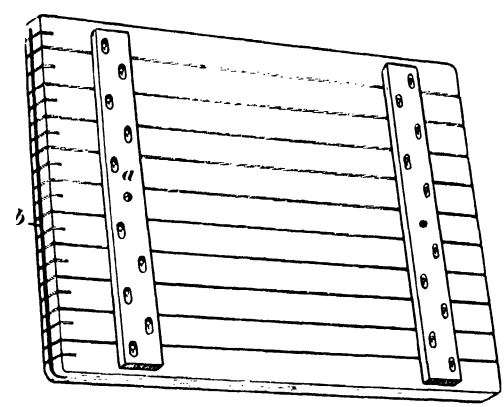


Fig. 2. Back View of Good Type of Drawing Board

so that the T-square will pass easily over them. The heads should be rather large, say about $\frac{3}{4}$ in. in diameter.

India-rubber. A soft rubber should be used; the hard composition "rubbers" should be avoided. *Ink erasers*, which are made of a hard, gritty composition, can be obtained; they are useful for erasing ink marks, but they should not be used for rubbing out pencil marks, as they injure the surface of the paper. A sharp penknife is, however, generally employed for erasing ink lines.

T-Square. The length of the T-square, Fig. 1, should be such that the blade is about an inch longer than the drawing board. Ordinary T-squares are usually made of pear wood; the blade should be tapered and bevelled at the drawing edge, but very cheap makes are made with the blade parallel and without bevel. The blade must be screwed firmly on the stock; it is not very important that the blade be accurately at right angles to the stock, but the joint must be rigid.

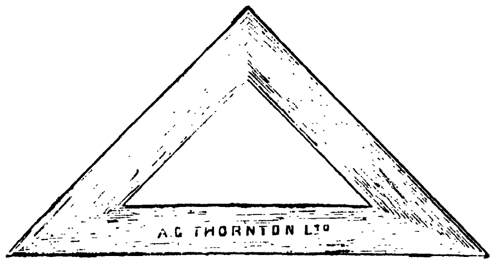


FIG. 3. FRAMED WOODEN SET-SQUARE

The best T-squares are made of mahogany and have an ebony working edge. Some are provided with a celluloid edge, which is very convenient but is easily damaged.

FIG. 4. TESTING RIGHT-ANGLE OF SET-SQUARE

Set-squares. Wooden set-squares, usually made of pear wood, were at one time largely used, but they have been largely displaced by set-squares made of celluloid. If wooden set-

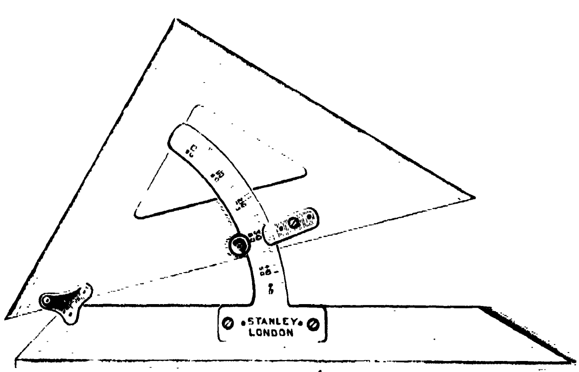


FIG. 5. ADJUSTABLE SET-SQUARE

squares are used they should be framed (see Fig. 3), so that any shrinkage of the wood will have the minimum effect on their accuracy. The great advantage of celluloid set-squares is that they are transparent and the lines underneath them can be seen.

Two set-squares (a pair) are required, as shown in Fig. 1, one being known as a 45° set-square and the other as a 30° or 60° set-square. A convenient size has a long edge of about 9 in.

Perhaps the most important feature of a set-square is that the right angle should be accurate, and this is tested as shown in Fig. 4. Place the set-square on the T-square and draw a line; then turn the set-square over and draw another line near to the first line. If the two lines are parallel, then the right angle is correct; but if not, then the angle is out of truth by half the small angle between the lines.

A type of set-square now largely used, and which can be highly recommended, is the *adjustable set-square* shown in Fig. 5. It will perform all the functions of both the ordinary set-squares, and of a protractor as well. The arm is pivoted so that it can be adjusted to any required angle by means of the scale, and fixed in position by the screw. The latter screw is also very handy for lifting and moving the set-square.

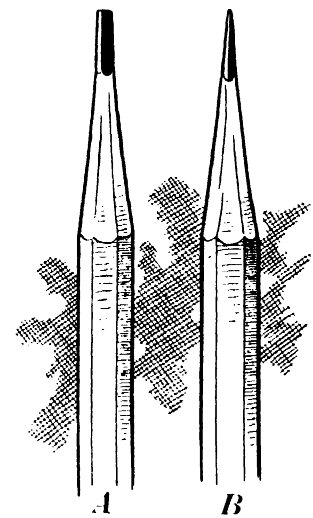


FIG. 6. CHISEL AND CONICAL POINTS

Pencils. It pays to buy good pencils; they work smoothly, are free from grit, and do not break easily. Perhaps the best make is the Koh-i-Noor.

Pencils are made in various degrees of hardness from 6B to 6H, as follows-

BB, B, HB, F, HB, H, HH.

A HH pencil is satisfactory for most drawings, and a F pencil for writing and lettering. Hexagonal pencils are better than round ones, as they do not roll about the board.

The drawing pencil may be either sharpened to a conical point or to a chisel edge (see Fig. 6). The chisel edge lasts longer and gives finer lines than the ordinary point, but it is not so convenient to use. The point should not be stumpy, but should be about $1\frac{1}{4}$ in. long.

After sharpening with a penknife, the point should be rubbed up on a piece of fine glasspaper. Most draughtsmen have a strip of glasspaper glued to a small piece of wood for this

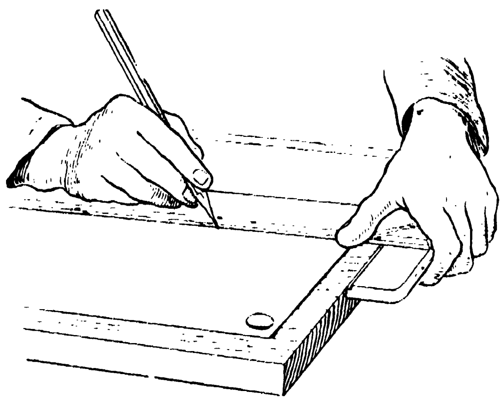


FIG. 7. DRAWING HORIZONTAL LINES

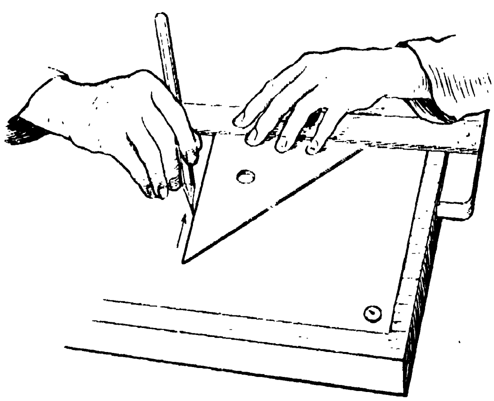


FIG. 8. DRAWING PERPENDICULAR LINES

purpose. Small sharpening blocks, containing about a dozen strips of glasspaper pinned together, can be purchased.

Drawing Straight Lines. Horizontal lines are drawn with a T-square, care being taken that it is held firmly to the left-hand edge of the board, as shown in Fig. 7. Vertical lines are drawn by placing a set-square on the T-square, both instruments being then held gently but firmly with the left hand while the line is drawn. Fig. 8 shows a line being drawn along the right-hand side of the set-square, the pencil being moved towards the draughtsman. In Fig. 9 the line is being drawn along the other side of the set-square, and the pencil point is moved away from the draughtsman. It is very bad practice to draw vertical lines by using the T-square against the top or bottom edges of the board.

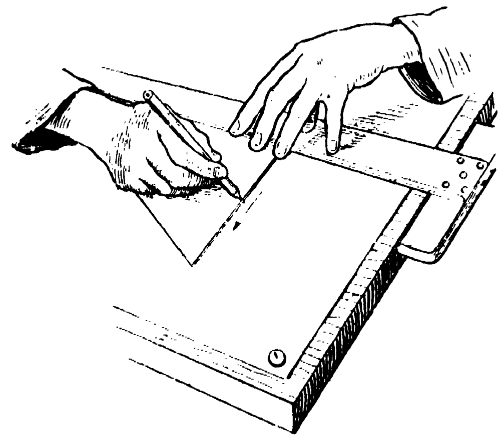


FIG. 9. ALTERNATIVE METHOD

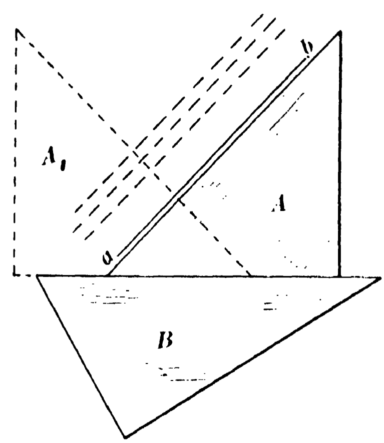


FIG. 10. DRAWING PARALLEL SLANTING LINES

Slanting parallel lines are drawn by using a set-square, as shown in Fig. 10. Suppose one or more lines have to be drawn parallel to *ab*. Place one set-square *A* parallel to *ab*, and then place another set-square *B* on the T-square against an edge of the first set-square. Slide the first set-square forward to the required positions and draw the lines.

Other lines at right angles to the first lines can be drawn by holding the second set-square in position, and turning the second set-square to the position shown at *A*.

BUILDING SCIENCE

By Raymond R. Butler, M.Sc., A.I.C., F.C.S.

LESSON I

CHEMISTRY OF BUILDING MATERIALS

Introduction. A detailed examination of the substances available for use as building materials, and of their resistance to various forms of corrosion, involves a knowledge of their chemical and of their physical properties. It will be convenient if we deal with the chemical aspects first, including in our study any microscopical evidence available to us.

A simple experiment will demonstrate the essential difference between limestone (or marble) and the much harder building stone—granite. If we pour a comparatively strong acid, such as hydrochloric acid (spirits of salt), on to a small portion of each of these substances we find that the acid has little or no effect on the granite, but rapidly attacks the other stones, destroying the fabric and causing the evolution of a gas which we term carbon dioxide (carbonic acid gas). Apart, therefore, from any physical differences which exist in the stones, there are definite chemical differences. These can be revealed to a certain extent by the use of the microscope.

Fig. 1. Photomicrograph of Rubislaw Granite (Aberdeen)
Showing crystal structure

Fig. 2. Photomicrograph of Bath Stone
Showing rounded (oolitic) grains of calcium carbonate

In Fig. 1 we have a photomicrograph of a cross section of granite from Rubislaw, Aberdeen, in which three distinct crystalline substances can be observed. Geologically, we find that there are three principal crystalline minerals usually to be found in granites, which are termed *felspar*, *quartz* and *mica*. Felspar and mica are found to be complex chemical substances produced by the fusion of sand (silica) with other materials found in the earth's crust, and they are known as silicates; quartz, on the other hand, is just crystalline silica (SiO_2), one of the most resistant and refractory materials known to us. The sand of the seashore is composed almost entirely of this material. The dense compact nature of granite has been produced by the slow cooling of fused masses of rock below the earth's surface, resulting in the formation of very hard crystalline masses.

Neither felspar, mica, nor quartz, is appreciably attacked by hydrochloric acid.

If we examine a photomicrograph of Bath limestone (Fig. 2) we find a totally different structure. We have here a partly crystalline mass in which the main bulk of the stone consists of rounded grains, resembling the eggs in the roe of a fish. It is this shape of the particle which has led us to call the Portland and Bath stones *oolitic limestones.*

Chemically they consist mainly of a material —calcium carbonate ($CaCO_3$)—very widely distributed over the earth's surface. The cliffs of Beachy Head; the "middle-chalk" quarried at Beer in Devon; the white marble of Carrara; the dark marbles and hard limestones of the Devon quarries; the coral and shell formations slowly forming on the bed of the ocean; and the stalactites and stalagmites of a limestone cave are all examples of the part played by calcium carbonate in the formation of the earth's crust.

In Fig. 3 we have a photomicrograph of the

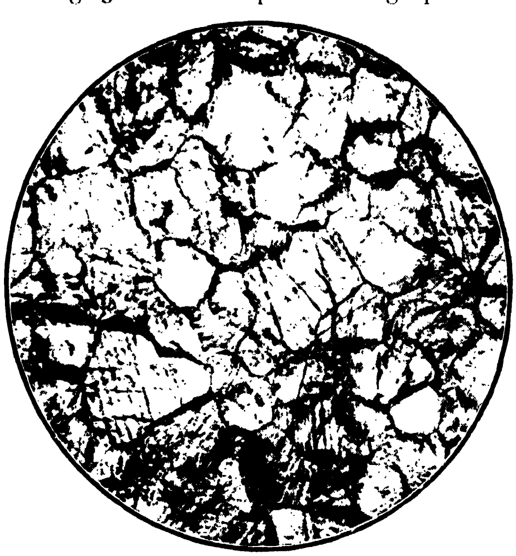


FIG. 3. PHOTOMICROGRAPH OF CARRARA MARBLE
Showing crystalline calcium carbonate

white crystalline calcium carbonate found at Carrara in Italy, consisting almost entirely of calcium carbonate. In this photograph we find no evidence of the oolitic structure which is the characteristic of Bath and Portland stone. Instead, we have a close-grained crystalline structure, differing from that of granite in containing only one type of material instead of three.

Both this and Bath stone—in fact, all materials containing $CaCO_3$—are readily attacked by acids, with the consequent deterioration and corrosion of the stone.

Elements and Compounds. From these considerations alone it will be obvious that we must pay some attention to the chemical nature of matter before proceeding to any intimate study of building materials.

Certain substances, such as iron, carbon, sulphur, calcium, oxygen, nitrogen, zinc and lead, are defined as *elements.* They resist all attempts to separate them into new and simpler substances. If these elements were merely mixed together in building materials, their separation would be simple. They are frequently, however, more intimately connected one with another, and such combinations of elements are termed *compounds.*

Thus, white lead is a compound of lead, carbon and oxygen; quicklime is a compound of calcium and oxygen; marble consists mainly of calcium carbonate, which is a compound of calcium, oxygen and carbon.

Symbols. To facilitate our studies of the chemistry of nature we devise symbols to designate the elements, and in this kind of chemical shorthand we are able to express not only the simpler statements of chemical combination, but also any numerical considerations involved. This is rendered possible by our conception of *atoms* and *atomic weights.* We find by very careful analysis that the atom of the element carbon is approximately twelve times as heavy as the atom of the element hydrogen, while the atom of the element calcium is practically forty times as heavy. We can write, therefore (in our chemical shorthand), Carbon as C,

TABLE I

CHIEF ELEMENTS CONNECTED WITH BUILDING MATERIALS

Name	Symbol	Approximate Atomic Weight
Aluminium	Al	
Barium	Ba	137
Calcium	Ca	40
Carbon	C	12
Chlorine	Cl	35·5
Copper	Cu	63
Hydrogen	H	1
Iron .	Fe	56
Lead .	Pb	207
Magnesium	Mg	24
Nitrogen	N	14
Oxygen	O	16
Potassium	K	39
Silicon	Si	28
Silver .	Ag	107
Sodium	Na	23
Sulphur	S	32
Tin .	Sn	119
Zinc .	Zn	65

Hydrogen as H, Calcium as Ca, Oxygen as O, and so on.

Moreover, we agree to indicate by the symbol C one atom of Carbon, whose atomic weight is 12; by Ca one atom of Calcium, whose atomic weight is 40; and by O one atom of Oxygen, whose atomic weight is 16. A short table of the chief elements found in building materials is given in Table I.

Chemical Equations. Chemical calculations are thus rendered much more simple than if a system of words was required.

For example, when chalk or limestone is heated, quicklime is produced and the gas, carbon dioxide, is driven off. This, in our system of symbols, becomes—

$$\underset{\text{(chalk)}}{CaCO_3} \quad \text{heat} \quad \underset{\text{(quicklime)}}{CaO} + \underset{\text{(carbon dioxide)}}{CO_2}$$

If we give to the elements represented here their atomic weights, we find that (40 + 12 + 48) parts of chalk yield (40 + 16) parts of quicklime, and (12 + 32) parts of carbon dioxide. This follows from the fact, expressed in the equation, that chalk consists of one atom of calcium, one atom of carbon, and three atoms of oxygen; that quicklime contains one atom of calcium and one atom of oxygen; that carbonic acid gas contains one atom of carbon and two atoms of oxygen.

So that, returning to our calculation, 100 parts of pure calcium carbonate will yield 56 parts of quicklime, when suitably heated. This, expressed in suitable units of weight, means that 100 grm., or oz., or tons of $CaCO_3$ yield 56 grm., or oz., or tons (respectively) of quicklime; or, in another form, that 56 per cent of $CaCO_3$ is quicklime.

In the same way the decorator's colouring material, "rouge," which is iron oxide, Fe_2O_3, contains two atoms of iron combined with three atoms of oxygen. Calculating as before, 2 × 56 parts of iron are combined with 3 × 16 parts of oxygen; or 112 parts of iron are united with 48 parts of oxygen; or 160 parts of iron oxide contain 112 parts of iron; or the percentage of iron in iron oxide (Fe_2O_3) is 70 per cent.

Enough will now have been said to indicate the nature of, and method of using chemical formulae, and it may be interesting to draw up a list (Table II) of common substances, with their names and formulae, for reference purposes.

TABLE II

SOME COMMON SUBSTANCES WITH FORMULAE

Common Name	Chemical Name	Geological Name	Formula
Ammonia	Ammonium Hydroxide		NH_4OH
Sal Ammoniac	Ammonium Chloride		NH_4Cl
Alum	Potassium Aluminium Sulphate		$K_2SO_4, Al_2(SO_4)_3, 24H_2O$
Carbonate of Lime	Calcium Carbonate	Chalk, Marble, Limestone	$CaCO_3$
Chloride of Lime	Calcium Hypochlorite	—	$CaOCl.Cl$
Carbonate of Magnesia	Magnesium Carbonate	Magnesite	$MgCO_3$
Chrome Yellow	Lead Chromate		$PbCrO_4$
Epsom Salts	Magnesium Sulphate		$MgSO_4.7H_2O$
Glauber's Salts	Sodium Sulphate		$Na_2SO_4.10H_2O$
Green Vitriol	Ferrous Sulphate		$FeSO_4.7H_2O$
Heavy Spar	Barium Sulphate	Barytes	$BaSO_4$
Litharge	Lead Monoxide	—	PbO
Nitre	Potassium Nitrate	Saltpetre	KNO_3
Quicklime	Calcium Oxide		CaO
Red Oxide of Iron	Ferric Oxide	Haematite	Fe_2O_3
Red Lead	Red Lead	—	Pb_3O_4
Salt	Sodium Chloride	Rock Salt	$NaCl$
Spirits of Salt	Hydrochloric Acid		HCl
Silica	Silicon Dioxide	Quartz, Sand	SiO_2
Slaked Lime	Calcium Hydroxide	—	$Ca(OH)_2$
Sulphate of Lime	Calcium Sulphate	Gypsum	$CaSO_4.2H_2O$
Vinegar	Acetic Acid		$CH_3.COOH$
Washing Soda	Sodium Carbonate		$Na_2CO_3.10H_2O$
White Lead	Basic Lead Carbonate		$Pb(OH)_2.PbCO_3$
White Vitriol	Zinc Sulphate		$ZnSO_4.7H_2O$
Zinc White	Zinc Oxide		ZnO

PAINTING AND DECORATING

By CHARLES H. EATON, F.I.B.D.
Member of Council of The Institute of British Decorators

LESSON I

MATERIALS

Introduction. The subject of painting and decorating is one that has failed to receive proper consideration by the builder; hitherto, he has been content to regard it as a useful and profitable adjunct to his other legitimate business and to give it as scanty consideration as possible, provided always that he could just win through.

There is now, however, a tendency for the modern builder to realize that the painting and decorating department is one that, if not worthy of personal supervision, is at least worth the attention of some specially appointed person, well qualified to supervise all the work of this department. Where this is not possible, the tendency is more toward the placing of the work in the hands of a reliable firm who specialize in the business, rather than to continue the questionable practice of sub-letting the work to a scamping piece-worker, often at such a price that his only profit can be made out of the work he is able to avoid.

The work of the decorator is to-day very much better organized than it has ever been, both industrially and educationally; there are sound schemes by means of which the young folk can enter the trade and graduate from well-equipped schools to apprenticeship, coupled with further technical education until they become journeymen, and qualified, after five years training, to sit for the examinations of the City and Guilds of London Institute, followed by the Associateship of the Institute of British Decorators, a distinction which can be gained by an examination equal in its standard to a degree. The craft is one that is exceedingly interesting to a young person of artistic temperament, and so full of genuine opportunity, that it is surprising it has not yet succeeded in attracting to it a sufficiently large number to keep the ranks of well-skilled craftsmen from becoming sadly depleted. It must be frankly admitted that to-day there is not the number of really expert craftsmen that the trade requires; on the other hand, immediately a young man shows that he has real ability, he cannot fail to find himself in the front ranks in the course of a few years after attaining his majority. Parents would be well advised to give their sons, who show suitable ability, the opportunity of acquiring, in one of our modern craft schools, the requisite preliminary training which takes the place of earlier years of apprenticeship, and then establish them with a really reliable firm where they ma, develop their knowledge, and later, by their superior skill, assist in raising the craft from the place of low esteem into which it has fallen through the exploitation of the many who have used it for other purposes.

The craft of the decorator is one of the oldest in the building industry: there is much to prove that it was practiced before actual building was even thought of. Many of the earlier cave dwellings of primitive man boasted walls covered with simple line decoration, and later, fresco work of a simple character was introduced. Articles of everyday use, too, were frequently decorated in a simple way, and quite a long period elapsed before decoration, or decorators' materials, were applied for any purpose other than that of a purely decorative character. With the change of habits and customs of our early ancestors, and the consequent change in the character of their habitations, the need for a different treatment became apparent. With the introduction into building of materials of a decayable nature came the need for materials that would prevent decay; and later, as people began to understand the importance of cleanliness, came the demand for a method of treatment that was capable of rendering a surface easy to clean. We have, therefore, developed largely according to the change in the requirements of mankind, until to-day we have a range of materials and fabrics that render it possible to meet the most exacting requirements of a highly developed civilization.

It will be easy to realize that three main requirements have to be fulfilled by the modern decorator. He may be called upon to decorate, to preserve a structure, or to make it easy to clean. His method of dealing with each individual problem will be settled by the several requirements of the particular problem: he may decorate his surface with materials that do not preserve the structure; he may apply a material that does not decorate the surface but merely preserves the structure; or he may, in turn, apply a material that is easy to clean but has scarcely any other qualification.

Trade practice appears to have resulted in the painting and decorating executed by the builder being regarded from rather a different angle of vision than that executed by the specialist firm practising the one craft only, and there is much to be said in favour of placing each branch of the industry in the hands of such specialists. The builder generally is not regarded as capable of executing decorating, but rather that he applies painters' materials for the purpose of preserving the structure and making it easy to clean, decoration being a secondary consideration.

SPECIFICATIONS AND QUANTITIES

By Wilfrid L. Evershed, F.S.I.

Chartered Quantity Surveyor; Author of "Quantity Surveying for Builders" and "Specifications for Building Works"

LESSON I

INTRODUCTION

The information contained in this section should be of great interest to the student who has a leaning to the more practical side of building work, rather than the architectural side; but it is very essential, especially in connection with quantities, that he should first have a sound knowledge of the details of construction, and students are therefore advised, if necessary, to postpone the reading of this section until they have thoroughly mastered some of the sections dealing with construction.

It is a debatable question as to who is the best person to write the specification, but it is felt that the quantity surveyor, having a more intimate knowledge of the construction of the building, is the best person to do this, and it is for this reason that specifications are included in this particular section.

Specifications. The art of writing a specification depends upon a knowledge of the wishes of the architect, and also the ability to write in such a way that the person reading same can understand what is required, and it will therefore be realized that there is a difference between specification writing and writing the description attached to items in a bill of quantities; the latter is simply a description of the work and has certain dimensions attached to it, and will always be read by someone who understands what is required; while in a specification the reading should convey instructions to workmen and others who have not always the advantage of the education or knowledge that the man has who will read the bill of quantities.

Quantities. The preparation of quantities is a subject which requires infinite care and patience, and a mind fitted to deal with a mass of detail. It must be remembered that the architect's plans are being dissected, and where one or two lines on the plans may represent a door or window, this has to be split, from the surveyor's point of view, into a deduction from walling, plastering, facing, etc., and also into arches, lintels, sills, reveals, door or window frames, doors or sashes, various fastenings, painting, glazing, etc. It will thus be realized how necessary is the knowledge of construction before one attempts to "take off" this work.

The general course followed by students when studying the actual work in a surveyor's office, is first to square dimensions, or in other words, to work out into superficial and other measurements, the figures which have been placed on dimension paper by the "taker off." Following this, he will advance by slow stages to that of "worker up," which process is that of "abstracting" and "billing," and it may be some time before he is allowed to do any "taking off," and then will only start on the much easier portions of a building, such as plastering.

In this work, however, the lessons are given in the actual order in which the work is carried out, and therefore the "working up" process will not be described until towards the end.

Estimates. There are various methods employed to obtain estimates for both building and civil engineering works; but there is no real difference between the preparation of quantities for houses and public buildings, harbours, roads, etc.; the student who can "take off" a public building can just as easily apply his knowledge to harbours, roads, and sewers.

The various methods are—

Cubing the building.
Taking off rough quantities.
The use of schedules.
The preparation of an accurate bill of quantities.

Cubing. This method is only employed to obtain an approximate idea of the cost, and is often used by a builder or contractor as a check upon his priced bill of quantities. Before he can check in this way he must have some idea of the cost per foot cube for buildings of a similar description to that under review.

Rough Quantities. These consist of superficial dimensions of walls, floors, roofs, and similar items, approximately accurate as far as dimensions are concerned, but including in their description the brickwork facing, plastering, etc., for an item for walls, the doors and windows only being taken as extra value. This method gives a more accurate price than the cubing method, but should only be used for an approximate estimate.

Schedules. The use of schedules is for work the extent of which is not generally known, and consists of agreed prices for the various items of labour and material. The work executed is measured up on completion and brought into the form of an accurate bill of quantities.

Bill of Quantities. The preparation of a bill of quantities is the most satisfactory method of obtaining a tender, and this should always be prepared on the instructions of the building owner. More satisfactory tenders are obtained for the work, and in the long run the building owner benefits, as if he does not instruct the architect to have quantities prepared, he very often has to pay the builder in the tender for preparing them, and if prepared to his instructions they will always serve as a basis for the adjustment of variations from the contract.

Scope of Lessons. The lessons given will first deal with the preparation of specifications; following which they will deal with the preparation of bills of quantities, with typical examples of "taking off," and "working up."

SUPERINTENDENCE

(*Continued from page* 49)

later, when he became a sort of builder-architect, and was responsible for the construction of some of the buildings which are now regarded as national assets. The best known name of the earlier type of clerk of works is that of Geoffrey Chaucer, the poet, who held the position for two years. It is doubtful, however, whether the appointment was due to Chaucer's expertness in the art of building; more probably it was given to him as a compliment and source of income.

As far back as the sixteenth century the name applied to a person whose duties were very similar to that of the present-day clerk of works. There have been some variations in his status at different times. At Greenwich Hospital, for instance, the building of which was commenced in 1661, and continued for over one hundred years, many of the clerks of works employed were professional men, and some well known as architects. In the early part of the last century, the officer attached to the Corporation of the City of London, who is now the surveyor, was called a clerk of works. But there is little variation in the use of the term to-day. It applies to a man who supervises, under the instructions of an architect or engineer, the construction or maintenance of building and similar works.

It may be noted the name is rather misleading to the uninitiated, who naturally associate it solely with the keeping of records in a commercial or public office. Many applications received in response to an advertisement for a clerk of works are from clerks; the only other possessor of the name of clerk whose primary duties are not connected with a desk is that mythical personage, the clerk of the weather.

PLUMBING

By Percy Manser, R.P., A.R.S.I.
Honours Silver Medallist

LESSON I

THE PLUMBER'S TOOLS

Introduction. The plumber derives his name from the Latin *plumbum*, meaning lead; the plumber of olden times was chiefly a worker in lead. The modern craftsman, however, is no longer a worker in lead only; the materials of his trade consist of lead, copper, brass, iron, stoneware, marble, pottery, and several others. His work consists not only of one particular branch of the building trade, but covers a very wide area; and we find the present-day plumber skilled in the fitting-up, working, and uses of the most up-to-date installations and appliances.

It is a very old adage amongst craftsmen that *a man's character is carried in his tool-bag.* Usually, the plumber's tool-kit gives one a good idea as to his capabilities, and his character as a skilled, clean, and competent worker. One of the first things the apprentice should be taught is the necessity to keep the tool-kit clean and in good condition. The tools used by the plumber are many and varied; some are expensive, whilst others can be made by the plumber himself. This is often done, especially where intricate and peculiar shaped leadwork has to be carried out, and wood tools of a special shape are required. A few illustrations and descriptions of some of the plumber's tools will be found useful.

Dressers (Fig. 1). These vary in size and shape and can be obtained in various types of wood, the two chief kinds being hornbeam and boxwood; the former is used for the general work and boxwood for finishing. The chief points to be observed in the selection of a dresser are: It should have smooth sides and face, free from sharp edges, and the handle should be well pitched to allow room for the knuckles of the user.

Mallets are made in various sizes, and usually of lignum-vitae or boxwood. A *bossing mallet* (Fig. 2) should be perfectly smooth, the nose rounded, the face nearly flat, and the edges nicely rounded. The handle can be of ash or Malacca cane and should be well fitted, glued, and wedged to the head. It is used for lead bossing, the face or side being used as required to suit the particular job in hand.

Bending Dressers are made of boxwood. They are broad and slightly rounded on the face, both in width and length (Fig. 3), and are chiefly used for driving the lead when making bends in pipes. A great number of plumbers prefer a rounded hornbeam dresser for this work, as less marks are produced than with the harder boxwood bending dresser.

Bossing Sticks. A bossing stick (Fig. 4) is similar in shape to a bending dresser, but narrower and more rounded. It is used for working corners and breaks in leadwork. It should be perfectly smooth, and so shaped that it is well balanced in order to enable the *bossing* to be executed with ease. It is made of boxwood.

Chase Wedges. These are usually made of boxwood and to all sizes and shapes; some are known as *side-bent* and others as *front-bent* wedges, whilst driving wedges are generally quite straight. The larger type of chase wedge is fitted with an iron ferrule, as also is the driving wedge, to enable them to withstand the blows of the hammer. The smaller wedges are plain, and should be struck with a mallet. Fig. 5 shows two views of a driving wedge, and Fig. 6 shows two other forms of chase wedge. The plain wedge should have a blunt edge, and is used for chasing back the angles of leadwork, while the driving wedge has a square edge and is used for driving back the angles of overcloaks from the edge of the lead when a drift or drip plate is used.

Drift Plate. This is a small rectangular plate of steel (Fig. 7), and is used in the working back of overcloaks in lead roof coverings. *Lead will not slide on lead*, therefore this plate is placed between the undercloak lead and the overcloak, to enable the latter to be worked back into position by means of the chase wedge.

Knives. Plumbers' knives are of three kinds—

The *clasp knife*, Fig. 8 (*a*).
The *draw knife*, Fig. 8 (*b*).
The *chipping knife*, Fig. 8 (*c*).

The first-named is a pocket knife with a stout

Fig. 1. Dresser

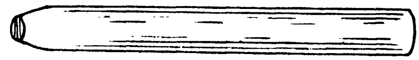


Fig. 9. Mandril

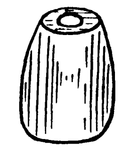


Fig. 10. Bobbin

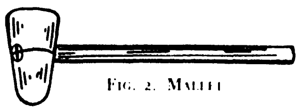


Fig. 2. Mallet

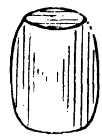


Fig. 11. Follower

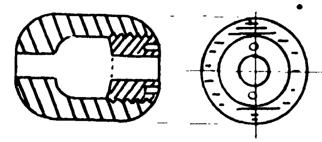


Fig. 12. Bobbin Weight

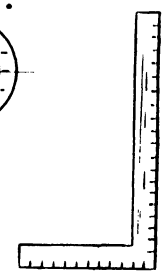


Fig. 13. Steel Square

Fig. 3. Bending Stick

Fig. 4. Bossing Stick

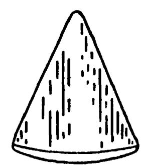


Fig. 14. Turnpin

Fig. 15. Bending Bolt

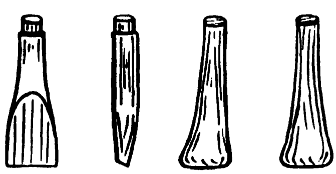


Fig. 5 Fig. 6

Chase Wedges

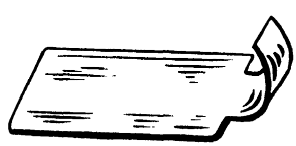


Fig. 7. Drift Plate

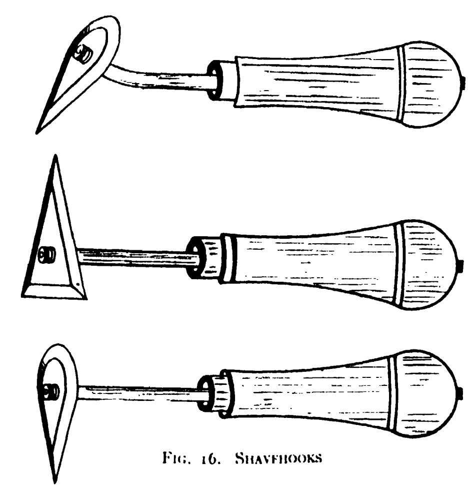
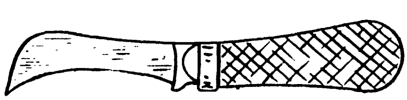
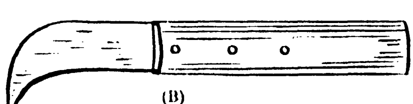


Fig. 16. Shavehooks

Fig. 17. Plumbing Iron



(A)



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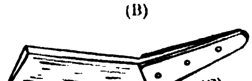


(C)

Fig. 8. Plumber's Knives

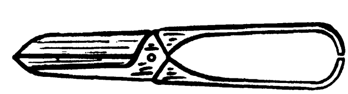


Fig. 18. Snips

single blade, rivet-hinged to a sheath handle. The draw knife (or sheet knife) consists of a steel blade with a sharp point firmly riveted to a wooden handle about 6 in. long; it is chiefly used for cutting up the lead from the sheet. A chalk line is struck, and the point of the knife is run down the line and almost through the substance of the lead, after which the lead can be rolled up along the cut, which is easily severed.

The chipping knife is a much stouter tool, fitted with two strips of leather riveted through the steel to form a handle, its use being chiefly for trimming or chipping thicker parts of the lead, and where a hammer is required to drive the blade through the substance. Plumbers' knives should always be kept sharp, and the draw knife fitted with a sheath to protect the point.

Mandrils. These are made in various diameters and lengths, and are either made of boxwood, lignum-vitae or oak (Fig. 9). They are used for passing through the lengths of pipe to remove any indentations, thus leaving the pipe true and cylindrical in readiness for preparation previous to fixing. They are also used to enable the plumber to make a bend close to the end of a length of pipe; by placing the mandril partly in the pipe a better leverage may be obtained.

Bobbins. A bobbin (Fig. 10) is a smooth boxwood or lignum-vitae tool, semi-oval in shape, with a hole running through the length; they are made in all diameters and used for trueing up bends in lead pipes. Followers (Fig. 11), made of beech and of a similar shape, are used to drive the bobbin round a bend; or a bobbin weight (Fig. 12) is used, a cord passing through the bobbin and fixed in the weight by means of a knot. The plumber and his mate each operate an end of the cord, which should be kept tight to prevent the weight jumping about and so damaging the pipe.

Steel Square. A square (Fig. 13) is a necessary tool in the plumber's kit. It is usually 18 in. by 12 in., with figured dimensions.

Tampin, or Turnpin. This tool is cone-shaped and made of boxwood (Fig. 14), its chief use being to open the ends of pipes when preparing a joint. They are made in all sizes.

Bending Bolt (Fig. 15), is a steel bolt tapered at one end; they are made in various lengths from 9 in. to 24 in., and $\frac{9}{16}$ in. to $\frac{7}{8}$ in. in diameter. When a branch joint is required, the bolt is used to open the lead pipe that is to receive the branch; a small hole is first made with a pipe opener, and the hole is then enlarged as required by means of the bolt and the hammer. They are also used for working out the throats of bends in small lead pipes.

Shavehooks. These can be obtained in a variety of shapes: heart, three-square, spoon, and what is known as a gaugehook. They are made of steel, sharpened at the edges, and riveted to a steel stem about $\frac{5}{16}$ in. or $\frac{3}{8}$ in. in diameter, fitted with a wood handle, through which the stem passes and is firmly riveted over a steel washer at the end. They are used for shaving the ends of pipes, and the surfaces of leadwork in preparation for soldering. Fig. 16 shows three types in general use.

Plumbing Iron. The plumbing iron (Fig. 17) is an elliptical-shaped bulb of iron with a crook handle. It is seldom seen amongst a plumber's kit at the present time, having been replaced by the blow lamp, which requires much less skill to manipulate when wiping a joint. The plumbing iron is heated to redness, the handle cooled in a pail of water, the bulb filed clean, and whilst held in a carpet hand-felt is applied to the solder to keep it hot, and so enable the plumber to wipe the joint or the seam, as the case may be. There are a great many plumbers' mates and apprentices of the present day who have not seen an iron of this description, and only know the use of the lamp for joint wiping.

Snips (Fig. 18), also known as shears, are made in various sizes with straight or bent cutting jaws, and are used for cutting sheet lead, copper, zinc, tin, iron, etc. They should be kept in good condition and well sharpened, as a blunt pair of snips is very trying to one's temper, as well as making a ragged cut.

Step Turner (Fig. 19). This is a useful tool that can be made by the plumber himself. It is used for turning the leadwork of step flashings, that is, that portion which enters the joint of the brickwork.

Ladles (Fig. 20). These can now be obtained made in one piece of metal (weldless) and of various sizes; a small pouring lip can be formed on one or both sides to enable the ladle to be used in either hand, which is most useful when in an awkward position.

Splash Stick (Fig. 21). This also is a tool best made by the plumber to suit his own particular requirements. It can be made of stout sheet steel. The edges should be well rounded to prevent scratching the " soil " when building up the solder on a joint. The handle portion should be neatly bound with fine string to prevent the heat injuring the hands of the user.

Scribing Gauges (Fig. 22). These are flat plates of brass or steel and are reversible. They are used in combination with a pair of compasses when scribing the shape of branch joints ready for shaving. A wooden gauge is also used for marking the length of shaving for underhand and upright joints, to obtain uniformity of size throughout the job.

Plumbers' Saws. Fig. 23 shows a double-edge type of saw, with fine teeth on one side and coarse on the other. A very useful size is about 18 in. in length.

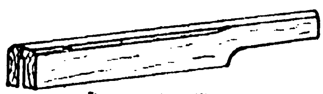


Fig. 19. Step Turner

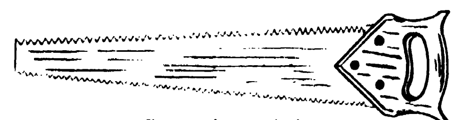


Fig. 23. Plumber's Saw

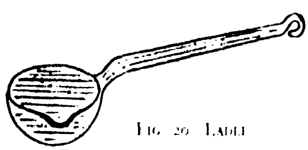


Fig. 20. Ladle

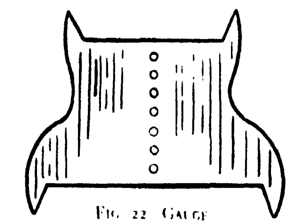


Fig. 22. Gauge

Fig. 21. Splash Stick

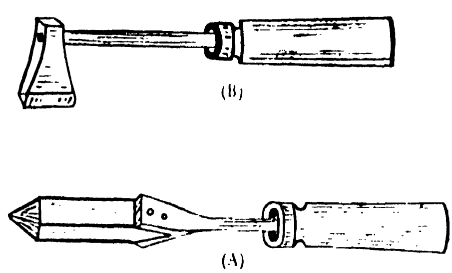


Fig. 24. Two Types of Copper Bits

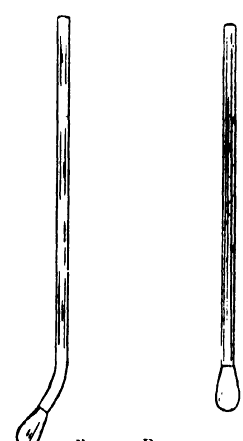


Fig. 25. Dummies

Copper Bits (Fig. 24) are made in various shapes and of sizes to suit the various uses to which they are put. The plumber generally carries two in his kit—a straight bit (*A*) and a right-angle or hatchet bit (*B*). They are used for tinning brasswork ready for soldering or wiping to lead pipe, and in some districts for making joints on lead and composition piping. The seams on the early forms of lead soil pipe were made with a copper bit and fine solder. A copper bit should never be made red hot, or the *face* will be destroyed and render the tool useless for soldering. To renew the *face* the copper should be heated, the point of the copper filed clean and dipped into a flux, and fine solder rubbed on the filed portion, which should then have a bright tinned appearance.

Dummies (Fig. 25). These are made in various lengths and consist of a bulbous head of metal fitted to a handle, which may be of steel or Malacca cane. They are usually made by the plumber himself, and are either perfectly straight or with a bent handle. They are used to work out the buckle that appears when making a bend in large pipes for soil and ventilation work. Loose dummy heads, with a screw boss, are also made to fit a ½ in. barrel, thus enabling the plumber to fit various lengths of barrel and make a short or long dummy as required.

ROOF COVERINGS

By John Millar, P.A.S.I., M.I.Struct.E.

LESSON I

INTRODUCTION

Roofing Materials. The materials for covering a roof are determined by the climatic conditions, and by the nature and importance of the building under consideration. Being one of the chief items of construction, the roof must be durable in proportion to the permanence of the building; and where the roof is prominent the roofing

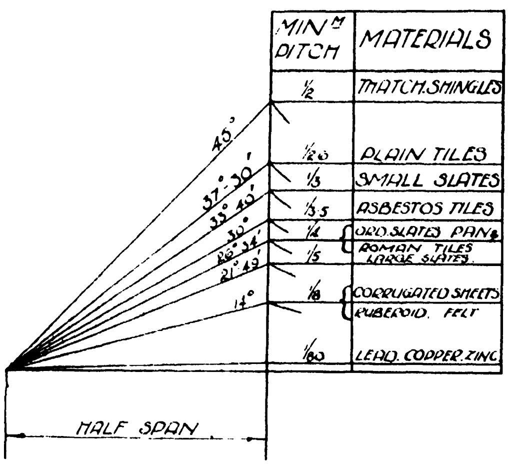


Fig. 1. Roof Pitches

materials should, of course, be given consideration from an architectural and aesthetic standpoint.

For coverings the following are in use: slates, tiles, asbestos tiles, and corrugated sheets, corrugated iron, lead, copper, zinc, asphalt, felt, glass, shingles, and thatch.

Poor conductors, such as slates and tiles, make better coverings than those which conduct heat, such as corrugated iron, as they tend to preserve a more equable temperature in the interior of the building.

Pitch. The term *pitch* is applied to the amount of slope given to the sides of the roof, and may be stated either in terms of the number of degrees in the angle which the roof makes with the horizontal, or by the ratio of the rise to the span; thus, for a span of 30 ft., if the rise is 7 ft. 6 in., the pitch is a quarter; if the rise is 10 ft., the pitch is a third. The correct pitch varies in accordance with the nature of the covering (see Fig. 1).

Table I gives the least pitch it is desirable to adopt for the materials in use for coverings.

TABLE I

Roof Pitches for Various Materials

Materials	Angle of Inclination in Degrees	Ratio of Rise to Span
Slates (Large)	22	$\frac{1}{5}$
,, (Ordinary)	26–34	$\frac{1}{4}$
,, (Small)	33–41	
Plain Tiles	37–41	
Pan Tiles	26–34	$\frac{1}{4}$
Roman Tiles	26–34	$\frac{1}{4}$
Asbestos Tiles	30	
,, Corrugated Sheets	14	$\frac{1}{8}$
Corrugated Iron	14	$\frac{1}{8}$
Felt	14	$\frac{1}{8}$
Lead	$\frac{1}{2}$	
Copper	$\frac{1}{2}$	
Zinc	$\frac{1}{2}$	
Asphalt	$\frac{1}{2}$	
Glass	26–34	$\frac{1}{4}$
Thatch	45	$\frac{1}{2}$
Shingles	45	$\frac{1}{2}$

SLATE

Planes of Cleavage. Slate, one of the commonest materials for roofing, is a rock of fine grain and compact structure, formed originally from material transported by water and deposited as fine silt on ancient sea bottoms.

Although a sedimentary rock it has, owing to intense lateral pressure, lost its original bedding plane, and has acquired its characteristic tendency of splitting into thin plates known as "planes of cleavage," which may be parallel to the original bedding plane, but more usually are at some angle from it (see Fig. 2).

The mechanical theory of cleavage is that the forces acting in a lateral direction have not only contorted the beds, but have so re-arranged the particles as to cause them to lie in a plane perpendicular to the direction of the forces themselves (see Fig. 3).

Slates are occasionally found with the cleavage planes slightly curved, due to some disturbance after the cleavage planes have been formed. This is termed "wavy cleavage," and the slates are then said to be "yorky."

The original stratification is sometimes discernible either by faint bands of colour on the cleavage surface, or by difference in texture. These bands of colour are not detrimental to the durability of the slate.

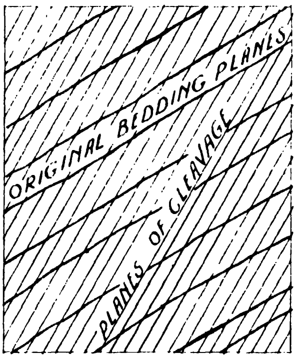


FIG. 2. SLATE FORMATION

Besides the cleavage planes, it is found that there are also other planes of weakness along which the block may be easily divided. These occur in a more or less vertical direction at right angles to the principal cleavage. This tendency is known as *pillaring*, a quality in slate known as "grain."

Characteristics of Slate. That the planes of cleavage permit the rock to be split into thin, uniform slabs is an essential characteristic of

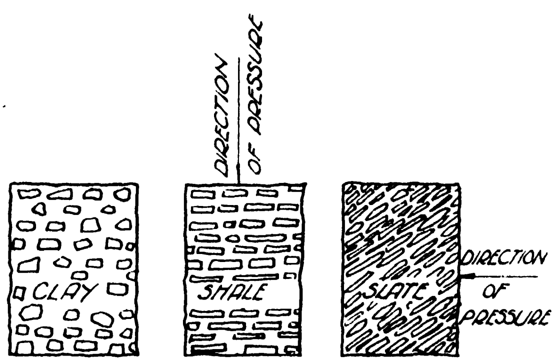


FIG. 3. PLANES OF CLEAVAGE

slate, without which it would be of little value as a roofing material. Other characteristics of a good slate are hardness and toughness of structure, uniformity of colour, and an absence of patches. It should give a clear ring when struck with the knuckles, not be greasy to the touch, but somewhat rough, and when it is stood in water to half its depth, the water should not rise more than $\frac{1}{8}$ in., nor, when immersed in water for twenty-four hours, should it absorb more than one two-hundredth of its dry weight. Other rocks, such as shales and certain kinds of sandstone, differ from true slate in that they possess no planes of cleavage, but only split along the planes of the original bedding. They are used for roofing purposes in some districts, and are hence misnamed slates.

Slate, being derived from clayey rocks, consists essentially of silicates of iron and aluminium which represent nine-tenths of the total mass. These two minerals give to the slate its permanent character. Table II gives the chemical analysis of a few different slates.

TABLE II

ANALYSIS OF SLATE

	Oakeley		Pre-celly	Tilber-thwaite
	Old Vein	New Vein		
Silica (SiO_2)	55·25	53·40	62·66	50·160
Alumina (Al_2O_3)	24·60	26·67	22·22	17·850
Iron Oxide (Fe_2O_3)	10·40	9·53	6·03	6·750
Lime (CaO)	1·00	0·90	0·06	3·670
Magnesia (MgO)	2·09	1·85	1·22	6·350
Potassium Oxide (K_2O)	1·47	1·42	3·21	2·060
Sodium Oxide (Na_2O)	0·53	0·52	1·01	3·110
Sulphuric Acid (SO_3)	0·21	0·23	0·31	0·100
Titanium Oxide (TiO_2)				1·030
Loss on Ignition (Water)	4·62	4·70	3·88	4·670
Specific Gravity	2·88		2·80	2·775

Weight of Slate. Welsh slate weighs 180 lb. per cub. ft., Cornish slate 173 lb. per cub. ft., and Westmorland slate 157 lb. per cub. ft. The estimated weight of roof covering per square of 100 ft. superficial is—

	Firsts	Seconds	Thirds	Randoms
North Wales	4–5 cwt.	7 cwt.	9 cwt.	
South Wales	7 ,,	9 ,,		$10\frac{1}{2}$ cwt.
Cornish	6 ,,	7 ,,		10 ,,
Lancashire	$7\frac{3}{4}$,,	9 ,,	11 ,,	
Westmorland	$7\frac{3}{4}$,,	9 ,,	11 ,,	

Physical Tests. The following tests were made on slates taken from the Oakeley quarries. The tests for absorption of water showed that, after being immersed for $2\frac{1}{2}$ hours at 60° F., the weight of the slate was not appreciably or measurably increased. The test for tensile strength gave 8,740 lb. per sq. in., and the resistance to compression measured 31,470 lb. per sq. in.

ARCHITECT'S OFFICE AND ROUTINE

By Herbert J. Axten, A.R.I.B.A., A.I.Struct.E.
Chartered Architect

PART I

OFFICES AND EQUIPMENT

Partnerships. It not infrequently occurs that two architects unite in practice, the one being possessed of a pronounced architectural ability, the other—though not devoid of that ability—having a greater development of business acumen, and therefore a leaning towards the administrative side. This is a happy combination, and usually results in the building up of a successful architectural practice.

Taking a partnership of this nature for consideration, the chart given in Fig. 1 shows the activities under the care and supervision of each of the principals.

Office Accommodation. Assuming two architects are in partnership the following office accommodation is necessary—

- Private office for senior partner (business).
- Private office for junior partner (architectural and works).
- Small drawing office for senior assistant.
- Large general drawing office.
- Small waiting-room for callers—if possible.
- Typist's, correspondence, and filing-room.

A provincial office would require a photo-printing room, which might also serve as a store for samples of building materials, strainers for competition drawings, spare trestle drawing tables, storage of drawings, and documents of completed jobs, etc.

The Equipment of the Offices will necessarily vary with the financial standing of the principals, but the following is the general arrangement of a medium grade suite.

Office of Senior Partner (Business). This being the office in which clients are received but in which no actual drawing is done, the principal furniture is—

- Large writing table with pedestal drawers and writing accessories, and armchair.
- Two large lounge armchairs and a few small chairs.
- Table upon which plans may be opened for perusal and discussion.
- Bookcase and books, stationery cabinet, letter trays.
- Safe for private documents.
- Turkey carpet, hat and umbrella stand, clock, and permanent date calendar

Office of Junior Partner (Architectural and Works). This being the office of the partner more intimately concerned with the preparation of drawings and the supervision of works in progress, the principal furniture is—

- Large drawing desk.
- Chest of drawers sufficiently large to contain double elephant drawings.
- Writing table with pedestal drawers.
- Stationery cabinet and writing accessories.
- Armchair, small chairs, and carpet.
- Bookcase, letter trays, clock, and permanent date calendar, technical books and periodicals.

Drawing Offices. Following is the equipment of these offices—

- Drawing desks or tables with large plan drawers.
- Stools.
- Plan drawer cabinets to take double-elephant drawings.
- Nest of drawers or filing cabinets for manufacturers' catalogues, and plates from architectural and building periodicals.

T-squares.	Railway curves.
Set-squares.	French curves.
Beam compasses.	Perspectograph.
Water colours.	Planimeter.
Pallets and brushes.	Clinograph.
Stickphast and sponge.	Mahogany straight edges.
Whatman drawing paper.	French chalk.
Cartridge drawing paper.	Dusters.
Detail drawing paper.	Stencils and rubber stamps.
Squared paper.	Pencils, pens, and coloured crayons.
Tracing paper.	Slide rule.
Tracing linen.	Drawing pins.
Indian ink.	Coloured and writing inks.
Theodolite and tripod.	2 ft. rules.
Level, tripod, and staff.	Sketch blocks.
Surveyor's chain and arrows.	Sketch books.
100 ft. tape.	Notebooks for recording visits to jobs.
Surveying book.	
Levelling book.	

Typist's and General Office. The equipment here is as follows—

Typewriter, table, and stool.	Safe, clock.
Stationery cabinet.	Shelving.
Clerks' desks and chairs.	Letter trays.
Vertical filing cabinets.	Writing and filing accessories.
Vertical card indexes.	Duplicating machine.

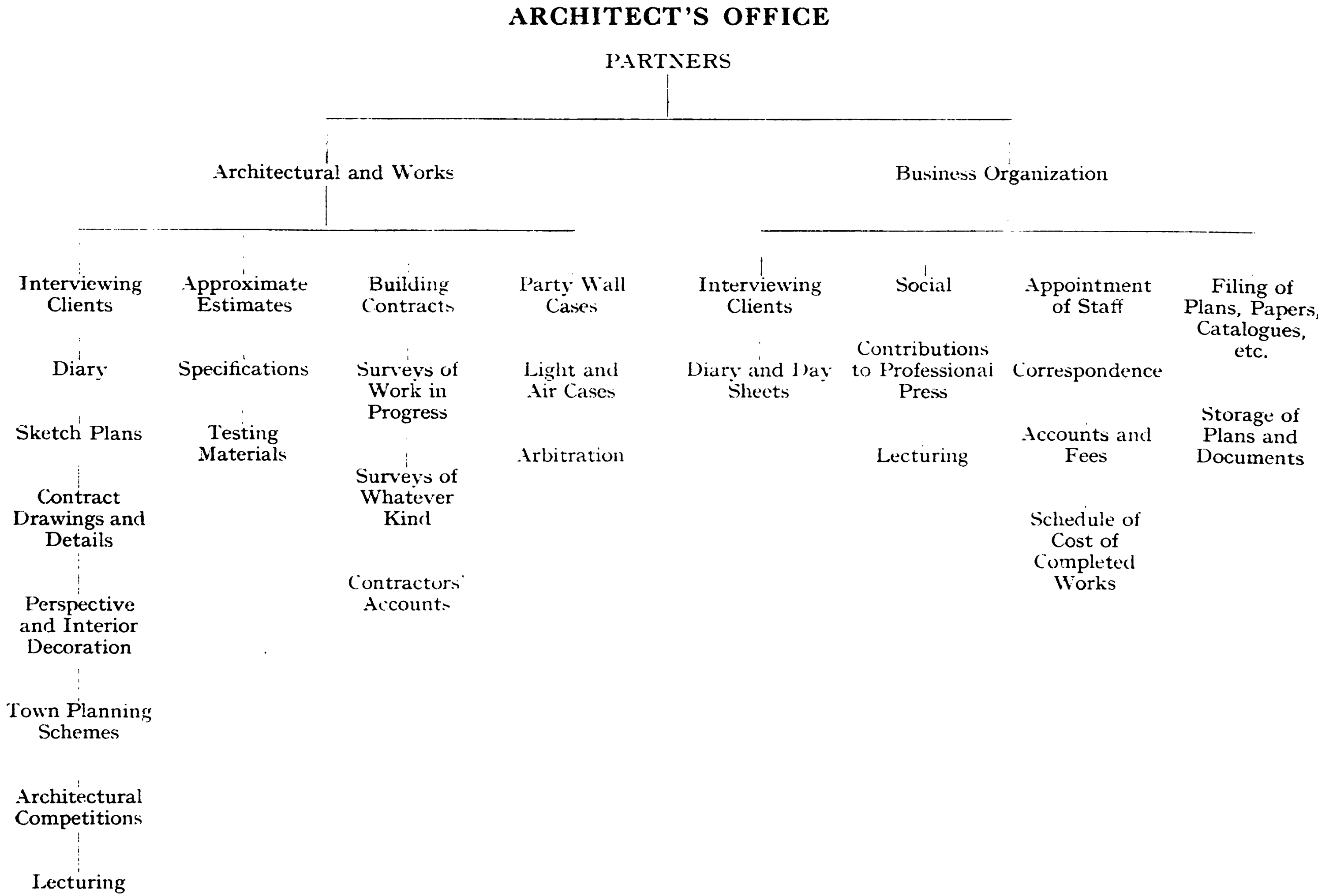


FIG. 1. CHART SHOWING THE ACTIVITIES OF ARCHITECT'S OFFICE

PRELIMINARY OPERATIONS

By R. Vincent Boughton

LESSON I

GENERAL PRELIMINARIES

Preliminary Operations in all building undertakings, whether small or large, require very careful attention by the architect who designs and specifies the various works, and very careful forethought and organization by the builder who executes the work. While the architect has to design and compute so as to assure that the foundations and general preliminary works of a structure will be safe and correct, and yet economical, the builder has, in addition to carrying out the work in accordance with the architect's designs and instructions, to give attention to many matters which are not always of great import to the architect but very essential to the builder to allow for the economical and proper working of a contract with that co-operation of all things and labour that is so vital where work has to be properly done and a profit obtained.

Order of Lessons. For the purposes of these lessons it has been deemed advisable to treat the preliminary operations in approximately the same order as a *builder* should conduct them, and to deal conjunctively with matters of design, computations, and other subjects which are usually within an architect's province; in other words to carry the student through the various stages from either a vacant site or existing structure where alterations are to be made, to the end of the operations which are termed preliminary.

Drawings, etc. The builder's first essential is a complete set of all the general drawings, comprising plans, elevations, sections, and a sufficiency of details to enable the work to be correctly set out and the ordering of all those materials and manufactured articles which are required very soon after the commencement of a contract. A complete specification is also necessary. Architects usually supply two copies of drawings and specifications, one each for the builder's office and the job. Two copies are usually insufficient for the proper prosecution of a contract, as from its commencement to almost its completion the builder has to send out inquiries for various materials, joinery, sub-contracts, etc., which necessitate copies of drawings, details and specifications being sent out with the inquiries. Therefore, it is necessary to endeavour to obtain from the architect, say, six or twelve blue prints of the general drawings, for which a small charge may be made, or the loan of original tracings to allow prints being taken; copies of details may be similarly obtained. It is often difficult to obtain more than two copies of the specification, so about six copies should be made if possible.

The possession of the above will be invaluable throughout the contract; for instance, prices will be required for joinery, probably labour prices for brickwork, plumbing, plastering, electrical work, and many other trades and materials, and all that need be done is to submit inquiries to four or five firms with prints and extractions from the copies of specification of the appropriate trades, annotated or adjusted as required, and stipulating that the drawings and specification must be returned with the quotation.

If bills of quantities have been prepared, a copy should be given to the foreman and a copy kept in the builder's office to facilitate ordering materials and checking the progress of the works. Some builders do not deem it advisable to let a foreman have a fully priced set of bills of quantities which may indicate the computed profit and general financial considerations of the contract, and consequently only supply an unpriced copy. The writer opines that a foreman should know the costs that he has to work to or " beat," and it is a good course to supply him with a set with net costs of labour and materials without additions for overhead, establishment charges, profit, etc.

Access to Site. A perusal of the drawings will enable the best position for access to site and storage space for materials to be gauged. Wherever possible, access to site for carts or lorries should be as central as conditions will permit and to allow for shortest " roads," to prevent not only the cost of making a " road " but " churning up " of ground in wet weather. Materials, particularly bricks, should be deposited either in a central position or in a number of positions nearest to the work, to save excessive handling costs. At the same time materials must not be placed in such positions that will necessitate their premature removal to permit the progress of other trades.

The Foreman's Office should be " sectional " to allow for easy assembling and dismantling at various sites, 6 to 7 ft. high at eaves, from 7 ft. × 6 ft. to 12 ft. × 8 ft. on plan depending on the size of the contract, and constructed with boarded floor on joists, timber-framed walls covered externally with match or weather boarding, and timber-framed roof, weather boarded or felted ; it should be fitted with door, window, pay hatch, letter box, bench, drawer, stool, and stove ; also shelves for storage of small valuable materials such as ironmongery, plumbers' fittings, etc. It should be erected on site in such a position as to allow, as far as possible, a view over the whole of the building operations.

A telephone should be installed on jobs of importance to allow for prompt decisions being made between the builder and foreman on the points that arise almost daily, and to allow the foreman to quickly communicate with merchants about delivery of materials and for general uses that will save time and correspondence.

Hoardings. The necessity of a hoarding, which is a rather costly item, depends on the locality of the works, the degree of protection that is required, and whether a watchman is employed or not. In a quiet, good class neighbourhood a hoarding may not be essential, particularly if there is an existing hedge or fence, or a cheap form of fencing can be erected. If the site abuts on a busy thoroughfare, or it is necessary to protect an existing building which is being altered, a proper close boarded hoarding will have to be erected.

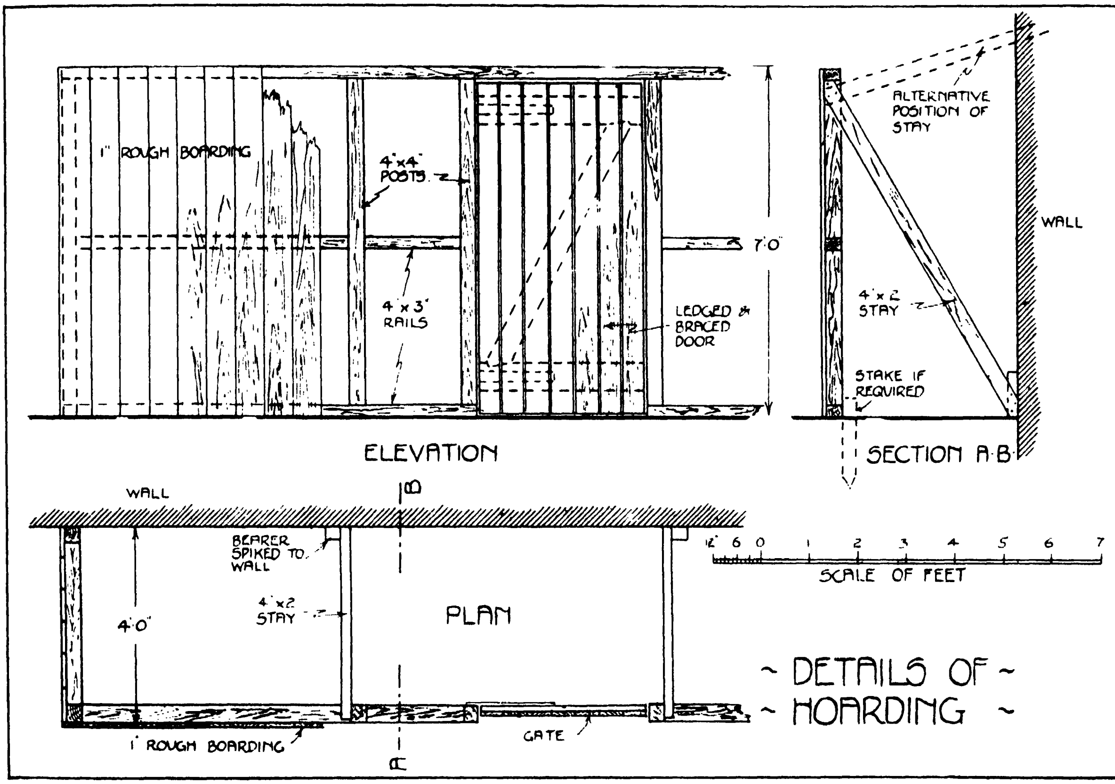


FIG. 1

There are several types of hoardings ; some are formed with stock sections kept by builders and fixed to a timber framework ; others of old doors, shutters, etc., secured to a similar framework. The most common type is that formed with rough 4 in. × 3 in. or 4 in. × 4 in. posts at about 6 ft. centres, with three rails of 4 in. × 2 in. or 4 in. × 3 in., and covered with 1 in.

rough boarding. The posts may be let into the ground where there is no pavement to disturb, or a better way is to place a sole or sill piece to which the posts are spiked or dogged. The posts must be suitably strutted or stayed to ground, building, or scaffolding. The hoarding should project at least 4 ft. beyond the building line and have access door fitted with lock, etc., to allow for materials and men passing through. Where a hoarding abuts on, or is constructed over, a public footway the doors must open inwards to prevent obstruction on the footway or injury to pedestrians; most local authorities' by-laws demand this. Fig. 1 shows a typical hoarding.

Water for building works is an important preliminary, and application should be made to the water company immediately a job is begun. If the work is in connection with an existing building, the water would be already in the building, and when the water company has been notified a connection may soon be made. In the case of a new building, it will probably take a few days to install the supply. As the building supply will eventually be the permanent supply, it is necessary to instruct the water company to lay their pipe in the correct position for the future rising main. Provide necessary water tanks, pipes, hose, taps, roses, etc., for the works.

Sheds for Storage of Materials and Mess-room. Weather-proof sheds must be erected, unless there are suitable erections on the site, for the storage of cement, lime, and general perishable materials, and also a mess-room for the men. The size of sheds will depend upon the magnitude and class of contract, and as they are costly they should be made in sections to allow for removal from one job to another. They should be of sufficient size to accommodate a reasonable quantity of materials to prevent shortage at any time.

They should be constructed with strong, dry, boarded floors, and have timber-framed walls and a roof covered with suitable material, as weather-boarding, boarding and felt, or corrugated iron, and be fitted with doors with locks, etc. Their position should be both suitable to give easy access for delivery of materials and for withdrawal to the works, near to mixing stages or platforms, and generally in a central position. If the building operations are likely to continue for a considerable time, a rough brick fireplace should be built in the mess-room.

Insurances must be effected, before work is started, against fire, employers' liability, including third-party risks, and any special risks.

ESTIMATING

(*Continued from page* 51)

In the foregoing sketch it is assumed that the structure is 32 ft. in length, the chimney stack is 1 ft. 6 in. wide, and the two dormers are each 3 ft. 6 in. wide. The "height" is found as follows: Half of 10 ft. is 5 ft., half of 2 ft. 6 in. is 1 ft. 3 in., and these figures added to the height of 24 ft. (from ground level to eaves) give 30 ft. 3 in. The height of the chimney stack is taken from the position where it first emerges from the roof. As one side of a dormer is a triangle, take the dimensions of the dormers *above* the roof and take *half* of their cubical contents.

The dimensions are as follows —

ft. in.	ft. in.	ft. in.
25 0	4 11.	2/½/5 0
32 0	1 6	3
30 3	8 0	4

There are other methods of finding the "cube," but the student must note that whatever method he adopts, he must strictly adhere to it.

EXERCISE I

1. If the structure as shown in Fig. 1 costs £1,525 11s. to erect, what is the cost per foot cube?

DRAINAGE AND SANITATION

By HENRY C. ADAMS, M.INST.C.E., F.R.SAN.I., ETC.

LESSON I

Ancient Sanitation. The disposal of the waste products of the human body presented no difficulty and called for no consideration until men began to congregate in large numbers in confined spaces. It is probable that for many generations, if not for centuries, the question then was not one of the danger to health but of the avoidance of discomfort and annoyance from the proximity of foul effluvia. It was no doubt discovered very early that fresh earth had a deodorizing effect, and the natural consequence would be to cover the impure accumulations with it. We are told that the Israelites in their wanderings carried little wooden spades with them for this purpose.

All the elders of the present generation can remember the privy middens that were in use even in the outskirts of London up to the last quarter of the nineteenth century, and are still to be found in all their foulness in many country places. The advent of the "night-man" to empty them was an occasion to be remembered for the next few days. No attempt at disinfection or deodorization was made simply because the people of those days knew no better. In the better class houses at the West End of London matters were rather worse, because cesspools were sunk in the basement, and as soon as one was full it was covered with stone slabs, and another sunk alongside. Even when drains were provided they were large brick culverts always in a foul condition. Efficient traps were unknown, the bell trap in the kitchen sink and the pan below the basin of the w.c. marked the limit of sanitary knowledge of the day, the w.c. being flushed by water direct from the daily water supply cistern. Although numerous Public Health Acts were passed, it was not until they were consolidated in the 1875 Act that any real progress was made.

CONSERVANCY SYSTEMS

The term *conservancy* is applied to any system where the foul faecal matter is retained on the premises for a more or less lengthy period. They are sometimes described as *Interception* systems. Even when constructed and maintained in the most hygienic manner these systems are quite unsuitable for use in towns. In the country, conservancy systems may be quite satisfactory if the conditions are suitable, as would be the case if every cottage stood detached on its own plot of ground; but in many circumstances the cottages are huddled together and the systems are allowed to degenerate until they become a real menace to health. The alternative to a conservancy system is the *water-carriage system*, in which water flowing through drains is used to remove the foul matter from the premises immediately it is produced. The success of this latter system depends upon the sufficiency of the water supply, and this, in general, does not obtain unless there is a proper piped public supply laid on to each house. A good supply of water is not only necessary to keep the drain in proper order, but to continue the transport of the foul matter through the public sewers. If the supply of water is deficient a water carriage system may become quite as unsatisfactory as a neglected conservancy system.

The foul matter derived from an inhabited house comprises certain liquid wastes, consisting of water polluted by its contact with grease, soap and other impurities resulting from personal washing and bathing, house cleansing, and laundry washing, together with the waste water from culinary processes; dry, or semi-dry vegetable refuse, urine and faeces. Conservancy systems are only intended to deal with the faecal matter, although a certain amount of urine must also of necessity be included. The remaining liquid waste should be distributed over the garden ground attached to the residence so that it drains away into the subsoil. The vegetable matter should be dumped on to a refuse heap where, in the course of from one to two years, it will completely rot and may then be used to manure the garden.

Middens. A midden is a pit or a hole in the ground formed for the reception of faecal matter. In its earliest form it consisted of a hole dug in the ground, and having a board, with an opening in it, supported over the hole for a seat. An improvement upon this occurred when it became customary to put a brickwork floor and walls to the pit, and to erect a small building over it to screen the user and protect him from the weather. The two principal objections to this system were the large volume of foul decomposing matter exposed to the air, and the invariable admission of water into the pit. The pits were large, so that the excreta were retained for very long periods until in the greater portion the process of putrefaction was complete.

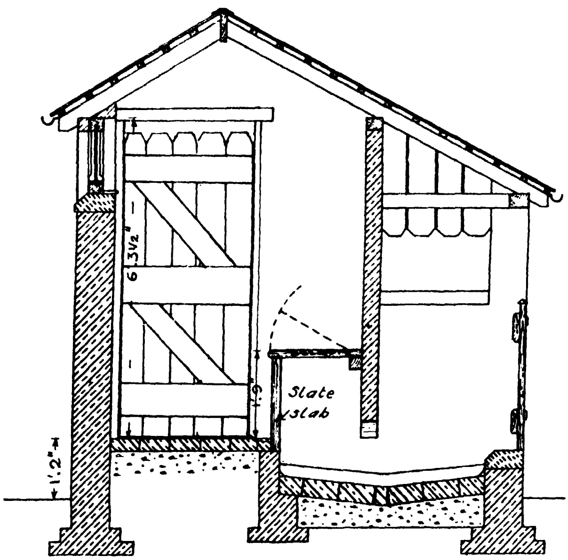


Fig. 1. Privy and Ashpit

Putrefaction, or decomposition, is the term employed to denote the decay or dissolution of organic matter brought about by the action of living organisms, or bacteria, present in the excreta or other organic matter. It is accompanied by the emission of foul gases, including ammonia and its compounds, which have a pungent odour, and sulphuretted hydrogen, which has a putrid smell. The foul gases are subsequently purified by the oxygen in the air, thus reducing the amount of oxygen normally present, and impairing the vitality of those breathing the polluted atmosphere. When the excrement is exposed for long periods in the open air it attracts dung-feeding and dung-breeding insects, including beetles, privy-bugs, and flies which spread zymotic diseases, that is, those diseases similar to small pox, supposed to be produced by germs entering the system and acting like a ferment. The admixture of water, urine, or dampness of any sort to excrement, causes it to give off a foetid odour; but so long as it is kept dry, by adding sufficient soil or other matter to absorb moisture, little nuisance will occur.

Privy Middens. A privy midden is a building with a fixed receptacle for faecal matter. Frequently the receptacle is also used for ashes, when it may be known as an ashpit-privy; its construction is shown in Fig. 1. Ashes may always, with advantage, be put into a receptacle primarily intended for faecal matter, but faecal matter should never be put into a receptacle provided for ashes. If used for faecal matter only, the receptacle must not exceed 8 cub. ft. in capacity, say, 3 ft. × 2 ft. × 16 in. deep, but if also used for ashes the capacity can be enlarged to 10 or 12 cub. ft. In the latter case too, there may be openings through which the ashes may be thrown, but for faecal matter only it is desirable that the pit should be enclosed, except for such openings as may be required for ventilation. If uncovered faecal matter is exposed freely to the air it attracts flies, which walk over it in feeding, and then, with the filth adhering to their legs, probably fly to the nearest pantry and walk over the food destined for human consumption.

The emptying of privy middens is generally a difficulty unless a cart can be brought up alongside. The material is spadeable and can be transported in a wheelbarrow. An iron barrow is desirable in order to avoid liquid drippings soiling the ground. If there is no way from the back to the front without going through the house, a privy midden should not be used, but if one does exist under such conditions the contents should be buried in the garden and covered over with at least 12 in. of soil. The emptying should take place at intervals not exceeding three months, and when the contents are removed the interior should be sprinkled over with chloride of lime.

Where privy middens are sanctioned by bylaws, it is generally provided that the buildings shall not be within 6 ft. of the dwelling house. This is very close and they should be at least 20 ft. away. The floor of the pit should be constructed of non-absorbent material, not less than 3 in. above the ground. The floor and the walls to a height of 4 ft. 6 in. should be rendered in cement mortar or covered with asphalt, unless they are formed in blue brickwork in cement. Every precaution against leakage should be taken, but, as an additional safeguard, the building should be located so that it is at least 40 ft. away from any well, spring, or stream used to supply water for human consumption. Under no circumstances should any drain be made in the pit, nor any connection to external drains. Not only would the drains most probably become blocked, but their presence would encourage the throwing of slops into the privy, with consequent nuisance. A drain would also prevent the early detection of wetness or dampness which must not be allowed to exist, and is the reason why the floor is kept above the ground.

Pail Closets. Pail closets are technically privies with movable receptacles. They are in every way preferable to privy middens, but they are not suitable for use in towns. The London County Council by-laws permit pail closets, but the restrictions surrounding them make construction almost impossible. For instance, the building must not be within 20 ft. of a dwelling house, nor within 100 ft. of any water supply. It must be located so as to be easy of access and such that the filth can be removed from the premises without being carried through any dwelling house or other building.

The general arrangement of a pail closet to comply with the usual by-laws is shown in Fig. 2. Sufficient openings should be provided for ventilation as near to the top as possible, and communicating with the open air. The floor should be not less than 6 in. above the ground, and should have a fall towards the door of $\frac{1}{2}$ in. per ft. The portion under the seat should be sunk 3 in. lower, leaving it 3 in. above the external ground. The floors and walls should be of flagging, slate, or good brickwork at least 9 in. thick, rendered in good cement or asphalted so as to be non-absorbent. The riser at the front of the seat is preferably formed with a 2-in. slate slab. There should be a door at the back or side of the pail chamber for the removal of the receptacle and the cleansing of the space. If this is impracticable, the seat may be hinged so that the pail can be lifted out.

The capacity of the pail must not exceed 2 cub. ft., or say, 16 in. diameter and 18 in. deep. This limitation is to prevent misuse and to ensure frequent emptying. Pails should be emptied at least once a week, but every three days is preferable. Guides should be provided to fix the position of the pail under the seat so that the excreta shall fall into the receptacle and not foul the floor or sides of the space. The

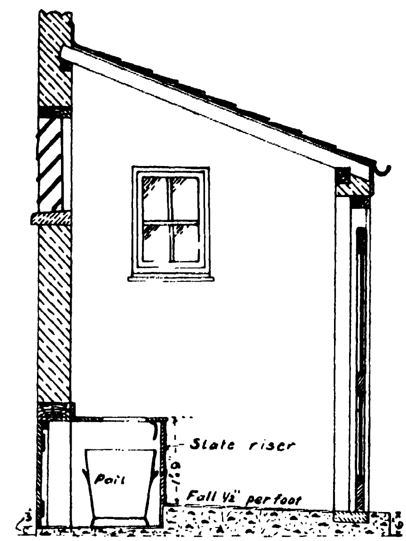


FIG. 2. PAIL CLOSET

best pails to use are of galvanized iron or mild steel. They should be oval in shape and formed higher at the front end than at the back.

A local authority may undertake the emptying of the pails, otherwise the occupier is responsible. They are generally emptied at night, a man going round with a "night-soil" cart and tipping the contents of the pails into it. Where the authority undertakes the work, an arrangement that is most satisfactory comprises the use of pails having air-tight lids, which are taken, with their contents, to a central depot for emptying and cleaning; a fresh pail is left in the meantime at each house in exchange for the pail removed.

BUILDER'S OFFICE AND ROUTINE

By R. F. Galbraith, B.Sc.

PART I

THE BUILDER'S OFFICE

Situation. The situation of the office of a builder is of considerable importance. It must be in close touch with both workshops and stores ; it must be near the centre of the circle of operations, and it should be accessible to architects and other clients.

If the office and workshops are in a big city the office will be convenient and accessible, but the rent and rates on the premises will be heavy. It is difficult to obtain a satisfactory builder's yard near the centre of a large city.

The alternative, the office and works situated in outlying districts, has the advantage of cheap rent and rates, combined with a convenient and ample yard, but the works are removed from the sphere of work, and transport charges are increased.

A city office with works in an outer district lacks the close co-operation between office and workshop which is essential.

In choosing a site, the advantages must be set against the disadvantages and a decision made on the merits of the case.

Size. The size and arrangement of a builder's office will naturally depend on the size and importance of the concern, but the following departments or divisions must be accommodated—

- Directors and management.
- Surveyors and estimators.
- Buyers (often the same staff as the estimators).
- Accountant and cashier.
- General clerical and typists.

No general rules can be laid down for the planning or arrangement of the office. Most building businesses grow gradually and the offices are enlarged as required, but it is most essential that the offices, wherever situated, should be well lighted and as quiet as possible, in order to obtain the maximum efficiency from the staff.

Equipment. The equipment of the office need not be elaborate, but should be carefully arranged. The essential requirements are suitable desks, files for letters and other papers, telephone, typewriters, and ample storage space. The ideal desk for general work is a flat table, 2 ft. 8 in. high with pedestals of drawers between each worker. Plan drawers should never be fixed under a desk to be used for writing, but should be fixed as a separate fitting. It is impossible to work properly in front of plan drawers, and it is not convenient to obtain plans from a set of drawers when someone is working in front. A low desk should be supplied for the typewriter and independent desks for the manager and other important officials.

Filing Equipment. Undoubtedly, the best form of file is a vertical filing cabinet. This is convenient to use, and papers required can be obtained from it easily. The initial cost is fairly high, but this will speedily be saved. Next to a filing cabinet, the book form of file is best. Holes are punched through the papers to be filed and the papers threaded on to metal pins and fastened in with a clip.

A separate file should be provided for "letters received," "letters dispatched," "invoices," and "accounts." At the end of each three months, the filed papers should be transferred to binding files and retained in a store for several years, as invoices and letters are frequently required at the settlement of a contract.

Drawing Office. The drawing office should preferably face north and be very well lighted. Ample storage room should be provided for plans and drawings. A flat desk, about 3 ft. high, is convenient for drawing boards, which should be slightly tilted. If an electric copying machine is provided, it should be housed in a separate room, and not in the general drawing office.

Mechanical Equipment. A typewriter is essential to a builder's office, as well as a telephone with the necessary extensions. A duplicator is useful, especially for dealing with inquiries, bills of quantities and specifications, etc. A fireproof safe should be installed for the custody of financial books, contracts and other important documents.

SUPERINTENDENCE

By P. J. LUXTON
Member of the Incorporated Clerks of Works Association

PART I

PERSONNEL

THE supervision of building work is the business of a number of different types of men, representing the person or persons for whom the building is being erected, and the contractor or contractors who have undertaken to do the erecting. Each have their separate and defined functions.

The Building Owner's Representatives. The building owner is represented by the *architect, his assistants*, and the *clerk of works*, who, for all practical purposes, may be regarded as the architect's assistant on the job. In addition, the building owner, who is generally termed the *employer* in contract documents, may be represented by various *consulting engineers*—structural, heating and ventilating, electrical—and even mechanical, where there are a lot of lifts or machinery. These act separately, in that they are employed as experts responsible for their particular section of the work, but all are either under or in consultation with the architect.

Whatever their work may be, it has to fit in with the general plan and scheme of the building which he has designed. It is usually on large jobs only—public buildings, extensive commercial premises, places of entertainment or big factories—that the consultant is required. On small buildings the building owner will probably be represented by the architect only, although assistants that the latter employs may be deputed to visit works in progress, if they are sufficiently experienced to be of use in that direction.

The Contractors' Representatives. The representative of the contractor is almost invariably his foreman: a *general foreman* if the job is large enough to require one whose whole time is devoted to supervision, and a *working foreman* on smaller works where the organization side does not require so much attention, or where the builder assists with the supervision. In this case the foreman, who is a craftsman, works at his trade.

The general foreman has practically full control of the job, as far as the contractors' work is concerned, and usually receives his instructions from a manager, or the estimator who has priced the bills of quantities; but these do not interfere, except in important matters, when the general foreman is a competent man who has the confidence of his firm. Whether the contractor or contractors—in the case of a firm with a board of directors—take any active part in the actual erection of the work, and frequently visit the job, depends upon its size, and the extent of the firm's general business. The largest firms leave that sort of thing to their managers: the contractor lower down in the financial scale cannot afford highly paid assistants, and keeps in close touch with all phases of his work.

The general foreman has deputies who see to the various trades, navvies, bricklayers, carpenters, plumbers, painters, and so on, who are described either as *deputy-foremen, gangers*, or by the rather objectionable term *leading hands*. When the job is going ahead, and many are employed, these supervisors have enough to do in keeping their part of the machine running smoothly. At other times, as when their branch of the work is only beginning or nearing its conclusion, they work as operatives.

Sub-contractors. One other type of supervisor, who acts indirectly under the general foreman, is the sub-contractor's leading man. Except on large jobs, he works at his trade. Typical examples are asphalters, steel erectors, floor layers of various kinds, slaters, tilers, erectors of special types of constructional floors, heating and ventilating engineers, electricians, marble fixers, and lift erectors. At intervals an outdoor manager, or similar representative of the sub-contractor doing the work, visits the job and gives any necessary instructions to his men; but for all practical purposes they have, while on the works under his control, to carry out the orders of the general foreman with regard to general procedure.

Thus there is a great variety of method, varying from that on the largest of jobs, where the contractors may be represented by a manager or agent, a general foreman, and his numerous satellites, and the owner by a chief and assistant clerks of works down to that carried out by the small speculative or jobbing builder, where the supervision is almost nil, and nothing but good luck produces a satisfactory financial result. This general description applies, of course, to the type of building work which is most frequently met with, where a contractor undertakes to perform specific services for either a lump sum of money, for prices set forth in a schedule, or for the actual cost of the work plus a percentage for overhead charges and profit.

Direct Labour. All building work, however, is not done on this basis. Some large commercial firms, with works departments, buy their own materials and plant and engage their own labour; whatever may be required, either the erection of new premises or the maintenance of existing, is done under the superintendence of their own staff, probably a manager and various kinds of foremen. Some municipal authorities adopt this method, and, to a certain extent, it is also resorted to on large estates, and such establishments as cathedrals and hospitals. On both the estates and the establishments the superintendent is usually the clerk of works; and he has a staff of supervisors, clerks, etc., varying in number according to the extent of the area covered, and the amount of money spent.

The two typical superintendents are the clerk of works and the general foreman. Whatever applies to them with regard to methods of supervision on large works, applies in a lesser degree to their prototypes on works of lesser importance. In the explanations supplied in this Section, they will be the principal persons dealt with, and as much relating to the purely technical side applies to both types, this part will be incorporated in the description of the clerk of works' functions.

Classification of Duties

The duties of the building superintendent can be divided into three groups: *technical*, *financial*, and *social*. The first applies to the materials and processes peculiar to the erection and equipment of buildings, and with it is closely interlocked the financial—the cost of the materials and processes. For instance, the cost of making and fixing a stone ball on a brick pillar will depend upon the judgment shown in selecting a suitable stone, and the method and craft of the mason doing the work.

The third group, the relationship of one individual to another, is largely independent of the other two. Any remarks on this subject have a general application, and no special significance for any particular superintendent: it will therefore be dealt with at this stage.

Now, it is true that in any occupation social harmony and co-operation are important matters, whether it be a printing office, football club, boot factory, or drapery store. But in constructional works, and building works in particular, which contain more detail than does, say, harbour construction or bridge building, there are factors which do not apply elsewhere.

The number and variety of persons concerned exceed those engaged in any purely manufacturing process in a factory. They range from the building owner, architect, and contractor, down to the mess-room lad, and include a variety of highly skilled craftsmen, whose accomplishments are the result of many years training. In many factories a process can be learnt in seven days. A skilled plumber has to spend that number of years at his trade, before he reaches a good standard of proficiency. Then there are always a number of unskilled men who are of all types. They are engaged without reference to character, they can go at an hour's notice, and be discharged at an hour's notice. They have not undergone the disciplinary training involved in acquiring a skilled craft, and sometimes they can be very unpleasant.

In addition to the principal persons, the owner or owners, the architect and the contractor, there are surveyors, persons who will be using the building and like to get a hearing at intervals, makers of different materials, the officials of public authorities concerned with Building Acts, By-laws and Regulations, representatives of sub-contractors, and even reporters and the police.

In the middle of all these, receiving instructions, hearing complaints, and supplying information, are the building superintendents. They have to adjust their dispositions to deal with all kinds of weather, personal risk, matters giving rise to controversy, trade disputes, cramped surroundings, often much dirt and discomfort, avoidable and unavoidable delay, and the exactions of their superiors. No two large buildings are alike; on each new one fresh problems arise, and when the work is finished the superintendents may have to find fresh employment. Holidays have to be taken when circumstances permit, and sometimes they do not permit for several years.

Mutual Co-operation. It is impossible to define lines of conduct applicable to these differing circumstances. The superintendents have their personal idiosyncrasies which are inherent. There are times when two men of different character constantly in contact, as the clerk of works and foreman are, cannot get on at all. There have been instances where the two have ceased to speak to each other, and during part of their time together have expressed themselves in writing only, although constantly meeting and occupying offices only a few yards apart. There are also circumstances when a fraternal relationship is impossible on account of the tactics adopted by one or the other, unscrupulous methods, unjust demands, or deliberate rudeness.

But these are exceptions; both men occupy responsible positions, with their separate duties to their employers; and an attitude of tolerance and respect, each recognizing that the other has many difficulties, is the only sane one. The clerk of works should appreciate the fact that the builder has undertaken to do the work because he hopes to make a profit, and that losses are experienced as well as profits. The foreman, in his turn, should realize that a contract is an obligation to perform defined services, and that the duty of the clerk of works is to see that this is done. But both should adopt a courteous attitude, refrain from trespassing on each other's rights, and render mutual assistance, without in any way neglecting their duties to their respective employers, whenever occasion for doing so arises.

The clerk of works should not interfere with the general conduct of the work, as long as the stipulations of the contract are being observed. He should deal direct with the foreman, or, in minor matters, with the deputies, when the general foreman does not object to that being done. He should not give instructions to workmen, or hinder their operations. He can, however, often make useful suggestions with regard to procedure which will not be resented; on the other hand, they will often be cordially welcomed.

It is not, as a rule, wise for the clerk of works to recommend that any particular person be employed unless he is very sure of his man; the foreman may be inclined to suspect that this is being done in order to obtain information. But he has the right to object to the employment of a man whom he regards as being unsuitable, such as an incompetent mechanic. Under the terms of the contract this should be done by the architect, but usually the authority of a clerk of works is recognized in such matters.

Geoffrey Chaucer
Father of English Poetry

With regard to the attitude of the foreman to those employed under him, there is usually something wrong if an atmosphere of general dissatisfaction prevails on a job. It is his business to see that the men know what they have to do, can perform their work in reasonable safety, are not compelled to lose time where such loss can fairly be prevented, and are supplied with proper accommodation for meals, safe storage for tools, and clean sanitary conveniences. When it is necessary to point out mistakes, this should be done without giving offence.

The Clerk of Works

It has been mentioned that there are several types of clerks of works. The name is an old one, and the earliest records refer to him as a court official who rejoiced in the name of *Clericus Operationum*. His duties appear to have been connected with accountancy—the keeping of records and costs—rather than with the supervision of building work. This followed

(Continued on page 31)

ESTIMATING

By Henry A. Mackmin, F.S.I., M.R.San.I.
Author of " Builders Estimates and Pricing Data " ; Lecturer on Quantities and Estimating, Wandsworth Technical Institute

LESSON I

METHODS OF ESTIMATING

Introductory. The preparation of builders' estimates is a task that needs considerable experience, and no matter what position one may occupy in regard to the construction of buildings, sooner or later will the question of cost arise. The client may either stipulate the cost of the work must not exceed a certain amount, or as soon as the drawings are ready he will require to know the approximate cost. The architect will either prepare a rough outline of the cost himself, or perhaps he may consult a quantity surveyor, which is the wisest thing he can do in the circumstances. In the provinces, it sometimes happens that the architect prepares his own quantities, but in London and other large towns, independent quantity surveyors do the work

Methods. The architect frequently bases his approximate estimate upon what are known as " cube " prices ; whilst the quantity surveyor is more likely to prepare " rough quantities " and price the items upon actual data required from other work, similar in character.

The latter method is more reliable than the former ; in fact, " cube " prices if used by the inexperienced can be very dangerous as well as misleading. When proper measurements are taken and a careful bill of quantities prepared, the preparation of prices is not so difficult a matter for the builder, or his estimating surveyor, as when drawings and specification are supplied ; for in this latter event, the person preparing the estimate will find it necessary to take off the quantities as well as prepare the prices. Many building firms of repute now refuse to tender unless bills of quantities are supplied, except of course for small jobs, repairs, or decorating work ; but when it does become necessary for the builder to take off quantities, the latter do not contain anything like the amount of detail as given in a surveyor's bill of quantities, but are in the form of " rough " quantities as mentioned earlier.

It may happen that the client himself consults a builder and asks him to prepare his own specification and estimate, in which case it also becomes necessary to prepare " rough " quantities. This name does not accurately describe the work, " grouped " quantities would be a better term. Often the client consults more than one builder, which means that several men are occupied upon similar tasks, but only one of them will be repaid. This is one of the difficult problems in the building trade, and the custom is probably due to so many persons offering to supply " estimates free," a description one so often finds upon billheads, and even displayed in advertisements.

The amount of time expended in the preparation of estimates for work which he does not obtain is a serious matter to many a builder. It is to be hoped that in the near future some remedy may be found, for it is not fair to expect one section of the community to work for nothing.

From the previous remarks it will be seen that there are practically three methods of estimating : " cube " prices, " rough " quantities, and detailed pricing of accurate bills of quantities. The writer hopes to be able to explain each method, but most attention will be paid to the latter process and the analysis of prices. There is one other form of pricing, which, however, can hardly be considered a method, but which is used by certain individuals, particularly with regard to painting and decorating work. It simply consists of guessing at the price. The individual concerned may claim that his past experience enables him to form his idea of price without taking any measurements ; but the writer has found that the more experienced a man becomes, the less he relies upon anything in the nature of gambling with prices and measurements. With " spot items " it is necessary to a certain extent to compile the prices without taking measurements, but even these figures can be compiled in a scientific manner.

To prepare a reliable estimate there is only one sound method, and that is to prepare, or to have prepared, a proper bill of quantities, and to price each item in a careful manner, using prices prepared upon a detailed analysis of each separate task.

Tenders. These can be of two kinds, that is, *lump sum tenders*, and *priced schedules*. For lump sum tenders it is usual for bills of quantities to be prepared, and these are forwarded to builders for them to price. After pricing each item in the bill, the builder forwards the total only, as his tender; and later, if his price is accepted, he forwards a complete priced bill. The priced bill becomes the basis for any variations that occur during the progress of the job; any extras or omissions are priced at the prices contained in the detailed bill of quantities.

Another form of tendering is for the architect to forward the builder a schedule of typical items that are likely to occur on the particular job, but without giving any quantities. The builder prices each item, and later on as the work proceeds it is measured up and priced at the rates quoted. Government departments and municipal authorities sometimes prepare a priced schedule of all items likely to occur in a building; and this document is forwarded to contractors, who quote a percentage to be added to, or deducted from, the prices given in the schedule. It is obvious that the great disadvantage of priced schedules is the difficulty of knowing in advance the size of the job, and the impossibility of finding if the job is profitable or otherwise until the work is measured up. Tendering by giving lump sums is preferable, and priced schedules should be used only when it is impossible to prepare bills of quantities.

Variations in Estimates. To the uninitiated the great disparity that occurs between the highest and lowest tenders, as shown in the lists published in the technical press, is remarkable, but even experienced practitioners are occasionally surprised. Two of the principal reasons for this remarkable difference are keen competition and incompetent estimating. An eminent builder recently wrote the writer as follows: "I think at the present time if every builder's surveyor were to price each item of a bill of quantities based upon what the work would actually cost, he would not get a single job."

It often happens that the experienced builder's surveyor will discover some pitfall or circumstance connected with the job that might add considerably to the cost, but which could easily escape the notice of competitors not so experienced; and in such cases he may sometimes price the items at rates lower than they should be, so that his tender may not appear extraordinary when compared with others. There are many other reasons for variations in pricing, but the most annoying one is incompetent estimating. Architects and surveyors are often surprised that such men can retain their posts, but the builder himself knows how very difficult it is to obtain a first class estimating

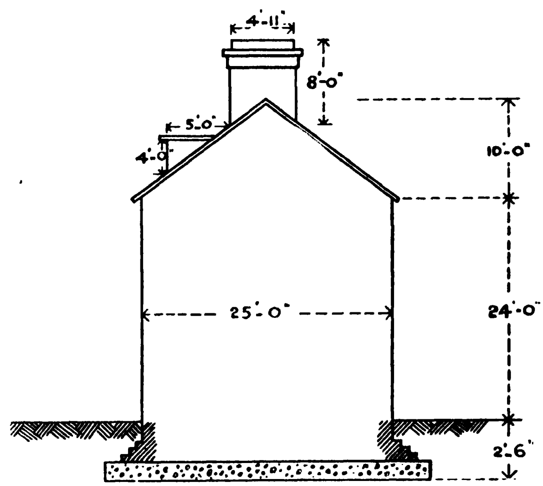


FIG. 1

surveyor, and will often put up with indifferent men until he can find someone more experienced. Many young men imagine that bills of quantities can be priced by simply copying prices from a standard list and then adding or deducting a percentage; it is the writer's intention in these lessons to try and explain how dangerous this may prove.

Cubic Contents of a Building. Before we attempt to explain cube prices and examples it is necessary to mention there are different methods of finding the "cube." Fig. 1 will explain the method preferred by the writer.

The sketch illustrates a small building with one chimney stack and two dormers. To obtain the cubical contents for the purposes of an approximate estimate, the length is multiplied by the breadth, and then by the "height," the latter being taken from a point half-way between ground level and the bottom of foundations to a point half-way up the height of the roof. Afterwards the cubical contents of the dormers and chimney stack are added.

(*Continued on page* 42)

GAS-FITTING

By R. J. Rogers
Chief Superintendent, Fittings Department, City of Birmingham Gas Department

LESSON I

GAS MANUFACTURE

Introduction. The first recorded instance of gas being used in the service of man was in 1790, when Wm. Murdock lighted his cottage with it at Redruth, Cornwall. The possibilities of its application were scarcely realized until Murdock, in 1798, having moved to Birmingham and still continuing his experiments, lighted his own home and the factory of Boulton & Watt in Soho, near Birmingham.

He obtained gas by heating coal in a cast-iron retort, and laid the foundations on which the science of gas manufacture has been built.

Many early experimenters found that in marshy and swampy ground where large quantities of vegetable matter were undergoing decomposition, a gas was evolved—*marsh gas*—which was easily ignited. This same gas under the name of *fire-damp* is known to occur in coal mines. In America and other countries this natural gas was, and is, found imprisoned in the lower strata in immense quantities, and under such pressure that it is possible to tap the supply and convey it long distances to supply neighbouring towns and villages. Although three million domestic consumers were supplied with natural gas in the United States of America in 1922, the quantity available is decreasing and its place being gradually taken by manufactured gas.

Manufacture. Fig. 1 illustrates diagrammatically the process of gas manufacture. The crushed coal is hoisted by means of a conveyor into an automatic hopper from which it is released into a *vertical retort* from which air is excluded. This retort is heated externally and the gas in the coal is driven off, while the coke is continuously ejected at the base. The gas given off is drawn through *cooling towers* where a proportion of the tarry matter is condensed, then through *scrubbers and washers* which remove the sulphur and ammonia compounds. The remaining sulphuretted hydrogen is

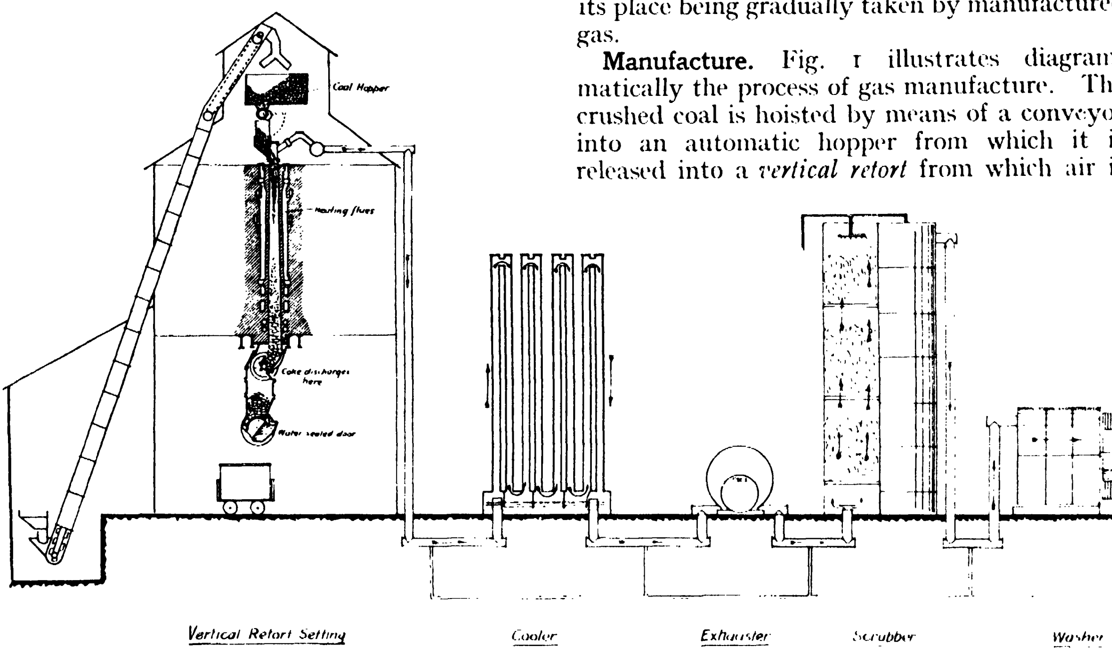


Fig. 1. Diagram Showing Process

separated from the gas by passing over hydrated oxide of iron in the *purifiers*, after which the gas is measured by the *station meters* and passes forward to the *gasholder*. It is the by-products removed in cleansing the gas which form the basis of all aniline dyes and coal tar products.

Composition of Gas. Coal gas obtained from this process of distillation is a mixture made up of various chemical compounds and elements, the proportions of which vary according to the particular coal used and temperature of carbonization.

The approximate composition of straight coal gas made from a Newcastle coal is as follows—

Hydrogen	48·49	Combustibles and Illuminants.
Marsh gas	35·00	
Light yielding hydrocarbons	3·83	
Carbon monoxide	6·01	
Carbon dioxide	0·12	Inert gases.
Oxygen	nil	
Nitrogen	5·05	
	100·00	

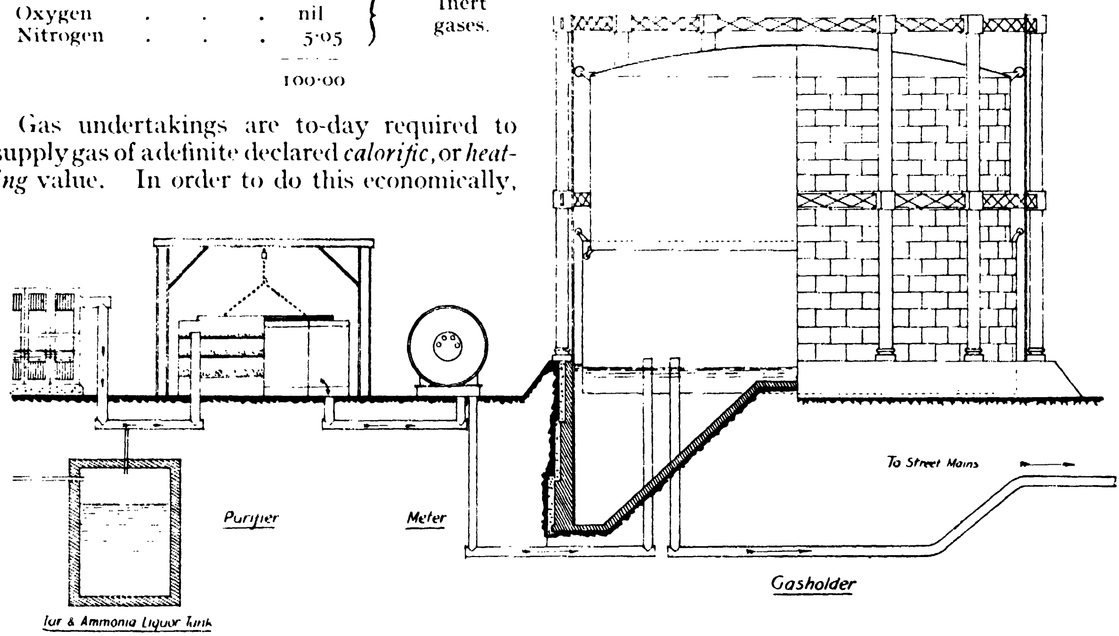
Gas undertakings are to-day required to supply gas of a definite declared *calorific*, or *heating* value. In order to do this economically, requires a known admixture of air for complete combustion. The composition of this town's gas varies according to the *declared value* adopted by the gas undertaking.

The following may be taken as a typical example—

Hydrogen	46·0
Marsh gas	23·0
Light yielding hydrocarbons	2·4
Carbon monoxide	12·6
Carbon dioxide	4
Oxygen	1·1
Nitrogen	10·9
	100·0

It is gas of approximately the above composition which is supplied by the great majority of gas undertakings in Great Britain, and which will be dealt with in these lessons.

Some gas undertakings have adopted a calorific value of 400 B.Th.U. per cub. ft.,



OF GAS MANUFACTURE

it is often the practice to add to the straight coal gas a proportion of *water gas* or *carburetted water gas*. These proportions are varied according to the type of coal used and method of carbonization, the aim being to obtain a town's gas of unaltering thermal value and one which whilst others supply gas as high as 560 B.Th.U. per cub. ft.

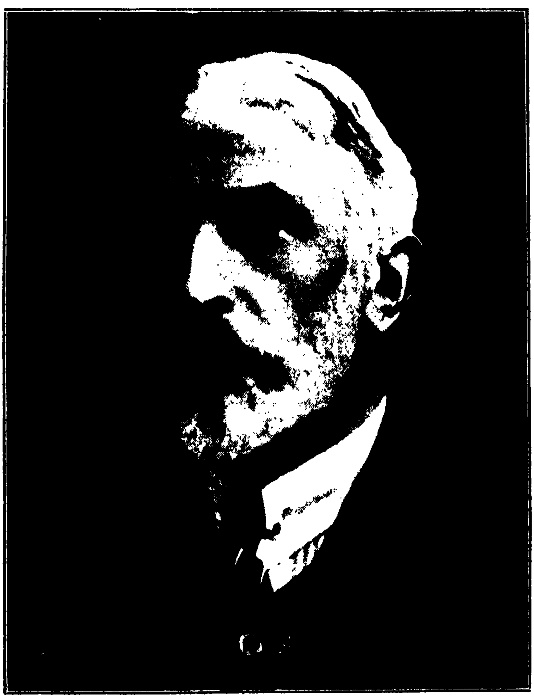
The majority of gas undertakings in the United Kingdom have, however, adopted a calorific standard between 450 and 500 B.Th.U. per cub. ft.

TRAINING AND OPPORTUNITIES
OF AN ARCHITECTURAL STUDENT

By Professor Beresford Pite, M.A., F.R.I.B.A.

PART I

Architecture is both scientific and artistic; its pursuit or practice is the profession of an art as well as a scientific business. By its response to natural gifts and aptitudes it may be truly named a vocation. As in the case of the arts of painting and sculpture, so in architecture, though more rarely, youth may feel its attractive power, and this so strongly that the thought of being bound for life to any other service is intolerable. Men have been born architects in the past; we may therefore look for their types among the rising generation, seeking symptoms of the natural imaginative genius that dreams of great buildings, takes peculiar delight in historic examples, and which strives for opportunity to express its visions.



Beresford Pite, M.A., F.R.I.B.A.

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Natural Gifts. The unquenchable desire to become an architect is among the gifts of nature: it is a symptom pointing towards genius, and may well be encouraged wherever it is clearly distinguishable. But it is well to add that such instinctive and irresistible calling is not common, perhaps very rare. Not many successful and leading architects would conscientiously own its impulse.

Less intense, but sufficiently real natural aptitudes of several kinds may well be taken into account at the critical period in youthful life when the choice of a life-work has to be made. It may not be unnecessary to insist upon the importance of the consideration that success means not only securing more than is sufficient of this world's requisites to live upon, but the rendering of life both useful and pleasurable.

The pursuit of architecture should be sufficiently remunerative for the healthy minded, certainly useful to the community, and also constantly pleasurable to the practitioner. Not only the pleasures of imagination but those of realization lie close to the architect's daily walk in life. They are different from those of the commercial world in essence, and are akin to, but more tangible than, those of many other professions devoted to the pursuit of art or science. To have not only the opportunity of dreaming a vision of beauty but of erecting it solidly on a great scale is the peculiar privilege of the architect, and necessarily it is a pleasure which is an enduring experience. Apart from the contingent responsibilities that wait upon everyone's duty, architecture can be recommended to the hopeful youth as a pleasurable occupation.

Aptitude for Drawing. Among natural aptitudes the first place may be given to the love of drawing, usually shown by facility in freehand representation of form of light and shade, and of perspective. A gift for drawing is not generally regarded as a valuable capital asset, for painters and sculptors are known to have a hard struggle, and the rewards of art are few and cruelly earned. But as the talent for drawing may be combined with useful business in architecture the doubt as to the practice of art as a means of livelihood may be quieted, and a career opened to the born artist in which his talent will not lie buried. This may be generally admitted to be true, subject to the important consideration that other qualities, such as business capacity, are requisite for success in bringing an artistic talent into contact with practical life.

Aptitude for Design. A second place among the natural aptitudes that may be looked for in early life is inventiveness. A marked originality of view is likely to be more useful in a profession which has to design or originate schemes and plans, than a disposition to conform without question to conventional procedure. An architect in busy modern practice, might with truth summarize his daily work as the solution of puzzles, and it may be anticipated that the faculty which in childhood finds the invention of solutions to puzzles to be pleasurable, will be usefully employed in undertaking the difficulties of planning the complicated requirements of a building.

Aptitude for Construction. A third place may be given to the aptitude for construction, perhaps belonging generally to the human animal; a special delight in building as construction, for its mechanical interest has both promise and importance when directed to the service of building. The practice of nursery brickwork is fairly widespread, and mechanical and constructional toys can be graded upwards until the practical interests of the home are brought within the grasp of an intelligent child. Electric bells and lighting lead now to broadcasting installations, but even the more commonplace necessaries, of locks, clocks, and taps, afford opportunities for the exercise of mechanical inquisitiveness and useful knowledge that need not be overlooked in the search for indications of a calling.

The combination of these three aptitudes in one personality, indicating artistic, inventive, and mechanical interests, will be rare, but either of the two latter united with the former will offer a strong promise of natural qualification for an architect's career.

Schooldays. After home and the earlier period, school training should have some proper relation to its end. Nothing, however, ought to qualify the general value of the foundation of a liberal education. Any idea of early specialization that would limit either classics and literature or mathematics and science in the curriculum of a good school must be avoided. The six or seven years given to unspecialized education have an enduring value and influence in after life. To have an outlook towards art and buildings all the time will be a help and not a hindrance to success in every department of study; but it is an ill-service to a youth to ask that time should be taken from the general course of a school for special studies of a limited nature. It is important however, in any extra subjects selected for an intending architect, that the hours of the week allowed either to drawing or carpentry should not be wasted in playing at these subjects, and on this point a word to the instructors ought to be given.

School Drawing. The teaching of elementary freehand drawing, which should be general in al' schools, ought to be accompanied by geometrical drawing. Measured drawings of rooms, of architectural features, as well as of constructional details, is a highly interesting as well as productive method. Sketching buildings in perspective is more illuminating than class room models, and light and shade observed in buildings is more interesting than in shadow copies or artificially lighted casts.

Carpentry, usually taught by a practical man, should be learnt from working drawings, and include setting out. These drawings, the teacher, as a rule, cannot supply, but if he is a practical man he will welcome the use of good architect's or workshop drawings of simple subjects by his pupils, who, by the way, should make their own copies, and thus relate their drawing lessons to their carpentry work.

The Classical or the Modern Side. Of the large question of the classical or modern side of a public school, unfortunately arising in the middle of this period, the necessity of which we will not stay to discuss, it may be said that as an architect needs grounding in each, if both cannot be taken together while at school, it does not matter very much which is taken first. On the classical side the intimate connection of architecture and art with Greek and Roman life, and the illustrations they afford of most of his historical studies, will add interest to his work; while on the modern or science side the practical usefulness to buildings of applied mathematics, physics, and elementary chemistry, in all that concerns materials and construction and the elements, will give point to studies and observation. On the large question of the classical or modern side it will be safe to follow the inclination created by natural aptitudes provided that definiteness of aim and consistency are maintained without rigidity or limited specialization. It often happens that the right and final decision cannot be made until after leaving school, when the wider outlook of a university may unexpectedly open the eye and mind to a truer view of life's calling.

On Holidays. Architectural proclivities may be tested by a judicious use of holidays, with which it is often possible to combine excursions to picturesque buildings and historic towns. A cathedral may be reckoned to have a valuable influence upon an impressionable mind, and the company of an artist friend or architect at the visit will improve the occasion.

16-18. The age for leaving school may not always coincide with that for entering upon professional education. It may be suggested that 18 is the best age for entry either at a university or school of architecture. If it may be assumed that by the time a boy is sixteen his future walk in life tends towards an artistic profession, the two intervening years may with advantage be devoted to drawing. Early facility in draughtsmanship is of great advantage, as later on it will not be easy to find time for the steady grounding which lays a life-long foundation. The changed method of education in the comparative freedom of an art school will have its advantages in independence of outlook and in the formation of critical observation.

There is no definitely authoritative process or period of architectural education. There is happily entire freedom of practice which involves freedom in education. The several usual and possible methods will be dealt with, bearing in mind that variation and interchange may take place between parts of the different processes.

R.I.B.A. Examinations. We will proceed to describe four typical programmes of education, in each taking the three qualifying examinations for the associateship of the Royal Institute of British Architects as indicating accepted courses of study having an examination as its goal.

It is, however, very important to bear in mind that architectural practice is not confined to exact sciences, like engineering, or building construction, to which examination questions and problems can be applied as tests of knowledge and intelligence. The scientific and theoretical branches of the general subject can without doubt be sufficiently tested by standards of accuracy, expressed in written papers and in diagrams, but the *raison d'être* of an architect is his power of inventive and artistic design—an individual gift, not always spontaneous and not invariably associated with the gift of rapid draughtsmanship. This quality, it may be safe to say, cannot be individually tested in the examination room. It requires a sympathetic treatment which can waive comparisons with the normal standards, a comparison that examiners cannot be trusted to exercise with fairness when in competition with their own personal tastes and the necessary ideals of an examination.

Examination System. This consideration, of course, implies entering a caveat against the whole effect of examinations in architecture. The examination courses may well be taken as providing a useful programme and a test of instruction, but they have unhealthy and fallacious results if regarded on completion as hall-marking the successful candidate as a tested architect. Their purpose is that of a fence to the enclosure of the Royal Institute. They must not be mistaken for the enclosure of the field of architectural education, or as an excluding wall to the sacred domain of art, which may shut out the gifted, if individualist, practitioner, or the erratic genius. For genius it is proverbially difficult to prescribe, but the sense of this cannot be sufficient reason for fixing an educational programme which, if rigidly insisted upon, will eliminate from the practice of the profession those gifted sons of art on whose inspiration great works of architecture depend. Considerations such as these will have to be taken into account in weighing the thorny problem of a registration of architects by examination.

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THE ORIGIN OF OUR ENGLISH HOUSES

By A. Gotch, M.A., F.R.I.B.A.

Few people are aware of the wealth of ancient houses that England still possesses, or realize how strong a light these houses throw on the manners and customs of our ancestors at successive periods. We are quite ready to believe that "an Englishman's house is his castle"—although, in view of the modern increase of residential flats, the statement is not of such universal application as it used to be. But we are not so familiar with the idea that at one time an Englishman's castle was his house, and yet it was so to a great extent. The castles, of which ruins are to be found in all parts of the country, and which are often made the excuse for picnic parties, were by no means all of them military strongholds. Most of them were, in fact, private houses; strongly fortified, it is true, in order to provide protection in an age when safety of life and goods was a private, and not, as it now is, a public concern.

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"THE HALL"

Such strongholds consisted in most cases of a tower with extremely thick walls, and containing only some three or four rooms, one over the other. Of these the principal room was the hall, in which the household lived night and day, eating and sleeping there in common, save that the lord and his family could retire to small chambers contrived in the thickness of the walls, very little larger than a sleeping compartment in a night train. Window openings were seldom glazed, but were closed with shutters, which excluded the light as well as the weather. The conditions of such homes would be intolerable to us, and although to our ancestors they evidently were tolerable, they left much to be desired by the inhabitants, and it is the pursuit of greater comfort which through many centuries has gradually transformed these rude, if secure, dwellings step by step into such houses as we live in to-day.

In addition to these very restricted towers there were, in districts where danger from attack was less, houses of much the same amount of accommodation, but in which the rooms were placed alongside of each other instead of one over the other. Here again the chief room was the hall, but speaking in general terms, it had at one end of it a kitchen and at the other end a parlour. The hall remained for centuries the principal room, so much so that it gave its name to the chief house of the village which became known as "The Hall," a designation which survives to the present day.

ELIZABETHAN HOUSES

As manners softened with the lapse of years, and as refinement increased, accommodation became less restricted; at one end of the hall the kitchen grew into a servants' wing, and at the other the parlour grew into the family wing. Thus emerged the great houses of Queen Elizabeth's time, conforming to a type which prevailed for some century and a half, a type which, again speaking broadly, presented the hall as the body of the house, flanked by a family wing and a servants' wing. This arrangement produced a plan which resembled either an H or an E, the middle stroke of the E being formed by a projecting porch. Fanciful writers have said that the E plan was so contrived out of compliment to Elizabeth; and although the form was the result of practical considerations rather than of politeness, yet the notion has the advantage of connecting this type of plan with the period when it prevailed.

By the time of Elizabeth the old conditions of insecurity—which made safety a primary consideration and thus severely limited the size of such vulnerable openings as windows—had greatly improved, and it is one of the characteristic features of Elizabethan mansions that they are full of windows. Indeed, cheerfulness, space, comfort and magnificence in appearance were now the controlling factors in the design of houses, many of which were built of great size in order to accommodate the Queen and her court when she made those "Progresses," or travels, which enabled her to keep in touch with her subjects.

THE RENAISSANCE

But now came another factor that deeply influenced design in architecture. The great awakening from the darkness of the Middle Ages, known as the Renaissance, changed the whole outlook on life so far as Europe was concerned. It had its origin in Italy during the fifteenth century, and one of its results was that the influence of Italy, especially in matters pertaining to art, gradually spread over the whole of the west. England felt it along with her neighbours, and in course of time her architecture answered to the new stimulus. Italian forms and methods of expression were adopted by English craftsmen, but they were harmonized to a certain extent with the old native traditions. The resultant architecture was a piquant mingling of the old and the new. But, as usual in such circumstances, the new ousted the old, and in the course of the seventeenth century the change became so complete that by the time of Queen Anne a style of architecture had become established widely differing from that of Elizabeth. One of the most potent agents in the change was the celebrated architect, Inigo Jones, who had passed a long time in Italy studying its buildings. Sir Christopher Wren followed the same lines, and after him Vanbrugh, and other architects of the eighteenth century, became more and more wedded to the new ideas.

During all this time the habits of English people had gradually changed. The great hall, which had been a common meeting place for the family and its retainers, fell into disuse; the family secluded themselves from the servants, separate rooms were provided for nearly all the household, and consequently, plans of houses became different from those of old.

The power and prestige of the nobility were now at their height; moreover, architecture had come to be regarded as an aim in itself, apart from the utilitarian purposes it had to fulfil; and thus arose those vast mansions of the early eighteenth century, which were designed to impress the spectator with the splendour of this duke or that earl, rather than to provide those noblemen with really comfortable dwellings.

OUR HOMES OF TO-DAY

Time marched on and brought with it further social changes. The great middle class, consisting of well-to-do merchants, professional men and the like, became of increasing account, and for them houses had to be provided, attractive and roomy but not magnificent. The squares of London and the pleasant houses on the outskirts of provincial towns are evidence of this development. Such houses derived their features, both of plan and appearance, from what went before them. They were strongly imbued with the classic, or Italian, spirit. As to what came after them, it is not difficult to see that the houses we live in to-day are closely related to these middle class houses of the eighteenth century; and thus, step by step, can the pedigree of our own homes be carried back to the lonely little towers that existed when Magna Charta was signed.

PRELIMINARY OPERATIONS

By R. Vincent Boughton

LESSON II

PLANT

The term *plant* comprises all those things temporarily required for mixing the various materials, hoisting, stagings, scaffolding, and to allow of the craftsmen's access to the various parts of the building during its erection. When it is considered that the "use and waste" of plant necessitates an expenditure of $1\frac{1}{2}$ per cent to $2\frac{1}{2}$ per cent of the cost of a building, it may be realized that care must be exercised in its requisitioning, use, and maintenance. The following is a brief description of some of the ordinary "plant" items.

Scaffold Poles used for the *standards, ledgers*, and *braces* of scaffolding vary in length from 12 to 33 ft.; they must be straight, free from defects, barked, not too slender, tapering from the butt to top, with the latter about 2 in. diameter for poles about 15 ft. long, $2\frac{1}{2}$ in. for 22 ft. long, and 3 in. for longer lengths. Scaffold poles should be from young larch or spruce trees.

Scaffold Boards used for the platforms of scaffolding should be as long as possible, up to about 13 or 14 ft., 9 in. wide, and not less than the usual thickness of $1\frac{1}{2}$ in.; they should be northern pine or spruce, or other tough, strong elastic timber, free from any defects that might cause snapping under suddenly applied loads, which often occur on scaffolds. The ends should be bound with hoop iron to prevent splitting or fraying, or protected by the economical method of cutting off the corners and spiking with 4 in. nails. Figs. 2 and 3 show these methods.

Putlogs are short lengths of timber, about 6 ft. long, and 3 in. × 3 in., 4 in. × 3 in., or 4 in. × 4 in. scantling, of the same timber as scaffold boards, or of birch.

Scaffold Cords should be of best tarred hemp, cut and whipped into 16 ft. lengths, not less than $\frac{1}{2}$ in. and preferably $\frac{5}{8}$ in. diameter ($1\frac{3}{4}$ in. circumference).

Scaffold Lashes are of flexible galvanized steel wire and are preferable to cords, as they do not stretch. They are obtainable in 12, 15 and 18 ft. lengths.

Ladders are purchased in lengths of rung units of 8 in. (sometimes $8\frac{1}{2}$ in. or 9 in.), from 14 to 100 rungs (or more). There should be sufficient short ladders to give access to the lowermost and intermediate stages of scaffolding, and also others capable of reaching the highest parts of the building. They should have sides of Norwegian spars, oak rungs, and iron tie rods.

Gauging Boxes for proportioning the materials for concrete, etc., are bottomless, and have four sides only; they are square on plan and of

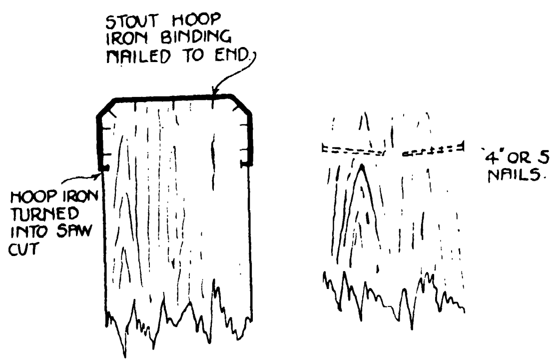


Fig. 2

area and depth to hold any required quantity of material. Fig. 4 depicts a gauge box to hold 1 cub. yard of materials.

Builders' Pails should be strong and riveted, and 12 in. to 13 in. deep, as Fig. 5.

Shovels and Spades. A type of shovel, as used for shovelling materials, is shown by Fig. 6, and a spade, as used for digging, by Fig. 7.

A Digging Fork is shown by Fig. 8, and has four or five square prongs and riveted eye handle.

Earth Rammers are as Fig. 9, and have wide cast-iron bases, stout ash handles, about 5 ft. long, and weigh about 11 lb.

A Sand-washing Sieve is shown by Fig. 10. These sieves are obtainable with four to sixteen holes to the inch. The rims are usually of oak and the bottoms of iron or copper wire. The sizes are about 20 in. diameter, 5 in. deep inside and 7 in. deep outside.

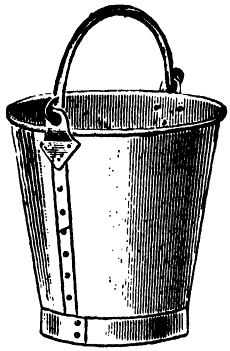


FIG. 5. BUILDER'S PAIL

FIG. 6. SHOVEL

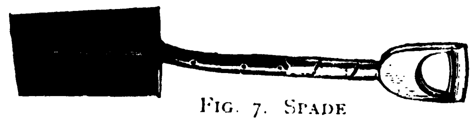


FIG. 7. SPADE

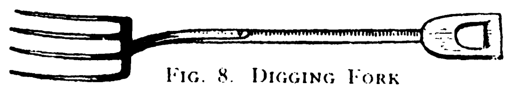


FIG. 8. DIGGING FORK

FIG. 9. BASE OF EARTH RAMMER

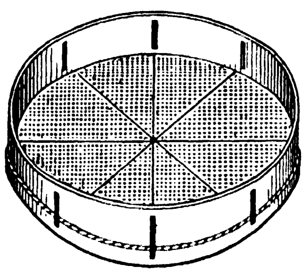


FIG. 10. SAND WASHING SIEVE

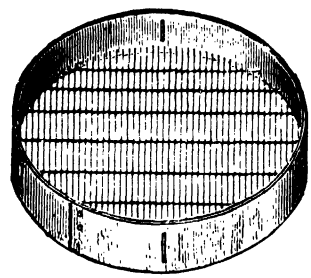


FIG. 11. GRAVEL SIEVE

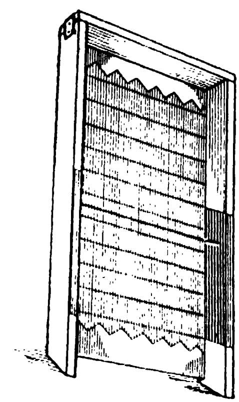


FIG. 12. SCREEN

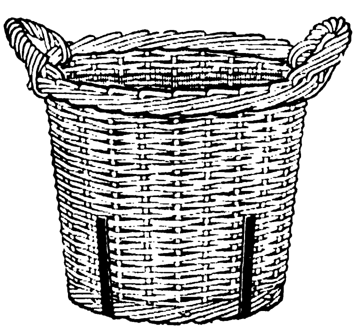


FIG. 13. BUILDER'S RUBBISH BASKET

FIG. 14. BASKET SLING

FIG. 15. BARROW SLING

FIG. 17.
SINGLE PULLEY BLOCK

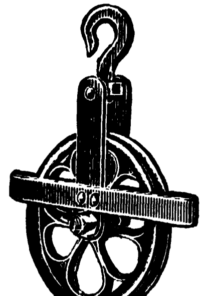


FIG. 16. GIN BLOCK OR RUBBISH WHEEL

FIG. 18.
DOUBLE PULLEY BLOCK

Gravel Sieves are as Fig. 11. They are 20 in., 22 in., or 24 in. in diameter, with wires set to various gauges, from $\frac{1}{8}$ in. to 1 in., and sometimes more, with oak rims about $3\frac{1}{2}$ in. deep. The mesh is straight, as illustrated, or square.

A Screen is shown by Fig. 12, and these are obtainable in sizes 5 ft. × 2 ft. 6 in., 5 ft. 6 in. × 2 ft. 9 in., and 6 ft. × 3 ft., with straight mesh varying from $\frac{3}{16}$ in. to $\frac{1}{2}$ in.

Fig. 16, are used for hoisting light loads, and have stout metal frames and about 10 in. diameter wheels; the top hook is for securing to scaffolding, etc. Strong manilla fall ropes, $1\frac{3}{4}$ in. to 3 in. circumference, are used for hoisting.

Pulley Blocks, as Figs. 17 and 18, which show single and double blocks, are used for hoisting heavy loads, such as girders, etc., and are made to take $\frac{3}{4}$ in. or 1 in. diameter ropes. The action

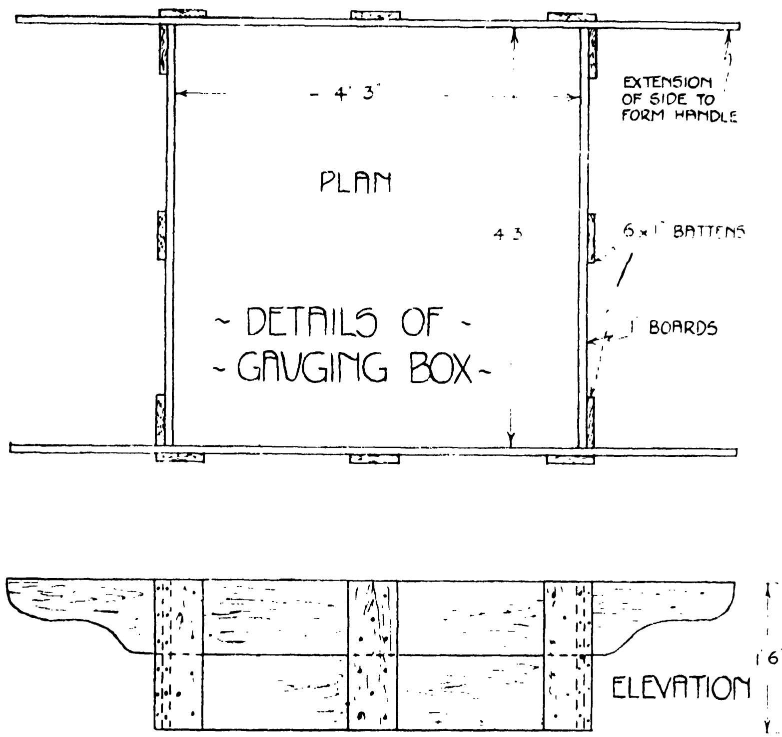


Fig. 4

Builders' Rubbish Baskets are as shown by Fig. 13, and are made of stout cane with iron binding at bottom and of half-bushel capacity.

Basket Slings have two lengths of chain connected to a ring at top and a hook at each end to engage the handles of basket. Fig. 14 illustrates.

Barrow Slings have three lengths of chain connected to a ring at top; two of the chains have eyes at end to fit over handles of barrow, and the other chain has a hook to grip the barrow wheel. Fig. 15 illustrates.

Gin Blocks, or Rubbish Wheels, as shown by

and use of pulley blocks will be described in a later lesson.

Navvy Barrows are made in a variety of forms, Figs. 19 and 20 depicting barrows with wood and iron wheels, respectively. A good barrow should have ash frame, legs, and wheel runners, and elm body; $\frac{1}{2}$ in. cross-frame bolt; steel strengthening stays; either hardwood wheel, with $1\frac{1}{2}$ in. iron tyre, or stout cast-iron wheel $\frac{7}{8}$ in. diameter or tread; and have a capacity of two bushels.

Miscellaneous Plant Requirements include water tank, pipe, hose, a few squares of rough

(*Continued on page* 66)

ARCHITECTURAL DESIGN

By T. P. Bennett, F.R.I.B.A., and T. E. Scott, A.R.I.B.A.

LESSON II

PRINCIPLES OF DESIGN

Truth in Architecture. Guadet has said that in architecture there are " material " and " moral " needs. Not only must the building satisfy the practical requirements of the programme, but it must be beautiful. The designer will automatically anticipate effect as soon as he considers the programme; the extent to which his artistic expression should be controlled by considerations of economy, efficiency, and other material matters will be determined by the nature of the building he is designing. But always his efforts are to create a building whose character is the truthful expression of its purpose.

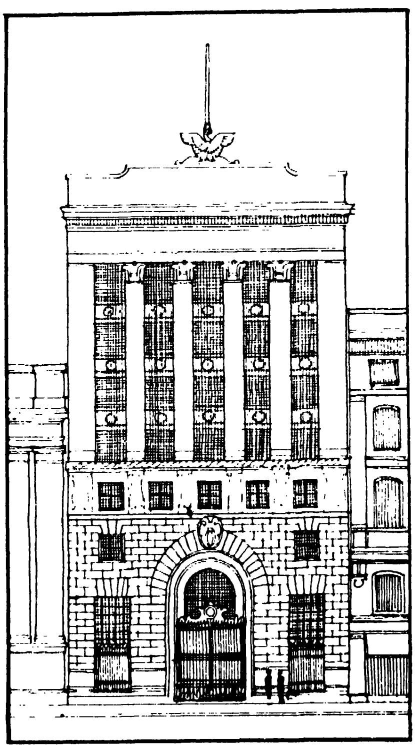


Fig. 4. An American Bank Building

Truth is the essential characteristic of fine architecture.

It results from the faithful adherence to the programme to the last detail. By the programme, reference is not only made to the material requirements of the client, but also to the mental appeal of the building.

Proportion. The relative importance of the programme must be realized; it is wrong to produce a miniature opera house for a village concert hall, or a grandiose town hall for an emporium.

By the true interpretation of relative importance, *character* is created. There are many shades of character in architecture: Refinement, Grandeur, Gaiety, Solemnity, Vigour, Restfulness, always expressive of the purpose of the edifice.

These qualities are expressed primarily by means of *proportion*. Proportions will not only regulate the individual elements which go to make up a composition, but also the relationship between them. Proportions will be determined by a variety of considerations: the relative importance of the various requirements of the programme; the traditional forms which have been evolved from the constructional development and use of materials; the traditional proportions which are associated with various historical styles; and the artistic taste of the designer. Many theorists have produced geometrical rules for proportion and have illustrated their theories with certain interesting coincidences in antique architecture. Even if these theories are accepted, it is questionable whether their application to modern practice would do other than confuse the designer. Their only value would appear to be the establishment of a certain consistency of proportion throughout a design; but this surely will always be the aim of intelligent architects. To appreciate proportion it is necessary to study fine architecture, and thereby cultivate good taste, for a sense of what looks well is the surest criterion for proportions. There is, however, one aspect of proportion which appears to be decisive. The proportions which go to make a shape should be definite. A square should be an exact square, and an oblong definitely so; similarly, there should be no hesitation in circles and ellipses, for the eye will not be satisfied by shapes which might be either.

Scale. But proportion must also be considered in its broadest sense.

In any work of architecture it is not only necessary to study the relationship between the component parts, but also the proportions between the building and other comparable objects.

This is known as *scale*. Scale, more than anything else, will determine the character of a building.

In the design of a building in which there are big parts, such as a railway station, a theatre or a bank, the external motifs must be also big, so that they may express the truth of the building (see Fig. 4).

The same scale should be maintained throughout a building, but always there must be some readily appreciated feature which will give the general scale its full value. Referring again to Fig. 4, it is seen that the upper floors are united in an " order " which maintains the scale set by the entrance, but that the impression of size is only realized by comparison with the single intermediate windows.

Simplicity and fewness of parts will convey an impression of bigness which is known as large scale; a multiplicity of elaborate parts—small scale. It is essential to grasp the importance of the programme and treat the elements accordingly, but a building should never be overloaded with small parts or broken up into small features. It must be allowed to look its size.

Scale is influenced greatly by environment; if any object, which is normally seen and used indoors, is examined in the open air, the result is surprising. Spaciousness greatly reduces scale. The Arc de Triomphe, in Paris, is worth study; its huge size is not realized without careful comparison with familiar objects, such as the human figure. But the edifice is in scale with its surroundings; it dominates without overpowering. Scale, however, must recognize human proportions. Whatever the requirements of beauty, the dimensions of useful elements, such as steps, doors, and balustrades, must always be consistent with their utility.

Architecture must be well mannered. The civil importance of state, municipal, and religious buildings must be recognized, and the commercial or domestic building so designed in scale that it is given its proper position of social precedence.

Construction must govern design, for if a building expresses its construction truthfully, it will surely have the appearance of stability and repose, which are two of the great essentials in design.

But architecture is only just emerging from a period of transition in construction. Steel and reinforced concrete construction have developed rapidly, but those architectural forms which have grown out of brick and stone construction are not given up without reluctance.

Perhaps this is natural, since traditional forms have, through long usage, acquired certain characteristics which are used to give expression to architecture. If the programme appears to

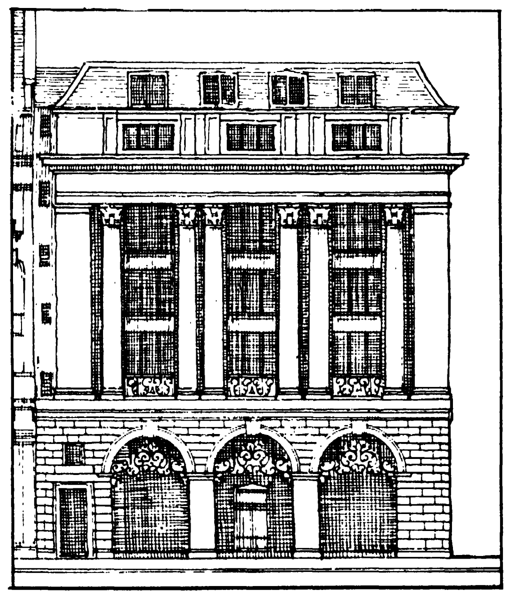


Fig. 5. The Wolseley Building, Piccadilly
(*W. Curtis Green, F.R.I.B.A., Architect*)

call for expression in one of the historic styles, inspiration may be drawn from that source without hesitation, but in spirit as well as in detail. Fig. 5 illustrates the use of classic motifs in a steel-frame building, in which all of the elements proclaim their structural function faithfully. It is also interesting to note that although the proportions of the upper windows are contrary to those usually associated with classic architecture, they are lost in the more pronounced proportions of the openings between the columns.

But with modern methods, proportions and shapes are possible (and even desirable under modern conditions) which are contradictory to those which appear rational in the use of stone, as with the stone lintel in Fig. 6. They must not be ignored, for in the mind of the beholder is the knowledge of the great strength of the hidden skeleton of steel; and since it is an essential requirement of the programme that the shop front shall provide a wide unobstructed space for display, then the result is the truthful expression both of the purpose and the construction.

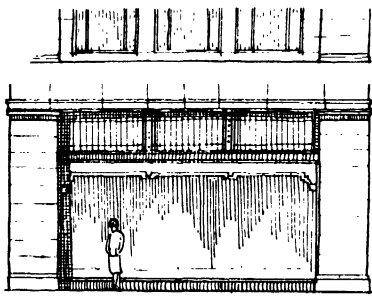


FIG. 6. A SHOP FRONT

Unity. Beauty in architecture depends largely upon *unity* of form. The various elements that go to make up a building must be so related as to produce a unified composition. There must be no hesitation or competition between the elements, the most important of which must always be in the right place, and be given its proper degree of prominence.

To express unity, a building must give the impression of completeness, a quality which is essential for the expression of stability. The study of the architecture of the past shows that all buildings were given a base upon which to

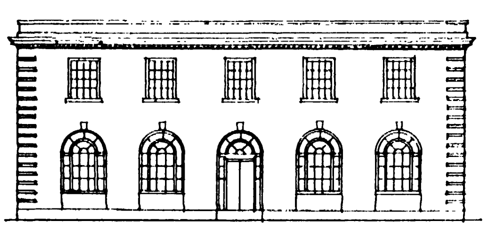


FIG. 7. A FAÇADE DEFINED BY QUOINS, CORNICE AND PLINTH

stand, a middle or containing part, and a roof or protective crowning feature, such as a cornice, while in a horizontal direction, additional support or protection was provided at the angles. For example, to buttress the end bays of an arcade, or the use of ashlar quoins to a rubble wall.

Regardless of any hidden construction which may render such treatment unnecessary to the actual stability of the structure, the artistic sense will require these refinements, both for the expression of stability and of completeness. In the absence of a generally understood term, this may be called "definition."

It is seen in Fig. 7 that the component parts of the façade are unified by the use of the crowning cornice and the rusticated quoins, which properly punctuate the building, announcing definitely its completion.

Symmetry. An expression of unity will result from a regular or geometrical disposition of the elements on either side of a centre line; this is called *symmetry*.

Symmetry is highly desirable, but it must be intelligent; it must not be sought if the programme requires elements of dissimilar shape and size, which cannot be grouped into equal masses without destroying their proper functional sequence. In such cases, an *assymmetrical* composition will provide the proper solution of the problem. This does not imply the entire

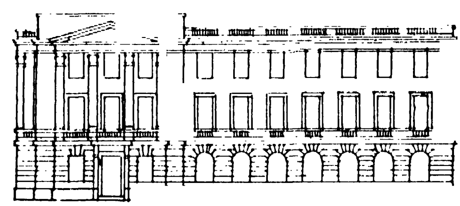


FIG. 8. AN ASSYMMETRICAL FAÇADE

absence of a focal point or of balance in the various parts, but, as will be seen in Fig. 8, a composition of unequal masses, with the centre of interest on the axis of the main mass.

The reverse of the symmetrical is the *picturesque*. Truly picturesque schemes are usually the result of accident or time. They are rarely successful if intentional, but rather result from the simple straightforward solution of some problems.

Harmony. Finally, the expression of unity must be maintained by a consistency of stylistic treatment throughout the composition, with a harmony of proportion and scale in all features.

But *harmony* must not be confused with monotony. It must result from the proper proportioning of contrast of shape, size, texture; verticality and horizontality; light and shade; solids and voids; plain and decorated surfaces. The proportions must never be hesitating; one must always clearly dominate, with the other acting as foil. There must always be sufficient variety to bring interest, but care must be taken to avoid too many contrasts, for they will break up a composition, or defeat their purpose by being monotonous.

St. Paul's Cathedral illustrates how a dome may dominate a composition, largely by virtue of the contrast of its shape with the rest of the building; but in St. Mark's, Venice, the oft-repeated dome brings a restlessness into the composition.

Again, in variety of texture or material, sudden or frequent changes must be avoided. The study of the brick and stone work of Wren at Hampton Court and elsewhere will show how logical is his use of material: the stone bases and cornices linked up by the use of stone quoins, and dressings to windows in the intermediate parts.

For the treatment of voids and solids, the finest works of the Gothic and Italian Renaissance periods are a valuable source of study.

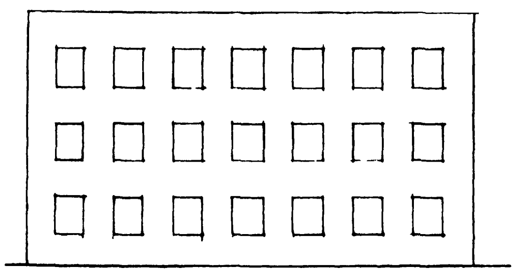


FIG. 9. THE ABSENCE OF DEFINITION AND INTEREST

There should usually be a decisive predominance of one or the other. In the diagram (Fig. 9) a façade, with equal divisions of void and solid, shows how dull a composition may be through the regular arrangement of openings in walls; this diagram illustrates also the feeling of incompleteness and lack of stability through absence of "definition."

Light and shade are related to voids, but result chiefly from the modelling of wall surfaces. The positions of the main shadows must always be very carefully considered, since they will break a façade up into a number of separate elements which must then be resolved into unity. It will be logical to express the plan with breaks in the elevation, and then, if the parts of the plan are properly proportioned, the resultant façade will be right.

The most important features should always have the strongest shadows. It will be seen in Fig. 10 that the pilasters have only little projection, but the entrance, being the focal point, is deeply recessed.

Ornament. The considerations of *ornament* are far-reaching. So many of the once structural elements are now used as decorative motifs, that almost all of the features, except walls and openings, might reasonably be considered ornamental.

It is always reasonable, however, to use features which have decorative value, so long as they are properly placed, and serve some definite purpose in the composition.

Decorative panels under windows may enhance their proportions; a carved keystone will give emphasis to an important door opening; or a series of decorative elements between the windows of the upper story of a tall building will give a depth to the crowning member proportionate to the height of the building.

FIG. 10. A MAUSOLEUM: NEW YORK

Existing architecture will show countless examples of ornament, but care must always be taken that decoration does not destroy the apparent structural function of a feature.

Essentials of Design. These remarks have only touched upon the fringe of architectural beauty. The student must increase his knowledge by study. The constant critical analysis of buildings, or photographs of buildings, is the only way to acquire the ability to create fine architecture.

The essentials of good design may be summarized as—

1. Faithful adherence to the programme and its attendant requirements.

2. Faithful expression of the programme.

3. Stability, both real and apparent.

4. Beauty, resulting not from astonishment at mere size or ingenuity, but from the happy infusion of interest and variety into the elements of a composition, always unified by harmony and proportion into a single idea.

The Three Sections of Design. To crystallize design into elements capable of practical application, it is necessary to consider the subject in three sections.

First, the study of the elements of architecture, such as walls, doors, windows, and the orders, etc., not merely as archaeological research, but as an analysis of their origin and subsequent development as functional elements in design.

Secondly, the study of the elements of composition, such as façades, rooms, communications, porticos, etc., and the principles governing their composition into the plan, which is usually the fundamental element in design.

Finally, the study of the requirements of the various types of buildings required by our modern civilization.

PRELIMINARY OPERATIONS

(*Continued from page* 61)

boarding for bankers, etc., and a few hundred linear feet of 3 in. × 2 in. and 4 in. × 2 in. fir for general purposes.

The plant described in this lesson represents the general things required for preliminary operations; the requirements for various trades such as bricklaying, masonry, carpentry, painting, etc., are in the nature of tools and implements, and cannot be dealt with in this section.

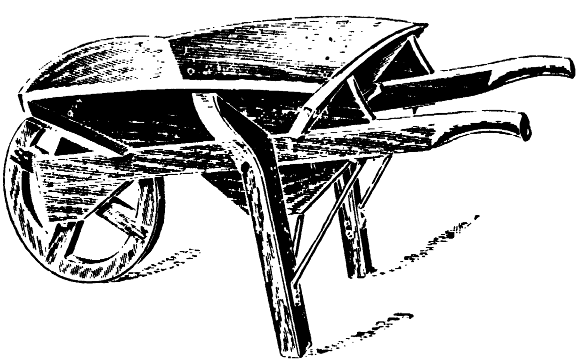
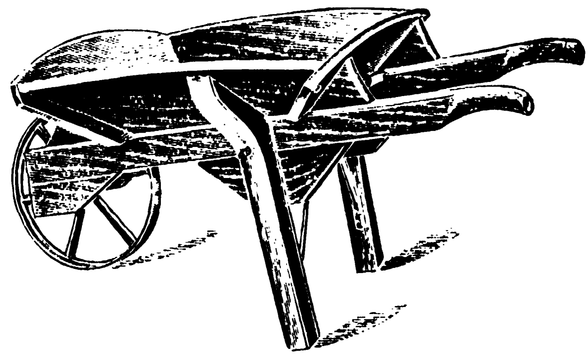


Fig. 19. Navvy Barrow with Wooden Wheel.



Navvy Barrow with Iron Wheel.

Records of Plant should be very carefully kept so that (*a*) its quantity and condition may be checked and stock taken periodically; (*b*) its movements from job to job, etc., may be recorded; and (*c*) a proper proportion of its value can be allocated to each job.

Builders adopt various methods of allocating the cost of plant to each job, and the following is a good method: A plant account book is kept showing all expenditures on plant; then a plant stock book will show all movements and the purchase price debited to each job. Upon the return of the plant to the yard, or transfer to another job, a credit of 75 per cent of purchase price is given to the cost of the job from whence the plant came. If plant has been misused a cost is debited to the job. The percentages shown will only give an approximate value of "use and waste," and may eventually show a profit or loss in the plant account, which would be adjusted periodically. The method outlined has the advantage of tending to prevent a foreman over-ordering or carelessly using plant.

STRUCTURAL ENGINEERING

By W. Arnold Green, M.A., B.Sc., A.M.Inst.C.E., M.I.Struct.E.

LESSON I

FORCES ACTING ON A STRUCTURE

Scope of Section. Although the term "Structural Engineering" is applicable equally to the building of a sand castle, an Egyptian pyramid, a Forth bridge, an Eiffel tower, and a wasps' nest, it is proposed in this section to deal with only a small part of what is commonly known as "building construction"; the principles, however, underlying the right use of materials in making a safe structure are the same whatever the structure and whatever the materials used.

Structures designed to deal with mass in motion are in the province of the mechanical engineer, and though it is impossible to draw a hard and fast line between structural and mechanical engineering, this section will be mainly concerned with *statics*, which may be defined as "that branch of dynamics which treats of the properties and relations of forces in equilibrium, the body upon which they act being at rest."

The structures herein dealt with have as their object the carrying of loads, which are either stationary or may be regarded as such for purposes of design.

EQUILIBRIUM OF A STRUCTURE

Conditions to be Satisfied. At all points in such structures there must be *equilibrium*, i.e. a complete balance of forces, as otherwise there would be movement. This balance must be maintained for the structure as a whole as well as for the individual parts. Thus the sum of the loads on and of the structure must exactly equal the sum of the reactions from the supports to the structure. This will ensure that there will be no movement of position; but to ensure also that there will be no movement of rotation a further condition must be satisfied. This condition may be expressed as follows: the tendency of the loads on and of a structure to cause rotation about any point must be exactly balanced by the tendency of the reactions from the supports to the structure, to cause an equal rotation about the same point in the opposite direction.

It should be noted that the term "support" may be regarded as relative. Any point of a structure may be regarded as the support to the adjacent portion, and the above-mentioned conditions of equilibrium must be satisfied.

Forces Acting on a Beam. To illustrate by an example, consider a beam of length l and weight w per unit length, supported at two points R_1 and R_2, and carrying two point loads of known weight W_1 and W_2 in the position shown in Fig. 1.

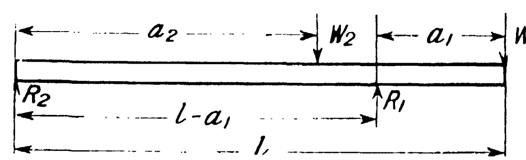


Fig. 1

It should be remarked that in practice there must be an appreciable bearing width both for the loads and the reactions, but at the moment, for simplicity, they are considered as acting at points.

The total weight of the beam, i.e. the weight of the structure itself, equals $w \times l$. The total load on the structure equals $W_1 + W_2$. The total reaction from the supports to the structure is the sum of the reactions from points R_1 and R_2, which may be similarly termed R_1 and R_2 respectively.

As the sum of the loads of and on the structure must equal the sum of the reactions from the supports to the structure, therefore—

$$w \, . \, l + W_1 + W_2 = R_1 + R_2 \qquad (1)$$

Moments of Forces. The *moment* of a force about a point, or the tendency of the force to cause rotation about that point, is proportional both to the force and its *lever arm*, i.e. the distance of the line of action of the force from the point.

The moment of a force about a point is thus expressed as *the product of the amount of the force and the lever arm*.

Thus the moment of W_1 about R_2 equals $W_1 \, . \, l$, and the moment of W_2 about the same point equals $W_2 \, . \, a_2$.

The lever arm of the weight of the structure itself is the distance of its centre of gravity from R_2. The moment of the weight of the structure itself about R_2 is therefore—

$$w \cdot l \times \frac{l}{2} = \frac{w \cdot l^2}{2}$$

These moments tend to produce clockwise rotation about R_2. The resisting counter-clockwise rotation about R_2, due to the reactions R_1 and R_2, equals $R_1 . (l - a_1) + R_2 . O = R_1 . (l - a_1)$. Equating the clockwise moment to the counter-clockwise moment—

$$W_1 . l + W_2 . a_2 + \frac{w . l^2}{2} = R_1 . (l - a_1) \quad (2)$$

from which the unknown reaction R_1 is immediately deducible, and hence R_2 from (1).

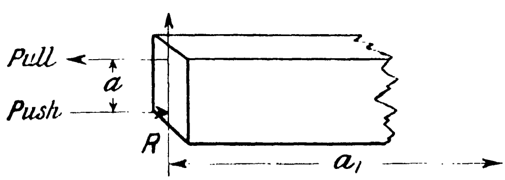


FIG. 2

The left-hand side of (2) may be written $(W_1 + W_2 + w . l) . a_3$, where a_3 is the distance from R_2 of the centre of gravity of the weights on and of the structure. Thus—

$$(W_1 + W_2 + w . l) . a_3 = R_1 . (l - a_1)$$

or

$$(R_1 + R_2) . a_3 = R_1 . (l - a_1) \quad (3)$$

If a_3 is less than $l - a_1$, R_1 is obviously less than $R_1 + R_2$, so that R_2 will be of the same sign as R_1, i.e. both reactions are upward.

If a_3 is greater than $l - a_1$, owing to the relatively great weight of W_1, then R_1 will be greater than $R_1 + R_2$, and R_2 will be of the opposite sign to R_1, i.e. it will act in the opposite direction to R_1, and serve as an anchorage to prevent the beam rotating in a clockwise direction about R_1.

The same results could have been deduced by taking rotation moments about any other point, but by choosing a reaction point as the assumed centre of rotation (or fulcrum) the value of that reaction is eliminated from the resulting equation of moments.

Balancing or Resisting Moment. Consider now the cantilever portion of Fig. 1. Fig. 2 shows a "close up" of the end of this at R_1, and represents an imaginary vertical section through the cantilever just above R_1.

The forces acting on the overhanging portion, to the right of the section, are W_1, a distance a_1 away and the weight of the beam $w.a_1$, acting at its centre of gravity a distance $a_1 \div 2$ from the section.

The support for this overhanging portion is the vertical face of the remaining beam, to the left of the imaginary section. This vertical face must provide a vertical reaction R equally $W_1 + w.a_1$. It must also provide reactions to produce a counter-clockwise moment balancing the clockwise moment $(W_1 . a_1 + \frac{w . a_1^2}{2})$, due to the load on and of the structure.

A horizontal pull on the top portion of the section, and a horizontal push on the bottom portion, will produce this balancing moment.

As there is no horizontal force acting on the cantilever, the pull and push must be equal. If this pull and push is denoted by P, and the distance between their centres of action as a, then $P . a = W_1 a_1 + \frac{w . a_1^2}{2}$.

The method of determining P and a will be discussed later.

A further and important condition that must be satisfied, if moment towards the ground is to be avoided, is that all members composing the structure, and the joints connecting them, must be adequate for all loads coming on them.

EXERCISE I

1. If, in Fig. 1, $l = 20$ ft., $a_1 = 5$ ft., $a_2 = 10$ ft., $W_1 = 10$ tons, $W_2 = 3$ tons, and $w = 1$ cwt., find R_1 and R_2.
2. What value of W_2 will make $R_2 = O$?
3. What is the moment to be resisted at R_1?

SUPERINTENDENCE

By P. J. Luxton
Member of the Incorporated Clerks of Works Association

PART II

ENGAGING A CLERK OF WORKS

The clerk of works who supervises the erection of new buildings is the one most frequently met with, and the circumstances connected with his appointment will be explained first. Almost invariably he is employed to act under the instructions of an architect or engineer, usually the former, except in the case of local authority work, where he may be under the control of the chief technical officer, variously described as the city or borough engineer, or surveyor.

It is important that he should remember that all his instructions come from his technical chief, and not from his employer. When he is employed under a local authority, there may be a tendency on the part of members of the authority to interfere with the conduct of his work, and to act on the assumption that they have a right to give instructions. The clerk of works should courteously inform them, when such circumstances arise, that he will bring the matter to the notice of the architect, or, if the the point raised is clearly covered by the contract, he can explain the position. It is very easy indeed for a layman to jump at entirely wrong conclusions when building work is in an unfinished condition.

In one instance a member of a committee sent a letter to the architect complaining that very rough wood was being used for door jambs, mahogany being specified. The latter wrote to the clerk of works, enclosing the letter, and asked him what he meant by doing that sort of thing. On investigation being made, it was found that what had been taken for finished jambs was some rough deal casing attached to them for protection, while the plastering and other work was going on.

Why a Clerk of Works is Appointed. The clerk of works is at the disposal of an architect on jobs where constant supervision is required. This is not part of the architect's duties, and obviously, in the case of a man with a large practice, is impossible. The *Conditions of Engagement*, under which a member of the Royal Institute of British Architects is employed, includes the following paragraph—

> That in all cases in which constant superintendence is required, a clerk of works shall be employed for this purpose. He shall be nominated and approved by the architect, and appointed and paid by the client. He shall be under the architect's direction and control, but the architect shall not be held responsible for any fraud or negligence on the part of the clerk of works.

Method of Engagement. When the whole of the preparatory work has been completed, the contract signed, or nearing that stage, and the client has decided to engage a clerk of works, the architect sets out to find his man. He may advertise in the technical journals, inquire of other architects or surveyors, or what is frequently done, apply to the secretary of a society such as the Incorporated Clerks of Works Association. On the other hand, he may have a waiting list, or the addresses of men previously engaged, whose services he would like to again obtain. The probability is that there will be several applications, even hundreds, for well advertised jobs, and a choice has to be made.

What guides this choice? Many things; age, length of experience in superintending works both as clerk of works and foreman, the nature of the experience—whether on similar works to the one contemplated—trade (if any), quality and source of references, technical qualifications such as examination certificates, salary required, and inferences drawn from the phrasing and writing of the application. When the batch of applications has been reduced to a few by applying these tests, interviews are requested, and a choice is finally made.

The architect himself may make the choice, and obtain his client's approval, but in public authority work it is done by a committee, perhaps a few men allotted the task because of their special knowledge, perhaps the whole council. An applicant must be prepared to face a roomful of councillors, but not many will ask him any questions which matter, probably the architect and the chairman only. The final selection is made by voting, and that is where the dumb councillors come in. The impression left by the appearance and answers of the candidates decides their votes.

JOINERY

By T. CORKHILL, F.B.I.C.C., M.I.STRUCT.E., *Double Medallist*

LESSON II

METAL PLANES

NEARLY every form of wooden plane has its duplicate in metal, but they are not all popular with the joiner. The jack and try planes are not so satisfactory as the wooden types; but most joiners include an iron smoothing plane in their kit, and one or more of the smaller types of planes. The planes are made in various metals, including cast iron, malleable iron, cast steel, and gun-metal. Cast-iron planes are cheap, but should be avoided because they are easily broken.

Smoothing Planes. The Stanley smoothing plane shown in Fig. 18 should be of the "bed-rock" type, otherwise it is apt to *chatter* on hardwood, knots, etc. It is a very useful plane because the irons are easily adjusted. Unfortunately, it is easily broken, but with care is a very serviceable plane. The sole must be kept clean, and occasionally smeared with oil to ease the friction, which is greater than with the wooden soles. The irons are fixed by the cap *c* which is adjusted by the lever *l*. The lever *a* adjusts the irons sideways, and the milled nut *b* adjusts for thickness of shaving.

The English pattern of smoothing plane is shown in Fig. 19. This is a strong and serviceable plane, but is not adjustable except as an ordinary plane. The irons are fixed by the lever *l* by means of the screw *s*. It is the best plane for hardwoods and across the grain because of its rigidity. The mahogany handle *h* is continued to form the bed for the irons. Some forms of metal planes have corrugated soles to ease the friction; theoretically these are good, but in practice the corrugations are apt to clog, especially on resinous timbers. All these planes produce a straight and highly finished surface.

Block Planes. Fig. 20 shows a useful type of block plane, especially for fitting mitres and other small work. The blade *b* is held by the cap *c*, which is fixed by the lever *l*, and adjusted by the milled nut *a*. The throat is adjusted by the lever *t*. This type of plane has no back iron, but the cutting edge is supported by turning the iron over so that the *bed* is carried up to the cutting edge. The bed is also very flat where a single iron is used, that is, the angle between the sole and the iron is very small.

Some types of block planes have the iron close up to the nose of the plane for working into corners; these are often called *chariot planes*. Sometimes the type shown in Fig. 20 has a removable front for the same purpose.

Bullnose Planes. This is a similar type to the block-plane, but it is arranged as a rebate plane. Fig. 21 shows a useful type. The blade is held by the cap *c*, which is fixed by the milled nut *b*, and it is adjusted by the nut *a*. It is an indispensable plane for working into corners, especially in hardwoods.

Compass Plane. Fig. 22 shows a very useful plane for circular work. The sole *s* is adjusted by the screw *a* for either concave or convex surfaces. The principle of the plane irons is the same as for the Stanley smooth plane. The quickness of adjusting both the irons and the curvature has given this plane first place, although the "old-time" joiners still stick to the wooden type, which, generally speaking, is now obsolete. For "flat" concave work, however, it is a common practice to plant an auxiliary sole on an ordinary smoothing plane, the false sole being shaped to the required curvature.

Shoulder Plane. This rebate plane, shown in Fig. 23, is excellent for planing across the grain, such as the shoulders of rails, and for ordinary rebates in hardwoods. It is a perfect plane for this class of work owing to its rigidity and close mouth.

Side-rebate Planes. Fig. 24 shows the usual type of side-rebate plane. They are useful for cleaning up the sides of plough grooves, etc., where no other tool is applicable. They are sold in pairs, right and left hand, but usually the joiner is contented with a right-hand plane only. The front *f* is removable for working up into corners. The blade *b* is held in position by the cap *c*, which is fixed by the thumb screw *s*.

Chamfer Planes. These planes are not a necessary part of the equipment but they are very useful where machines are not available. Fig. 25 shows the usual type, but they may be obtained in wood; in fact, many joiners make

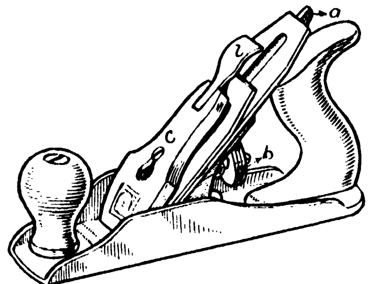


FIG. 18. STANLEY SMOOTH PLANE

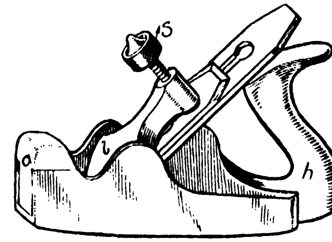


FIG. 19. SMOOTHING PLANE

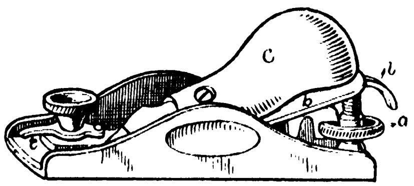


FIG. 20. BLOCK PLANE

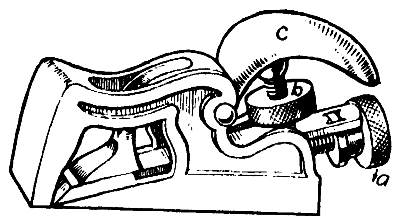


FIG. 21. BULLNOSE PLANE

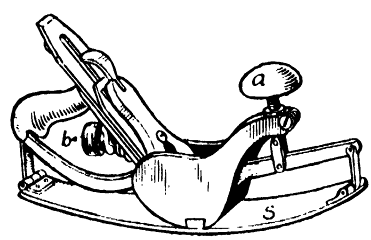


FIG. 22. COMPASS PLANE

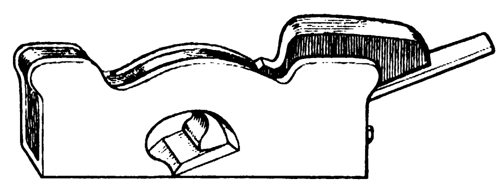


FIG. 23. SHOULDER PLANE

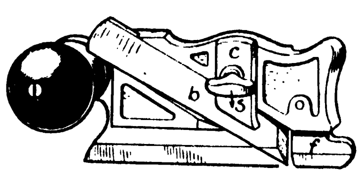


FIG. 24. SIDE-REBATE PLANE

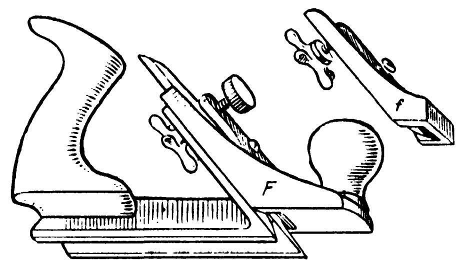


FIG. 25. CHAMFER PLANE

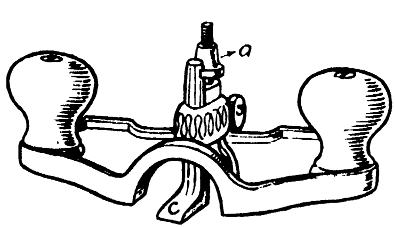


FIG. 26. ROUTER PLANE

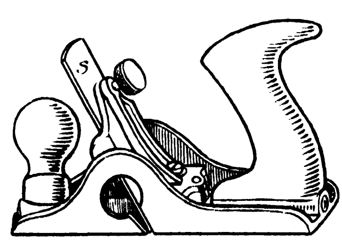


FIG. 27. SCRAPER PLANE

their own. The metal plane is supplied with two fronts so that *f* may be substituted for *F* when required for stop chamfers.

Router. Fig. 26 shows the metal form of Old Woman's Tooth. The nut *a* adjusts the cutter for depth and the milled nut *s* fixes the cutter.

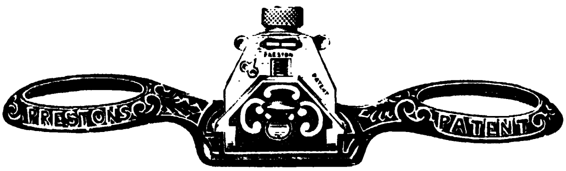


Fig. 28. Metal Spokeshave

Scraper Planes. The scraper plane, Fig. 27, is seldom used by the joiner unless he is constantly working on hardwood; but it is a common plane for the cabinet maker. The joiner uses the hand scraper, which is explained later. The scraper *s* may be substituted by a toothing iron and used for preparing the surface for veneering, to give a key for the glue. This blade is grooved on the back so that when it is ground, the cutting edge is serrated like saw teeth.

Spokeshaves. The iron spokeshave shown in Fig. 28 is an improvement on the wooden type, because of the adjustable cutter and mouthpiece. The cutter can also be sharpened on an oilstone like an ordinary plane iron; but it is usual to fix it in a slot in a wooden holder for convenient handling.

Circular Router. The circular quirk router shown in Fig. 29 is indispensable for working

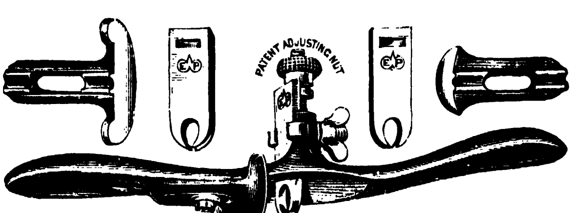


Fig. 29. Circular Router

mouldings by hand on circular work. It is supplied with three thicknesses of blades, which are adjusted by the milled nut. The thumbscrew fixes the blade in position. Three different fences are supplied for straight and curved work of different radii.

Stanley Universal Plane. This plane is an ingenious contrivance to take the place of the many moulding planes used by the "old-time" joiner. It is often called the "55" plane because it is supplied with that number of cutters. The difficulty of this plane lies in the *setting up* for the various operations, but it is useful for small jobs when it is not worth while

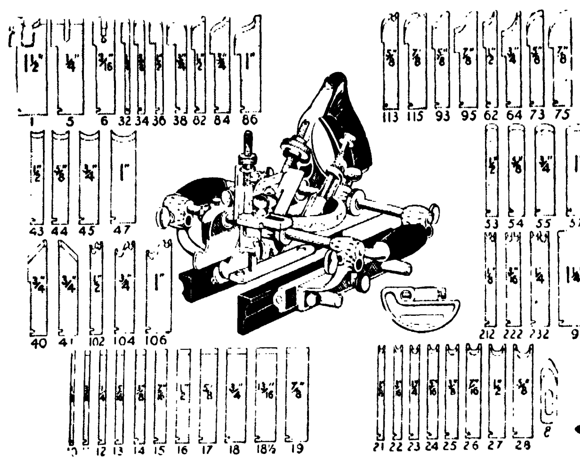


Fig. 30. Universal Plane

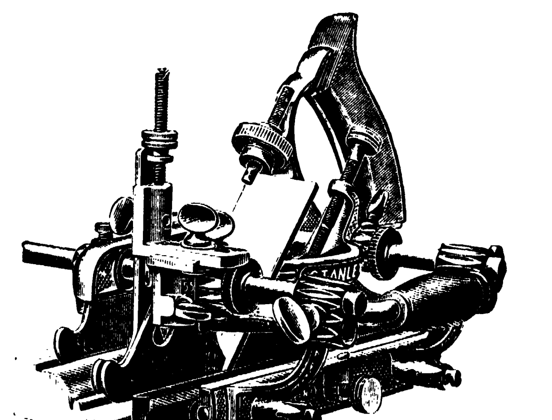


Fig. 31. Universal Plane in Use

setting up the machines. The expense, however, makes it more of a *shop* tool than an individual tool. Almost any moulding may be *struck* by this plane because blank cutters may be obtained and cut to any required shape.

A general view of the plane surrounded by the cutters is shown in Fig. 30, and in Fig. 31 the plane is *set up* for moulding an architrave.

PETERHEAD GRANITE

Takes a very High Polish and is excellent for Monumental and Ornamental Purposes.

SCLATTIE GRANITE

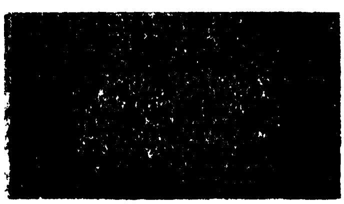
A good Granite, regular in Texture, and suitable for Building and Monumental Work.

PORTLAND STONE
(Whitbed)

A Hard Limestone (Oolitic), excellent for all General Building Work.

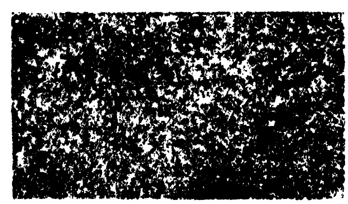
BATH STONE
(Monk's Park)

A Good Limestone and, if well selected, suitable for Internal and External Building Work; the best of the Bath Series.



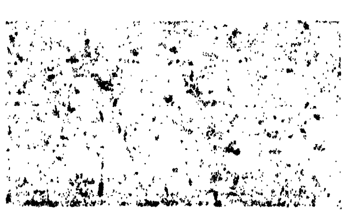
FOREST OF DEAN STONE

A very Durable Sandstone and excellent for General Building Purposes.



HAM HILL STONE

A Laminated Limestone; it gives a very pleasing Colouring Effect in Panels, etc., when surrounded by Portland Stone.



LIGHT HOPTON WOOD

An excellent Stone for Monumental Purposes, and also for Internal Decoration when Polished.

KETTON STONE

A very Durable Limestone, suitable for General Building Purposes.

SOME STONES USEFUL IN BUILDING

MASONRY

By E. G. Warland
Instructor in Masonry at the L.C.C. School of Building, Brixton

LESSON II

CLASSIFICATION AND CHARACTERISTICS OF STONES

Classification. Building stones are classified in a general way under the heading of *igneous*, *aqueous*, and *metamorphic* rocks.

Igneous Rocks. These are formed by fusion below the earth's surface.

Aqueous Rocks. All sedimentary stones, including sandstones and limestones, come under this heading. They are formed in deposits by the agency of water or winds, and are known as *stratified* rocks.

Metamorphic Rocks. These may be either of the above when changed in formation by heat and pressure. Marbles and slates come under this heading.

Granites

Characteristics. Granites are igneous rocks made up of granular particles, the latter being crystalline, and usually composed of quartz, felspar and mica.

Quartz. The durability depends largely upon the amount of quartz and its combination with other minerals, quartz being practically indestructible. Quartz, sand, and the chemical name *silica* may be said to be interchangeable terms.

Felspar is the most easily distinguished mineral and its colour varies considerably. The pink felspar is known as *orthoclase*, and is a potash felspar; this constituent is very characteristic in granite. Sometimes the white soda or lime felspar known as *plagioclase* is found. Felspars are commonly found with about equal quantities of quartz.

Granite is an igneous rock that has never flowed out over the earth's surface as lava, but became consolidated at a great depth under extreme pressure.

Mica is of two kinds: *muscovite*, which is potash mica (light); and *biotite*, which is a dark brown, iron and other substances being present. The light micas are more stable.

The proportions of mica should be small compared with *quartz* and *felspar*. *Hornblende* and *augite* sometimes occur and take the place of mica; the stone is then known as a *syenite*.

Iron pyrites produce oxidation and hydration either in the form of local spots, or as a uniform tinge of brown, and should always be looked upon as a fault.

The characteristics of a good granite are: fineness of grain, the disposition of the various minerals forming the mass, and the high percentage of quartz present.

In Cornish granite the felspars often look like flakes of falling snow, this appearance being caused by their flat surfaces lying in planes.

Varieties of Granites

Those from Devon and Cornwall are chiefly coarse-grained, having large crystals of felspar distributed throughout. The granite from Penryn district is bluish grey in colour, and composed of felspar, quartz, and mica, the mica being usually of mixed colours, black and white. The Penzance district provides a good granite, the colour of which is greenish grey. The Delank granite is of coarse grain and has a high percentage of quartz. It is a splendid weathering stone of a deep bluish grey colour, and is excellent for all types of building, engineering, and monumental purposes.

Scotch Granites. Aberdeen provides the most important granites, being light blue or grey, to pink or red. The *Peterhead granite* is pink or red. *Rubislaw granite* is bluish grey. The *Sclattie granite* is grey, has a fine texture, and is a splendid weathering stone. The *Aberdeen granites* are, generally speaking, *true granites* composed of quartz, felspar, and mica. *Hornblende* is sometimes found in place of, or in addition to the mica. These granites are largely supplied for monumental and building purposes. They take a very high polish.

Syenites are quarried in North Wales, Malvern, Hills, Leicestershire, and the Channel Islands.

Sandstones

Characteristics. Sandstones are formed by the disruption of pre-existing rocks due to the action of winds or moving water, the particles being deposited in beds, or strata. The chief constituents are the original quartz crystals (or grains) and the cement that binds them together. The quality of the sandstone depends upon the *cementing* material. The presence of an inferior cementing material is the chief cause of disintegration upon the exposed surfaces. The cementing materials are numerous, and may be silica, clay, iron oxides, calcite, or dolomite. Usually there is a combination of these substances, but one kind predominates. Sometimes the grains, or quartz crystals, are consolidated by heat and pressure as in *quartzite*. Sandstones vary from fine grain to coarse grit stone. The colour depending chiefly upon the cementing material. Red, brown, and yellow, are due to oxide of iron. White owes its colour to the combination of clear quartz with white argillaceous or clay-containing matter free from iron stains.

If the stone contains a high percentage of mica distributed along the planes of bedding it is known as a *micaceous* sandstone. Great care should be exercised in placing sandstones in the building so that the *laminae* are horizontal. There are exceptions to this rule, as will be explained later.

Varieties. The following is a list of a few of the best known building stones, and will, no doubt, be of interest to the student and young craftsman.

Forest of Dean: Gloucestershire. Obtained in two colours, grey and blue. The " Grey Bed " is medium-grained slightly micaceous sandstone. The " Blue Bed " is a compact hard sandstone. Both are excellent stones for all building, engineering, and monumental purposes. They are excellent stones where strength combined with durability is required.

Grey Bed: weight 149 lb. per cub. ft.
Crushing strength 569 tons per sq. ft.
Blue Bed: weight 151·4 lb. per cub. ft.
Crushing strength 631 tons per sq. ft.

Red Wilderness: Mitcheldean, Gloucestershire. A stone of fine texture and suitable for all classes of external and internal work.

Crushing strength 695 tons per sq. ft.

Bristol Pennant Stone: Gloucestershire. A very hard fine-grained sandstone. Blue in colour. An exceedingly good stone for all engineering purposes owing to its exceptional strength. Its hardness makes it suitable for steps, landings, etc., as they do not become slippery by wear.

Weight 172 lb. per cub. ft.
Crushing strength 1,001 tons per sq. ft.

Darley Dale: Derbyshire. Known as " Stancliffe stone." Colour is light drab to yellowish white; compact close-grained and micaceous sandstone; eminently suitable for all building and engineering work. Blocks of any reasonable size can be obtained.

Weight 148 lb. per cub. ft.
Crushing strength 670 tons per sq. ft.

Howley Park: Yorkshire. Light brown fine-grained stone suitable for general building work, landings, copings, etc.

Weight 140·3 lb. per cub. ft.
Crushing strength 466·7 tons per sq. ft.

Robin Hood: Yorkshire. Bluish grey, fine-grained; suitable for all general building work, copings, etc.

Weight 145 lb. per cub. ft.
Crushing strength 574 tons per sq. ft.

LIMESTONES

Characteristics. The chief characteristic of limestones is the presence of a large proportion of carbonate of lime. They were formed chiefly by the accumulation of shells or calcareous skeletons of marine or fresh water organisms, which were deposited as sediment in the waters of seas or lakes. The common or chalk limestones are more suited for the production of lime. The *Oolitic limestones* are of marine origin; they are composed chiefly of carbonate of lime, with other substances, such as carbonate of magnesia, silica, alumina, and iron. The *oolite* resembles the roe of a fish, and results from the accumulation of carbonate of lime around the small nuclei of fragmentary shells or grains of mud or sand. They are spherical or oval shape, and can easily be seen with the naked eye. They vary in hardness and texture; some are fairly fine, others coarse and porous.

All limestones are soft when first quarried, but harden on exposure to the atmosphere.

The stone should be uniform in colour throughout in the case of both sandstones and limestones.

Varieties. The following are a few of the limestones in general use for building purposes.

Ancaster: Lincolnshire. Colour is cream to buff; texture varies from a fine-grained *oolite* to coarse and shelly, the latter being called " Rag " or " Weather Bed "; partly crystalline and of good weathering qualities. Used considerably in church work.

Weight 135·3 lb. per cub. ft.
Crushing strength 218·6 tons per sq. ft.

Bath Stones. These include a series of *oolitic* stones quarried or mined in the vicinity of Bath, and are excellent for all styles of architecture. They average cream to buff colour and are soft and easily worked. If well selected and placed upon their *natural bed* they *weather* well. There are old buildings in London constructed of this stone still in a splendid state, the stone showing very little signs of disintegration; while close at hand Portland stone buildings are showing distinctly the effects of the London atmosphere, although built considerably later. The following belong to the Bath series

St. Aldhelm: Box Ground. A good stone and most suitable for cornices, strings and sills, and projecting members. Bedding planes show distinctly.

Weight 129 lb. per cub. ft.
Crushing strength 107 tons per sq. ft.

Corsham Down. Fine grained, suitable for ashlars and facing stones in conjunction with Box Ground and for interior church work.

Weight 129 lb. per cub. ft.
Crushing strength 128 tons per sq. ft.

Combe Down. Quite a good weather-resisting stone if well selected; fairly fine-grained and suitable for all positions as "Corsham Down."

Weight 128 lb. per cub. ft.
Crushing strength 151 tons per sq. ft.

Farleigh Down. Very soft and suitable for interior work; does not weather well if used for exterior work.

Weight 120 lb. per cub. ft.
Crushing strength 62 tons per sq. ft.

Monk's Park. Splendid stone for all kinds of exterior and interior work; colour is cream, but dries almost white; it is close-grained, and weathers exceedingly well in town atmospheres if well selected. Undoubtedly the best of the Bath series for all general building work.

Weight 137 lb. per cub. ft.
Crushing strength 223·5 tons per sq. ft.

Hartham Park. Bedding planes more or less distinct; suitable for exterior and interior work.

Crushing strength 123·5 tons per sq. ft.

Beer Stone: Near Seaton, Devon. Of the chalk series; whitish colour; soft. The freestone consists of beds which lie at the junction of the chalk and the green sand. Made up of minute fragments of shells, close-grained. Suitable for internal work and lends itself to rich moulding, carvings, etc.

Weight 131·7 lb. per cub. ft.
Crushing strength 151·2 tons per sq. ft.

Chilmark: Wiltshire. Upper *oolite*; colour, yellowish brown; siliciferous limestone.

Weight 135 lb. per cub. ft.
Crushing strength 136·0 tons per sq. ft.

Ham Hill: Somersetshire. Yellow and grey beds; composed of fragmentary shells and high percentage of iron. Bedding planes very distinct; hard, coarse-grained stone. A stone splendidly adaptable for panels as a contrast in colour to the surrounding stones, but not suitable for exposed positions.

Yellow Bed: weight 136 lb. per cub. ft.
Crushing strength 207 tons per sq. ft.
Grey Bed: weight 141·6 lb. per cub. ft.
Crushing strength 259 tons per sq. ft.

Ketton Stone: Rutlandshire. Even texture; cream colour to yellowish brown; fairly soft to work when fresh, but hardens on exposure. Quite a good stone for all external purposes.

Weight 156·7 lb. per cub. ft.

Hopton Wood: Derbyshire. Carboniferous limestone. Can be obtained in three colours, light, grey, dark. Takes a good polish; suitable for monumental and decorative purposes. It is a good stone and its weathering properties are excellent.

Weight 158 lb. per cub. ft

Portland Stone: Dorsetshire. *Oolitic* limestone. Generally speaking there are three beds of stone, Roach Bed, Whitbed, and Best Bed (*Base Bed*).

The *Roach* is chiefly suitable for marine construction, although it has been used occasionally for building purposes.

The *Whitbed* is a hard, fairly fine-grained stone, cream to light brown, but whitens when dry. Acknowledged to be one of the finest weathering limestones on the market. Suitable for all external purposes.

Best, or *Base, Bed* is a fine even-grained stone. White in colour; suitable for fine enrichments and carvings, internal and external work.

Weight 137·6 lb. per cub. ft.
Crushing strength 287 tons per sq. ft.

Daulting: Somersetshire. *Fine beds*, light brown to cream or grey, uniform in texture; fairly soft but hardens on exposure. Most suitable for internal work. The *Chelynch Bed* is a good stone for external dressings, etc.

Weight 125 lb. per cub. ft.
Crushing strength 103 tons per sq. ft.

Kentish Rag is a hard siliceous limestone containing a high percentage of silica.

Weight 166·6 lb. per cub. ft.

Magnesium Limestones

Magnesium limestones are those containing an appreciable amount of *carbonate of magnesium* and *calcium carbonate*. They are usually termed *dolomites*, and vary in colour from white and cream to yellowish brown.

Anston: Yorkshire. Warm yellow colour; suitable for exterior dressings if carefully selected.

Weight 134 lb. per cub. ft.
Crushing strength 833 tons per sq. ft.

Mansfield Woodhouse: Nottinghamshire. Warm yellow brown colour; suitable for internal and external dressings, etc.; weathers well.

Weight 145 lb. per cub. ft.
Crushing strength 577 tons per sq. ft.

Bolsover Moor: Derbyshire. Similar to the above. A fairly good stone for external purposes, but only small blocks are obtainable.

Roche Abbey: Yorkshire. Pale grey in colour; suitable for dressings and carvings, etc.

Weight 139 lb. per cub. ft.
Crushing strength 250 tons per sq. ft

BEDDING AND SEASONING

Natural Bed, or Planes of Cleavage. All stratified rocks, which include sandstone and limestones, are deposited in layers, and thus have more or less distinct planes of cleavage. In most sandstones the planes are easily discernible, but in some limestones it requires an intimate knowledge of the particular stone to ascertain in which direction the planes run. It is very important that the ends of the laminae should be exposed to the surface, when the stones are placed in the building. It is often suggested that cornices and overhanging courses of stonework should be placed joint bedded to prevent the drip caused by the throating falling off; but with the exception of distinctly laminated stones, such as Ham Hill stone, it is preferable to select the stones for these courses and place them in the building with the planes of cleavage horizontal or at right angles to the pressure. Arch stones, etc., should have their planes parallel to the centre line of the individual stone, or *voussoir*, and at right angles to the face of the arch, or as nearly as possible square to the direction of the thrust.

It is very important to study the bedding of most stones, the life of the stone depending to a great extent upon the mason rigidly adhering to this principle in the selection of each individual stone. It is not so important in the selection of Portland stone, in which it is very difficult even to the trained eye to state which way the planes run, except where shells are visible, and then in some instances one has to be very cautious in coming to a decision. Stones, such as columns, etc., for receiving weight, should be specially selected, and should always be placed with their beds horizontal.

Most stones before they are removed from the quarry have a distinct indication marked on them, or cut in, by the quarryman, for the guidance of the masson. In soft stones such as Bath stone a *kerf* is drawn through the block at right angles to the natural bed with the axe, and in other stones the numbering of the block is placed parallel with the *natural bed*, or an arrow is painted on the block indicating the *bed*.

Seasoning. Most building stones, including granite, undergo a process of hardening upon exposure. They contain moisture, or *quarry sap*, which evaporates upon being drawn to the surface of the rock. Stones are more readily worked when freshly quarried, especially granite and the harder stones, but the softer stones such as Bath stone are best worked after being stacked for some months. The face of the stone hardens by evaporation of the sap, and if this face is removed by re-working, a weakness is caused, and the stone will not weather so well. After all labours have been finished on the stones, the clean surfaces should be slurried with stone dust and a small percentage of plaster, thus protecting all exposed surfaces and preventing a face forming.

Stones should be selected to suit the particular work for which they are required. The weight or density of the material must be taken into account. Dense stones must be used for buttresses, engineering work, etc., but for vaulting and internal decoration light stones are preferable, except where polished surfaces are required.

SPECIFICATIONS AND QUANTITIES

By Wilfrid L. Evershed, F.S.I.
Chartered Quantity Surveyor

LESSON II

SPECIFICATIONS

Meaning and Use of Specifications. The preparation of specifications for building work is very clearly linked up with that of the bills of quantities, and is often carried out by the quantity surveyor after he has prepared the bills from the drawings which have been supplied by the architect.

The general meaning attached to the specification is that of a detailed description with regard to the construction and formation of the building to be erected, and has generally application only to one particular set of drawings.

It should embody practically all the particulars of the contract entered into between the building owner and the builder, together with the relationship of the architect to both parties; the whole specification, together with the drawings, and sometimes the bills of quantities, forms part of the contract documents.

To be of real service it should be brief, but containing sufficient information for the parties using same to be quite clear as to the meaning and intent thereof. To obtain this clearness, care should be taken to use only the ordinary technical terms that are clear to tradesmen and workmen generally employed on a building, and all technical words seldom used should be avoided. It should be written in a definite order; each paragraph relating to an item should be carefully marked so as to separate them one from the other; and it is always a great service both for inter-reference and reference by the builder, if the paragraphs are numbered.

Mention has already been made of a quantity surveyor writing the specification, but if it is not done by him, the person who writes it should be well acquainted with the ideas of the architect, and should also be quite familiar with the latest form of construction and materials likely to be used.

Where specialities of any particular firm are to be used, care should be taken to obtain, from their catalogue or price list, the correct description, and if possible, a catalogue number and prime-cost figure; but catalogue prices should not be quoted.

Writing a Specification. The best method of procedure for writing a specification is to outline on sheets of foolscap the general trade and sub-headings and items required.

It is advisable to keep a series of these sheets, so as to be able to refer constantly to what may be termed an outline for the preparation of writing up any new specification required; but it is a great mistake to cut and alter any old specification, unless great care is exercised in reading the description, or it will be found that paragraphs are included which do not apply to the particular job in hand, or which may contradict a description in another part of the specification.

The *heading* of the specification should consist of the title, showing completely the position of the job, and particulars as to the building owner and architect. The *preliminary clauses* should contain extracts from the form of contract, and which will be of service to the builder or the workmen, a list of the drawings, and also general information for the guidance of the builder carrying out the work.

The *body* of the specification should contain a full and accurate description of the materials and labour necessary for the job, this being divided up under the various trade headings, of which the following are the most general: Excavator and Concreter, Drainage, Bricklayer, Tiler or Slater, Mason, Carpenter and Joiner, Ironmonger, Founder and Smith, Plumber, Plasterer, Glazier, Painter, together with such additional trades as Paperhanger, Heating and Ventilating Engineer, Electric Wiring and Bells, Gas Fitter, Coppersmith, Reinforced Concrete, Structural Steel and others.

It is of great service to every-one concerned if an index is made of the various clauses; and when these are numbered, as previously suggested, the finding of any required item is facilitated.

In writing the paragraphs, care should be taken to avoid any loose expressions which in particular throw the decision upon the builder. An expression such as "or equal," or "similar to," and also such expressions as " as required," " in a proper manner," are of no help to the builder. The writing should be quite definite as to the requirements of the architect.

It is advisable in writing a specification to bear in mind certain of the rules laid down by the joint committee of the Surveyors' Institution and the Master Builders, and embodied in the *Standard Method of Measurement for Building Works*; for instance, the standard method gives certain rules for calculating the amount of lead at the eaves of a sloping roof, and also for the amount of passings to be allowed in connection with flashings, and, unless there is some particular reason, these allowances should be embodied in the specification.

It is impossible in the space available to give complete paragraphs for the whole of a specification required, but it must be borne in mind that in drawing up these various paragraphs instructions are being given to the builder for certain work, and the specification should be so worded that it is in the nature of a written order for what has to be done to complete the building; the paragraphs should therefore, not read like a description from a bill of quantities, any more than a description in a bill of quantities should be like a paragraph from a specification.

When specifying that an item, such as a stove, has to be set by the bricklayer, remember also that the stove itself has to be mentioned in the Founder and Smith, and a note should be made in connection with the fixing, referring the reader to the paragraph where the provision of the stove is specified.

A point to be remembered in writing a specification is that it is not an instruction how to lay bricks or execute other work, but what is required by the architect to complete the job. The bricklayer knows how to lay his bricks, probably better than the architect, but will not know the architect's actual requirements in designing unless he is told.

Brevity and Clarity. In writing, do not use unnecessary words, as it only makes so much additional reading to be able to understand what is required; if instructions can be put into a concise form, they are more easily understood and carried out than if written up with numerous useless words. For instance, an item from a specification reads as follows: " The whole of the roofs to be framed together and constructed in the strongest manner, collars to be spiked to the rafters, and the rafters to the plates and purlins. In constructing the roofs, timbers of the following scantlings are to be used: plates 4 in. × 3 in., rafters and ceiling joist 4 in. × 2 in., ridges 8 in. × 1½ in., valleys 8 in. × 2 in., hips 8 in. × 1½ in., collars 4 in. × 2 in., purlins 5 in. × 3 in."

This extract can, it will be realized, be made much shorter and more easily understood by saying that the roofs are to be framed up and spiked, in the strongest possible manner, of the following scantlings—

Plates . . .	4″ × 3″
Rafters and ceiling joist	3″ × 2″
Ridges . . .	8″ × 1½″
Valleys . . .	8″ × 2″
Hips . . .	8″ × 1½″
Collars . . .	4″ × 2″
Purlins . . .	5″ × 3″

A clause in a specification which reads as follows: " Provide and build in all external openings suitable concrete lintels and provide all requisite board casings and struts, the lintels to be reinforced as necessary with ½-in. diameter steel bars," is not at all definite, and the sizes of these lintels and the number of bars required should be definitely stated to the various widths of openings.

HISTORY OF ARCHITECTURE

By Thomas E. Scott, A.R.I.B.A.

LESSON II

THE ORIGIN OF ARCHITECTURE

EGYPT—WESTERN ASIA

The origin of architecture is as remote as the origin of mankind. It is certain, however, that the need for shelter from the elements, and protection against wild animals, were the first incentives to build, and that the earliest structures were as primitive as man himself.

It is not possible to classify with any certainty the few remains of prehistoric buildings, so they are of little value, although it is possible to trace in some of the earliest efforts the origin of later works. In England, the great circle of stones at Stonehenge, and the Tumuli, or raised mounds, marking burial grounds, are familiar ancient works which are examples of primitive building.

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EGYPT

The earliest civilization of which there is any reliable information is that of Egypt. Its history is derived from the Scriptures, from Greek and Roman writers, and from its buildings; through the latter it may be traced back to about 4,000 years B.C., and even at that early date there is evidence that the Egyptians were possessed of great constructional ability.

A very peculiar point about much of their work, however, is the inaccuracy in the setting out of buildings and preparatory work generally. This is probably explained by the driving haste necessary in order to complete works in anything like a reasonable amount of time.

The remains of Egyptian architecture suggest that the chief buildings were temples and tombs, and the substantial way in which they were built is expressive of the importance of religion and the power of the priesthood. The Egyptian appears to have regarded life as a transitory existence, anticipating that his soul, after death, would sojourn for 3,000 years with *Osiris*, or in the body of an " unclean " animal, according to the judgment of the deities, ultimately returning to its former body. Not only was the body most carefully embalmed for preservation, but colossal tombs were erected for its protection, and for the storage of certain worldly possessions against the return of the soul. How well this was done is evident from recent discoveries by the late Lord Carnarvon and Mr. Howard Carter.

Of domestic buildings, there are no remains of any account; this is natural, not only because of the relative unimportance of earthly life on religious grounds, but also on account of the nomadic existence necessary in hot climates.

Temples. The temples were jealously guarded sanctuaries, which only the king and priests might enter. They were vast structures, created to impress, and suggestive of the mystery of the rites and processions which took place within. The Temple of Khons, Karnak (Fig. 6), built about 1200 B.C., is a characteristic example. It will be appreciated that the raising of the floor levels and lowering of the roof increased the appearance of size, the forest of columns gradually fading away in the almost black darkness of the unlit interior.

Tombs. There were three general types of tomb.

The *Pyramids*, familiar in form to all, were built by the kings to contain their preserved bodies. The Great Pyramid of Cheops, 3733 B.C., was a gigantic undertaking; it is about

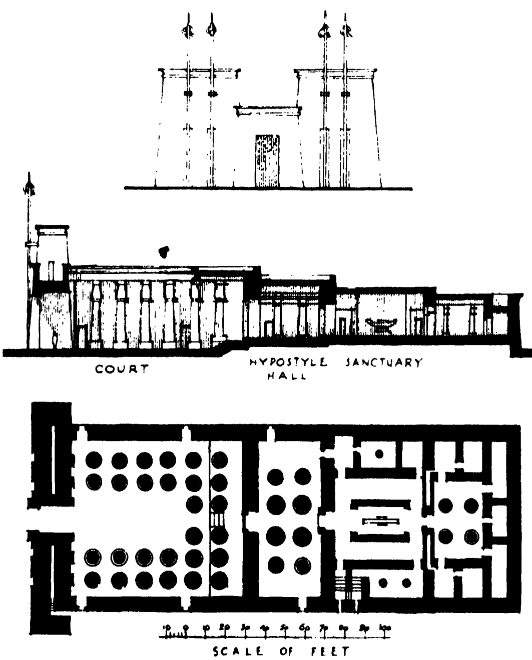


FIG. 6. THE TEMPLE OF KHONS, KARNAK
Front elevation, Section, and Plan

756 ft. square and 482 ft. high, and the accuracy of workmanship in its erection is astounding. Some of the blocks of stone weigh as much as fifty tons, and yet they were fitted with great exactitude, and in the lengths of the sides there is a variation of only 1·7 in. Even with the vast amount of slave labour available, it is almost impossible to realize how so stupendous a task was carried out.

The *Mastabas* were small structures, used as tombs for less important personages. In later periods, tombs were usually cut into the face of the rock, an entrance giving access to an underground corridor which led to the various chambers. At Beni Hasan there is a remarkable group of tombs, built between 2500 and 2200 B.C., the entrance to one of which (Fig. 7) is particularly interesting as a possible prototype of the Greek Doric Order.

Space will not permit more than a passing reference to the Great Sphinx, the origin and meaning of which are unknown.

The *Obelisks*, of which the well-known "Cleopatra's Needle" in London is an example, were decorative pillars which stood in pairs at the entrance to temples. Their quarrying, transport, and erection are interesting subjects for speculation.

Craftsmanship and Materials. The abundance of unskilled slave labour is a factor which has contributed largely to the massive character of Egyptian buildings, but it was the organization and engineering skill of the Egyptians which made such works possible.

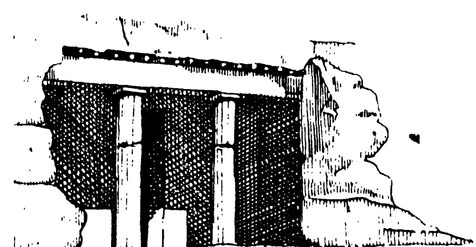


FIG. 7. ROCK-CUT TOMB, BENI HASAN

The materials used were granite, sandstone, limestone, and sun-dried bricks; timber, although available in small sizes, was not generally used for the temples, but was possibly employed in the building of houses. Alabaster was used as a decorative material.

Architectural Character. It is highly probable that a mud and reed form of building, practised on the banks of the Nile, was the prototype of the stone architecture which followed. Walls were immensely thick, usually battered or sloped on the outer face, and, when built of stone, were frequently decorated with carving and hieroglyphics, the latter contributing very largely to our knowledge of Egyptian history. Walls of brick, and sometimes those of stone, were plastered, both as a protection against the weather and to provide a suitable surface for colour decoration. This was applied in the form of a low relief sculpture, the process probably consisting of the drawing of the figures by an artist, their outlines cut, and the forms slightly modelled by a sculptor, and the whole finally coloured by the painter. Colour decoration was used internally, where, owing to the subdued light, it was necessary that the colours should be strong and bright, red, blue, and yellow being most frequently used. The reader is referred to the *Grammar of Ornament*, by Owen Jones, for some excellent illustrations in colour of Egyptian and many other types of decoration.

Window openings were rarely used, light being admitted over dwarf walls between the columns (Fig. 4, Lesson I).

Roofs were flat, consisting of slabs of stone supported by the walls and massive, closely spaced columns (see Fig. 6). The decoration of these columns appears to have evolved from the bundles of reeds, of which the earliest buildings were probably constructed. The treatment of the upper parts of the columns, known as capitals, was inspired by local plant life, such as the lotus bud and flower, and the papyrus, the former being the symbol of fertility (Figs. 8A, B, and C).

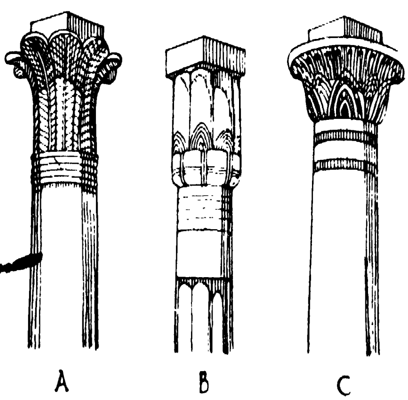


FIG. 8. EGYPTIAN CAPITALS
(A) Palm Leaf Capital. (B) Lotus Bud Capital. (C) Bell, or Lotus Flower, Capital

Beams consisted of plain stones, sometimes surmounted by a simple moulding (Fig. 9A).

Ornament was usually simple, consisting of symbolical features, such as the sacred beetle, or scarab, the globe and vulture, which was a symbol of protection, while diaper patterns and running bands of various types were used (Fig. 9).

Egyptian architecture, although occupying no very important place in the history of the arts, must always be recognized as one of the finest evidences of the expression, in building, of the life story of a nation. It should always be studied too, for its massiveness, its eternal nature, its strength, and mystery—qualities in the expression of which it has never been excelled.

WESTERN ASIA

Little now remains of the architecture of the nations who ruled the countries of Western Asia; but there is sufficient evidence to show that the Greeks were, to some extent, influenced by the works they found there. Histories usually refer to three styles · Chaldean, Assyrian, and Persian but there is little vital difference between them, although they all differ greatly from Egyptian work.

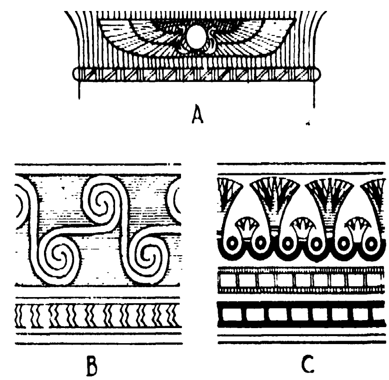


FIG. 9. EGYPTIAN ORNAMENT
(A) "Gorge" moulding, with feather ornament and winged solar disc. (B) Spiral ornament. (C) Frieze with lotus motif

The scarcity of stone and timber led to the use of sun-dried bricks, and buildings in consequence lacked the durability of those of the Egyptians; and thus little remains of the magnificent palaces which excavations show to have existed.

The architecture of the Persians, at one time rulers of Western Asia, attained great magnificence, and the vast Hall of Xerxes at Persepolis, the capital, was undoubtedly one of the largest and most imposing buildings of antiquity. There exist now, however, only the vast platforms and terraces of rock (natural precautions against floods) upon which these palaces were built.

BUILDER'S GEOMETRY

By RICHARD GREENHALGH, A.I.STRUCT.E.
Honours Medallist in Geometry

LESSON II

DRAWING INSTRUMENTS—(*contd.*)

Choice of Instruments. It is always advisable for the draughtsman to purchase the best instruments within his means. Good work cannot be done with cheap instruments; the joints of compasses, etc., move jerkily and soon work loose, and the points cannot be adjusted accurately. It is preferable to buy one or two instruments of good quality as required, rather than a case full of inferior make.

The joints should be of the double-jointed kind, that is, where the joints are pivoted and the two parts fit into

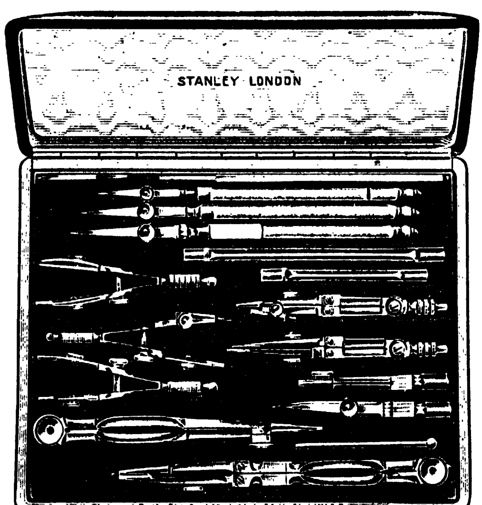


FIG. 11. POCKET CASE OF DRAWING INSTRUMENTS

each other, there should be double slots and tongues. The needle points should be replaceable and should fit tightly where they emerge from the bottom of the leg, so that there will be no play or side movement when in use.

A pocket case of good quality drawing instruments is shown in Fig. 11.

Compasses. Compasses may be obtained in three patterns, the type shown in Fig. 12 being adapted for large circles. When complete with a lengthening bar (top illustration) and a pen (bottom at right), the various parts are known collectively as a *half set*. The lengthening bar is used when drawing very large circles, the compass leg being removed and replaced by the

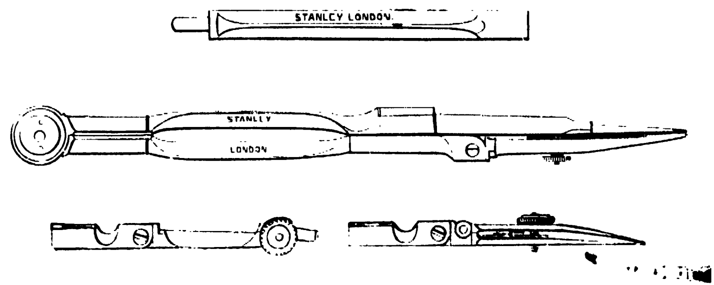


FIG. 12. HALF SET OF COMPASSES

lengthening bar, and then fitted into the lower end of the lengthening bar. The pen leg can be used in place of the pencil leg.

For circles of medium size, say between 1 in. and 4 in. in diameter, *bow compasses*, as shown in Fig. 13, are the most useful. These compasses have a knob at the top, and the points are not detachable, so separate instruments are required for pencil and ink.

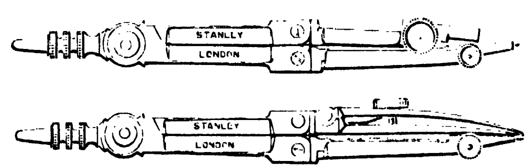


FIG. 13. BOW COMPASSES

Spring-bow compasses, a good pattern of which is shown in Fig. 14, are used for very small circles. They are usually supplied in sets of three: pencil, pen, and divider points, but the latter are of little use.

Using Compasses. To use a pair of compasses efficiently requires a fair amount of practice. Two rules should be observed. First, put as little pressure as possible on the point; and, secondly, always keep the legs as upright as possible. If these two rules are followed, an unsightly hole will not be made in the paper, thus also tending to make further curves inaccurate when struck from this centre. The top of the compasses should be held lightly

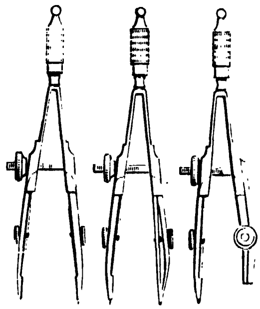


FIG. 14. SPRING-BOW COMPASSES

between the thumb and first and second fingers, as shown in Fig. 15.

The young draughtsman should try to handle and adjust the compasses with one hand, as shown in Fig. 16, which shows the compasses [redacted] to inscribe a circle in a triangle. Practice will soon enable the student to adjust his compasses in this manner.

Dividers. These are not very necessary, as compasses can generally be used instead, but they are looked upon as part of a draughtsman's equipment. The points should be kept very fine and

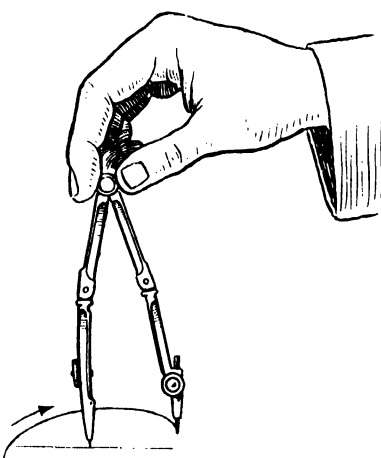


FIG. 15. METHOD OF USING COMPASSES

sharp, and the knuckle should work smoothly. When setting the dividers to a required length, there is a tendency to jerk the points a little over or under the required setting, and therefore some dividers are provided with a *hair adjustment*, as shown in Fig. 17. This means that one leg is jointed near the middle or near one end, and the lower part can be adjusted

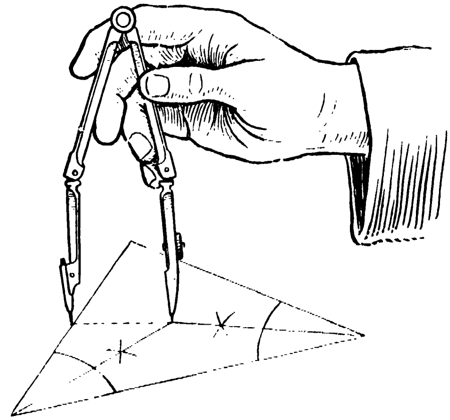


FIG. 16. SETTING THE COMPASSES

a little by turning a screw, as shown. It is a rather unnecessary refinement.

French Curves. Curved lines which are not parts of circles and which cannot be drawn freehand are usually drawn by the aid of French

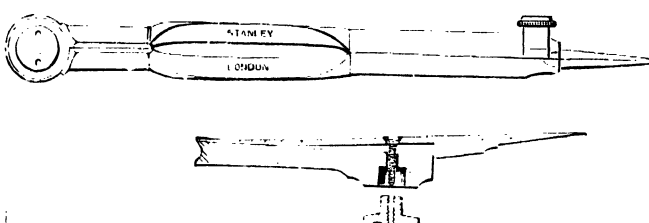


FIG. 17. HAIR DIVIDERS AND SECTION THROUGH LEG

curves, a typical example of which is shown in Fig. 18. Many varieties of shapes can be purchased in either wood or celluloid, the latter being preferable. Some draughtsmen make their

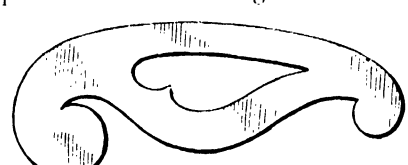


FIG. 18. FRENCH CURVE

own from a sheet of celluloid, which can be cut with a penknife and glass-papered to a smooth edge.

When using French curves, care must be

exercised or "kinks" will show in the curve drawn. The French curve should be adjusted to at least three points on the required curve, and it is often advisable first to sketch the line freehand. As the line is drawn, the French curve is moved about to successive positions, and should always be adjusted so that part of it coincides with a portion of the curve already drawn.

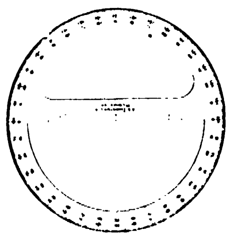


Fig. 19. Circular Protractor

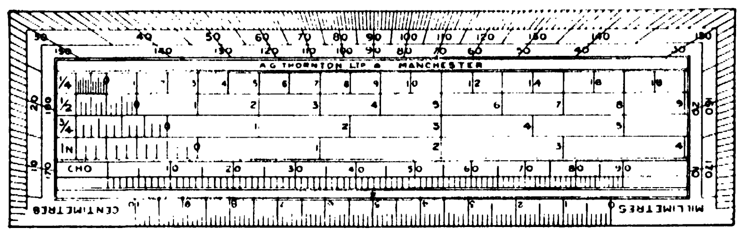


Fig. 20. Rectangular Protractor

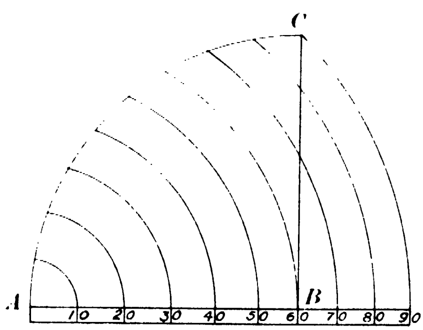


Fig. 21. Constructing a Scale of Chords

Flexible curves may also be obtained for drawing curved lines, but they are not much used.

Protractors. The instrument used for measuring or setting out angles is known as a protractor. It is usually a semicircle of celluloid with the

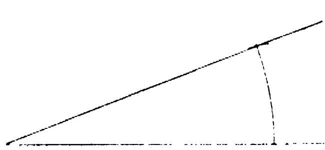


Fig. 22. Setting out Angle with Scale of Chords

degrees marked round its arc, but is sometimes a complete circle as shown in Fig. 19. Protractors are also sometimes made of wood, metal or ivory, but celluloid is the best material because it is transparent. Rectangular protractors, as shown in Fig. 20, are also made. In setting out an angle, the base of the protractor is adjusted to the line, with the middle point of the base over the spot from which the angle has to be drawn; a point is then marked off at the rim of the protractor.

Scale of Chords. A scale of chords is also

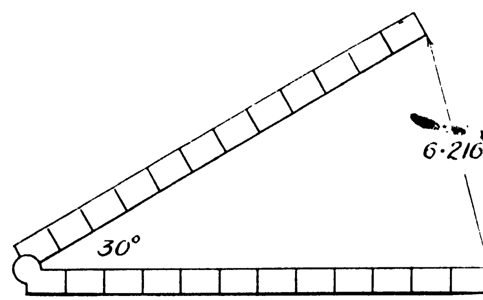


Fig. 23. Setting out Angle with Rule

used for setting out angles, and is often found marked on rules.

Table for Setting Out Angles with Rule

Degrees	Chord	Chord at 12 in
5	0·087	1·044
10	0·174	2·088
15	0·261	3·132
20	0·347	4·164
25	0·433	5·196
30	0·518	6·216
33⅓	0·577	6·924
35	0·601	7·212
40	0·684	8·208
45	0·765	9·180
50	0·845	10·140
55	0·923	11·076
60	1·000	12·000
65	1·075	12·900
70	1·147	13·764
75	1·218	14·616
80	1·286	15·432
85	1·351	16·212
90	1·414	16·968

(*Continued on page* 91)

BRICKWORK

By William Beaber
Lecturer in Brickwork at the Northern Polytechnic, London

LESSON II

BRICKS *(contd.)*

Moulding. A piece of board, Fig. 1, called a *stockboard,* having a reverse mould of the indentation, or *frog,* of the brick, is fixed at one corner of the moulder's bench, Fig. 2. A wooden or metal box, as shown in Fig. 3, and called a *mould,* is fitted over the stockboard. This mould is minus top and bottom, and of the exact shape but larger by one-tenth in all dimensions than a brick.

The mould having been wetted or sanded to prevent the clay sticking to its sides, the clay is dashed into it and pressed into the corners, [redacted]s being removed by drawing a short [redacted] straight-edge (*strike*) over the top edges of the mould. The moulder then places a piece of $\frac{3}{8}$ in. board, called a *pallet,* on the top, lifts the mould and its contents off the stockboard, reverses it, and removes the mould, thus leaving the raw brick on the pallet.

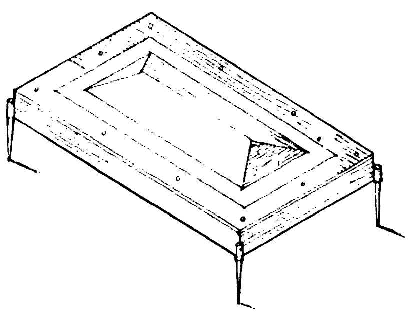


Fig. 1. Stockboard

The bricks are loaded on to a specially constructed wheelbarrow fitted with springs to prevent damage through vibration, and taken to the drying hacks. The hacks are long, level, concrete banks about 6 in. above the general ground level, where the bricks are stacked on edge about $\frac{3}{8}$ in. apart and about seven or eight courses high, with their ends exposed to the weather. Here they remain for about two weeks. At the end of this time they are stacked diagonally about 2 in. apart, each course in opposite directions, so that the wind may more effectually dry them. The bricks are protected from the weather by wooden frames, matting, or tarpaulins.

Burning. Fig. 4 shows a *clamp* as used for burning bricks. A level platform is formed, on raised ground, with underburned bricks from

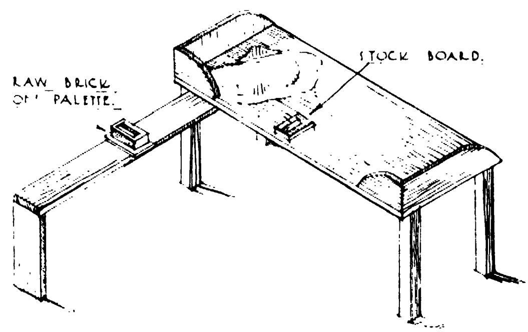


Fig. 2. Moulder's Bench

previous burnings, in which a series of horizontal channels, called *fire-holes,* are arranged. These holes are filled with faggots. Two layers of bricks on edge are then placed over the whole surface, spaced about 2 in. apart, and laid diagonally across the clamp. The spaces are filled with breeze; over this a layer of unburned bricks on edge is stacked close, and covered with

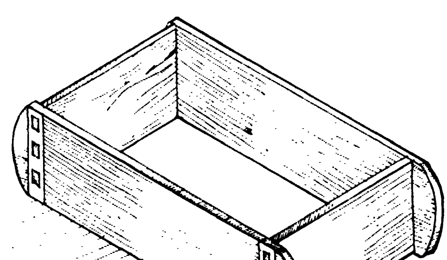


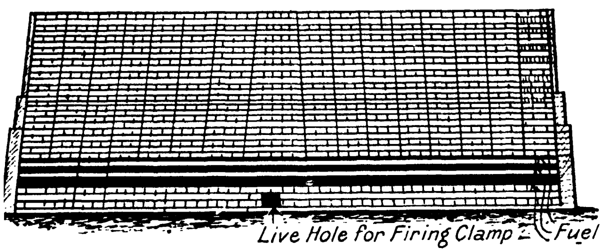
Fig. 3. Mould

7 in. of breeze. These are followed by two courses of unburned bricks, with 4 in. of breeze between, and a 2 in. layer over all. The clamp is completed with a series of close-stacked, thin

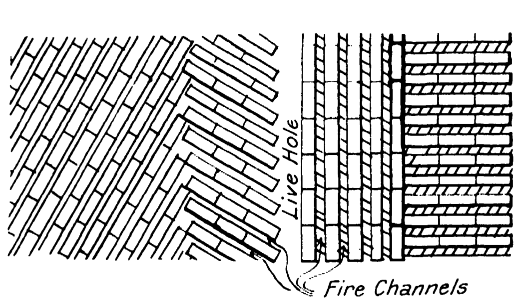
walls, called *bolts*, built up to a height of about 14 ft., the outer walls battering, or sloping, inwards. The clamp is ignited through the fire-holes, the whole burning through in from three to six weeks.

When the mass is sufficiently cool to permit of handling, the work of unloading is commenced.

Stock bricks are produced by this process, and are classified according to quality. This is determined by the amount of care exercised in the preparation of the earth, and the degree of perfection to which the bricks have been burned.



Cross-section of Clamp



Method of Stacking Bricks at the Base of Clamp to form Fire Channels

FIG. 4. PART-PLAN AND CROSS-SECTION OF CLAMP

The latter depends upon their position in the clamp.

The bricks at the base of the clamp, being subject to a very intense heat, fuse, and run together into lumps, and are useful only for rough walls, rockeries, etc.

The centre of the clamp produces bricks of the best quality, the more uniform temperature minimizing risks of fusion and distortion.

Toward the outside of the clamp, the bricks are inclined to be underburned, while those on the extreme outside are rendered, by the action of the weather, so full of cracks and flaws, as to be useless for constructional work.

Stock Bricks. The types of stock bricks are as follows—

1. Malms. 2. Malmed. 3. Common stocks.

Malms are not now made in any quantity, as the careful washing of the earth in its preparation renders the process uneconomical, producing an article too expensive for general use.

For the second type, washed and unwashed earths are mixed in certain proportions, thus reducing cost, and also quality.

Common stocks are most generally used, and can be obtained in various qualities to meet those requirements for which their colour is suitable.

Machine-made, kiln-burned stocks are being extensively manufactured in Kent, great quantities being used in and around London. These are usually termed Kentish stocks.

Kiln-burned Bricks. The preparatory processes are similar to those previously described, though usually carried out by machinery. The burning, or perhaps more appropriately, the baking, is carried out in enclosed structures, through which circulates, for varying periods, air at a very high temperature.

Many types of kilns are used in different localities: the Hoffmann, Fig. 5, the improved Hoffmann, and the Scotch, Fig. 6, being [illegible] generally employed.

Scotch kilns, as shown in Fig. 6, generally take the form of rectangular chambers, roofless and furnished with fire-holes at the bases. Bricks are stacked in the kiln, and so spaced as to allow the heat to circulate freely. The top layer is protected by a covering of old bricks, which also conserve the heat during the burning process.

These kilns are a big improvement on the clamp, the bricks being more uniform in colour and shape, their quality depending, as in the clamp, upon their position in the kiln.

The Hoffmann kiln, Fig. 5, is undoubtedly the most successful type. In these kilns, the whole of the heat generated is utilized progressively, with the result that the process of burning is very gradual. This minimizes the risk of cracking and distortion, and ensures the production of a good quality brick, providing all other conditions are satisfactory.

These kilns are circular in structure and divided into twelve chambers, interconnected by small openings at the bottom of the dividing walls. Each chamber is provided with a flue, which carries the gases of combustion and steam into a shaft. When the chambers are stacked with bricks, fuel is fed from traps in the flat top of the kiln into spaces left against the division walls.

When the kiln is in action, two adjacent

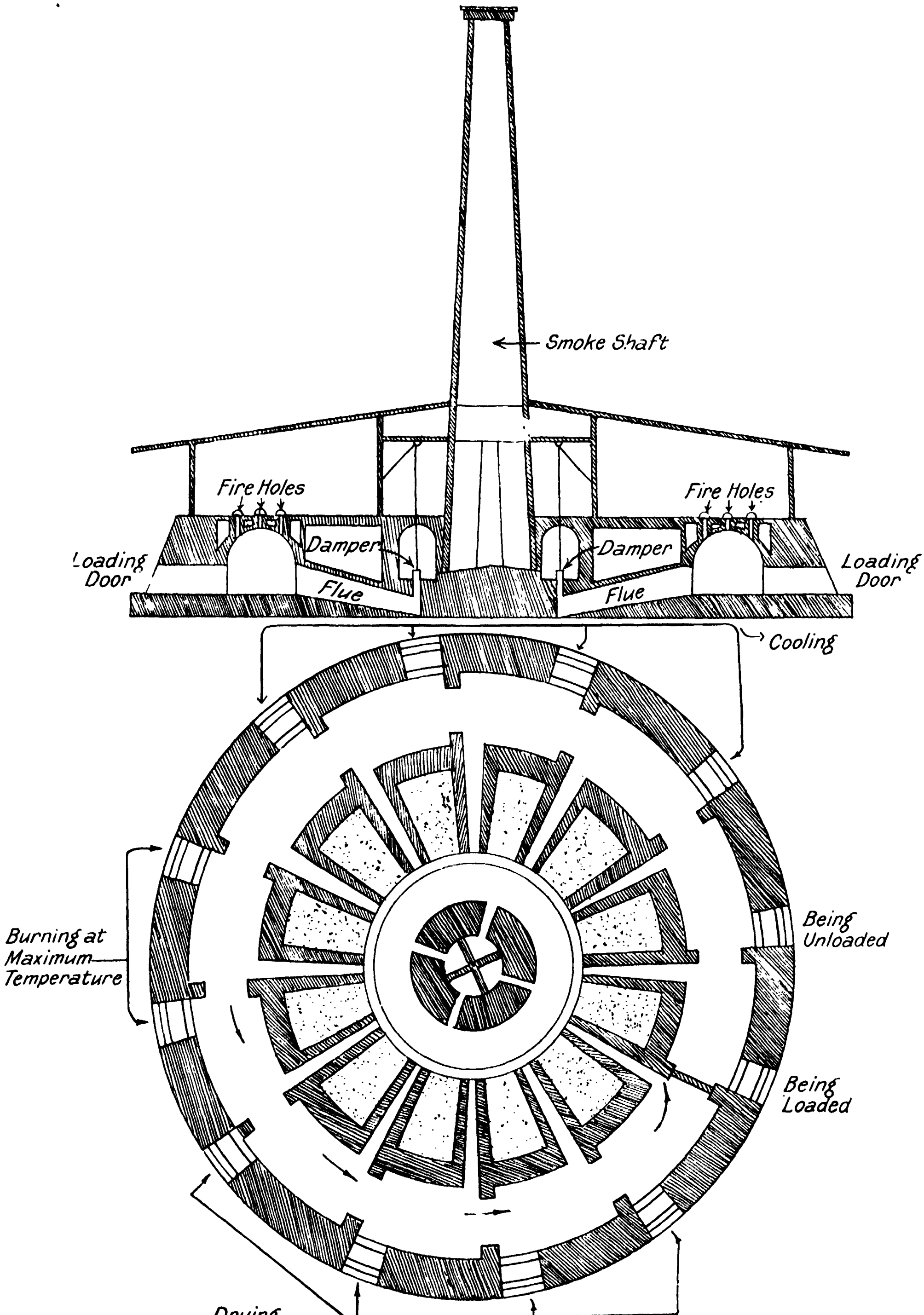


FIG. 5. SECTIONAL ELEVATION AND SECTIONAL PLAN OF HOFFMANN KILN

chambers are open, one being unloaded, the other loaded. The following four chambers are in the cooling stage, the next two burning at the maximum temperature, and the remaining four in various stages of drying. The opening between the last chamber and the chamber being loaded is covered with sheets of paper, to prevent air passing from one to the other during the loading process.

When loading is complete, the opening to the next chamber, which by this time has been

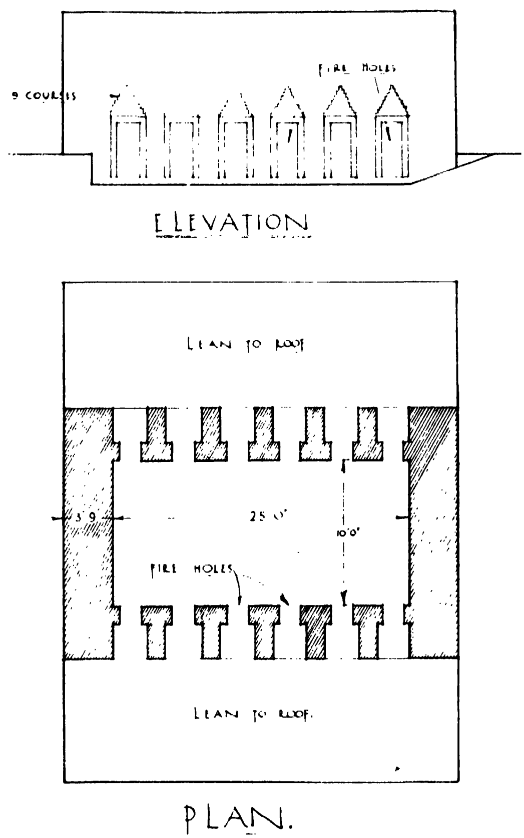
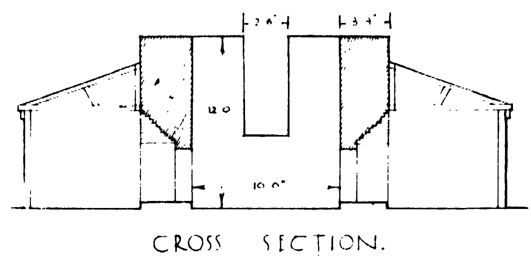


FIG. 6. RECTANGULAR KILN, WITH OPEN TOP
Scotch type

unloaded, is in its turn sealed with paper, and the last damper opened. Thus the cycle of drying, burning, cooling, loading, and unloading proceeds continuously, and only ceases when repairs to the kiln become necessary.

The improved Hoffmann, or *Warren's Perfected*, is similar in most respects, except that it is rectangular in shape, with rounded ends, and usually contains about fourteen chambers. In these kilns, considerable economy in heat is effected by the use of a hot-air flue, to which each chamber is connected by ducts. When a cooling chamber is opened, its duct is also opened, creating a draught around the cooling bricks. The heated air passing through the flue, and from thence to the drying chambers, utilizes the heat to the uttermost, thereby economizing in both fuel and time.

Machine-made Wire-cuts. After thorough incorporation in the pug-mill, the clay is pressed through a rectangular die, from which it emerges



in the form of a long slab about $9\frac{1}{2}$ in. × 5 in. in section. A series of wires attached to a [illegible] work is pulled across the bench on which the slab rests, and cuts the slab into 3 in. blocks, which are afterwards kiln burned.

Fletton Bricks. These machine-made bricks are manufactured in the Peterborough district, from a local shale known as Oxford clay. The process of manufacture is entirely different from all others, except in the burning, usually carried out in a Hoffmann kiln. The clay is dug, dried, and ground in a mill similar to a mortar-pan. The resulting powder is shot into a revolving sieve, the residue being carried back to the mill for further pulverization. The sieved earth is moulded under great pressure in a machine which also measures the exact quantity required for the finished brick. The bricks are carried direct from the machine to the kiln. Burning continues for about three weeks.

Millions of bricks are turned out weekly by this process, which is so rapid that it is possible for only twenty minutes to elapse between digging the clay and stacking the kiln.

The finished bricks are tough, compact in texture, well-shaped, with clean and sharp arrises.

Their colour varies from a dull cream to light red, not very pleasing in tone, and unsuitable for use as facings in important positions, but excellent for interior work. For walls that are to be plastered, a special kind is made, having undercut grooves on the face, which form a key for the plaster.

LAND SURVEYING AND LEVELLING

By Professor Henry Adams, M.Inst.C.E., F.R.I.B.A., F.S.I., etc.

LESSON II

SURVEYING SIMPLE PLOTS

Surveying Straight-sided Plots—Scales—Field Book—Marking Boundaries—Compass Direction—Offset Piece

Measuring Simple Plot. The simplest case one can have in practical work is to measure a rectangular straight-sided plot, but it is not sufficient to measure round the sides and assume that the angles are right angles; the figure must be proved by measuring the two diagonals as well as the sides, as in Fig. 6. Sometimes, instead of the diagonals, tying triangles are measured across two adjacent corners as in Fig. [illegible] not less than one-quarter of the length of the sides, as shown. The first triangle ties the figure and the second forms a check. The measurements are given in chains and links, but the decimal points may be left out, and then the same figures represent links of $12 \times \frac{66}{100} = 7.92$ in. The measurements might also have been made in feet and inches if they had been taken with a 100-foot tape or chain. These examples should be plotted to a scale of, say, 1 inch to 1 chain.

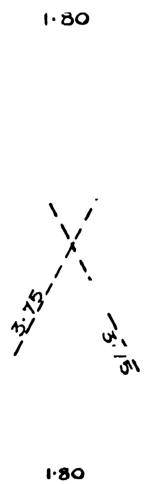


Fig. 6. Survey of Straight-sided Plot by Diagonals

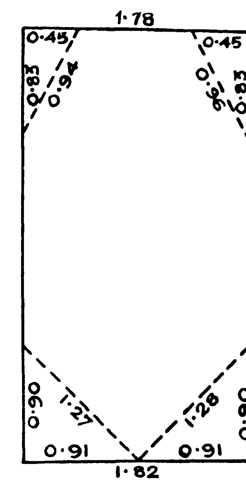


Fig. 7. Survey of Straight-sided Plot by Corner Triangles

The Scales used in making survey plans differ somewhat from ordinary builders' scales, but they are easily understood. They are all decimal scales, that is, the unit distance is divided into 10 parts, so that a scale of 1 chain to 1 inch can be used equally well for 10 chains to 1 inch, or for 100 chains 1 inch. A so-called "universal scale" will be found very handy; each edge on each face has a double scale, 10·20—40·80—30·60—50·100. Special scales are made to suit the ordnance maps, and some also have chains on one edge and feet equal on the other. Offset scales are similarly divided to the larger scales, but are only 2 inches long and used as divided set squares. Plots of building land may be found with straight outlines such as we have already considered, although in nearly every case that a land surveyor is called upon to deal with the outline is more or less irregular, but he still bases his work upon the triangle, which is marked out in the field by "pickets" or "station poles." These are 6 ft. deal rods with iron points and small flags at the top. The irregular strip between the line formed by two poles and the boundary is called an *offset piece*, and as that is an element of practically every survey, we will take one or two examples.

Chain Lines. In Fig. 8 the straight line represents one of the chain lines, the number on it shows that it is number three line, and the arrow head shows the direction in which it was measured. It is not convenient to put the measurements on the lines, and a *field book* is therefore prepared. A field book opens longways like a shorthand writer's notebook. There is a central line, or better, a central column, running down each page. The measurements on the chain line are put up the centre, working from the bottom upwards, so that the writer stands with regard to the figures the same way as the surveyor stands with regard to the chain.

On the right and left sides, the offsets or measurements to the boundary are put opposite the distances on the chain line where they occur, and on the proper side. Sketches are also made following the figures to show the lines or curves of the boundary, with letters indicating its nature, *H* for hedge, *D* for ditch, *F* for fence, *W* for wall, *Fp* for footpath, etc.

North Point. The direction of the *first line* is given by comparison with a pocket compass, remembering that the magnetic variation alters from year to year, and that at present the needle points about $13\frac{1}{2}$ minutes west of true north. It changes altogether 25 or 30 degrees east and west of true north in the course of about 160 years, and is at the present time getting nearer to the true north at the rate of about 5 or 6 minutes per annum. It moves rather slower as it gets near the true north, which it will pass and will then lean towards the east. To avoid any mistake, the true north point and the magnetic variation should be shown upon every survey plan. The true north can be ascertained approximately by pointing the hour hand of a watch to the sun, bisecting by the eye the angle between that direction and 12 o'clock, and carrying the line backwards. If the minute given by this line be noted and also the minutes indicated by the direction of the chain line, then six times the difference in minutes can be plotted as the angle made by the chain line with true north. The directions of other lines after the first are obtained by the intersection of their lengths to form triangles. For Fig. 8 the field book will be as shown in Fig. 9, the station poles being indicated by a circle with central dot. The direction is shown as 17 degrees east of true north.

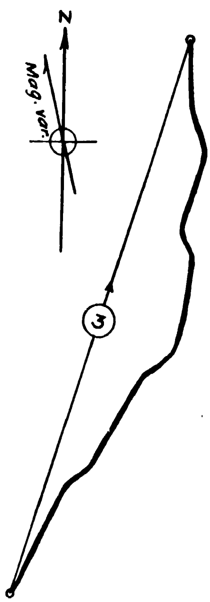
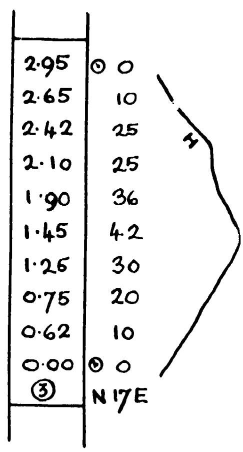


Fig. 8. Offset Piece



9. Field Notes for Fig. 8

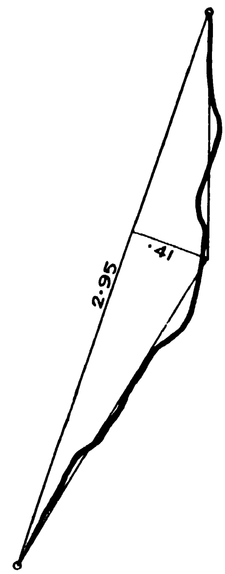


Fig. 10. Equalizing Line for Fig. 8

Area of Offset Piece. The area of an offset piece can be obtained by using equalizing lines to form a triangle and then measuring base and perpendicular, as in Fig. 10. Then the area will be -

```
  2·95
   ·41
   295
 1180
2|12095
  60475          Ans.
      4    0 a., 2 r., 16¾ p.
  24190
     40
 167600
```

This offset piece should be plotted for practice to a scale of, say, 1 inch to 1 chain. By laying the 12 inch scale down with the zero corresponding to the zero of the chain line, and using the offset scale as a set square, the offset distances can be pricked off very rapidly and the boundary drawn through.

Offsets should, as a rule, never exceed one chain in length; if they would do so when measured direct, as in Fig. 11, it is usual to take them by means of a triangle based on the chain line, as in Fig. 12. This is done owing to the difficulty of judging true perpendiculars from the chain line by the eye. It is not necessary to take the area of each offset piece separately. Equalizing, or "give-and-take," lines may be run round the whole boundary and joined up into triangles across the interior, summing up the results of base by perpendicular and not forgetting the dividing by 2. All the triangles of a survey should be "well-conditioned," that is, they should have no angle less than 30 degrees, or more than 120 degrees.

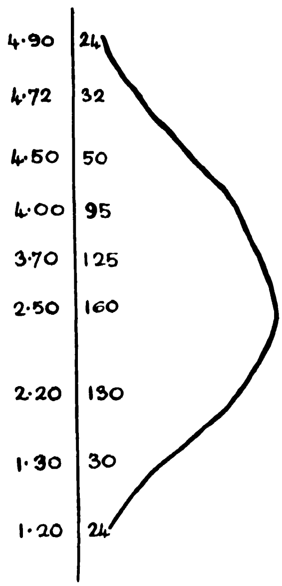


FIG. 11. EXAMPLE OF LONG OFFSETS

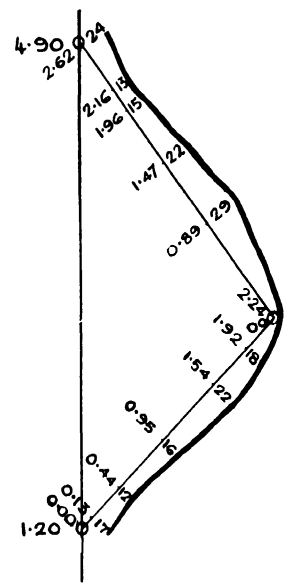


FIG. 12. TRIANGLE TO AVOID LONG OFFSETS

BUILDER'S GEOMETRY

(*Continued from page 84*)

To construct a scale of chords, draw a quadrant ABC (Fig. 21) and divide the arc AC into nine equal parts. With A as centre turn these points down on to AB (produced).

To set out any angle, say 20°, proceed as follows: Draw a line (Fig. 22) and describe an arc with AB (Fig. 21) as radius. Now set the compass from A to 20 (the *chord* of 20°) on the scale of chords and cut off the arc to this length.

A scale of chords is shown on the rectangular protractor in Fig. 20.

Setting Out Angles with Rule. The table on page 84 gives the values of the *chords* of a number of angles; that is, the figures in the centre column give the ratio of the chords to the radii of the various angles, the radius in each case being unity. If the radius is taken as 12 units, say inches, the chord will then be 12 times the size given in the centre column; therefore the figures in the last column are 12 times those in the centre column.

The latter figures can be used for setting out any angle with a 2 ft. rule. Thus, in Fig. 23, the inside corners of the ends of the rule are adjusted (as nearly as possible) to 6·216 in., as given opposite 30° in the table, and the legs of the rule thus make an angle of 30°.

ARCHITECT'S OFFICE AND ROUTINE

By Herbert J. Axten, A.R.I.B.A., A.I.Struct.E.
Chartered Architect

PART II

STAFF AND DUTIES

Staff. Senior (or managing) assistant.
Architectural assistants.
Clerks and shorthand-typists.
Office boy.

ARCHITECTURAL STAFF

Duties of Staff. The duties of the *architectural members* of the staff vary of necessity with the size and importance of the office on the one hand, and with the actual amount of architectural work executed by the principals on the other.

Should there be only one principal, he may not have sufficient time to execute the original designs for every job undertaken, and in that case the senior or chief assistant would prepare the sketch designs in addition to his other duties, but in the case of the architectural partnership, referred to in Part I, the following might be a brief outline of the duties expected to be undertaken by the architectural assistants.

The client's instructions having been given and formally acknowledged, the principal, accompanied by the senior assistant, would visit the site and prepare sketch designs, plans, and elevations. Upon these being approved by the client, they would be handed over to the senior assistant. From this point onwards until the completion of work, the senior assistant would be strictly responsible for the preparation of all the necessary contract drawings, details, and other drawings, including obtaining necessary information and particulars from the site and from the local and other authorities, for all of which purposes he is assisted by the remainder of the staff as and when required. In the case of a small job, one or other of the assistants may be given the work, and under the guiding hand of the senior assistant made responsible for its satisfactory execution; in this way the juniors gain experience and self-reliance.

The senior assistant must also be capable of making land surveys and taking levels; making surveys of dilapidations; making sanitary surveys; making surveys for valuation regarding the purchase or sale of various types of properties; measuring up and drawing out existing buildings requiring alteration or extension. He must also be well versed in the imperial and local legislation affecting the construction of buildings, in order to discuss intelligently all matters with his principals; prepare drawings that will not infringe any Acts or by-laws; supervise the execution of the work; examine and test the building materials being used upon a job; prepare specifications and approximate

No.	Date	Subject Matter	Client	Remarks
239	2/2/26	Proposed Warehouse, Riverside, Northampton . . .	Hardware Manfg. Co.	
240	4/2/26	Survey and Report, Proposed Purchase of Factory, Slough	Central Eng. Co., Ltd.	
241	5/2/26	Proposed Detached House, The Grove, Ealing	A. Client	Scheme Abandoned after Sketch Plans Prepared
242	8/2/26	Dilapidations 6 Houses, St. George's Square, N.W.2 . .	Quill & Co. (Solicitors)	

Fig. 2. "Jobs" Book

estimates; inspect buildings during the progress of erection and completion, for the issuing of certificates for payments to the builder and sub-contractors; adjust contractors' accounts.

The other architectural assistants are required to carry out preliminary and other work required by the senior assistant, for the purpose of expediting the work of the office, for example—

Assist in all survey work;
Work out the levels in the field book;
Plot simple work;
Prepare tracings in ink or pencil;
Enter up the "jobs" book;
Enter up "plans" register;
Enter up all plans sent out and returned;
Colour working and other drawings;
Prepare schedule and analysis of cost of completed works.

Arising out of the latter the books given below call for explanation.

"Jobs" Book. This book is kept for the purpose of recording every "job" as it comes into the office, whatever its nature.

The jobs are entered in order of date and given a "number," which they retain throughout their progress; all the drawings and correspondence bear this number, as also does the "jacket" containing the papers when put into the store.

Fig. 2 shows a specimen of entries in the jobs book.

Plan Register. As its title infers, this book is for the purpose of registering all drawings prepared. The pages are headed with the number of the job obtained from the "jobs" book, the nature of the work, and the name of the client.

All plans are numbered in accordance with this register and also bear the job No., thus—

Job No. 239
Drawing No. 3

WORK No. 239

PROPOSED WAREHOUSE, RIVERSIDE, NORTHAMPTON, FOR HARDWARE MANFG. CO.

No.	Date	Drawings	Copy Sent to	Date Sent	Date Recd.	Remarks
1	4/2/26	22 Scale Site Plan Plotted from Survey				
1A	5/2/26	Tracing of ditto, but Showing Proposed Road Widening	Office Copy			
1B	5/2/26	Linen Tracing of No. 1A	N'ton Boro' C'n'l	5/2/26		Appd. 12/2/26
2	5/2/26	$\frac{1}{8}$ in. Scale Pencil Sketch Plans and Elevations	H.M. & Co. .	8/2/26	11/2/26	Appd. Subj. to Slight Amendts.
3	12/2/26	Complete $\frac{1}{8}$ in. Working Drawings and Block Plan				
3A	19/2/26	Linen Tracing	O. C.			
3B	22/2/26	Photo Copy on Linen	N'ton Boro' C'n'l	22/2/26		Appd. 27/2/26
3C	22/2/26	Photo Copy on Linen	O. C. . . .			Contract Copy
3D	22/2/26	Photo Copy on Linen	Contractor .	8/3/26		By Hand
3E	22/2/26	Photo Copy on Paper	Contractor .	8/3/26		By Hand
3F	22/2/26	Photo Copy on Paper	O. C.			
3G	22/2/26	Blue Print	Heating Engrs. .	22/2/26		For Estimate
3H	22/2/26	Blue Print	Electrical Engrs.	22/2/26		For Estimate

FIG. 3. PLAN REGISTER

The entries are made in tabulated form, of which Fig. 3 illustrates a typical page.

Plans " Sent Out " Book. In this book a record, in order of date, is kept of every drawing sent out of the office ; in it is entered the name of the person to whom the drawing was addressed, and the date noted upon which it was returned, and any remarks thereon. Fig. 4 shows the " ruling " of this register.

Date.	No.	To Whom Sent	Date Retd.	Remarks
5/2/26	239, 1B.	Northampton Borough Council . .		Approved 12/2/26
8/2/26	239/2	Hardward Manufacturing Co. . .	11/2/26	Approved Subject to Slight Amendments

FIG. 4. PLANS " SENT OUT " BOOK

Schedule of Cost of Completed Works. A schedule and analysis of the actual cost of completed works may be kept under the following headings: cost per foot cube ; per foot super of floor space ; per room ; per scholar ; per " sitting " ; per bed ; per car ; and so forth. This forms an exceedingly useful addition to the working data in forming the basis of the preparation of approximate estimates.

BUSINESS, OR CLERICAL, STAFF

The " *business*," or *clerical*, staff and office boy carry out all the typing, correspondence, filing, and storage of documents and drawings. This involves the keeping of the following books :-

Letter Register. A letter register is kept in which is recorded day by day the letters received ; these are stamped with a rubber stamp bearing the date and serial number of the letter.

Postage Book. This book is for keeping a record of the postage of all letters and parcels, and of the expenditure upon stamps. The money for the purchase of the stamps is drawn from " petty cash," and a check between the postage book and the petty cash book is made from time to time.

Telephone Book. In this book is recorded all the outgoing calls on one side of the page, and all the incoming calls on the other side. The former not only serves as a record of a telephone conversation, but may also provide a method of approximately checking the Post Office quarterly account of charges.

Callers' Book. In this book is recorded day by day the time and names of the several callers, with a short title of the matter to be discussed. Fig. 5 shows an example of the ruling.

Date	Time	Name of Caller	Subject	Seen By

FIG. 5. CALLERS' BOOK

Diaries. The diaries kept by the principals are only a record of appointments giving the time, name of caller, and subject matter. The details of the interview are written out upon separate day sheets, and filed with the documents relating to each particular job.

The diaries kept by the assistants record the time spent upon each and every matter dealt with, and their " petty cash " expenditure thereon. These items are afterwards

(*Continued on page* 97)

BUILDING SCIENCE

By Raymond R. Butler, M.Sc., A.I.C., F.C.S.

LESSON II

THE ATMOSPHERE

Constituents. A knowledge of the composition of the atmosphere is essential to an accurate understanding of the basic principles underlying the problems associated with the corrosion of building materials.

If clean iron wire is allowed to rust in a volume of air enclosed in a glass inverted over water, it will be found that after a long period the water will have risen in the vessel by about one-fifth the volume of the vessel. An examination of the residual gas reveals the fact that it is no longer capable of supporting the combustion of a taper or match, and that in general it is inert. From this and other experiments we conclude that air consists of a mixture of two different gases in the proportion of one part of active gas (*oxygen*) to four parts of inactive gas (*nitrogen*), approximately.

There are, however, a number of other constituents of the atmosphere which are of direct interest to us. Thus we find—

(*a*) Water vapour.
(*b*) Carbon dioxide.
(*c*) Suspended dust and soot.
(*d*) Ammonia.
(*e*) Acid fumes, in cities.

Water Vapour. The air is capable of holding in suspension comparatively large quantities of water vapour. For example, one cubic metre of air will contain, when saturated with water vapour at 0° C., 4·87 grms.; at 10° C., 9·36 grms.; at 20° C., 17·16 grms.; and at 30° C., 30·09 grms. One cubic mile of air, saturated with water vapour at 35° C. would, if cooled to 0° C., deposit approximately 140,000 tons of rain, because at the lower temperature it could not contain the quantity which would remain suspended at higher temperatures. The deposit of moisture on the inside of shop windows in winter; the "sweating" of cisterns, walls and ceilings when warm winds follow a period of frosty weather; and the deposit of dew on grass after sunset, caused by the rapid cooling of the ground by radiation, are all examples of the deposit of excess moisture from the air on any surface capable of cooling the air below its saturation limit.

Carbon Dioxide. This gas occurs naturally in the atmosphere to the extent of about 3 parts per 10,000, although in crowded rooms the quantity may reach ten times that amount.

It is the result of combustion, respiration and putrefaction, in each of which processes the carbon of substances becomes oxidized to CO_2. Thus, in the burning of coal and coke, the direct combination of carbon and oxygen results in a liberation of heat energy and the setting free of carbon dioxide. In the process of respiration, compounds containing carbon are similarly oxidized, and exhaled air contains on an average about 4 per cent of CO_2. These points are of importance in ventilation problems.

The effect of inhaling large quantities of carbon dioxide is shown by Table III, the result of actual experiments. It should be noted that the gas does not appear to be an active poison, but rather a comparatively inert substance which affects the human being by depriving the lungs of the active gas, oxygen, which is essential to life.

TABLE III

Effects of Carbon Dioxide

Percentage of carbon dioxide in the inhaled air.	Effect on human beings
	Breathing deepens
	Produces panting
10	Severe distress
15	Partial loss of consciousness
25	Death in a few hours
50	Death in a very short time

In contrast to this, the other gaseous oxide of carbon, carbon monoxide (CO), is an actively poisonous substance. This gas does not occur naturally in the atmosphere, but is found in the gas supply of many towns, and frequently in the exhaust gases of internal combustion engines, in which it occurs due to incomplete combustion. It forms with the haemoglobin of the blood a very stable compound which we term *carboxy-haemoglobin*, and which, when once formed, interferes with the normal action of the haemoglobin as an oxygen carrier.

The comparison, Table IV below, will be of interest.

TABLE IV

EFFECTS OF CARBON MONOXIDE

Percentage of carbon monoxide (CO) in the inhaled air.	Effect on human beings
Per cent	
0·05	Giddiness in half an hour
0·1	Inability to walk
0·2	Loss of consciousness
0·8	Probable death
1·0	Fatal in very short time

Partial suffocation by CO_2 was undoubtedly one of the causes of the tragedy known in history as the Black Hole of Calcutta, in which 146 prisoners were packed by the Nabob of Bengal into a room twenty feet square, with only two small gratings to admit air. There were only twenty-three survivors.

The air in which a candle has gone out shows a great similarity to that from the lungs after deep respiration.

	Per cent oxygen	Per cent nitrogen	Per cent CO_2
Air from lungs (deeply respired) – –	16·15	79·90	3·95
Air in which a candle has gone out – – –	16·05	80·80	3·15

The presence of the carbon dioxide in the air makes possible the use of a mixture of slaked lime and sand as a binding material between masonry courses. Ordinary mortar depends upon the CO_2 in the air for the conversion of the slaked lime into hard calcium carbonate. The chemical equation representing this reaction is—

$$\underset{\text{(slaked lime)}}{Ca(OH)_2} + \underset{\text{(carbon dioxide)}}{CO_2} \longrightarrow \underset{\text{(calcium carbonate)}}{CaCO_3} + H_2O$$

It is obvious, therefore, that the old-fashioned mortar could not be used as a binding material for underwater work, as its setting depended upon the presence of carbon dioxide, and would, therefore, not set under water.

To meet this difficulty, hydraulic cements have been introduced which set in the presence of water and are independent of the carbon dioxide of the air (see later).

Suspended Dust and Soot. The city "fog" consists mainly of mist (fine particles of water vapour) condensed on floating nuclei of dust. The nature of this suspended solid matter may be judged from a chemical analysis of the sooty deposit left after fog, which reveals the presence of carbon (soot), oily matter, sulphuric acid, iron and iron oxides, and silica (sand).

Researches carried out in London by Dr. J. S. Owens in connection with the question of atmospheric pollution reveal the extent to which the domestic fire adds to the impurities of the atmosphere. It is calculated that over an area round London and up to a height of 400 ft., a 4-hr. fog contains approximately 190 tons of soot. Every year about 17,000,000 tons of coal are brought to London, of which 7,000,000 tons are for domestic use.

If we take the average quantity of soot produced from home fires as 2 per cent of the quantity of coal consumed, and that produced from factory fires as less than ¼ per cent, we calculate at once that over 165,000 tons of soot fall over London in a year. Given ordinary winter temperatures, the London Nov[redacted] is dependent mainly on the absence of air movement. The mean daily movement of the air past Greenwich is 280 miles—hardly more than a perceptible draught. If this movement drops to about 11 ft. per sec., or 200 miles a day, given winter conditions, a fog is certain.

The presence of sulphuric acid in the fog deposit is accounted for by the fact that all coal contains sulphur compounds, which on combustion produce sulphur dioxide, a gas having a suffocating odour and readily soluble in water. In the presence of water and the oxygen in the air this gas becomes converted into sulphuric acid, the chief corrosive agent responsible for the decay and deterioration of building stones.

Ammonia. The presence of ammonia is noticeable where organic matter is allowed to stagnate (e.g. in ill-kept public lavatories). The quantity in the atmosphere at any particular time is usually very small, figures of three manufacturing towns being given below—

London	0·005 per cent by weight of air			
Glasgow	0·006	,,	,,	,,
Manchester	0·010	,,	,,	,,

Acid Fumes. Reference has already been made to the presence of sulphuric acid in the fog deposits of large cities. Coal contains on an average some 67 lb. of sulphur per ton, mainly as pyrites (sulphides of iron and copper). The amount of sulphuric acid produced in this way is very considerable, and it has been estimated that some 400,000 tons of sulphuric acid are produced annually over London, a great portion of which descends in rain and fog upon the buildings of the metropolis. All carbonate materials (Portland stone, Bath stone, etc.), Portland cement, most metals, and many other substances are attacked by this corrosive acid.

In addition a further problem occurs in towns (such as Widnes, for example), where chemical manufactures are centred. In chemical areas, the air may be still further polluted by active gases such as chlorine, hydrochloric acid, and similar products; and though each single factory may be conforming to the official requirements regarding the pollution of the air, the cumulative effect is to produce an atmosphere containing considerable quantities of matter of a corrosive nature.

Recent figures available for London air indicate the extent to which climatic conditions influence the amount of acid impurity in the air.

Sulphur Dioxide (SO_2). On a fine November day—one volume of sulphur dioxide in two and a half million volumes of air.

On a foggy November day—one volume of sulphur dioxide in one million volumes of air.

Sulphur Trioxide (SO_3). The amounts of sulphur trioxide present in the air on an average day in different towns are shown in Table V—

TABLE V

London	25·7 to 62·2 pts.	SO_3 per million	pts. air
Glasgow	20·9 to 28·9	,,	,
Hull	45·9 pts.	,,	,
Liverpool	44·1 ,,	,,	,
Newcastle	36·0 ,,	,,	,
St. Helens	32·8 ,,	,,	,
Southport	14·7 ,,	,,	,
Malvern	10·0 ,,	,,	,

This will ultimately descend in the rain as sulphuric acid, causing damage to marble and limestone surfaces.

ARCHITECT'S OFFICE AND ROUTINE

(*Continued from page 94*)

transferred by a clerk to the day sheets, for the purpose of obtaining complete records of the jobs, and for checking the expenditure thereon with the fees received therefrom.

Day Sheets. These are virtually very detailed diary entries of every item in chronological order respecting each job. In these are entered the particulars of all interviews, instructions, correspondence, assistant's time in the preparation of drawings, surveys, visits to works, petty cash expenditure, etc.; in fact, everything appertaining to the carrying out of the particular job.

These sheets are kept posted up by a clerk who extracts, day by day, items from the assistant's diaries, postage book, and telephone book—the report of interviews and instructions being dictated by the person concerned to a stenographer, who writes them up. In this way a comprehensive record of the progress of the negotiations, deliberations, and procedure of the work is kept; and when "priced out" it serves as a very useful basis for the preparation of accounts for professional charges, especially regarding matters which do not come under a direct percentage charge; it also serves as a very useful check where the percentage charge is applicable.

PLUMBING

By Percy Manser, R.P., A.R.S.I.
Honours Silver Medallist

LESSON II

MATERIALS

Properties of Metals. Before proceeding with the description and source of the various materials used by the plumber, we must first say a little about the *physical properties* of metals. All metals possess properties peculiar to themselves which fit them for many varied and different purposes. Briefly outlined, the physical properties of metals are *tenacity, malleability, lustre, ductility, conductivity, fusibility*, and *volatility*.

Tenacity is the property of offering a resistance to being torn asunder. The tensile strength of a metal is usually given as the breaking strain in tons per square inch. The following list gives the relative tenacities in tons per square inch of those metals of most interest to plumbers -

Steel	30	Zinc	2
Wrought Iron	22	Tin	$1\frac{1}{3}$
Copper	18	Lead	1

It would be seen from the list that steel would support 30 times as much as lead, and so on for the other metals.

A simple practical illustration of tenacity is shown by the fixing of lead and iron or copper pipes; whilst the fixings for lead must be only a short distance apart, those for iron and copper may be kept at greater distances, owing to the higher tensile strength of these two metals.

Malleability is the property a metal possesses which enables it to be hammered or rolled into sheets without fracture. The following metals are given in order of their malleability: gold, silver, copper, tin, lead, zinc, and iron.

Lustre is the property of reflecting light. Most of the commoner metals very soon tarnish when exposed, owing to their affinity for oxygen. Tin is an exception; we speak of tin as possessing a very brilliant lustre, and it is not affected when exposed to the atmosphere. Large quantities of iron plate are coated with tin and used in the manufacture of domestic utensils. Copper plates are also coated with tin, and used for lining sinks and making domestic utensils and reflectors.

Ductility is the property a metal possesses to enable it to be drawn into a fine wire without fracture. In their order of ductility the commoner metals are iron, copper, zinc, tin, and lead.

Conductivity is the property of transmission by heat or electricity. All metals are conductors of heat and electricity, and placed in their order are as follows -

Conduction of Heat	Conduction of Electricity
Copper	Copper
Zinc	Zinc
Iron	Iron
Tin	Tin
Lead	Lead

Fusibility is the property a metal possesses of being fused or converted to a molten condition. The fusing or melting points of the common metals are -

Tin	442°
Lead	617°
Zinc	773°
Copper	1,996°
Cast iron	2,785°
Wrought iron	4,000°

Volatility is the property whereby a metal can be volatilized, i.e. converted into vapour.

Specific Gravity means the weight of a given mass when compared with the weight of an equal mass of water. For example—

1 cub. ft. of lead weighs 710 lb.
1 ,, water ,, 62·5 lb.

Therefore $\frac{710}{62 \cdot 5} = 11 \cdot 36$, which is the specific gravity of lead. The standard of comparison in England is water, and this is taken as one (unity).

METALS

LEAD

Properties. Chemical symbol Pb, from the Latin *plumbum*. Melting point 617° F. Specific gravity 11·36.

Lead is found in Cornwall, Derbyshire, Cumberland, also U.S.A. and Spain. It is bluish grey in colour, soft, and malleable. When quite new it has a bright lustre, but soon tarnishes when exposed to the air, owing to the action of acid vapours and oxygen in the air. It is low in tenacity and would be of little use where great strains or stresses were required. The rate of expansion and contraction is high, and examples of this may be seen on lead-covered roofs, where the changes of temperature, due to the heat of the sun and the cold of the night, has caused buckles to appear, which eventually form a rib and finally a crack. This will be dealt with more fully under "Roof Work."

Ores. The chief ores of lead are *galena*, the blue lead ore; *sulphide of lead*, a combination of lead and sulphur (PbS); and *Cerussite*, a *carbonate of lead* composed of lead, carbon, and oxygen ($PbCO_3$).

Manufacture. The first process is the extraction of the lead from the ore; this is carried out by means of a reverberatory furnace (Fig. 26). The ore is sorted over and placed in the furnace, where it is roasted in a very fierce heat on the hearth, after which it is run off into pigs from the tap hole. These pigs vary in weight from 1 cwt. to 2 cwt.; and from these pigs are obtained the sheet lead and pipe with which we are more familiar.

Sheet Lead. This may be either *cast* or *milled*.

Cast Sheet Lead is obtained by pouring the molten lead on to a prepared bed of sand contained in a casting frame (Fig. 27). The surplus metal is removed by means of a tool called a strike; this is a specially shaped piece of wood, and so adjusted as to leave the cast sheet the desired thickness. The tail end of the sheet is then trimmed off, after which the sheet is removed and rolled up.

Milled Sheet Lead is obtained by means of a milling machine. The process is as follows: A cake, or plate, of lead about 7 ft. by 8 ft. and 5 in. to 6 in. thick is first cast. This cast cake is then placed by a crane on to the milling machine. This consists of two powerful steel rollers in the centre of a long table; on either side of these rollers are a series of auxiliary steel and wood rollers to assist in the movement of the lead. The cake, or cast, is placed between the main rollers; the machinery is set in motion, and the lead is made to pass backwards and forwards between the rollers. Power is applied to the latter, which roll or mill the lead down to the required substance. The milling machine is on the principle of a huge mangle. If very thin lead is required, two or more sheets are milled together.

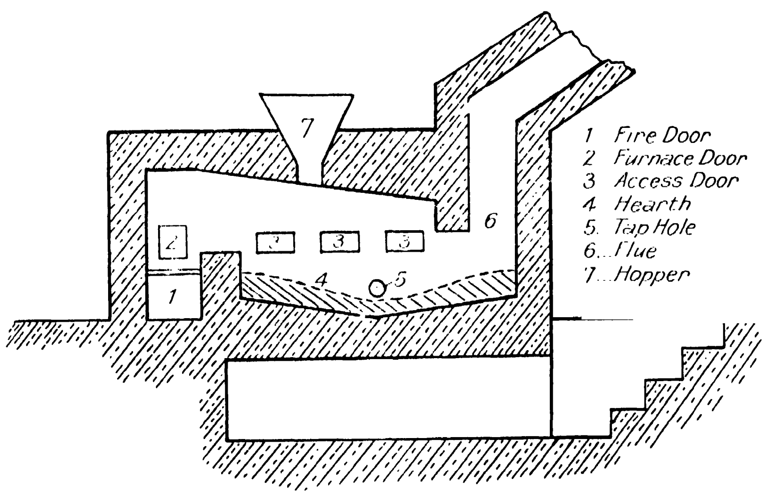


FIG. 26. REVERBERATORY FURNACE

Lead Pipe. The early method of making lead pipes consisted of folding sheet lead round a mandril, and joining it with a fine solder joint by means of a copper bit, and much praise could be given for the skilful manner in which some of these seams were made. The pipe used at the present time is, however, made in a hydraulic press, and is known as *solid-drawn lead pipe*; so also are the lead traps used by the plumber. Properly speaking, the term *drawn* is not quite correct, as the pipe is forced through the machine. The lead press is cylindrical in form, and fitted with a steel core and die and a powerful piston.

The core is of the same diameter as the internal bore of the pipe to be made, and the die equal to the external diameter. The lead is run into the cylinder, the upper portion of which is heated to keep the lead in a semi-molten state. Pressure is applied to the lower portion of press, and the piston forces the lead up between the core and die, from whence it issues in the form of a pipe. It is then cut off in lengths or wound round wooden drums to form coils.

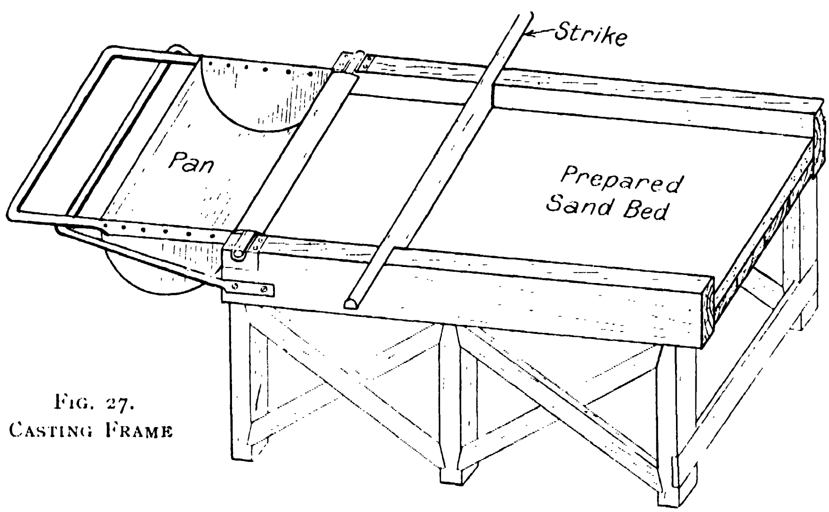


FIG. 27.
CASTING FRAME

Red Lead. This substance is obtained by heating lead in a current of air, when it combines with oxygen and forms lead monoxide, or *litharge* (Pb.O), which has a yellow colour. If this litharge is further heated in air, it absorbs more oxygen and is converted into *red lead.*

White Lead is *lead carbonate,* a chemical compound of lead, oxygen, and carbon. The *Dutch process* of conversion is a good one, though slow in operation. It consists of placing thin sheets of lead on end into earthenware jars; the jars are partially filled with dilute acetic acid and covered with spent tan. Heat is thus produced by decomposing organic matter and causes the acid to attack the lead, so converting it into carbonate of lead. After a few weeks the lead is taken from the jars and bent to and fro to release the carbonate, which easily scales off. The scales are now ground to fine powder in water, dried, and is the resulting powder known as *dry white lead.* This is now mixed with linseed oil to make the white lead ready for the painter and plumber.

COPPER

Properties. Chemical symbol Cu. from *cuprum.* Melting point 1,996° F. Specific gravity 8·9.

The chief ores of copper are *cuprite,* a red oxide of copper, and *copper pyrites,* a yellow ore. They are found in Cornwall, Devonshire, United States of America, and Australia.

Copper possesses a fine red colour; it is a tough metal and rather hard. It tarnishes when exposed to the air, and is a good conductor of heat and electricity. It is a very ductile and malleable metal and can be drawn into very fine wire; also beaten into very thin sheets and worked into all manner of shapes.

Manufacture. The first process is the extraction of the copper from the ore; this is crushed and washed to free it of as much earth as possible, and in charges of about 30–40 cwt. is roasted in a reverberatory furnace on a bed of sand. When fusion has taken place, the metal is run out from the tap hole of the furnace into *pigs,* after which it is again melted and refined. After the refining and purifying process is complete, the metal is again run out into ingots ready for conversion into various forms.

Copper forms one of the chief materials used by the plumber. Copper tubes are now largely used for water services and hot-water work in place of iron and lead. It also forms the greatest proportion in the composition of alloys for valves and other fittings. Copper nails, tacks, and clips are used for fixing sheet lead work on roofs. Copper clips, screws, and fastenings are used for fixing the lead-covered steel bars used for patent roof glazing. It is also largely used as a roof covering.

TRAINING AND OPPORTUNITIES
OF AN ARCHITECTURAL STUDENT

By Professor Beresford Pite, M.A., F.R.I.B.A.

PART II

FIRST PROGRAMME

The first sketch programme may now be proposed. Leaving school at 17 or 18 years of age, with a school leaving certificate, university preliminary examination or matriculation, the candidate will as the first step enter for a three years' course at a university having an architectural department with a degree course. This stage will be concluded when he is 21 with a degree and studies completed for his qualification for the intermediate, or second, examination of the Royal Institute of British Architects. (The first examination being equivalent to matriculation, etc.) Or the first stage may be taken at a recognized school of architecture, not attached to a university and therefore without a degree course, but which attains the intermediate examination standard in the same period.

The next and second stage is that of practical education in an architect's office—a different atmosphere to that of the university or school. The office selected should be a busy one, and for the privilege of, at first, being a nuisance, a premium may be required; this will ensure also that the series of designs which have to be made for admission to the final examination can be taken in part of the office time—though this is a doubtful privilege if the work of the office is engrossing.

This stage will occupy at least two years, and at the age of 23 the candidate will take the third, or final, examination of the R.I.B.A.

The third and last stage, sitting for the "final," is often taken before the student is really finished, and for the reason that he is packed with examination material rather than fully ripened; in this event, he should spend one year or more as assistant to a clerk of works upon an important building work: a big job usually takes a full year from start to finish. Then, if possible, and this may depend upon savings or upon winning a travelling studentship, a year should be devoted to foreign travel, completing a last stage of two years. As half a loaf is better than none, six months may serve if the building job takes a year and a half.

Thus at 25 the fully equipped student may "set up" in practice, having completed a sound and happy course of seven years' study, and stimulated to remain a student all the days of his life.

Cost. For this programme, perhaps the ideal one, the cost will be that of the university years and of a moderate premium for the following first year in an architect's office, capital being thus required for four years after leaving school. From that point only examination fees will have to be provided, for maintenance will be earned by salary for services, which should be remunerative, and enough may be saved, as suggested, to pay for the foreign travel.

Further capital may be required for a partnership, or if a time of waiting for work ensues upon setting up in practice; but the student at that period will be a fully qualified assistant able to command a living wage sufficient for two.

SECOND PROGRAMME

The second sketch programme covers the same period of years and undertakes the examinations at the same epochs. It differs in making the architect's office the principal field of study, and therefore makes the business of building, that is, of the production of architecture, the main element of education.

After leaving school at 18, qualified for the first examination, only a year is spent in a school of architecture for elementary training in drawing and building construction. This will take the edge off difficulties when entering an office and save valuable time. The drawback of a busy office is that there is neither time nor teacher available to start the beginner fairly. His incompetent draughtsmanship is useless, and his ignorance of construction fatal even in tracing. One year occupied with the elementary work of a good school will save more time than this in office usefulness by initiating a standard of drawing and giving a sense of principle to construction drawings.

The removal after the first year to the atmosphere of real effective working drawings conditioned by actual rather than imaginary building is not to be regretted. A well-trained architect will always demand good drawing from his office staff, and it may be taken as

ALTERNATIVE SCHEMES FOR AN ARCHITECTURAL STUDENT'S COURSE

FIRST PROGRAMME

	Age
1. Leave school, with qualification for R.I.B.A. Examination I, as probationer, e.g. matriculation	18
2. Three years at university having an architectural school, or at a recognized school of architecture. Course terminating with a degree, and with qualification for R.I.B.A. Intermediate Examination II	
3. Two years, at least, in an architect's office; with a premium perhaps for first year and as improver for the second; ending with qualifying for R.I.B.A. Final Examination III	23
4. Two years on building works and for travel, say 1½ years on works and ½ year on foreign travel	25
Fit for practice	25

SECOND PROGRAMME

	Years	Age
1. Leave school, with qualification for R.I.B.A. Examination I, as probationer, e.g. matriculation or College of Preceptors Certificate		18
2. One year in architecture school for elementary course or in art and technical classes		
3. Four years as articled pupil, with premium, in an office. Taking evening classes—		
At end of second year taking R.I.B.A. Intermediate Examination II .		
At end of fourth year taking R.I.B.A. Final Examination III . .		
4. Two years for building works and for travel, say 1½ years for former and ½ for latter		

	Age
1. Leave school, with qualification for R.I.B.A. Examination I, e.g. matriculation or College of Preceptors Certificate	18
2. In a country architect's office as articled pupil, with premium	
Three years as articled pupil, taking R.I.B.A. Intermediate Examination II at end of third year	
Two years as improver, taking R.I.B.A. Final Examination III at end .	23
3. One and a half years in a town office	24½
4. One year on town building works	
5. Half a year for foreign travel	
Fit for practice	

FOURTH PROGRAMME

	Years	Age
1. Leave school and take situation as "office boy."		16
2. Five years in office at rising salary from 10s. to £3 per week		21
The first two years in evening classes for matriculation examination to qualify as probationer R.I.B.A. Examination I. The next three years in evening classes to prepare for R.I.B.A. Intermediate Examination II . .		
3. Two years as salaried assistant £4 to £5 per week		23
Continuing evening classes to prepare for R.I.B.A. Final Examination III .		
4. Clerk of works or assistant at increased salary for, say, two years . . .		25
Fit for practice or for chief assistant		25

certain that fantastic and undeveloped constructive design will have to be rubbed out and stern economy and rigid stability insisted upon.

After the preliminary year in an architectural school, the second stage will comprise four years as an articled pupil, and it may be suggested that this period may be divided between two offices for the sake of varied experience. Four years will not be too long for pupilage. Probably it will only suffice for seeing two considerable commissions carried out from inception to completion. The intermediate examination should be undertaken at the end of the second year; for this examination, regular evening study will have to be made in preparing the drawings required as testimonies of study, and by attendance at classes in architectural history and building construction. Measured drawings will be made in the vacation and add zest to an architect's holiday.

There are great advantages in this parallel course of practical lay and theoretical and academical evening work. The office drawing imparts and the theoretical is constantly illustrated by the practical to the student's advantage, in a manner which is not attained by dividing the whole course vertically into school and office periods.

The final examination will fall at the end of the four years during which professional practice and the conduct of building works will be acquired daily, and the preparation of the periodical designs required for admission to the examination will occupy the evenings.

This second sketch programme will conclude with the further two years, experience as a clerk of works and in travelling abroad as described in the first programme.

Cost. The question of the amount to be paid as premium for pupilage need not be discussed. It, of course, depends upon the position of the architect who undertakes the pupil, but it may be suggested that the total amount of tuition fees and school costs per annum represents a fair premium for an equivalent term in a good office. It should be borne in mind that a low premium for admission to a poor office will seldom prove to have been a good investment.

THIRD PROGRAMME

A third programme differs materially from these. As the preceding courses have each necessitated a close connection with an educational centre or university town, it is necessary to consider the position of the country man who, without being in the backwoods, has only the architectural resources of a town that is not an educational centre. An architect's country practice, like the business of a country builder, has attractions and compensations, for which the town dweller sighs. In the country, the successful men who have architectural as well as social reputations are perhaps not large in number. They have had to maintain an unfair battle with the tendency to go to London or Utopia for a qualified architect for all important jobs. Their success as a rule is well founded and substantial, but they concern us at present, because of the satisfactory reputation of the well-trained all-round men who have been produced in country offices. In these offices, land surveying, elementary engineering for road making, water supply and drainage, are included in their normal practice; and property valuation, which includes agriculture in its purview, has often to be dealt with by the architect. The recourse to specialists, for quantities, estimates, and for constructional steel-work, etc., which is constant in a town office, is here reduced to the minimum, and resorted to only for the largest work; the result is that the office experience covers a wider area, and may be described as healthier, like country life.

The attractions of a good country office indeed are such, that they ought to be more frequently considered by urban parents who desire for their sons a healthy apprenticeship.

The drawback has to be faced that office work is not supplemented by evening classes and lectures in theory and history. This must be balanced by definite reading and home study. Winter evenings in the country provide opportunities that are long and are less liable to interruption than in town.

Material for the testimonies of study required for examinations must be obtained from one or two folio books, which may be considered to be expensive but which will ultimately prove most useful; it may be hoped that some will be found in the office bookcase.

Constructional theory will present little difficulty, the books are plentiful and not dear. For constructional drawing there will be material in the office. Measured drawing subjects will be within reach almost everywhere in England, and more plentiful in the less advanced commercial centres.

In this course of study, three years will be required as an articled pupil, taking the R.I.B.A. Intermediate Examination when 21.

Two further years will follow as an improver with a salary rising from nominal to real value, and the Final Examination taken when 23.

Experience in a London or large town office would then be advantageous and may be associated with the supervision of building works, either as assistant or as clerk of works. The period may be extended over two years, and it may include some months for foreign travel, bringing the course to completion at 25, before reverting to the original joys of country life.

Cost. The education cost of this third programme will be that of the premium paid at the outset on behalf of an entirely untrained pupil.

The old fashioned system, once uniform, of large premiums for long terms of articles has fallen into desuetude under the influence of schools of architecture, but in the country, where these are not available, a premium for the first three years may at least be required. As indicated previously, a fair measure will be obtained by comparison with the gross cost of school or university fees, without maintenance. This figure may be taken to be between £50 and £70 per annum. It may be advisable to provide for more, both as to money and time. Each case will stand by itself; the locality and personality of the architect and the gifts and energy of the pupil, must affect the sum involved.

FOURTH PROGRAMME

The fourth and last programme will deal with another type of student. The architect's office often has a junior or office boy, recruited mainly from the public elementary schools, who receives by means of his daily work an education in practical business and the draughtsmanship for which others either pay premiums or school fees large in amount, but for which he is paid weekly wages.

To supplement the fruits of his observation and industry in the office, he has at hand the advantages of State and State-aided technical institutes and art classes, and while he is under 21 the fees will cost him a very small part of his earnings.

The enterprising youth will aspire to the R.I.B.A. examinations, and his first step will be the completion of his general education in order to qualify as a probationer on first examination. Evening continuation classes, which may occupy two years, will provide what is required. As he probably first entered an office at 16 the first stage should be passed at 18.

From this point he will, with two years' office experience at his back, proceed to the intermediate examination, making full use of evening classes, at 21.

His final examination will follow in due course at 23, and his further progress in the profession will be secure as a fully qualified assistant.

Assistants. This rising generation of architects' assistants, from junior to senior, constantly recruits the profession with able men. There is more room for fully qualified assistants than for young practitioners in a world which prefers to bestow its more important commissions upon leading practitioners. They are in constant demand by municipal and other bodies with building departments. This is a large field, and the quality of its fruit is of importance to the community. Its work tends to specialization and routine, but it should be considered as offering to architectural students opportunities of achievement on a large scale. It also possesses the attractions of adequate and secured income, constant employment, and that superannuation which is a comforting goal to the unambitious.

A Good Office. A place in a good office conducted by a highly qualified artistic architect has very great value. Such an office will have its own tradition of working drawing draughtsmanship, and ineffective work will not be known. The industrious pupil, or assistant, in such a situation, who, in addition, thoroughly enjoys his independent evening studies, is happily a paragon who is not rare.

It would be unfair to the architectural profession to cheapen the cost of its educational courses, but it would be equally unfair to gifted students without financial resources to close the door of hope. Happily, perseverance and talent hold the key. Scholarships for assistance are available in nearly all the universities, and schools of architecture and education committees have many to award, both for day and evening classes. These all help, but the best advice to any who have talent, but not money, is to face the situation sketched in Programme IV and from the bottom rung persist in reaching the top of the ladder.

Not a few leading architects to-day, and many in the past, have attained education and success without the financial help of parents or guardians. Character and talent combine to overcome handicaps and difficulties.

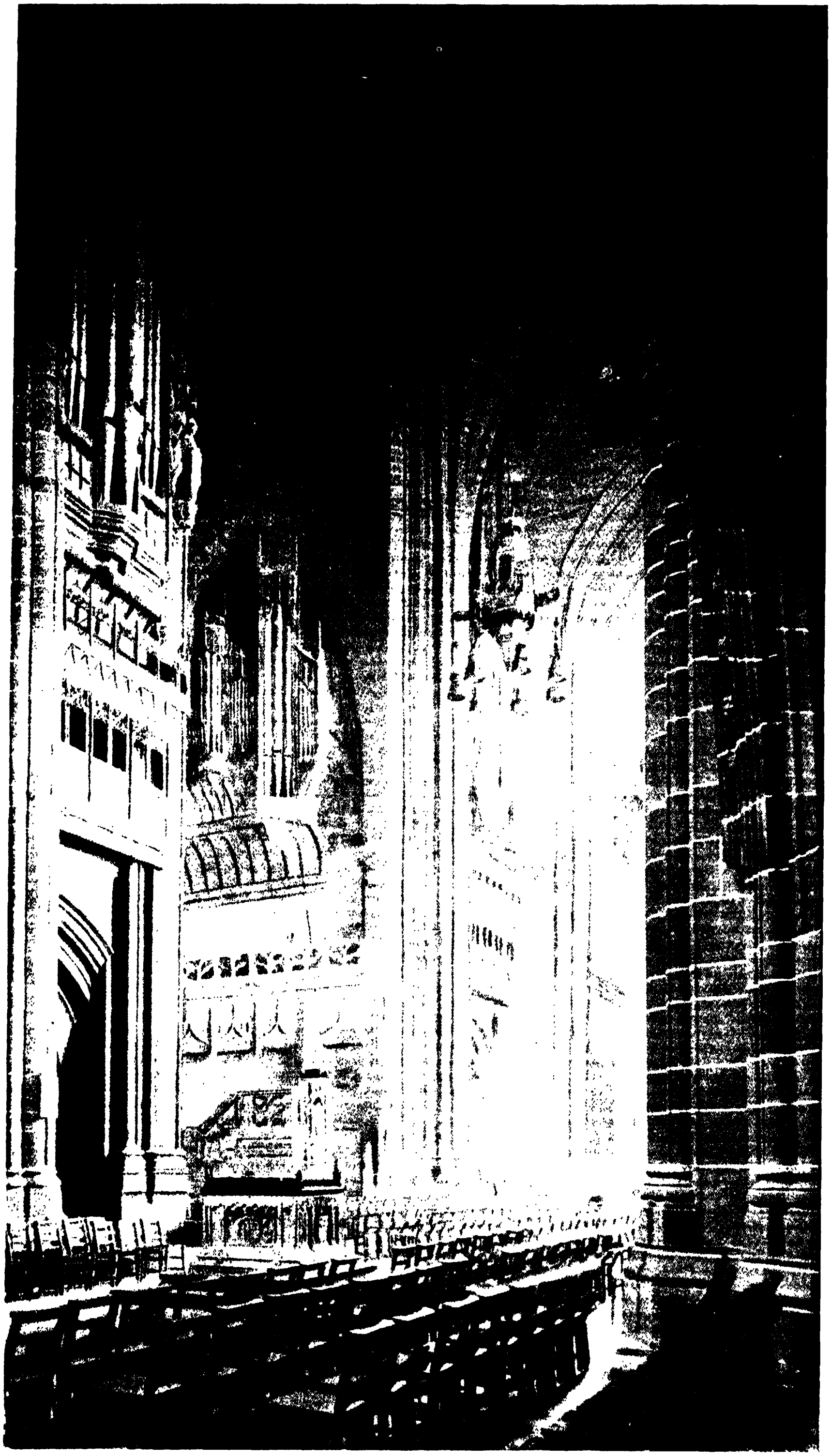


Photo by F. R. Yerbury

LIVERPOOL CATHEDRAL

THE RELATION OF CONSTRUCTION TO DESIGN

By PROFESSOR A. E. RICHARDSON, F.S.A., F.R.I.B.A.

AN eminent French architect in the course of a lecture remarked "anything that could not be constructed was as nought." This quotation can be taken as the basis of architectural study, for it points to the difference between the fanciful and the real. Before the age of steel, the art of fine building implied construction closely allied to architectural character. In mediaeval times this was most certainly the case, and in a lessening degree the same regard for structural properties distinguished certain buildings of the Renaissance in every country. But with the evolution of standard forms of cast and wrought iron, steel, and latterly, reinforced concrete, architects began to lose their regard for the essentials of a fabric which should be morally honest and thorough. This assertion, although general and sweeping, applies to most of the buildings of the nineteenth century.

NINETEENTH CENTURY BUILDINGS

From the vantage point of to-day, we view the works of the immediate past as presenting a curious interest.

Some buildings express structural forms belonging to the remote past; other buildings have iron and steel skeletons masked by external and internal decoration. The latter buildings represent in their pictorial form a close study of historical styles. Such works reveal many tendencies; some are frankly copy-book studies, others are definite attempts to improve on the pictorial concepts of the past. It is important to stress the faults of the buildings of the nineteenth century in order to understand the present position. To be brief, it is now realized that the nineteenth century was a period of compromise. The construction of buildings was sound, but the prejudice for styles, fashions and modes, retarded the development of a building system having a value both vital and lasting. None will deny the achievement of English constructors, but the misdirection of talent, inspired in the first place by the increasing complexities of the age, introduced a line of thought inimical to the best interests of the scientific art. This tendency towards artificiality of a specious kind fostered scholarship, it is true; on the other hand, there ensued a disregard of the very quality which raises building from scenic display to real art.

CONSTRUCTION AND DESIGN

Under the old system of *two-part design*, architecture weakened. The system of construction considered apart was sound; the pictorial effect, also a separate issue, pointed to enthusiasm for an eclectic range: fine building, however, as a vital issue was rare. Even to-day there are many who prefer to consider construction and design as two distinct subjects, hence the lack of imagination, the make believe and the subterfuges.

It is a little difficult to comprehend the fact, that designers have not yet risen to the idea that *structure in three dimensions* is superior to seductions of style and fashion. In a vague way we all know something of structure, but our theories are half-hearted. We seek to accomplish a national expression in building by copying the experiments of other countries; first admiring the latest buildings fron New York; then raving about the architecture of Sweden, Holland or Spain; or fruitlessly striving to imitate the novel forms without inquiring into the spirit which produced them. With such illogical methods it cannot be expected of English building that it will do more than mirror the faults as well as the triumphs of foreign achievement; we have not yet wholly realized the fact that structure, rightly handled, will make us independent of serfdom.

SCHOLARSHIP

In architectural training many things are essential. Scholarship and a knowledge of the past is as imperative as the ability to draw and to express ideas graphically. The study of the components of construction, of materials and methods of working, both past and present, is as important. To these items must be added a knowledge of the science of planning, which in turn, connotes almost every type of building in existence. Then follows a study of the structural systems of old buildings. Another aspect of the situation demands some acquaintance with the technical requirements of different modern buildings. There are the laws of grouping, of the dispositions of voids to solids, the geometric basis of building arrangement, perspective and decoration.

Such matters as the foregoing are bound up with the historical aspect of the art. They are necessary adjuncts to any theory of evolution in the devisement of buildings, but all such are subordinate to the principles of three-dimensioned structure. Those who have studied the masterpieces of building have been impressed with the philosophy which seems to permeate every part of a well constituted fabric. Construction is found to be indivisible from design, the plan is an integral part of the edifice, the sections accord with the plan and the elevations express the whole. It will be said we know this already; we do, but with a difference, for present-day work lacks the imaginative quality which is never absent from fine building. The real point is that, however plans may be schemed on the horizontal plane, they fall short of the ideal if the structure is deprived of construction that is imaginative.

ANATOMY OF ARCHITECTURE

The real weakness to-day is the failure to understand how the components of construction can be assembled to accord with the requirements of structure. In other words, few realize how to structurally modify their designs. It cannot be said that this aspect of building has yet been grasped by modern architects in any country. Here and there we encounter isolated attempts to overcome what might be termed the designer's chief bugbear, and such adventure is welcome; there is a great difference, however, between real building and straining after effects which are merely novel.

To put the case in the briefest manner, we can proceed to discuss the very bones of architecture. The first consideration is the plan, the projection of which belongs entirely to the province of the architect. The character of the plan is determined by the site, by the conditions which demand the building to be of a specific type, and by questions of economy. The actual internal spacing of the plan, the geometrical lay-out, and the points of support, are in turn influenced by the designer's acquaintance with systems of planning employed in similar cases. The nature of the material to be used for the fabric influences the thickness of the walls; the system of covering over the spaces indicates the mass of the points of support. A plan in the embryonic stage begets ideas. It is an idea in itself, and from this can be deduced a structural system which, while imaginative and free, will be adventurous and sane. The ultimate fairing of the building within and without, if rightly considered, must be sympathetic to the fabric.

There is little more to be said. The designer's knowledge of tradition will inspire confidence and emulation. His task is to be reasonable and skilful; not to display his knowledge of the past styles; and not to spoil the fabric by giving it an exterior mask foreign to its purpose, or an expression needing labels and decorations to make the meaning clear to the man in the street. Fine building is not a culture that can be forced by external applications, neither can it be developed entirely by pedantry.

It is characteristic of the present age to demand novelty of form in building as well as in the other arts. There is to-day much loose talk regarding the way a new development can be furthered. A little reflection should show the futility of expecting any reasonable improvement to come from experimenting with surface differences. The truth lies deeper than architectural decoration; it cannot be masked by ingenious face values which are unrelated to the anatomy of structure.

DOMESTIC WORK AND REGIONAL MATERIALS

If we proceed with our inquiry into present-day conditions of building, we find two main sections into which the art is grouped. First comes the domestic aspect, which includes the whole range of the housing question—from cottages, farm buildings, and small holdings, to houses of large type. Architects are realizing the importance of regional materials, and this factor is bringing about a closer relationship between construction and design. The country can be divided into two parts for the purpose of this summary. There are, for example, the brick and tile districts, and the stone and slate districts. The actual treatment of these materials in each case varies according to tradition and local custom. The regional traits, in turn, vary from county to county, and almost from village to village. The character of English domestic architecture inheres as much in the observance of the value of local materials as it does on the ability of the individual designer. The structural quality, therefore, on this showing has never quite lost its full force, so far as small buildings are concerned. The introduction of substitute materials on the other hand does not wholly satisfy, the sole exception being concrete, which can be faired with cement or rough cast in accordance with custom that is centuries old.

For domestic work the traditional methods have a double import. There is scope for development and novelty without risk of sacrificing the amenities of the countryside. Non-observance of regional and structural principles in this regard results in the nondescript. Under the latter category can be classed the ridiculous bungalows and cottages of recent growth. These are despicable. In the province of present-day ecclesiastical architecture the structural law is to some extent observed, and at this juncture it will be opportune to state the nature of that law.

THE STRUCTURAL LAW

Structure is the modelling of the fabric of the building to form one complete whole. It is independent of style and fashion; it is distinct from crude building: it can be defined as a systematic evolution of an idea from the embryonic stage to the finished exterior. The structural law itself modifies the idea in every part. Put briefly it can be defined as the imaginative assembling of components. The law itself demands a high moral standard. In other words, every part of a building must have a reason to be.

Reverting to ecclesiastical architecture, it can be said that if modern church buildings were a little less Gothic in their minor parts they would be the nearer to the ideal of fine building. Knock off the crockets, the finials and the copy-book motives, and you can visualize the theory. Church buildings can be constructed of brick or stone, in masses, of concrete in masses, or of reinforced concrete. If the latter method is employed there will be a certain loss of the perspective quality to which we are at present accustomed. But there is no reason why designers and the public should not in time become accustomed to this system of construction.

CIVIC AND COMMERCIAL ARCHITECTURE

Present-day architecture fails most on the civic and commercial architecture side. Here are to be found the most blatant shams and subterfuges. Plans unrelated to sections; elevations consisting of columns masking badly lit interiors; steep roofs, domes and attics introduced into the building without any structural reason. The invertebrate state of this division of building has resulted from oversight on the part of architects towards the adjustment of construction to structure. Buildings of the civic and commercial type more often than not are schemed as compositions rather than as integral structures. All the faults of the Renaissance have been copied and magnified most ignobly. To be brief, we have been demoralized by a desire for pictorial display totally divorced from the conditions of our own time. Hence the giant order, which serves no structural purpose, the avalanche of stone carried above sheets of plate-glass, and the blaze of loose decoration which accompanies such shams. Such works are devoid of reason; they represent confectionery of an insipid and cloying kind, which is not even worthy to rank as furnishing. Steel-work, in a measure, is responsible for the madness which has enveloped architectural sense. The ease with which, by the aid of steel, large spaces can be spanned and covered has not been carried to a logical conclusion in other parts of buildings, particularly the external expression.

In this particular branch of practice is revealed the weakness of present-day thought. We have the consolation of knowing that steel-work for construction is both economical and expeditious to handle. We must recognize the truth that for many years to come it will be an important factor in building. The steel skeleton, with its slight points of support, to-day takes the place of the masses of material which were at one time consistent with contemporary methods. A steel-framed building has to be faired with brick or stone. If this procedure is carried out logically, without any attempt at falsity, the result can be accepted as satisfying the structural law: the building is constructed of steel, it is veneered with another material. The main theory of three-dimensioned structure is unaffected by the nature of the components. All that is asked of an architect is that he should show skill in assembling the constructional components in an imaginative way; that he should invent with reason, and that he should employ his knowledge of the whole theory of historical architecture in the right way. The application of the features of the dead styles to a steel-framed building, or for that matter, to any type of building, reduces the work to the status of insipid reproduction. Tradition in the devisement of buildings has its uses, but reason is more important. From the foregoing can be deduced the axiom that civic architecture demands more adventure than is the case with domestic work. Design, in its catholic aspect, is the logical expression of construction tempered with artistic finesse.

ARCHITECTURAL PRINCIPLES

The first step towards unravelling the tangled skein of architectural theory is to allocate the different attributes which make up a design. To a reasoned way of thinking the following summary most nearly suggests the procedure—

1. Cause governs effect.
2. The site determines the block of the building.
3. The conditions which demand the building indicate the lines on which the plan must develop.

(*a*) The plan which results from the fulfilment of the foregoing passes through three stages. These are, respectively, the embryonic stage, when the internal spaces are in process of formation about the axes, the structural stage, when the points of structure amplify the cellular disposition, the vertical development, forecasting the sections and the elevations.

(*b*) The structure thus schemed in three dimensions must be further modified. First, there is the necessity for re-studying the structural accents of the plan and for experimenting with forms of construction which, while imaginative, are closely allied to the nucleus of the fabric. Secondly, it is imperative to use the technical conditions ruling the proposed building as useful factors of resistance in the fulfilment of a design.

(*c*) The forms of architecture associated with the age old story of building may be regarded as constants. These are the beam and support, the arch, the vault, the dome, and the pyramid. There are, as is well known, many variants of these forms.

(*d*) The next issue is that of geometry, which can be defined as the structure of form. Most architects are geometricians by intuition, others have a more scientific grasp of the mathematical aspects of the subject. Pure form, however, cannot be developed in buildings without the mental scaffolding of geometry.

(*e*) Imaginative construction, which should be so closely related to design that it is indistinguishable from it, has not yet been investigated as it deserves to be. Put briefly, this implies the ability to reconstruct the known forms of architecture, that is, the beam, the support, the arch, the vault, the dome, and the pyramid, in steel, concrete, or for that matter any material, with a greater regard for economy as well as vital expression. In other words, while the elements of form in an abstract sense are constants, the modern system of handling materials introduces a revision of theory in all that pertains to their realization as features of structure.

THREE-DIMENSIONED STRUCTURE

It is often argued that ancient architecture to some extent supplies the forms; this is inevitable, but modern conditions of building have introduced a system of mechanics which affects these forms statically. It is believed that in time constructive skill will succeed in altering old forms, but the process will be gradual and its results collective.

It will be seen, therefore, that in all that pertains to construction and design, there is plenty of scope for adventure in the devisement of assembled components which will eventually become new constructive forms.

Any analysis of design procedure is bound to lead into a labyrinth. To be brief, the devisement of buildings in the past century has been overshadowed by the pictorial sense rather than aided by the instinct for structure. The concept of a building—the presentiment, the idea, or, in other words, the castle in the air—arises in the mind of the designer at the earliest stage of the procedure. This is explanatory of the fact that so many architects are prone to begin with elevations first, and endeavour to fit a plan within a predetermined elevation without regard to the sections or the structural attributes. History affords so many building images, style and fashion are together so imperative, that the very essentials of building are allowed to gravitate. For this reason the theory of design needs immediate revision. A plan considered on the horizontal plane may be excellent in its dispositions, the sections considered piecemeal may be satisfactory as internal elevations, the external expression may represent scholarship. But if the structure is loosely knit together by construction that is adventitious, the building as a coherent structure will be still-born.

In the foregoing, it has been endeavoured to show that present-day building in some aspects, instead of being three-dimensioned structure, is

(*Continued on page* 136)

JOINERY

By T. Corkhill, F.B.I.C.C., M.I.Struct.E., *Double Medallist*

LESSON III

SAWS

Cross-cut Saw. The "cross-cut," or *hand saw*, has the position amongst saws that the jack plane has amongst planes. It is intended for cutting across the grain, but it is often used with the grain as well, and many carpenters use it for nearly all purposes. The saw is usually about 26 in. long, and has about 6 *points* of the teeth to the inch. Fig. 32 shows an American pattern. The English pattern has a straight back. The hollow back is supposed to have a better appearance and to give a better clearance in the cut. The clearance, however, depends upon the *set* of the saw, and all blades are thinner at the back to assist the clearance; so that the English pattern is as satisfactory as the American for practical purposes, except that it is heavier. The best quality saws are of silver spring steel, and should spring back to the original shape, no matter how they may be bent. The handle is made of beech or apple-wood, and it is fixed to the blade by brass screw rivets. Once a saw is *buckled* by careless handling, that is, it has assumed a permanently bent shape, it is useless for good work; but if the saw is of good quality it can be *hammered* straight again by the makers.

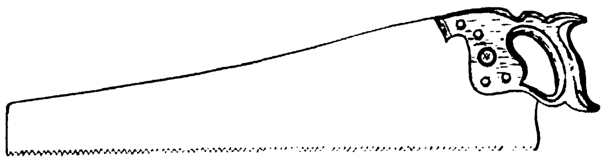


Fig. 32. Cross-cut Saw

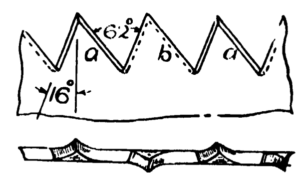


Fig. 34. Cross-cut Saw Teeth

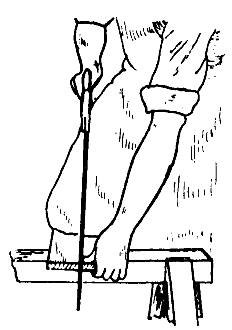


Fig. 33. Using Rip Saw

Rip Saws. The rip saw is very similar to the cross-cut except for the size and shape of the teeth. These are usually four points to the inch, and have a different cutting action. The saw is usually 28 in. long, and is used only for cutting along the grain as shown in Fig. 33. It does not require so much *set* as the hand saw.

Panel Saws. This is a small cross-cut, about 20 in. long, and having 10 points to the inch.

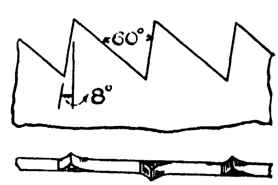


Fig. 35. Rip Saw Teeth

It is very useful for bench work, and for taking the place of the tenon saw where it is necessary to cut *through* wide stuff, such as panels, etc.

Sharpening. The cross-cut and panel saws have their teeth sharpened in the same way, as shown in Fig. 34. The triangular file is held higher at the back, and also sloping towards the handle at the back. This brings the teeth to a *pin* point. The rip saw teeth are more like chisels at the point, as shown in Fig. 35.

In this case the file is held nearly level, and nearly square to the saw; but it has a little inclination towards the handle at the back. The difference in the angles is shown in the illustration. The alternate teeth *a* are sharpened from one side; the saw is then turned round and the intermediate teeth *b* are sharpened.

Before sharpening, the teeth are levelled, or *breasted*, then set, and finally sharpened. Fig. 36 shows the usual device for levelling the saw teeth. A flat file is let into a piece of wood and

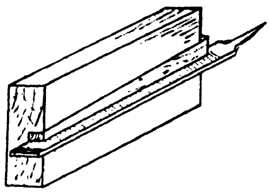


FIG. 36. LEVELLING SAW TEETH

held secure by a wedge. The file is then run along the teeth of the saw.

Setting. A convenient type of *saw-set* is shown in Fig. 37. The saw is placed between the set screw *a* and the pad *b*, both of which are adjusted to give the required set. By squeezing together the handles, the plunger *p* is pressed forward to force over each alternate tooth in turn. The saw is then turned round and the intermediate teeth are pressed over in the opposite direction. An expert saw sharpener uses a hammer and *set*; and sometimes the joiner uses a hammer and nail punch, with the saw resting on a hardwood block. Both of these methods require skill to keep the set equal throughout the two sides. If the set is greater on one side than the other, the saw will

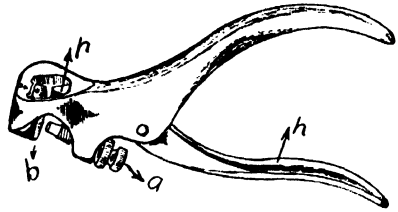


FIG. 37. SAW SET

run when being used, that is, there will be a difficulty in cutting to the lines. The rip saw does not require so much set as the cross-cut.

When the saw is set it is placed in a pair of *saw chops* to be sharpened. Fig. 38 illustrates the usual type of hand-made saw chops, because it is convenient for outside workers; a similar device is made to fit in the vice for shop use. A metal vice, very easy to manipulate, is shown in Fig. 39.

There are various methods of sharpening cross-cuts other than the one shown in Fig. 34, though that gives the best results for general work. For quick cutting in soft woods the *peg-tooth* and *flame, or fleme, tooth* are very good, but they are of very little use for hardwoods, and they are easily damaged.

Use of Saw. The method of using the rip saw is shown in Fig. 33. The teeth edge is held nearly vertical; the usual angle is about 80 degrees with the stuff. For cross-cutting, however, the teeth edge is held at an angle of about 45 degrees with the stuff, as shown in Fig. 40. When cross-cutting heavy or long stuff, the sawyer generally holds the piece *a*, and piece *b* is balanced on the saw block. If it weighs down at the back it is liable to split away before the cut is completed. The saw should be pulled upwards once or twice to start the cut; otherwise the saw will *jump* and probably cut the operator's thumb, which is used to guide the saw as shown in Fig. 33.

Tenon Saw. The tenon saw, Fig. 41, is used for finer work than the cross-cut or panel saw, but the teeth are sharpened in the same way, except that they are a little more vertical. It is usually about 14 in. long, with 10 or 12 points to the inch. As the blade is very thin it is strengthened by a *back*, which may be of brass or steel, the better qualities being of brass.

The Dovetail Saw, Fig. 42, is for finer work still and has an open handle. It is about 10 in. long, with about 14 points per inch. If either the tenon or dovetail saw is buckled, it may be straightened by tapping the top edge of the back with the hammer.

Other Varieties. Curved work requires a different type of saw, and Fig. 43 shows a *bow saw*, or *turning saw*, which is specially adapted for cutting open curves. The frame, which is usually beechwood, consists of three parts. The bar *a* is stub-tenoned into the sides *d*. The saw *s* is fixed in the handles by a small pin *p* at each end, and is then tightened by means of the lever *b*. By turning the lever the double string *c* is twisted and so shortened. This pulls the ends of the sides together at the top, thus stretching the saw on the other side of the fulcrum bar *a*. The usual length of the saw is about 12 in.

For closed curves it is necessary to use a fine saw as shown in Fig. 44 or Fig. 45. The former is called a *keyhole*, or *pad*, saw. In the

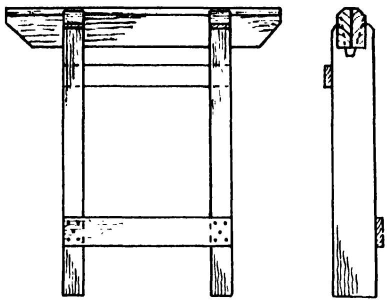


FIG. 38. SAW CHOPS

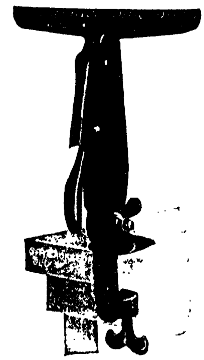


FIG. 39. SAW VICE

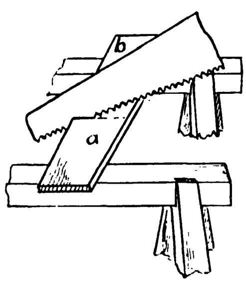


FIG. 40. USING CROSS-CUT SAW

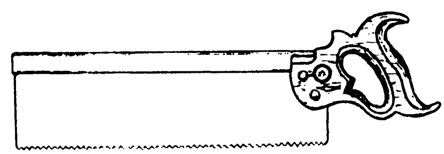


FIG. 41. TENON SAW

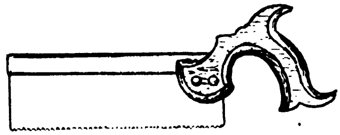


FIG. 42. DOVETAIL SAW

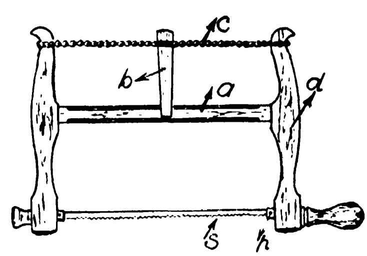


FIG. 43. BOW SAW

FIG. 44. KEYHOLE SAW

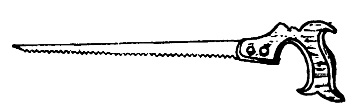


FIG. 45. COMPASS SAW

illustration the saw is inside the handle to protect it whilst not in use. When it is required the screws are slackened and the saw is pulled out to the required distance and then fixed by the screws *a*.

Fig. 45 shows a *compass saw*, which is used for bigger work than the pad saw. Sometimes the blade is slotted to push into the handle, and is then fixed by the screws. There are usually three blades, of different sizes, to this type of saw.

A very useful saw for fine curves, scribings, etc., is the American *coping* saw. It is similar to a small fret saw; the blades are easily inserted and the tension is taken up by turning the handle. The blades are very cheap and are discarded when dull.

CHISELS, etc.

Firmer Chisel. The ordinary type of chisel used by the joiner is the firmer chisel shown in Fig. 46. The steel blade *b* has a tang *t* (Fig. 47), to fix into the handle, and a shoulder *s* to withstand the use of the mallet. A brass ferrule *f* prevents the tang from splitting the handle. If the blade is loose in the handle, it should be packed with a shaving and put in with damp salt; this corrodes the tang sufficiently to fix the blade securely. The blade is ground and sharpened in the same way as the plane irons (see Workshop Practice).

A **Bevelled-edge Chisel** is shown in Fig. 47. This is used for more delicate work than the firmer chisel; the blade is not so strong and is generally confined to hand work, without the mallet. Both the firmer and bevelled-edge chisels may be obtained from $\frac{1}{16}$ in. to 2 in. wide, the smaller sizes rising in $\frac{1}{16}$ in. and the larger sizes rising in $\frac{1}{8}$ in. Chisel handles are made of ash, beech, or box.

Paring Chisels are about twice the length of those just described and may have either bevelled or square edges. They are useful for deep mortises.

Socket Chisels, Fig. 49, are used for heavy work. They are made of cast-steel, and the wooden handle is fitted into the socket of the handle *s*. They may be obtained in sizes from $\frac{1}{4}$ in. to 2 in. wide.

Mortise Chisels, as the name suggests, are used for mortising. Fig. 48 shows the usual type. The blade is very strong and thicker than it is wide, so that it will stand the leverage when mortising. It is generally made of soft steel faced with tool steel so that it is easy to grind.

Other Varieties. *Pocket*, or *sash, chisels*, Fig. 50, have a wide and very thin blade. The blade is sharpened on both sides, and is used for cutting the pockets in pulley stiles for sash frames.

A *drawer lock* chisel is shown in Fig. 51. It is used for the mortise in the rail which receives the *bolt* of the drawer lock.

The *swan-neck*, or *mortise lock, chisel*, Fig. 52, is used for mortising the door stile and rail to receive the mortise lock. The mortise should be first bored with a brace and bit, sufficiently large to take the barrel of the lock. The swan-neck is then used to lever out the core, especially in the end of the rail. Like the socket chisel, a wooden handle is fitted into the socket.

Gouges. Gouges are really curved chisels and may be obtained from $\frac{1}{8}$ in. upwards, similarly to chisels. Fig. 53 shows an *outside ground* gouge, and is the usual type for heavy work. For paring and scribing, an *inside ground* gouge is generally used. These require more careful handling than the outside ground type because they *snip* very easily.

There are many other forms of chisels and gouges, but they are generally considered as carving or turning tools. The bent gouges, however, are useful to the joiner for curved work, such as the inside of a wreathed handrail. A **V**-shaped tool is useful for similar purposes.

Miscellaneous Cutting Tools. The *draw-knife*, Fig. 54, is useful for reducing the width of boards where the waste wood is of no value. It is also useful for chamfering. The bevel is held downwards to prevent the wood from splitting along the grain or the knife going too deep. The stuff is held in the vice when using the draw-knife.

Fig. 55 shows the usual pattern of joiner's *axe*. This is useful either as a cutting tool, or as a percussion tool. It is used mostly for making wedges and driving them home; or for the same purposes as the draw-knife where no vice is available. It is very useful for chopping the under edge of skirting boards when scribing to the floor. The carpenter looks upon it as the most serviceable tool in his kit, both as a cutting tool and for heavy driving.

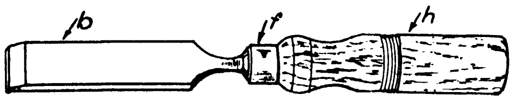


Fig. 46. Firmer Chisel

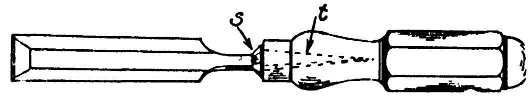


Fig. 47. Bevelled-edge Chisel

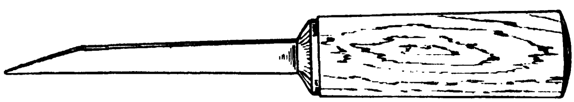


Fig. 48. Mortise Chisel

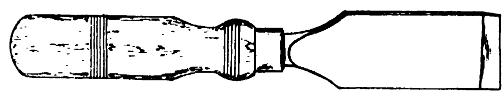


Fig. 50. Pocket Chisel

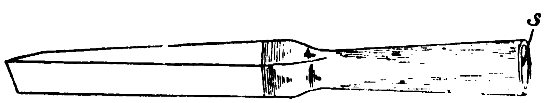


Fig. 49. Socket Chisel

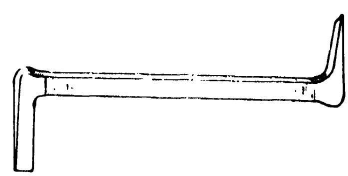


Fig. 51. Drawer-lock Chisel

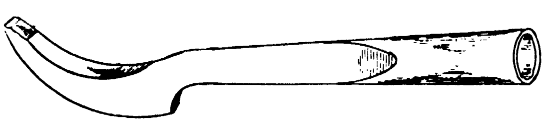


Fig. 52. Mortise-lock Chisel

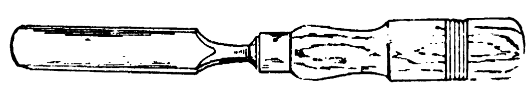


Fig. 53. Gouge

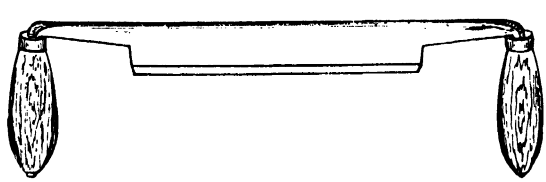


Fig. 54. Draw-knife

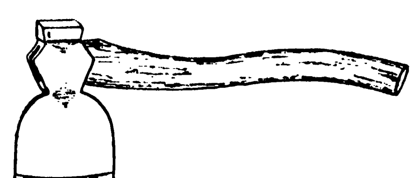


Fig. 55. Axe

BUILDER'S OFFICE AND ROUTINE

By R. F. Galbraith, B.Sc.

PART II

OFFICE STAFF AND DUTIES

The following departments or sections must be staffed—

Management, to deal with all questions of organization and routine and to supervise the whole of the work of the business.

General Office.

Surveyors and Estimators, to undertake the preparation of estimates and to adjust variations that occur during the course of a contract.

Buying, to undertake all purchases made.

Accountant and Cashier, to keep the various financial books of the company and make the necessary payment.

MANAGEMENT

The management is usually undertaken by a board of directors and a secretary in the case of a limited company, or by the owners or partners, or else by a manager in the case of an unlimited company.

In addition to the ordinary duties of management, the correspondence of the firm, the arrangement of finance, the co-operation with architects and supervisors of the various contracts and jobs, special duties are imposed by law on the secretary or owner of a business.

Form "E" must be filed with the Registrar at Somerset House thirty days after the annual general meeting of a limited company. Particulars of the share capital issued, debentures and loans, are required, as well as the names and addresses of the director of the company and all shareholders. A fee of 5s. must be paid on each form.

Income Tax. A yearly return of the salaries and bonuses to be paid to all employees other than manual wage earners, and a half-yearly return of the actual wages and bonuses paid to all manual workers earning over £75 per half-year, must be made to the Inspector of Taxes by the secretary or owner.

A return of the profits earned by the business must be made annually on the appropriate form. This is usually prepared by the auditor after preparing the balance sheet.

In connection with the assessment of profit for income tax, certain questions will be raised by H.M. Inspector of Taxes. The basis of valuation of stock, amounts included for repairs and materials, and similar questions, will have to be certified. The answers to these questions are usually best answered after consultation with the auditor.

Census of Production. Periodically a census of production is taken by the Board of Trade. Various details as to output and production have to be answered.

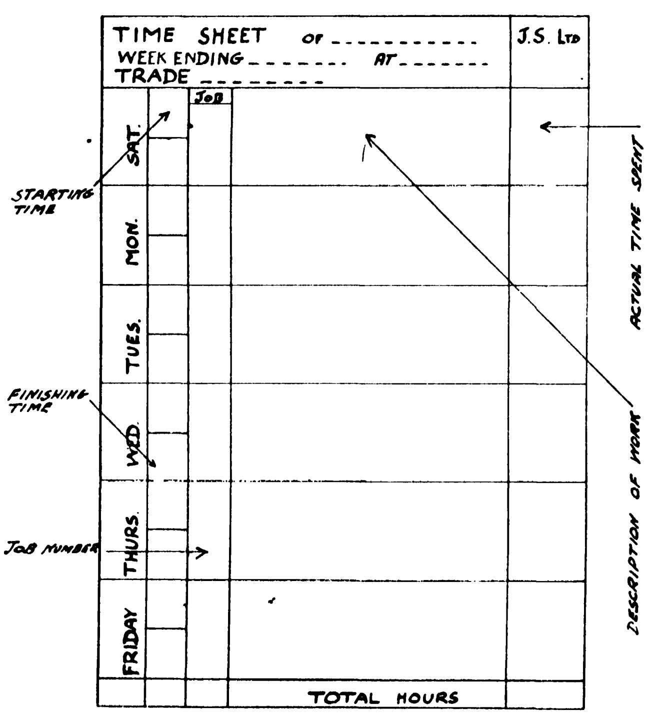


Fig. 1. Time Sheet

GENERAL OFFICE

The following duties and items of routine are undertaken by the general office staff.

Time-keeping. Time-keeping at works. A check must be kept of the actual hours worked by each workman; the time spent on each "job" or "operation" must be separated, usually by means of time sheets. The number of hours worked is entered every day in a time book; and at the end of the week, after checking against the time sheets, the total number of hours worked by each man can be arrived at and the total gross wages obtained. A deduction must be made from the gross wages for unemployment and health insurance.

at the end of the week to the office, and the other copy is signed and returned to the carman.

Materials delivered by merchants are also accompanied by a *delivery note,* and it is only by means of these delivery notes that invoices can be properly checked. Delivery notes should be filed under "jobs," in preference to alphabetical filing.

Advice Notes. Goods dispatched by train are usually "advised" by post, giving details of quantity and the nature, station consigned to, and whether carriage paid or carriage forward.

		LABOURERS	MACHINISTS	MECHANICS	PRINTERS	TOTAL WAGES	MATERIALS	SUNDRIES	INSURANCE	ESTABL. CHARGES	TOTAL
27/2/25	Factory, London	1 5 3	3 10 7						2 4		
6/3/25	6 pairs Teak		5 6 3	3 10 -					5 ·		
13/3/25	Swing Doors.		1 7 3	8 5 4					7 ·		
20/3/25				8 5 4					7 ·		
27/3/25				1 6 5					1 6		
3/4/25					6 7 6	39 3 11	28 16 6	10 3		9 15 11	79 8 5

FIG. 2. PRIME COST JOURNAL

Time Sheets. Each workman must fill in a time sheet, Fig. 1, at the end of each week, showing the actual time worked on each job and in what manner he was employed.

Filing Letters, etc. All letters, invoices, accounts, delivery tickets, etc., should be filed after they have been answered, or the necessary details entered through the various "books" of the builder. This duty should be performed regularly and promptly, in order that a particular paper required may be found in the correct file when required.

Delivery Tickets. All plant and material delivered to a job from the yard should be accompanied by a *delivery ticket,* stating quantity, size, and description of the goods. It is usual to send the ticket in duplicate form, one copy being retained on the job and returned

The details should be checked on receipt of goods and any difference reported immediately.

Invoices. Invoices, showing the quantity, quality, price, and total cost of goods supplied, or work done, are sent to the builder a few days after the goods have been delivered. The total cost of the goods is entered in the purchase journal by the accountant, and the invoices are checked against the delivery ticket, to see that the goods charged for have been delivered. The price should be checked by the order issued by the buying departments and the working out of the cost checked. Any error should immediately be dealt with, and the invoice returned for correction. Invoices for goods supplied or work done *by the builder* should be prepared as soon as possible after the job is complete. The surveyors should supply the necessary details, or supervise the preparation of these invoices, from the delivery tickets or prime cost journals.

Prime Cost. The expression "prime cost" means the actual cost of producing a particular article or piece of work. The prime cost of joinery, which is the builder's chief concern, should include cost of materials, wages, ironmongery, and establishment charges, to cover cost of rent, rates, water, power, and supervision. Establishment charges are usually added in the form of a percentage of the labour costs. The percentage varies between 20 to 30 per cent, according to the nature of the work usually undertaken.

Probably the best way to ascertain the "prime cost" of joinery is to allocate each "job" a distinguishing number. The distinguishing number would be used on all occasions; the workmen would mark his time sheet with the job number; the materials used are booked under it; and, when the job is finally delivered, the job number is marked on the ticket. All the costs in connection with the job are collected into a prime cost journal, as shown in Fig. 2.

The labour costs are obtained from a dissection of the wages, and the materials from the shop foreman's book, in which full details are given of each piece of timber used, and quantities of screws, glue, etc. The prime cost of stonework can be obtained in a similar manner, but the percentage for establishment costs will have to be varied to suit altered conditions.

The prime cost of manufacturers' goods is transferred to the general cost of the contract.

MASONRY

By E. G. Warland

Instructor in Masonry at the L.C.C. School of Building, Brixton

LESSON III

QUARRYING

Methods of Quarrying. Quarrying for stone differs in various parts of the country, each district having its own methods of obtaining the rock which it considers the best for the particular kind of stone. In some districts *electric* and *pneumatic* drilling machines are used, and the huge masses are separated by *blasting*; in others, methods which were in existence centuries ago are still in use, and the stones are obtained entirely by hand labour, these methods having proved most suitable for the production of the stone.

All sedimentary rocks, having been deposited in layers or strata, have natural divisions between them. These are termed "risings" in some districts. The "risings," together with natural vertical joints and fissures which divide the mass, are of great assistance in the quarrying operations. Photographs illustrating the methods of quarrying of a few stones used in building are given, together with a short description of the local quarrying methods. Figs. 3 and 4 are descriptive of a Portland stone quarry.

Portland Stone Quarrying

This *oolitic* limestone has practically changed the appearance of London, and has been introduced into many provincial towns. It has been used for war memorials all over the country. The stone is quarried in the little peninsula jutting out into the English Channel from the coast of Dorset. Sir Christopher Wren quarried here for the material for his masterpiece, St. Paul's Cathedral, from 1675–1717. He selected the "East cliff" at the northern end of the island for his quarrying operations, where the stone was exposed owing to a landslide, and by so doing was relieved of the necessity of transporting the superimposed *Purbeck beds*, or *rubble*, which in places are forty feet deep. For some years now quarrying operations have commenced inland and from the top surface, which entails an immense amount of labour in clearing the site down to the *Portland beds*, ready for quarrying the marketable stone. From the section shown in Fig. 5 of one of the Bath and Portland Stone Firm's quarries, a general idea of the composition of the strata comprising the rubble and cap of the Purbeck beds can be

FIG. 3. PORTLAND STONE: PERRYFIELD QUARRY
Showing depth of stone compared with the amount of waste or rubble
By kind permission of The Bath & Portland Stone Firms, Ltd., Bath

FIG. 4. PORTLAND QUARRY: CLOSE-UP VIEW OF BEDS OF STONE
Showing the method of cutting the blocks from the strata
By kind permission of The Bath & Portland Stone Firms, Ltd., Bath

obtained, although in each district there is some difference in the way the deposits are arranged.

There is a thin layer of soil averaging 1 ft. deep, then a bed of shivered stone, or *slat*, from 3 ft. to 8 ft. deep; this *slat* can be split into

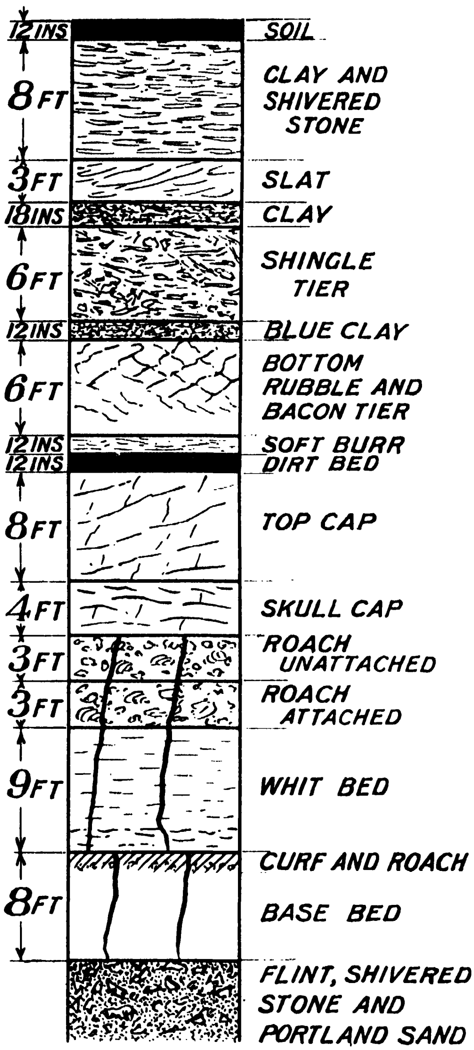


FIG. 5. TYPICAL SECTION THROUGH A PORTLAND QUARRY

quite thin slabs. A *tier*, or layer of clay, is next, but is entirely absent in some districts. Then another bed of *slat* averaging 3 ft. 6 in. deep is reached; this is composed of a compact hard limestone useless for building purposes. Next we come to three thin layers, which in order are termed *Bacon tier, Aish,* and *Soft burr.* Under these is the *Dirt bed,* which is of great interest to geologists. This bed contains numerous trunks of silicified trees, proving this layer to have been at one time at the surface and covered with a dense forest.

Immediately under the *Dirt bed* is the *Top cap,* which varies in its structure but is chiefly a very compact mass of stone 6 ft. to 8 ft. deep; it has to be removed by blasting. Although it is a compact hard stone it is quite unsuitable for building purposes, and except that it has been used occasionally for marine construction such as breakwaters, etc., it is a waste product. The last bed of the "Purbeck stone" is the *Skull cap* about 3 ft. deep, also a waste product, which in turn lies upon the *Portland beds.*

It will be noticed from this description, that an enormous amount of waste material must be transported to another part before any marketable stone can be obtained. Indeed, this does not complete the sum of the waste material, for the *Roach bed* upon which energy must also be expended, is again not suitable for general building purposes, being a very porous stone and full of cavities formed by the moulds of shell fish, etc. It has been used for *rock-faced work* for plinths, etc., and is well suited for that class of work. It has also been used for marine construction, but there is no great demand for it; hence the major portion becomes a mass of waste to be removed and deposited with the rest of the rubble. The *Roach* is about 2 ft. 6 in. in depth, and is usually attached to the *Whit bed*; this contains the stone which is in such great demand for external work of every description. This bed varies from 3 ft. to 10 ft. deep, and is generally of a light brown colour, containing numerous shells which lend a variation and charm to the finished stone; some architects object to these shells showing in the finished faces.

Under the *Whit bed* is often a tier of *flint* and *rubble* which has to be removed. We then come to *curf,* which is sometimes attached to the *Base,* or *Best, bed.* This bed varies in thickness and quality. It is a nice white, clean, and even-grained stone, often softer than *Whit bed.* Usually, if a good deep *Whit bed* is obtained, the *Best bed* is rather poor, and if the *Whit bed* is thin and of poor quality, a very good deep hard *Best bed* is usual. It is then excellent for monumental and building purposes and will withstand the atmosphere of towns remarkably well.

When the *Roach bed* is reached, natural

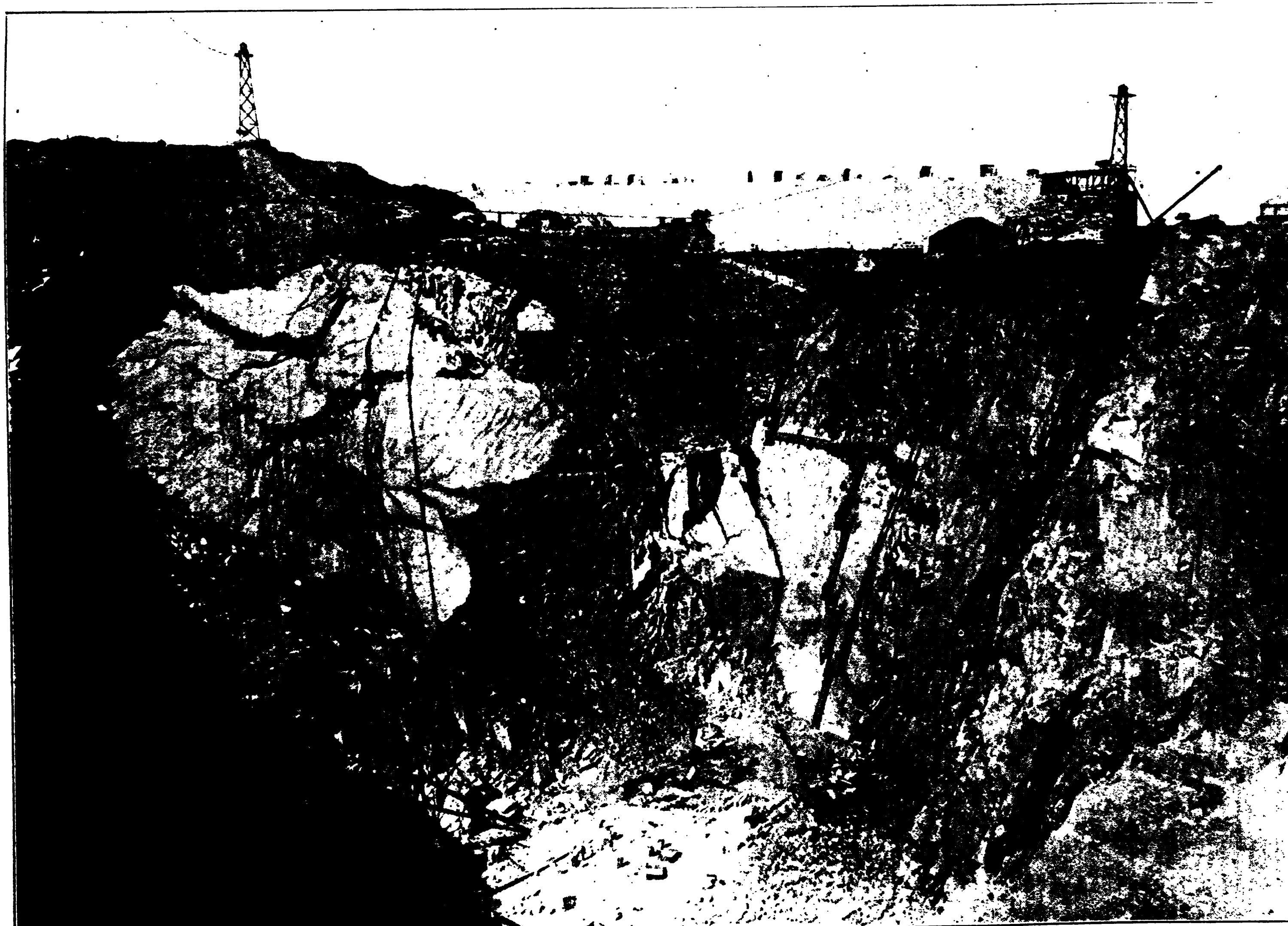


FIG. 6. ABERDEEN GRANITE: "SCLATTIE" QUARRY

By kind permission of Messrs. A. & F. Manuelle, Ltd.

vertical joints appear, dividing the mass of rock into huge blocks. These joints are named by the quarrymen according to the direction they run, such as *Southers*, *East-wester*, *North-easter*, *North-westers*, or *Raingers*. Large *fissures*, termed by the quarrymen *gullies*, run approximately "Southern." They are from 6 in. to 2 ft. wide, and from 70 ft. to 90 ft. apart. It is from these gullies that the quarrymen work, starting from the gully on the left, and moving towards the gully on the right, so that the rock frees itself; the huge blocks of stone are *reamed* or wedged away from the natural joints; slots are cut half on each side of the joint, and *pigs* are inserted. *Pigs* are pieces of iron 15 in. × 6 in. × 3 in. These are placed face to face, 2 or 3 ft. apart, and large *wedges* are driven down between the *pigs*. The wedges are each struck with a sledge hammer at the same time until the joint opens. This process is termed *reaming the rock*. The blocks are also lifted from the *risings*, which are the horizontal divisions of the stratum. If the *rising* is too far down, the blocks are *lifted* through a bed of shells called a *Cockle bed*, through which the stone will split readily. A groove is cut with the *twible* or *pick*. *Scales* and *small wedges* are inserted close together in the groove, as shown in Fig. 4; the *wedges* are struck with the hammer, thus causing the block to split along its bed.

The blocks when reamed weigh anything up to 100 tons. When the blocks are cut they are squared up with the *cavil*, an instrument 6 lb. to 18 lb. in weight, and hammer faced at one end (with surface slightly concave) and pointed or *broached* at the other. They are then *axed* over. After the stones are roughly squared they are measured, and the cubical contents, together with the number and trade-mark, is painted on them at the same time.

The quarrymen are paid according to the cubical contents of the block measured, and the railway companies accept the marked measurement for rail charges.

The blocks are lifted by the cranes on to trollies and hauled direct out of the quarries by traction engines to the railway sidings, or loaded direct into railway trucks from the quarry. A large quantity of block stone is conveyed by means of an inclined railway to the loading pier, and shipped into barges.

Aberdeen Granite Quarrying

The granites found in the immediate vicinity of Aberdeen are grey, and include *Sclattie*, *Rubislaw*, and *Kemnay*. The red granite comes from Peterhead, which is thirty miles farther north. These districts supply a building and ornamental material unsurpassed for beauty and durability.

The quarries are from 800 to 1,000 ft. long, by 400 to 600 ft. wide, and 300 to 400 ft. deep, which increases year by year.

The quarrying operations have a tendency to deepen rather than to expand, owing to the fact that the overburden of boulder clay and sand, and top rock, which extends from 5 to 20 ft. deep, is very costly to remove.

The granite for commercial use is found in isolated masses divided by "bars" of very inferior rock and by *natural vertical joints*; usually, these "bars" lessen in extent, and the quality and texture of the granite improves as the quarry deepens.

The quarries are deepened by sinking a shaft about 40 ft. in a corner, and the quarryman always tries to take advantage of some inclined vertical joints which will facilitate the blasting out of the shaft. When the hole is made big enough a *sump* is formed, and a powerful pump is installed for draining the quarry; during a wet period as much as 50 tons of water per day may have to be pumped out. The pump is a vital unit in big deep quarries, and is, therefore, very carefully protected against accidents during blasting operations.

After the *sump* is formed the new *dip* is then worked outwards across the whole floor of the quarry, the direction being determined by the natural vertical joints. As the *dip* extends, stones are quarried along the whole working face.

The sides of the Aberdeen quarries are almost perpendicular, and are not worked in galleries as sandstone and other quarries where there is danger of "caving" and the sides collapsing.

The Blondin Cable lifting apparatus is in general use and is admirably adapted for such deep workings, but is not so suitable for shallow quarries.

The Blondin at Sclattie—the most modern and efficient of the kind in the country—lifts 10 tons. The winding machine is fitted with friction clutches, flexible couplings, and helical gear; the rope drums are 6 ft. diameter. One of the masts is 60 ft. high; the main cable is 700 ft. between masts fixed on each side of the quarry; this cable is 7½ in. circumference, and the breaking strain is 190 tons. The time required to lift a load from the bottom of the quarry to mast-head is 90 sec. The Blondins are often served by fixed cranes on the floor of the quarry.

The Sclattie quarry is now worked entirely by electricity, thus accelerating the output of good stone for all building purposes, the removal of waste, and reducing the quarrying costs. A photo of this quarry is shown in Fig. 6.

The mass of rock is moved by boring and blasting. Holes 3 to 4 in. diameter are drilled 20 ft. deep into the rock, by rock drills fixed on tripods. Hand drilling in quarries is now obsolete, and all boring is done by steam or compressed air at a pressure of about 80 lb. to the square inch. Air mains are carried from the compressor station round the quarry and down the face of the rock to the point required; from the mains, pipes lead to the stones to be drilled. A flexible rubber hose is then connected from the pipe to the drill. The modern rock drill is a wonderfully efficient tool, and from 3 to 6 ft. per hr. (of the large-size holes) can be bored in granite.

Black Powder only is used when quarrying stone for building and ornamental purposes, as the high grade explosives fracture and shatter the stone too much, though they are very suitable for roadstone quarries.

When blasting, the holes—usually three to six, according to the weight of the blast—are lightly charged at first and fired several times in succession, with half-hour intervals for cooling off. When it is seen that the cracks are forming satisfactorily and that the vertical joints are yielding, a heavy and final "charge" of powder is given to blow the rock clearly away from the face. This charge may be anything from 50 lb. to 150 lb., or even more.

After the rock is blasted out and the blocks lie loosely round, they are split up into the shapes and sizes required by the quarrymen. A straight line of holes about 4 in. deep and ¾ in. diameter is drilled by *pneumatic plug drills*. Wedges are now inserted between two *halfrounds*, or *feathers*, and after a little driving the block breaks in two pieces. The quarry blocker then roughly squares and straightens the stone, and soon it is ready to leave the quarry to be dressed in the mason's yard. The blocks are graded according to colour, the perfect ones being reserved for polishing and ornamental work, the others are cut up for local building purposes and road or paving setts.

Some of the quarry waste is crushed by stone-breakers for road metal, while some is used in the construction of side-walk slabs, and for concrete blocks.

For slabs and blocks the stone passes through a ¼ in. screen; it is then mixed with Portland cement, placed in moulds, and subjected to a pressure of about 400 tons per sq. ft.

Great difficulty is often experienced owing to the fact that the masses of rock are interrupted by natural joints and *faults*. These *faults*, or *bars*, are nearly always discoloured rock, which is valueless for polishing and ornamental purposes, and sometimes thousands of tons have to be removed before stones of important sizes can be obtained. This accounts for the relatively high costs in Aberdeen quarries compared with those of Norway and Sweden. However, when good blocks have been secured, no stone yet discovered in Scandinavia equals the Aberdeen granite in beauty, high polishing gloss, and durability.

BUILDERS' GEOMETRY

By Richard Greenhalgh, A.I.Struct.E.
Honours Medallist in Geometry

LESSON III

PLANE GEOMETRY

PRELIMINARY DEFINITIONS AND CONSTRUCTIONS

Lines. A *straight line* is a line describing the shortest distance between two points. *Parallel lines* are such that if produced indefinitely they would never meet.

Circle. A *circle* is a plane figure having a boundary, or *circumference*, which is equidistant at all points from a given point called the *centre*. A *chord* (see Fig. 24) is a line drawn across the circle, and the *diameter* may be said to be the largest chord. A *segment* is the figure enclosed between an *arc* and a chord. A *sector* is the part of a circle enclosed between two radii

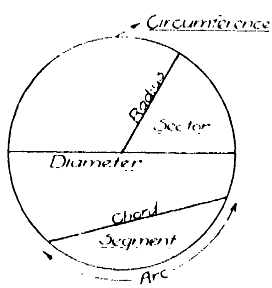


Fig. 24. Parts of a Circle

and an arc. A *tangent* is a line that just touches a circle or other curve.

Angles. An *angle* is the amount of angular space between two lines, or, in other words, it is the magnitude of rotation that one line must make to coincide with the other. If one line stands on another line, Fig. 25, so that the adjacent angles are equal, then the two angles are *right angles*. The unit of angular measurement is a *degree*, and is the ninetieth part of a right angle. There are four right angles or 360° in a circle. An angle less than a right angle is termed an *acute angle*; an *obtuse angle* is greater than a right angle.

Triangles. A triangle is a figure bounded by three straight lines. An *equilateral* triangle has all its sides (and angles) equal. In an *isosceles* triangle, two sides (and angles) are equal. A *scalene* triangle has all its sides of different lengths.

Beginning a Drawing. It is first necessary to pin the drawing paper to the board. Insert the top left-hand drawing pin. Adjust the drawing paper so that its top edge is level, as given by

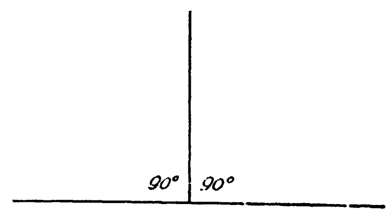


Fig. 25. Right Angles

the T-square; stretch the paper towards the diagonally opposite corner, and insert the bottom right-hand drawing pin. Pull the paper towards the other two corners, and insert the other two pins.

Some draughtsmen use a back sheet under the drawing paper, particularly if the board is pitted with drawing-pin holes; this sheet then prevents the pencil bumping into any crevices in the board, and enables the compasses to be used with greater ease if the leg happens to come over a pin hole.

Care should always be taken to keep the drawing instruments clean. Before using the set-squares, they should be rubbed on a sheet of clean paper until they fail to make a mark. The back of the T-square should be well cleaned; in fact, on elaborate drawings, some draughtsmen fold over the drawing paper for about a half-inch at the left-hand side, so that the T-square will not rub the lines of the drawing.

In beginning a large drawing or when making several drawings on a big sheet, care should be exercised at the start in placing the drawings, so that when finished the work will be evenly balanced on the paper.

Bisecting a Line. If a line is of definite length, say, 3 in., the easiest way to divide it into two equal parts is obviously to apply a scale. Where the line is of uncertain length, the draughtsmen generally uses the method given in Fig. 26. Adjust the dividers or compasses as near as can be guessed to half the line, and mark off the distance from each end *A* and *B* of the line, thus giving two points *a* and *b* close together. The centre of the short distance between these two points can then be judged with considerable accuracy.

The geometrical method given in most text-books is shown in Fig. 27. Adjust the compasses to rather more than half the length of the line, and describe arcs as shown from each end *A* and *B* of the line. Draw a line through the points *C* and *D* where these arcs intersect each other. The line *CD* bisects the given line.

Bisecting an Angle. Let *ABC* be any angle. With *B* as centre and any radius, describe an

repeats is then set out along a straight line, as shown in (*B*). If there is part of a division left over, as *bc*, the dividers are set to this bit and transferred to (*B*).

Another method is shown in Fig. 31. A straight line is marked on a piece of tracing paper *C*. The latter is then adjusted over the curved line, so that one end *A* of the straight line coincides with *a*, and a sharp point, as a divider leg, is pricked through *A* into *a*. The tracing paper is swivelled about until the straight

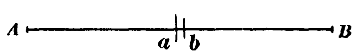


FIG. 26. BISECTING A LINE BY TRIAL

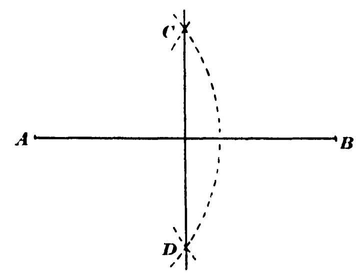


FIG. 27. BISECTING A LINE

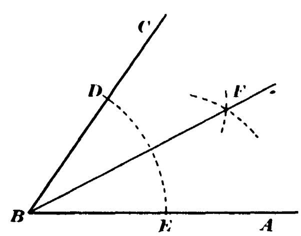


FIG. 28. BISECTING AN ANGLE

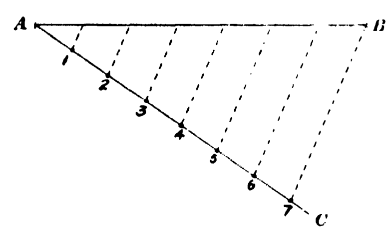


FIG. 29. DIVIDING A LINE INTO EQUAL PARTS

arc cutting the lines at *D* and *E*. With the latter points as centres, and compasses set to any length greater than half the arc, describe two small arcs intersecting in a point *F*. A line from *B* through *F* bisects the given angle.

Dividing a Line. The method of dividing a line into any number of equal parts is shown in Fig. 29. Assume that the line *AB* has to be divided into seven equal parts. Draw any line *AC*, making an angle with *AB*. Set off seven equal spaces with the dividers along *AC*. Join the last point 7 to *B*, and draw lines parallel to 5*B* from the other points. The line *AB* will thus be divided into seven equal portions.

Length of Curved Line. The easiest way of finding the length of an irregular curved line is shown in Fig. 30. Set the dividers to a small length, and step out this length from one end *a* until the other end *b* is reached. The number of

line on the tracing paper lies approximately in the same direction as a short portion of the curved line; really, the line on the tracing paper coincides with the chord of the small curved arc *a*1. The divider point, or pricker, is then pricked through the tracing paper at point 1, and the tracing paper is again swivelled to lie in the same direction as a second short portion of the curved line. The illustration shows the tracing paper adjusted to a third short arc. The operation is repeated until the end of the curved line is reached, when the true length, or stretch-out, will be shown on the straight line. The advantage of the tracing paper method is that the steps can be readily made short or long, according to the "quickness" or "flatness" of the curve being measured.

To Draw a Right Angle. Of course, the usual method for the draughtsman when drawing a right angle is to use a set-square, and for the practical man a try-square, but if these instruments are not available other methods must be adopted.

In setting out large angles, say, when setting out the corner of a building or making a builder's square (a large wooden square for setting out buildings, etc.) what is known as the 3 : 4 : 5 rule is often used. Suppose a line has to be drawn perpendicular to *AB* from the point *A*, Fig. 32. Set out 4 units (say, 4 ft.) from *A* along *AB*. From point 4 strike out 5 units and from *A* strike out 3 units, thus giving point *C*. Then *CAB* is a right angle. This method can conveniently be performed by means of any tape measure. The beginning of the tape is held at *A*, and the 8 ft. mark at point 4; if the tape is held at the 3 ft. mark and pulled taut, point *C* will be located.

The 3 : 4 : 5 rule is based on a well-known theorem in Euclid, which states: *In a right-angled triangle, the square on the hypotenuse is equal to the sum of the squares on the other two sides.* Thus, if a right-angled triangle has the two short sides 6 ft. and 8 ft. long respectively, the squares on these two sides are 36 sq. in. and 64 sq. in. respectively. Therefore, the square on the hypotenuse must be 36 + 64 = 100 sq. in.; that is, the hypotenuse is 10 in. long.

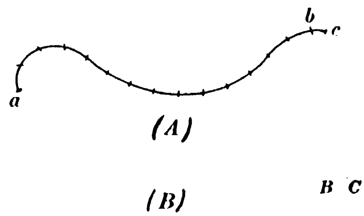


Fig. 30. Obtaining Length of Curved Line

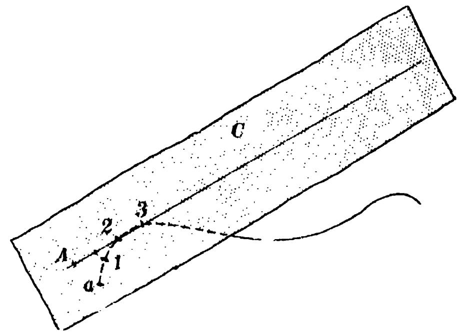


Fig. 31. Tracing-paper Method

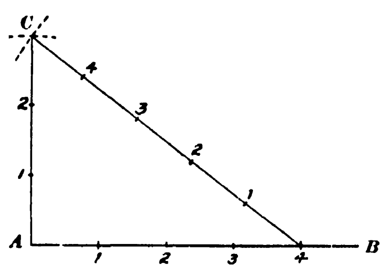


Fig. 32. Constructing a Right Angle. 3 : 4 : 5 Rule

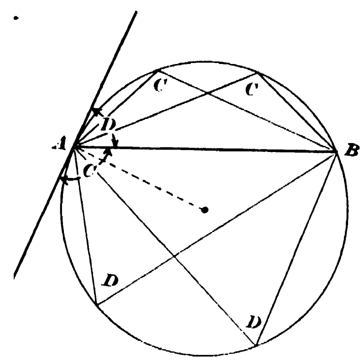


Fig. 33. Angles in Segments

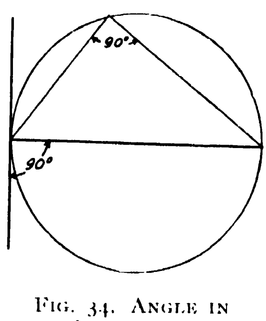


Fig. 34. Angle in Semicircle

D

Fig. 35. Constructing a Right Angle, using Compasses

This theorem relating to the squares on the sides of a right-angled triangle, besides being of use in drawing right angles, is much used for many kinds of simple problems involving the finding of the length of the hypotenuse of a right-angled triangle. Thus, assume that a roof has a span of 22 ft. and a rise of 8 ft. The half-span would be the base of a right-angled triangle having the rise, 8 ft., of the roof as perpendicular, and the slope of the roof as hypotenuse. The length of the slope of the roof would thus be $\sqrt{11^2 + 8^2} = \sqrt{121 + 64} = \sqrt{185} = 13{\cdot}7$ ft. Of course, problems of this kind can always be solved geometrically by drawing the base and perpendicular of the right-angled triangle to scale, and then scaling off the length of the hypotenuse.

Angles in Segments. A useful and well-known geometrical principle is illustrated in Fig. 33. *AB* is the chord of a circle dividing the circle into two unequal segments. If several triangles are formed on the chord and with their apexes on the arc, then all the upper angles of these triangles are equal to each other. Further, if a tangent to the circle is drawn through one end of the chord, then the *angle between the chord and the tangent is always equal to the angle in the opposite segment of the circle.* Thus, in Fig. 33, all angles *C* are equal, and all angles *D* are equal. These statements should be proved by drawing out the figure and measuring the angles with a protractor.

A particular case of the above theorem is shown in Fig. 34. Here the segments are equal, that is, they are semicircles; and as the angle between the chord and the tangent is a right angle, it follows from the above rule that *the angle in the semicircle is a right angle.* The principle is often made use of in drawing a right angle, as shown in Fig. 35.

Let it be required to draw a line at right angles to a line *AB* from a point *B* in it. Select

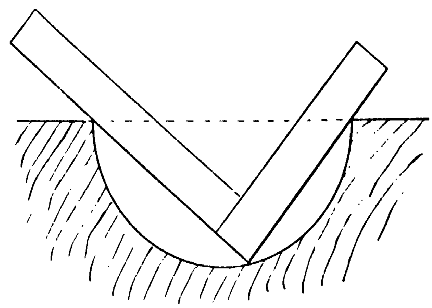
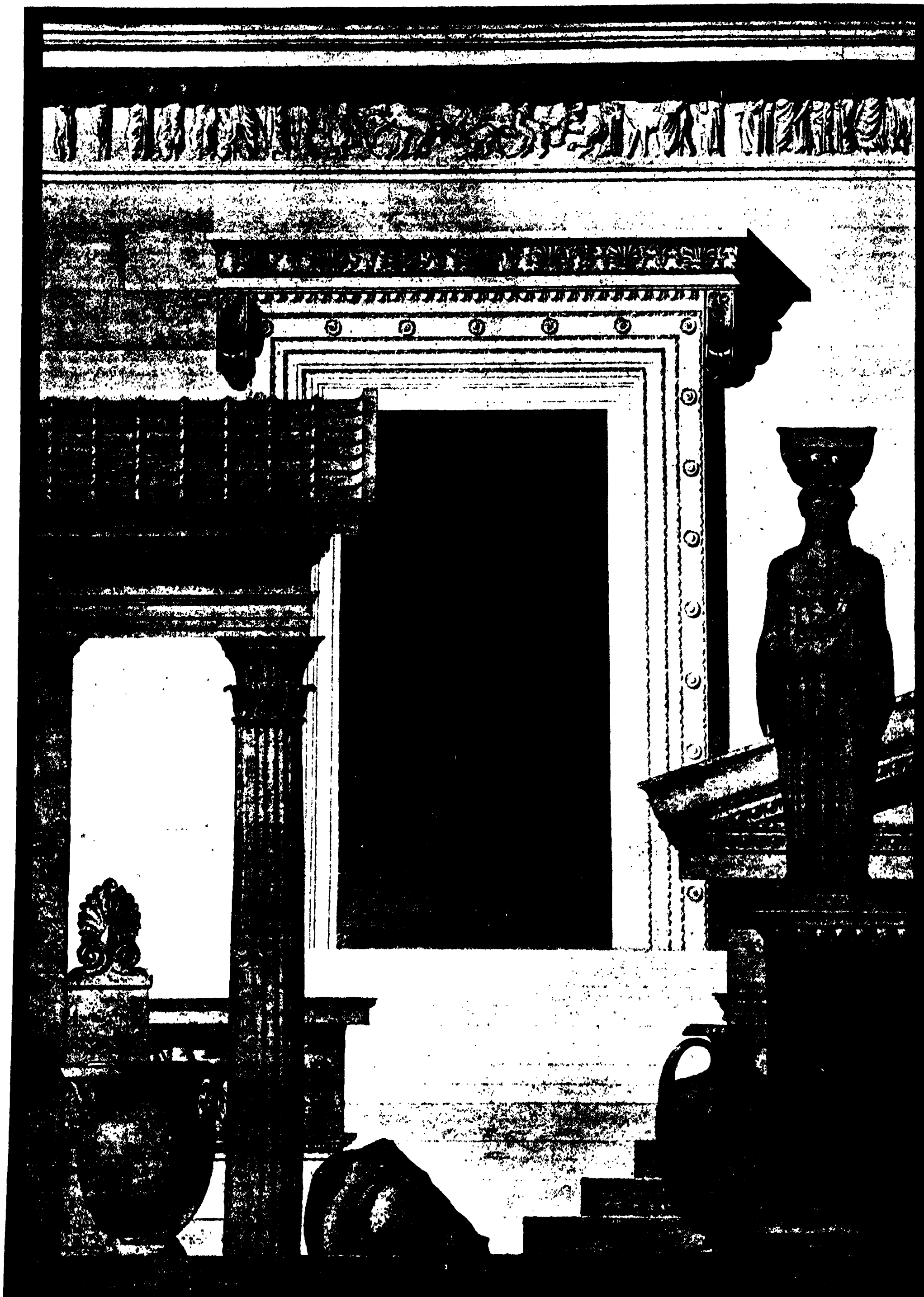


FIG. 36. USE OF TRY-SQUARE TO TEST SEMICIRCLE

a point in a position as *C*, and with *C* as centre describe an arc passing through *B* and cutting the line *AB* in another point *D*. Join *DC*, and produce to cut the arc in *E*. Join *BE*, which will be found to be at right angles to *AB*. The correctness of this construction is obvious, as the angle *DBE* is the angle on the diameter of a circle and must, therefore, be a right angle.

Another application of the principle that the angle in a semicircle is a right angle is illustrated in Fig. 36, where a try-square is shown being used to test the accuracy of a semicircular sinking in a piece of wood or stone.



From a drawing executed in the School of Architecture, Northern Polytechnic, London

FIG. 10. A COMPOSITION OF ELEMENTS OF GREEK ARCHITECTURE

Background, a doorway from the Erechtheion. Foreground, *Right*, a Pediment, a Caryatide ; *Left*, the " Order " from the Tower of Winds a " Stele " or tombstone

HISTORY OF ARCHITECTURE

By Thomas E. Scott, A.R.I.B.A.

LESSON III

GREEK ARCHITECTURE

Origin. Although Greek architecture did not emerge from its archaic or primitive state until about the seventh century B.C., the few remains of the earlier works are interesting, for they must be accepted as the foundation upon which European architecture was built.

The earliest known inhabitants of Greece were the Pelasgi, but it seems probable that the civilization which produced the great works, which will be described later, at first developed in Crete, an island to the south of Greece.

Recent explorations reveal a marvellous civilization which existed in Crete over four thousand years ago; space will not permit an adequate description of the achievements of these early people, but the high degree of their civilization is illustrated by the fact that, at the palace at Knossos, there existed a drainage system which was not equalled in Europe from that day until the nineteenth century.

Cretan settlements were established on the mainland at Mycenae and Tiryns, the former of which gives the name of "Mycenaean" to this early Greek architecture.

The Mycenaean Period. This period is usually considered to last until the eighth century B.C. The remains found in many parts of the country are chiefly of town walls, fortifications, and tombs. The chief feature of the work is the use of massive blocks of stone, which were built in their rough state or hewn into rectangular blocks and bonded together; mortar was not generally used. This masonry is called "Cyclopean," tradition ascribing its origin to the legendary giants, the Cyclopes.

At Mycenae, the town wall contains the famous Gate of Lions (Fig. 11), the carved panel over which is probably the earliest example of Greek sculpture remaining.

Perhaps the oldest existing Greek structure of architectural importance is the Treasury of Atreus at Mycenae; this was undoubtedly built as a tomb. Although the large chamber is shaped like a dome (Fig. 12), it is not constructed as such, but consists of overhanging courses laid horizontally. This chamber is about 50 ft. broad and 50 ft. high; the great size of the stones used in its erection will be appreciated when it is said that the lintel over one of the doorways is 27 ft. long and 16 ft. deep, and weighs over 100 tons. It is interesting to note over this lintel the corbelling which forms a triangular opening, and thus relieves the lintel of the weight of the wall

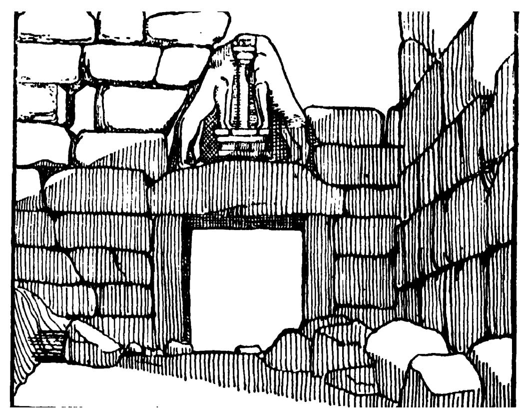


Fig. 11. The Lion Gate, Mycenae

over. A similar arrangement is to be seen in Fig. 11, in which case the opening is filled with the carved panel.

The Hellenic Period. The mature architecture of the later period differs greatly from the early works of the Greeks. There are not sufficient remains to enable its evolution to be followed with any certainty, but it is possible to trace the factors which undoubtedly influenced its development during the centuries which intervened between the Mycenaean and Hellenic periods.

The study of a map of the Mediterranean Sea will show that the position of Greece was such that contact with Egypt and Asia was inevitable. The Greeks came into touch with Egypt through commerce, and were doubtless influenced by the columns used there; it is quite possible that the fluted column of the Doric Order was inspired by columns at the rock-cut tombs at Beni-Hasan, already referred to. The Greeks were great colonists and established settlements as far afield as Asia Minor. In this way they became acquainted with the buildings of the

Assyrians and Persians, from which they acquired a love of rich detail.

Although the Greeks appear to have been influenced by the work of other countries, their architecture rarely contains mere copies of foreign details, but rather an intelligent application of carefully selected features, which have

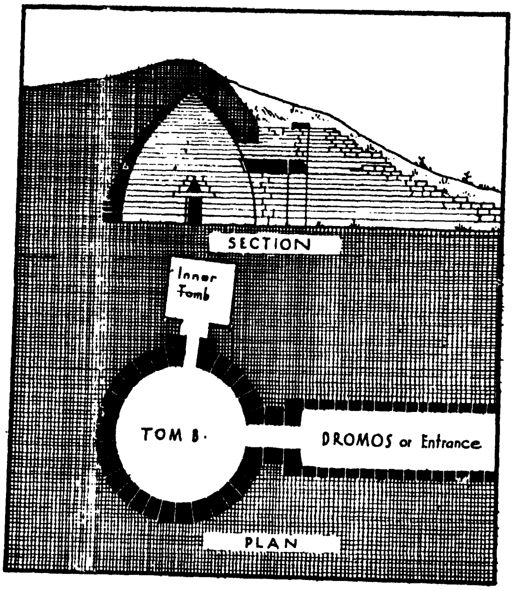


FIG. THE TOMB, OR TREASURY, OF ATREUS MYCENAE

been refined by their wonderful feeling for delicacy and proportion.

Many races are known to have settled in Greece during the early centuries ; the resulting people, known as the Hellenes, were never a united nation, but rather a group of self-governing states, drawn together by a passion for athletic games, religious festivals, and a love of fine arts, the drama, and music.

The history of Greece during the Hellenic period, known as the Golden Age, is well told by historians ; it may be said to begin with the commencement of the Olympiads, 776 B.C., and to end with the sacking of Corinth by the Romans during the second century B.C., although Greek architecture was continued with more or less purity for some time afterwards. Outstanding events were the defeats of the invading Persians on land at Marathon in 490 B.C., and on the sea at the battle of Salamis in 480 B.C. These victories were followed by a period of great prosperity, which produced the finest buildings of the Greeks. Temples and public buildings were rebuilt on a scale far surpassing those which had existed previously, and new temples were erected in thanksgiving to the local deities. A period of decline ensued, to be followed by a short revival under Alexander the Great.

Greek Buildings. The climate of Greece permitted an outdoor life which influenced the arrangement of their buildings. Both religious and civil ceremonies were usually carried on in the open air, so that the effect aimed at was usually an external one.

The Greek religion consisted chiefly of the worship of deities which personified certain qualities, such as Athena, the Goddess of Wisdom, and Hercules, the God of Power. Each district had its own deities.

The temples were built as shrines to contain the images of the gods, rather than as places of

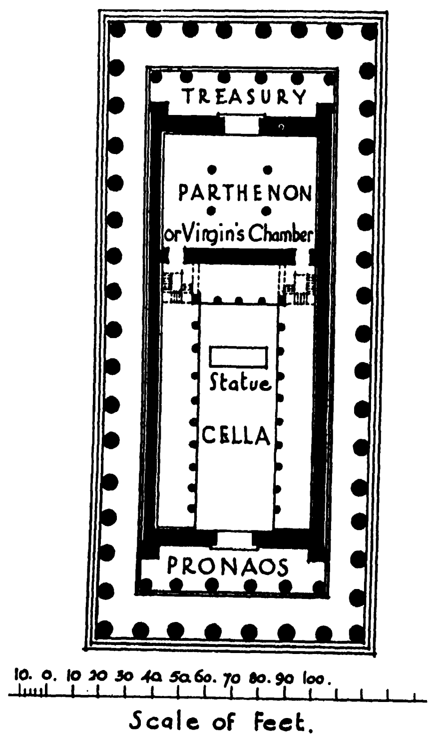
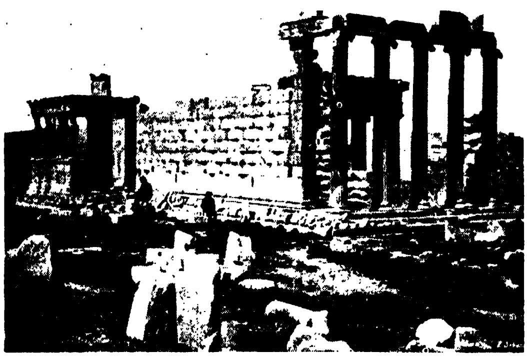


FIG. 13. PLAN OF THE PARTHENON, ATHENS

assembly for the people, who offered their prayers from any point in sight of the temple. For this reason, the temple, together with smaller shrines and other buildings connected with religion, were frequently grouped together in a prominent place. Sometimes a part of the city was set apart as sacred ; that at Athens, known as the Acropolis, or Upper City, is perhaps the best known. There is a very good model of it in the British Museum.

The temples were usually very simple in plan, containing a rectangular apartment for the image, called the *Naos*, and a colonnaded portico, called the *Pro-naos*. Some temples also contained a chamber behind the *Naos* which was used as a store for treasures; and in



R.I.B.A. Cates Collection

FIG. 14. THE ERECHTHEION, ATHENS FROM THE S.E.

larger buildings, columns were ranged all round, forming an ambulatory or covered corridor. The whole stood upon a platform, and was covered by a simple roof with a gable at each end.

The absence of windows leads to much speculation as to the lighting of these temples. It seems probable that a system of clerestory lighting was used, and also top-lighting through an opening in the roof. Many of the temples were so placed that the morning sun might enter the door and light up the statue opposite.

The finest of the temples was the **Parthenon**, at Athens, dedicated to the Goddess Athene. It was built during the years 454–438 B.C. in the time of Pericles, one of the greatest rulers in Greece; the architects were Ictinus and Calicrates. The plan (Fig. 13) was quite simple, consisting of a sacred chamber and a small treasury behind it, with a portico at each end. Round these was a range of columns, called a peristyle, eight at each end and seventeen on each side. These columns were a little over 34 ft. high, and had a diameter at the base of 6 ft. 3 in. They supported an entablature 11 ft. high, which, at the ends, was taken up in the form of a gable, known as a pediment (Fig. 1). The main chamber, or cella, was divided into a nave and aisles by columns, whose chief function was to support the roof; there were also four columns in the treasury for the same purpose. The architectural treatment of the columns and entablature will be referred to in a later lesson. Near the western end of the *Naos* was placed the statue of the Goddess *Athene Parthenos*, one of the most wonderful works of Phideas, the celebrated Greek sculptor. It was constructed of ivory, and covered in places with plates of solid gold; including its base, it was about 40 ft. high. The illustration of the Parthenon shows the positions of the sculpture on the elevations; there was also a very fine sculptured frieze on the outside of the cella walls, an indication of which will be found on the upper part of the wall in Fig. 10.

Another small but very fine temple was the Erechtheion (Fig. 14), situated near the Parthenon on the Acropolis. The reason for its irregular plan (Fig. 15) is a matter for conjecture, though there may be some connection between the three porticoes and the three deities whose shrines it contained. The porticoes are of different designs, two being of the Ionic order,

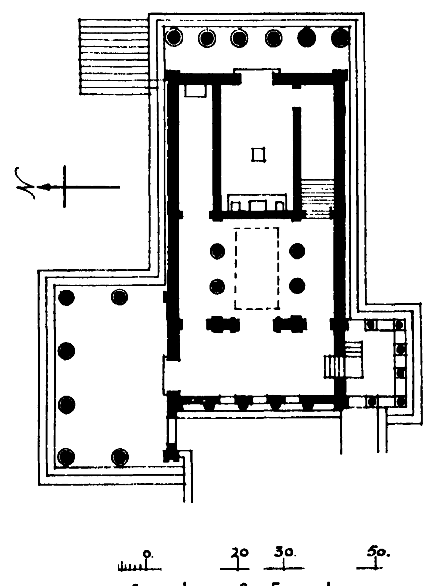
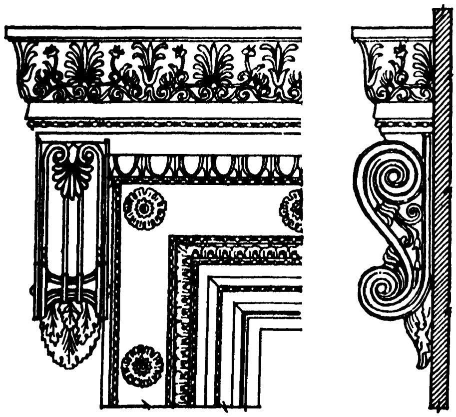


FIG. 15. PLAN OF THE ERECHTHEION, ATHENS

which will be described later, and the third a *caryatid* portico, consisting of six draped female figures standing upon a wall and supporting an entablature of rather unusual design; a restoration of one of the *caryatides* is to be seen in Fig. 10. The doorway illustrated in Figs. 10 and 16 is one of the finest examples.

The remains of the secular work of the Greeks are very scarce. One of the best known is the monument of Lysicrates at Athens (Fig. 17), erected in 335 B.C., in commemoration of his



)ORWAY, THE ERECHTHEION, ATHENS
s of the Console, Architrave and Cornice

success in the choral competitions. It was a circular structure with a square base, in all just over 20 ft. in height. Around the upper part were six half columns, with capitals known as Corinthian, a type not common in Greek work. The entablature and a finely enriched crowning part were formed from one slab of marble.

The burial places of the dead were usually marked by a simple form of tombstone known

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FIG. 17. CHORAGIC MONUMENT OF LYCICRATES, ATHENS

as a *stele* (Fig. 10), somewhat similar in form to the modern variety. A number of large monuments are known to have existed, the finest of which was undoubtedly the Mausoleum at Halicarnassos, in Asia Minor. Although it is not definitely known what this monument was like, remains suggest that there was a square plinth or base supporting a number of Ionic columns, with a fine sculptured group forming an important feature. It is believed to have been about 140 ft. high, and is ranked as one of the seven wonders of the world. Many very interesting fragments, and a drawing of a conjectural restoration, are to be seen at the British Museum.

Theatres appear to have been very important in Greek life. Dramatic performances were looked upon as festivals, in which every inhabitant of the district took part. The theatres were usually hollowed out of a convenient hillside and, as will be seen from Fig. 18, were rather more than a semicircle on plan, with a central space for the chorus and a narrow stage for the actor or actors. The auditorium was cut

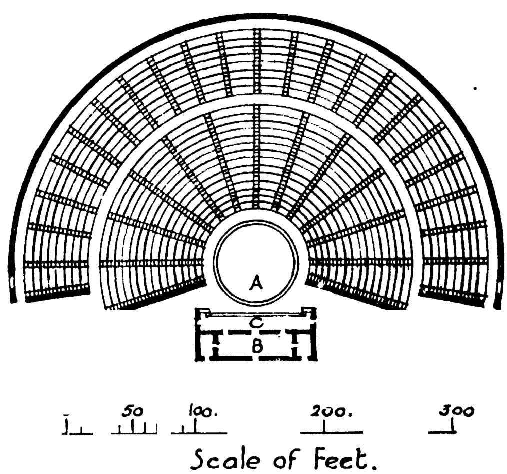

FIG. 18. PLAN OF THE THEATRE AT EPIDAUROS
A. Orchestra *B*. *Skene*, or dressing room

out of the solid rock, with tiers of marble seats. In the Theatre of Dionysos at Athens, over thirty thousand people could be accommodated.

The Agora, or market-places, were large open spaces surrounded probably by colonnades, and around them were grouped various public buildings, many of which were used for the athletic performances, which were so important a feature of Greek life, such as the Stadion, for foot racing, and the Hippodrome, for horse racing.

Of the domestic works of the Greeks little is known, for comparatively little attention was paid to personal accommodation. However, the houses of Pompeii, which will be described later, contain so many characteristics of Greek work, that it is reasonable to assume that the houses of the Greeks were very similarly arranged.

BRICKWORK

By William Blaber
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LESSON III

VARIETIES AND CHARACTERISTICS OF BRICKS

Colour of Bricks. The colour of bricks depends principally on the chemical nature of the earth, and the effects of burning. Clays containing considerable quantities of iron oxide, but otherwise free from alkalis, burn to a clear bright red. The presence of alkalis, in conjunction with prolonged burning at a high temperature, will change the colour to a dark bluish green, as in the case of Staffordshire bricks. Clays free from iron burn white, while small quantities of chalk and iron produce a creamy tint. Clays with much iron and manganese in their composition burn black. Magnesia, with small quantities of iron, gives a yellow colour to the brick.

Varieties in General Use. The varieties of brick in general use are Stocks, Flettons, Wirecuts, Gaults, Suffolks, red and blue Staffordshires, red facings and rubbers, Luton greys, paviors (Dutch and adamantine clinkers), fire-bricks, salt-glazed, and enamelled bricks.

Gaults are manufactured near Rochester, at Hitchin, and in Suffolk. Gault clays frequently contain large quantities of iron oxide and sometimes large quantities of chalk. In the first instance the colour is red, and the brick of an inferior quality. The chalky clay produces a white brick. Owing to the strong nature of the clay, gaults are frequently made with perforations, to reduce the possibility of twisting and warping during burning. These are a good, hard, and durable type of brick, and the best of the kind is the white Suffolk.

Red Facings are made from a loamy earth containing a proportion of sand and iron oxide, and are generally sand-faced. Messrs. Lawrence & Co., Bracknell, and Messrs. Collier, of Reading, are well-known makers, and they also produce the 2 in. old English multicoloured facing-bricks and red rubbers. The latter are manufactured from specially selected earth, carefully washed and sieved to remove the smallest stones, and burned to a state little short of vitrification. These bricks contain rather more sand than the ordinary facing brick. They are largely used for decorative work, as their fine texture and the presence of the extra sand enables them to be easily carved, cut with a wire brick saw, or rubbed to a very fine arris on a stone.

Fire-bricks are made from clays of a highly refractory nature. They are capable of resisting high temperatures without fusion, and with very little change of form due to expansion or contraction. Manufacture is carried on in various parts of the country: at Stourbridge, Stamford in Lincolnshire, Poole in Dorsetshire, Wortley in the West of Scotland, and in Wales. Although the Stourbridge brick is in most general use, the Dinas brick, made by the Ynysmuden Co. near Swansea, is considered by many to have a far greater heat-resisting capacity. Fire-bricks are of a yellow colour and are close in texture.

Salt-glazed Bricks. The faces to be glazed are exposed when these are stacked for burning. When burning has reached a certain stage, salt is thrown into the kiln; the salt when volatilized by the heat, penetrates into the pores of the exposed surfaces, covering them with a thin coating of glass, which forms part of the brick itself.

Enamelled Bricks are obtainable in white, cream and other colours. Enamelling is accomplished by partially burning the raw brick, afterwards coating it with enamel by dipping its face in a vitreous *slip*, or thin paste; this slip is made from ground flint and china clay, with the addition of a metallic oxide. Lead oxide was at one time extensively used, but owing to objections arising on account of its being injurious to health, the oxides of sodium, potassium, zinc or tin, are now generally employed. The process is completed by subjecting the brick to a further burning. This process is called *biscuiting*. Enamelled bricks are also manufactured by enamelling the raw brick and fixing the colour in one burning. Greater durability is thus obtained, but costs are much heavier owing to large numbers being spoiled during burning.

The following characteristics of various bricks will enable them to be more easily recognized.

Hand-moulded and Clamp-burned. These bricks are of irregular shape and colour, arrises not sharp, only one frog. When broken, traces of breeze may be seen. Texture is tough, and inclined to be vitreous, but not dense.

Wire-cuts. These have no frog, are regular in form, and dense. The cutting wires leave slightly serrated edges, and their marks may be seen on the beds of the brick. Generally of inferior quality, and difficult to cut.

Machine-pressed and Kiln-burned. Regular in form, clean, sharp arrises, cleanly formed frog, frequently on both beds, and maker's name or mark stamped thereon. Colour in the best types is uniform, but inferior kinds are graded in colour, and their faces have a striped appearance. Texture very dense.

Characteristics of Good Bricks. Regular in shape, uniform in size, compact in texture; free from particles of lime, stone, pebbles, and cracks or flaws of any description. They should not absorb more than about one-sixth of their weight of water. They should be well burned, hard, tough in texture and, when struck together, give a metallic sound. A dull thud indicates a soft brick, or the presence of limestone or pebbles in its interior. A good criterion of the quality of bricks in bulk is the condition of deliveries. If a lot of dust and a quantity of broken pieces are present, one can generally be sure that the quality leaves something to be desired.

Sizes. Sizes of bricks still vary considerably in different localities. Considerable success has, however, attended the efforts of British architects and brick manufacturers to standardize sizes. These now vary from $8\frac{7}{8}$ in. × $4\frac{5}{16}$ in. × $2\frac{5}{8}$ in. to 9 in. × $4\frac{3}{8}$ in. × $2\frac{11}{16}$ in. In parts of the Midlands and in the north much thicker bricks, from 3 in. to $3\frac{1}{4}$ in. in depth, are still being made. The proportion of the depth to the other dimensions is of no great import, but the relation between breadth and length is very important. Twice the breadth, plus the thickness of one joint, should equal the length. The reason for this will be more clearly seen when the principles of bond are being considered.

MORTAR

The mortars used in bricklayers' work consist of an admixture of lime, or Portland cement, and sand. A knowledge of the properties of these materials is very necessary to the craftsman, if he is to obtain the best results from his labours.

Lime is manufactured by the calcination, or burning, of a carbonate of calcium, of which chalk is the commonest example. During calcination, decomposition occurs, and carbonic acid and water are driven off, an oxide of calcium (quicklime) remaining.

If water be added to lumps of quicklime, rapid combination ensues, great heat and volumes of steam being generated. The lumps disintegrate with a series of small explosions, and are eventually reduced to a very fine powder. This process is termed *slaking*; and when making mortar it is highly necessary that it should be thoroughly carried out, as any unslaked particles subsequently expand and seriously damage the work.

Limes may be divided into three distinct classes—

1. Rich limes.
2. Poor limes.
3. Hydraulic limes.

Rich limes contain not more than 6 per cent of impurities, slake very rapidly, and are entirely dependent on external agents for setting power. They are chiefly used for interior plasterers' work.

Poor limes contain from 15 per cent to 30 per cent of useless impurities, and possess the general properties of rich limes, only to a lesser degree. They are only fit for unimportant work.

Hydraulic limes contain certain proportions of impurities, which, during calcination, combine with the lime, and endow it with the valuable property of setting under water, or without external agents. The proportions of these impurities determine whether a lime is *eminently*, *moderately*, or only *feebly* hydraulic. The principal limes used in making mortar for constructional work are of the Greystone variety, obtained from Dorking, Halling, Merstham, and the district around the River Medway. These have hydraulic properties, and will take a large proportion of sand, without weakening their setting powers. The usual proportions are from two to four parts of sand to one of lime.

The *setting of lime* depends largely upon its absorption of carbonic acid from the atmosphere. The particles return to their original form of a carbonate, and crystallize. These crystals have a tendency to adhere to anything rough, such as sand or the surfaces of a brick.

Pure lime mortars built into thick walls never harden in the interior. The crystallization of the exterior of the joint when set prevents access of carbon dioxide to the inside of the wall. For this reason, pure lime mortars should not be used for constructional work, only those which are not entirely dependent on external agents. For more important work, where great strength is required, Portland cement is used instead of lime.

Portland Cement is an artificial cement, manufactured by calcining chalk and clay, or river mud containing certain chemical constituents in definite proportions. The chalk and clay are ground and mixed into a slurry, which after being strained through very fine sieves, is pumped into an orifice in the top of an inclined revolving cylinder. A blast of intense flame is directed through this cylinder, which is lined with firebrick. As the slurry drops through the flame, it is burned into small clinkers, which are afterwards ground exceedingly fine in specially constructed mills, and then passed through sieves, having as many as 32,400 meshes to the square inch. The powder is aerated by being spread on wooden floors, with an occasional turning, to ensure the thorough slaking and cooling of all particles. It is then put up in sacks ready for use.

This process of aeration has now been superseded in many cement works by the addition of a small quantity of gypsum (plaster of Paris), which retards the otherwise rapid-setting tendency of a freshly-ground cement.

Sand. When used for mortar, sand should be angular in grain, free from clay or dirt, and moderately coarse. If too fine, the proportion of lime or cement will have to be considerably increased.

Mixing. This should be carried out on a close-boarded platform, or stage. In the case of *lime mortar,* sand is best measured when brought to the stage, and the heap opened out into the form of a ring. The correct proportion of lime is measured into the ring, clean water being added to start the slaking, and more as the process advances. When the generation of steam ceases, the mass should be stirred with a long-handled, hoe-shaped tool called a *larry,* until a thick, cream-like consistency is obtained. The sand may then be gradually drawn into and thoroughly mixed with the lime by means of the same tool. The mortar should be allowed to stand for some days before use, and again well beaten up with larry and shovel.

For *cement mortar,* the sand is measured and heaped on the stage, and a bottomless box of definite capacity is placed on the top of the sand. This box is filled with cement, and then removed. The dry heap is turned over at least twice, and opened out into a ring. Clean water is added in sufficient quantity to wet the whole mass, which is then thoroughly mixed in the same manner as lime mortar.

Cement mortar should be used directly after being made, and should not be subjected to further mixing after setting has commenced. If this is done, the cement rapidly loses its strength, and further repetition would render it practically inert.

The *proportions* of sand and cement or lime, are from two to four parts of sand to one part of either, according to the class of work for which the mortar is required.

On large works, mixing is usually performed in a *mortar mill,* which consists of a pair of heavy millstones and a pan, or container, into which the measured ingredients are fed. The mill, by reason of its large and rapid output, has a distinct advantage over hand-mixing. It also has many disadvantages unless operated by a reliable man. Grinding may be carried on to such a stage that the sand is ground so fine as to render the original quantity of lime or cement inadequate. Cement mortars may be also ground long after the initial setting has commenced, and thus rendered useless for the required purpose.

The writer has also seen mortar mills made the receptacle for all manner of rubbish which is ground in with the mortar, a practice which cannot be too strongly condemned.

ESTIMATING

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LESSON II

CUBE PRICES

IN the previous lesson the method of obtaining the "cube" was explained, but a few words are necessary to warn the beginner not to place too great reliance upon prices obtained by such methods. If a building costs a certain amount, and from this amount the price per foot cube is obtained, it is a fair assumption that a similar building in the same neighbourhood will cost about the same amount per foot cube. In making calculations for cube prices, it is usual to omit drainage, lighting, paths, and fences, as these can vary so much. In making an approximate estimate on a cube basis, the surveyor usually prices the cubical contents at a price he considers suitable, and adds the extras we have mentioned. As a general rule, the builder is in a better position to obtain cube prices which will be more reliable than those prepared by a surveyor or architect, for the builder will be dealing with actual costs, while the prices prepared by others will be based upon tenders. It is a good plan, when pricing a job where quantities are not supplied, to cube the structure afterwards, price it at a suitable rate, and compare the result obtained by the more detailed work. This will serve as a rough check for the accuracy of the "taking off" and the pricing. Cube prices should be used for no other purpose than obtaining a rough approximate estimate, and for this purpose the following prices are given for comparative purposes; they are *not* submitted as actual costs.

PRICES PER FOOT CUBE

Cottages, from 10d.
Bungalows, from 1s. 3d.
Small houses, from 2s.
Town houses, from 2s. 6d.
Village halls, from 2s. 6d.
Churches, from 3s. 6d.
Flats, from 1s. 9d.
Flats (high-class), from 2s. 6d.

The above indicates the kind of list that a surveyor may prepare, but against each cost he would give a brief description of the materials used and the class of work, as well as data regarding rates of wages and the situation of the job.

ROUGH QUANTITIES

For the purpose of obtaining an approximate estimate, a far better method of finding the price is to prepare *rough quantities*. This is a system often used by estimating surveyors when the architect supplies plans and specifications only, and there is insufficient time to "take off" the quantities in a proper way. It needs a considerable amount of experience; and for actual tendering it should be used as seldom as possible by the beginner, as it is liable to make him careless and may prevent him from learning to "take off" quantities in the proper manner. The system consists of grouping many items together, and omitting the various labours and fine detail of the quantity surveyor; afterwards the items are priced at rates which include all the labours and other items grouped in the particular dimension. The following is a list of the principal items as grouped together in "rough quantities."

TRADES, Etc. GROUPED ITEMS

Items	How Measured
Excavator.	
Clear the site; provide site concrete and hard core (all in one item).	Per yard super.
Trench excavation, carting away, returning and ramming, also foundation concrete.	Per yard cube.
Drainlayer.	
Excavation, concrete, pipes, bends, accessories, gullies, and filling in trenches.	Per foot run.
(Manholes, enumerated complete.)	
Bricklayer.	
Brickwork measured over-all to include all labours—cuttings, arches, facings, pointing and all sundry items, also the plastering (internal and external)	Per rod super (or per yard super) reduced.

Partitions. **(Brick, slab, or stud.)**

To include all materials used in construction and the plastering both sides.	Per yard super.

Carpenter and Joiner.

Floors, to include all plates, joists, flooring, and skirting.	Per square super.
Ceilings, to include joists, plastering and cornices	Per yard super.
Roofs, to include all timbers, boardings, slates or tiles, flashings, leadwork, gutters, and rain water pipes. (Flat roofs to include all coverings.)	Per square super.

Plumber.

Sanitary fittings, to include traps, hot and cold branches, W.C. flush pipes, and all fixing and making good in all trades.	Per number.
Water supply pipes, soil and waste pipes, including all accessories.	Per foot run.

The various fittings and fitments are then enumerated, viz.—

Doors.

To include door, frame, linings, ironmongery, lintel, architraves, etc., and allowing for deductions from brickwork and plastering complete.	Per number.

Windows and Casements.

As for doors, and including glass.	Per number.

Stoves.

To include stove, setting, hearth, flue, pot, chimney piece, and allowing for deductions from brickwork and plastering.	Per number.

Staircases.

To include treads and risers, handrail, balusters, newels, strings, and all labours.	Per tread.
Landings extra, including skirtings, etc.	Per number.

The following items are priced per point: Hot-water supply, gasfitting, electric lighting, and bells.

It will be noticed that several trades are grouped in the same item, and that very many items which usually appear in a bill of quantities are omitted entirely. It is obvious that very little time is required for the "taking off"; in fact, when the builder is given insufficient time to prepare an estimate (if no quantities are supplied), it is the only method he can adopt. It is also more reliable for the architect or surveyor to prepare his approximate estimates in a similar manner, for he can obtain data for pricing by taking typical items of a similar job, having a detailed bill of quantities which has been priced by a builder.

DETAILED ESTIMATING

Preliminary Work. For the purpose of giving instruction regarding correct methods of the preparation of estimates, we will assume that the reader is in the position of an assistant to an estimating surveyor, and we will describe the work of pricing a bill of quantities from the time it first reaches the builder to the submission of the tender. The estimating surveyor will first read the *preliminaries* and the *preambles*, and make notes of items requiring further detail.

The beginner should note that there is a separate bill for each trade, and one other bill termed *Preliminaries* which contains items that cannot be allocated to any particular trade and the general conditions. The *Preambles* are descriptions at the commencement of each trade describing the work, the materials, and methods of preparation, also any details necessary to the estimating surveyor for the preparation of prices.

From a perusal of the bill it will be found that several special kinds of materials are specified; therefore it will be necessary to communicate with the different manufacturers and obtain quotations; this is usually the junior's first job. It will also be necessary to obtain quotations for essential materials, such as bricks, sand, ballast, cement, lime, and timber—delivered to the site if possible. If necessary, prices must be obtained for haulage and carting, and the exact distance of the nearest railway station ascertained. It may also be necessary to obtain the local rate of wages and lodging facilities. This information must be tabulated, so that the estimating surveyor has as much data as possible available for detailed prices.

Visiting Site. It is difficult to make any hard and fast rule regarding this. With a detailed bill of quantities, plans, and specification, it may not be necessary to visit the site at all, but in most cases it is advisable, especially if the work is in a district new to the surveyor. Sometimes it is necessary to inspect the site before preparing prices, but as a general rule it is possible to price a considerable portion of the bill first, in which case the visit can be deferred until the surveyor has made a list of items for which he will require local information.

Order of Pricing the Trades. It is not usual to price the bills in the same order as tabulated by the quantity surveyor, and in some cases, it is not possible to price the preliminary bill until all the others are complete, and others may require a visit to the site. As a general rule, it is a good plan to prepare the prices for the principal constructional trade first, which is either the bricklayer, or (with a stone building) the mason. In these lessons, therefore, we will commence with the bricklayer. It is not possible in a work of this nature to give detailed prices of every item that can possibly occur in any particular trade; such a task would require several books, but it is proposed to analyse the most typical items, so that the student will learn to prepare prices for himself upon a scientific basis.

BRICKLAYER

Limes and Cements. Before we can price items in the bricklayer's bill it is necessary to calculate the prices of mortar. Brickwork may be in lime mortar or in cement mortar, and the usual proportions are one part of lime or cement to three parts of sand. Sand is sold (usually) by the yard cube, and one yard cube is required to make one cubic yard of mortar. This is due to shrinkage of materials. Portland cement is sold by the ton, which contains eleven sacks or twenty trade bushels. Lime is sold by the ton and sometimes by the yard; it varies in different districts, but we will assume two yards or thirty-two trade bushels to the ton. Before we can calculate the price of mortars it is necessary to find the prices per bushel for limes and cements. The prices naturally vary in different districts, and cartage is a big factor, but for our purpose we will assume cement at £3 2s. 6d. per ton, and lime at £2 16s. per ton delivered, including unloading costs. There is a charge made by the merchants for the use of sacks, usually 2s. 9d. per ton, and this must be added to the cost of the material.

EXERCISE II

1. Find the cost per bushel for Portland cement and for lime, using the prices given in Lesson II.

ANSWER TO EXERCISE I

1. Price per foot cube, 1s. 3d.

THE RELATION OF CONSTRUCTION TO DESIGN

(*Continued from page* 108)

merely two-part construction. The plan is thought of as one thing, and the construction as a loose skeleton introduced to support the scenic display. Hence the invertebrate state of modern civic and commercial architecture.

A NEW STYLE?

It is not yet realized that building is dependent upon anatomy. There are rules for producing compositions based upon historic styles, but such formulae, while useful to endow a building with grace at the proper stage, have no vital function as aids to structural devisement. It can be said, with certain reservations, that the nearer building approaches to the spirit of fine engineering, in the widest acceptance of this term, the more consistent it will become, and the more intimately will it represent the life of to-day. There are certain modernists demanding a new style. They have nothing in their minds but notions of novelty and originality; their battle cry is a catch phrase. The truth is elusive, and will only result from a sane exposition of the structural theory; and this implies the exact adjustment of construction to structure.

BUILDING CALCULATIONS

By T. Corkhill, M.I.Struct.E., M.Coll.H.

LESSON I

INTRODUCTION

This course of lessons in mathematics has been arranged to contain the essentials required by those engaged in the building trades and professions. Modern building practice is becoming more of a science year by year, and the basis of science is mathematics. It is essential that the building industry shall keep pace with modern progress, otherwise the engineer will eventually take the prominent part both in building design and practice. This applies to all branches of building; "rule of thumb" methods are obsolete, and correct calculations are essential for successful competition.

The arrangement of the lessons has been considered with a view to the keen student continuing the subject beyond the limits of these pages. The large number of miscellaneous practical examples should prove of great value to those students preparing for examinations or striving to improve their position. Mensuration, although the most interesting section, has been placed at the end, so that the student can apply trigonometry and logarithms to the solutions of the problems.

Mathematical Abbreviations

+ signifies	*addition*	∵ signifies	*because*
− ,,	*subtraction*	∝ ,,	*varies as*
× ,,	*multiplication*	> ,,	*greater than*
÷ ,,	*division*	< ,,	*less than*
= ,,	*equality* (*equal to*)	△ ,,	*triangle*
∴ ,,	*therefore*	± ,,	*plus or minus*

Other signs will be explained as they arise.

ARITHMETIC

1. Revision of Numbers and Arithmetical Rules.

Explanation of Numbers

			Tho Hun Ten Unit
3,256 equals	6 units	=	6
	5 × 10 ,,	=	50
	2 × 10 × 10 ,,	=	200
	3 × 10 × 10 × 10 ,,	=	3000
	Total units	=	3256

The total reads, three thousand, two hundred and fifty-six.

Each column increases in value, from right to left, in multiples of 10. The unit may represent any one thing, such as bricks, feet, yards, squares of flooring, etc.

2. Addition. Find the sum of 3,765 and 276.

```
 3,765
   276
 -----
 4,041 Ans.
```

Explanation. (1) 6 + 5 = 10 + 1. Place 1 in the first column and carry 1 to the 10's column. (2) 1 + 6 + 7 = 100 + 40. Place 4 in the 10's column and carry 1 to the hundreds column. (3) 1 + 7 + 2 = 1,000. Place 0 in the 100's column and carry 1 to the 1,000's column. (4) 1 + 3 = 4,000.

3. Subtraction. Subtract 4,734 from 7,526.

```
 7,526
 4,734
 -----
 2,792 Ans.
```

Explanation. (*a*) Find how much must be added to the second line to give the first line, i.e. 4 and 2 = 6; 3 and 9 = 12, carry 1; 1 and 7 and 7 = 15, carry 1; 1 and 4 and 2 = 7.

This is the correct mathematical reasoning but probably explanation (*b*) will appeal to most readers.

Explanation (*b*). (1) Take 4 from 6 = 2. (2) Take 3 from 12 (having borrowed 1 from the third column) = 9. (3) Take 7 from 14 (again borrowing) = 7. (4) Take 4 from 6 = 2.

Example. To build a house 23,500 bricks are required. The bricks are delivered on the job in consignments of 3,500, 4,600, 4,200, 3,250, and 4,225. How many bricks are still required to complete the work?

Hint. First add together the consignments and then subtract from the required number.

	3,500	23,500 =	Number required.
	4,600	19,775 =	Number delivered.
	4,200		
	3,250	3,725 =	Number of bricks required.
	4,225		
Total	19,775		

4. Multiplication. Multiply 5 by 3.

This means 5 units are to be taken 3 *times*, and it is written 5 × 3, therefore the answer is 5 + 5 + 5 = 15 units. We refer to 15 as the *product* of 3 and 5; and we refer to 3 and 5 as the *factors* of 15.

5 is the *multiplicand* and 3 is the *multiplier*.

Hence, **multiplicand × multiplier = product.**

Table I should be memorized before the student can expect to work the exercises easily. The larger figures show the method of reading the table; thus, 8 × 7 = 56.

TABLE I

1	2	3	4	5	6	**7**	8	9	10	11	12
2	4	6	8	10	12	14	16	18	20	22	24
3	6	9	12	15	18	21	24	27	30	33	36
4	8	12	16	20	24	28	32	36	40	44	48
5	10	15	20	25	30	35	40	45	50	55	60
6	12	18	24	30	36	42	48	54	60	66	72
7	14	21	28	35	42	49	56	63	70	77	84
8	16	24	32	40	48	**56**	64	72	80	88	96
9	18	27	36	45	54	63	72	81	90	99	108
10	20	30	40	50	60	70	80	90	100	110	120
11	22	33	44	55	66	77	88	99	110	121	132
12	24	36	48	60	72	84	96	108	120	132	144

Multiplication by Factors. Find the product of 256 and 24. We may write this example as 256 × 6 × 4, because **6** and **4** are factors of 24.

```
            256
              6
          -----
          1,536 = 256 taken 6 times.
              4
          -----
Product = 6,144 = 256 taken 6 × 4 times.
```

EXPLANATION. (1) 6 × 6 = 36. Place the 6 in the units column and carry 3. (2) 6 × 5 = 30, add 3 = 33. Place the 3 in the 10's column and carry 3. (3) 6 × 2 = 12, add 3 = 15. Place the 5 in the 100's column and the 1 in the 1,000's column. (4) Repeat the process for 1,536 × 4.

When the multiplier is not easily factorized, proceed as in the following example—

EXAMPLE. Evaluate 3,462 × 435.

SOLUTION.

```
     3462
      435
    -----
    13848
   10386
  17310
---------
1,505,970 = Product.
```

The product reads: one million, five hundred and five thousand, nine hundred and seventy.

EXPLANATION. (1) Multiply 2 by 4, that is 2 units by 400, which equals 800; therefore place the 8 in the 100's column. (2) Continue the multiplication of 3,462 by 4, = 13,848. (3) Multiply 2 by 3 (2 units × 30 = 60), and place the 6 in the 10's column; continue the multiplication of 3,462 by 3 = 10,386. (4) Multiply 2 × 5 (2 units × 5 units = 10). Place the 0 in the units column, and carry the 1 to the next column; continue the multiplication of 3,462 × 5, = 17,310. (5) Add together the three lines of working, for the product.

5. **Division.** Divide 756,324 by 236. This may be written in the form, 756,324 ÷ 236 or $\frac{756,324}{236}$.

In all three cases we have to find how many times 236 will go into 756,324; hence division is the reverse to multiplication.

```
or Dividend      Quotient
236)756324(3204 = Ans.
    708 . . .
    ---
     483 . .
     472 . .
     --- . .
      1124
       944
      ----
       180 Remainder.
```

Therefore, 236 into 756,324, goes 3,204 times. There is a remainder of 180, which will be considered later in connection with *decimals*.

EXPLANATION. (1) 236 goes into 756 three times; place 3 in quotient. (2) Multiply 236 by 3 and subtract from 756 = 48. (3) Bring down the next figure of the dividend, to make a new dividend of 483. (4) Repeat the process.

Division may be performed by factorizing the divisor, but the student must be very careful with the remainders to get the correct full remainder.

EXAMPLE. Evaluate 66,261 ÷ 315.

SOLUTION. This may be written, 66,261 ÷ (5 × 7 × 9), because 5, 7, and 9, are factors of 315.

```
5 |66261
7 |13252 and 1 remainder
9 |1893 and 1 remainder
   210 and 3 remainder.
```

Therefore 210 is the answer, but there is a remainder. Combining the three remainders, we have—

$$1 + (1 \times 5) + (3 \times 7 \times 5) = 1 + 5 + 105 = 111$$

Therefore 315 into 66,261, goes 210 times, with a remainder of 111.

6. **Areas and Volumes of Rectangular Surfaces and Solids.** We will now consider areas and volumes, so that the student can apply his exercises to practical problems.

Fig. 1 shows a cube, that is, a solid with all its edges equal and all its corners forming right angles. The solid is drawn in isometric projection so that we can see three faces. Each of these faces is a square. Now let us consider the top face: all the edges are 12 in. long (these are called *linear* dimensions); therefore each edge is divided into 12 equal parts. If we take one strip of the top surface, 12″ long by 1″ wide, as

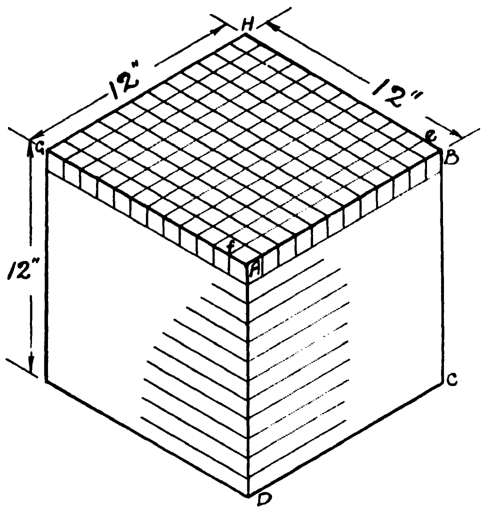


FIG. 1

shown by *ABef*, we find that we have 12 small squares each 1″ × 1″, i.e. 12 *sq. in.* If we take the whole of the top surface *ABHG* we get 12″ × 12″ = 144 *sq. in.*

Hence, **linear dimensions × linear dimensions = square measure.**

If we now take a layer of the cube 1″ thick, we have a thin slab 12″ long, 12″ wide and 1″ thick,

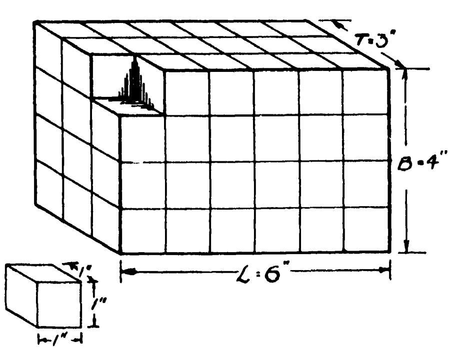


FIG. 2

that is, an area of 144 sq. in. × 1″; this equals 144 *cub. in.*

Hence, **square measure × linear measure = cubic measure.**

We can now see that the cube in Fig. 1 = 12″ × 12″ × 12″ = 1,728 cub. in., or 1 ft. × 1 ft. × 1 ft. = 1 cub. ft.

Fig. 2 further illustrates the volume of a solid. It is a pictorial view of a block 6″ × 4″ × 3″. The face is 6″ long by 4″ wide, therefore it contains 6 × 4 = 24 sq. in. The block is 3″ thick, therefore it contains 24 × 3 *cub. in.* A small cube (1 cub. in.), has been removed so that the student can readily understand the term cubic inch.

From Fig. 2 we can see that—

Area = Length × Breadth
= LB
and, **Volume = L × B × Thickness**
= LBT.

EXAMPLE. Find the area of the floor shown in Fig. 3.

SOLUTION. The dotted lines show the method of dividing the floor into rectangles, the area of each rectangle will be *LB*.

Area of rectangle	*A*	= 22 × 23	= 506 sq. ft.	
,, ,, ,,	*B*	= 16 × 9	= 144 ,, ,,	
,, ,, ,,	*C*	= 9 × 3	= 27 ,, ,,	
,, ,, ,,	*D*	= 8 × 2	= 16 ,, ,,	
Total area			693 ,, ,,	

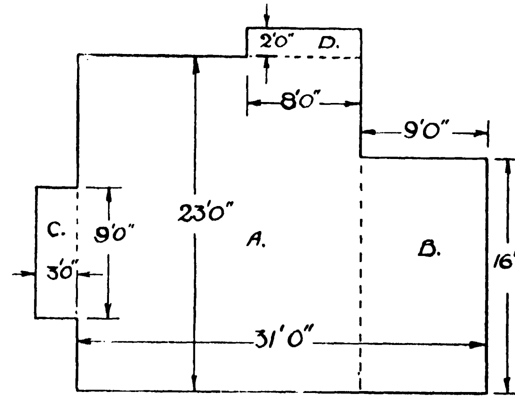


FIG. 3

EXERCISE I

1. A large rectangular hall contains 203,320 cub. ft. of air space. The area of the floor is 8,840 sq. ft., and the width of the hall is 65 ft. Find the length and height of the hall.

2. 236 cottages are to be built, each cottage containing 5 rooms of the following dimensions: 14′ × 13′, 13′ × 12′, 13′ × 11′, 11′ × 9′, and 10′ × 8′. How many squares of flooring are required, when 100 sq. ft. = 1 square?

3. A factory is six stories in height. There are 23 windows on each side and 14 on each end, to every floor. The lighting area for each window is 9 ft. × 6 ft. What is the complete lighting area to each floor, and how many panes of glass 3 ft. × 2 ft. are required for the mill?

DRAINAGE AND SANITATION

By PROFESSOR HENRY ADAMS, M.INST.C.E., F.R.I.B.A., F.S.I., ETC.

LESSON II

CONSERVANCY SYSTEMS—(*contd.*)

Earth Closets. Any midden or pail closet in which earth is applied to the excreta as a deodorant, becomes an earth closet. As, however, the applications of the earth might be discontinued at any time, most by-laws require that the earth shall be applied by mechanical means. It is essential that the material used should be earth, and a loamy soil is best. Such substances as chalk, gravel and sand, are useless as they are sterile and contain no bacteria. Ashes are useful in so far as they keep the excreta dry, but otherwise they have no effect.

Dry earth applied to excreta produces the change known as humification, namely the conversion into humus or soil. A complete combination takes place between the substances in a period of about three months, and is brought about by the bacteria which exist in the excreta. There is an entire absence of smell during the process, and the earth may be used over and over again. It is requisite that the mixture be neither too dry nor too wet while it is maturing; a moisture content of about 33 per cent gives the best results. Before re-use, the earth must be made perfectly dry. This is best done by storing it during the summer months under cover, but freely exposed to the air. Failing this it may be dried on a *drying hearth* consisting of an iron tray with a furnace underneath, as shown in Fig. 3.

Generally, only movable receptacles for the excreta are permitted, and their capacity should be limited to 2 cub. ft. The capacity of fixed receptacles does not, in general, exceed 12 cub. ft., although the Birmingham by-laws allow 40 cub. ft. In every case the excreta receptacles must be of non-absorbent material and so placed that no rain or other moisture reaches the excreta. The dry earth container should be easily accessible and of ample capacity to permit about $1\frac{1}{2}$ pints of earth being applied each time the closet is used.

A pedestal pail closet made by Messrs. Oates

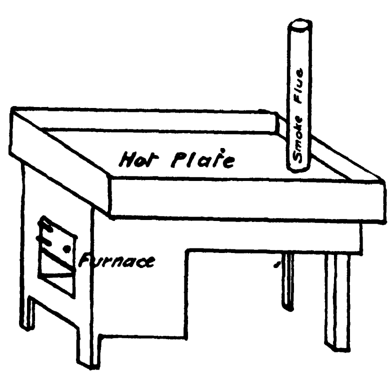


FIG. 3. DRYING HEARTH FOR EARTH

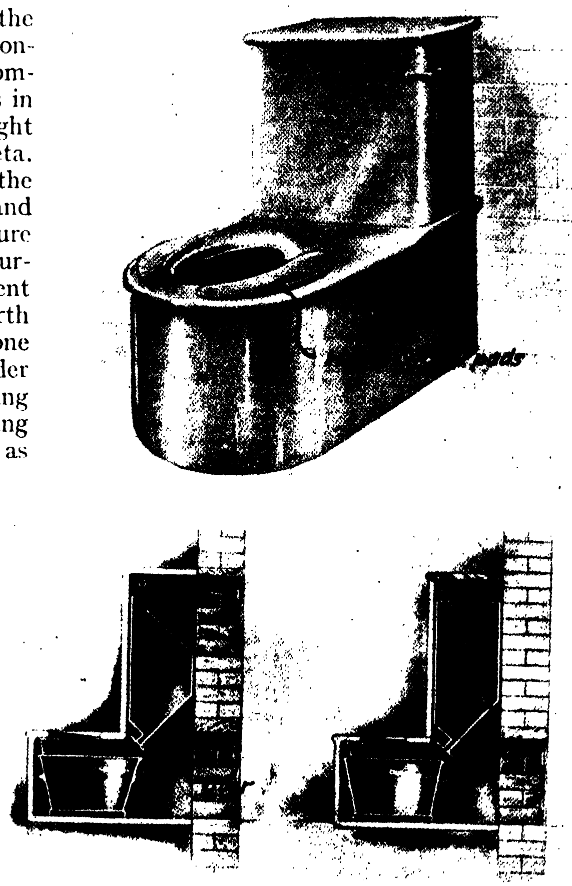


FIG. 4. PEDESTAL EARTH CLOSET

& Green, Halifax, is shown in Fig. 4. It is made in one piece of brown salt-glazed fire-

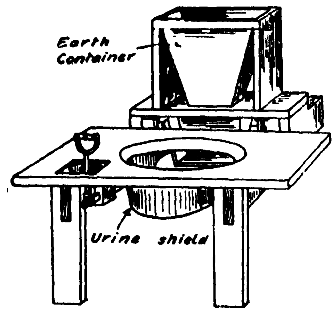


FIG. 5. MOULE'S EARTH CLOSET

clay, of heavy design to guard against breakage, and is fitted with hardwood "Fixton" pads. The pail is removable through a door in the wall at the back. This makes a very neat and clean arrangement, which can be used anywhere where a pail closet is suitable, but it is particularly adapted to use in schools and factories, where strength and stability are essential.

The earth may be applied by hand with the use of a shovel, and in such case it is easily distributed over the whole of the deposited excreta. It is, however, preferable to eliminate the human element and adopt

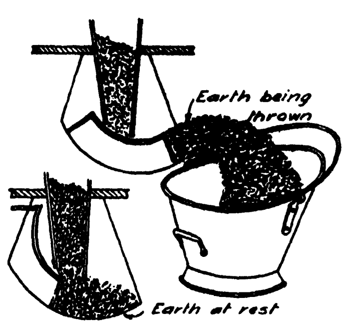


FIG. 6. METHOD OF APPLYING EARTH

mechanical means. Fig. 5 shows Moule's Earth Closet, in which the earth is shaken over the filth by a hinged spreader connected with the handle. An alternative method, which is more certain in its results, of applying the earth is shown in Fig. 6.

Bradley's patent automatic earth closet, made by George Jennings, Ltd., in which the spreader is actuated by the movement of the seat, is shown in Fig. 7. The weight of the user depresses the seat and a certain quantity of earth falls on to the spreader; then when the seat rises, the spreader throws the earth over the excreta. A rise of 1 in. of the seat is sufficient to operate the mechanism, which is very simple and not likely to get out of order.

A range of closets suitable for an elementary mixed school in the country is shown in Fig. 8.

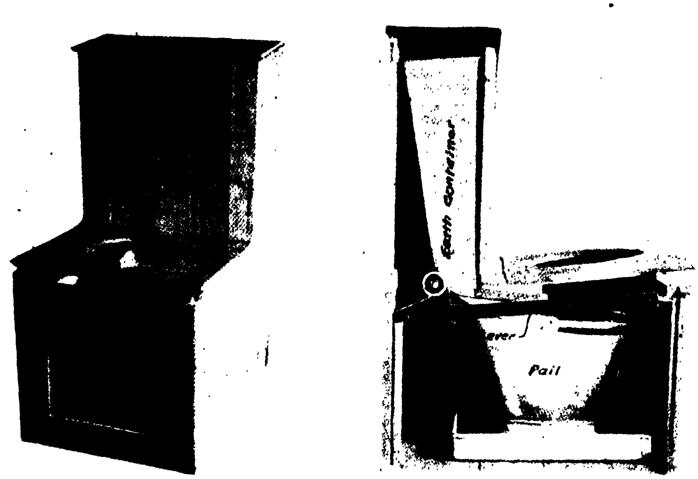


FIG. 7. JENNINGS'S EARTH CLOSET

The closets are back to back, with a passage way between for the removal of the excreta. In this case the earth would be applied by hand, as automatic arrangements very quickly get out of order in schools, factories, and such-like places. Fig. 9 shows a section through the girls' closets which are fitted with a half-pipe channel for the reception of urine, in order that as little as possible may be mixed with the excreta. Fig. 10 is a section through the boys' closets.

CESSPOOLS

A cesspool, frequently called a *dumb-well*, may be classed as a conservancy appliance because the sewage is retained on the premises, but a water carriage system is required in conjunction with the cesspool to convey the sewage from the house to it. Cesspools are usually circular in form and 4 ft. or more in diameter.

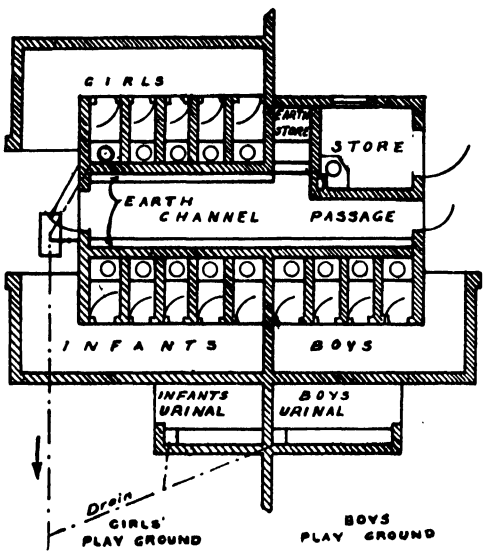


FIG. 8. EARTH CLOSETS FOR SCHOOLS

They should be built and maintained in a water-tight condition in order to prevent pollution of the subsoil and underground water, particularly if the latter is used for water supply. Underground water is always flowing in some definite direction, and pollution may be carried considerable distances. Any well for domestic use should be placed on the upstream side of a cesspool and as far as possible from it; a distance of 100 ft. to 200 ft. is by no means excessive.

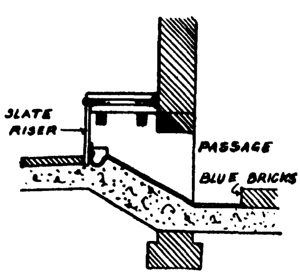


FIG. 9. SECTION THROUGH GIRLS' CLOSET

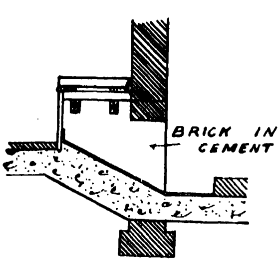


FIG. 10. SECTION THROUGH BOYS' CLOSET

A design for a cesspool is shown in Fig. 11. The brickwork is surrounded by 6 in. or 9 in. of clay puddle to prevent leakage. Clay puddle is prepared from tough tenacious clay which must be entirely free from sand or loam. The clay should be weathered and tempered, cut up and trampled on, until it is entirely homogeneous. To test the clay, a ball, some 3 in. diameter, should be made and put into a pail of water. If at the end of twenty-four hours the ball is intact, the clay is suitable for use, but if there is any sand or other extraneous matter in the clay, the ball will fall to pieces. The brickwork should be of hard bricks laid in cement mortar, or if of soft bricks it should be rendered in cement. The ground is excavated sufficiently large to receive the puddle outside the brickwork; then, after a few courses of bricks have been laid, the puddle should be laid in the annular space and tamped solid, care being taken not to disturb the brickwork. Then a few more courses of bricks are laid and more

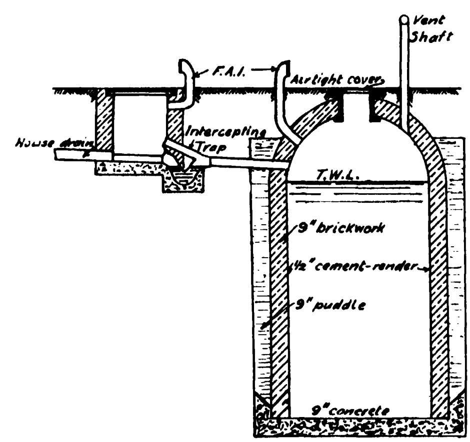


FIG. 11. CESSPOOL AND DRAIN CONNECTIONS

puddle inserted in a similar manner, and so on, until the top is reached.

The cesspool illustrated in Fig. 11 is covered over with a dome which is somewhat expensive to construct. An alternative method of covering, by corbelling over the brickwork and finishing with a stone slab, is shown in Figs. 12 and 13. Provision should be made in the top, not only for access, but for building in a ventilating pipe, and it is further advantageous to have, as a permanent fixture, a chain pump as shown in Fig. 14, for emptying the cesspool. If circumstances permit, the liquid from the cesspool can be pumped out at frequent intervals and distributed over the adjoining garden ground, and thus avoid the nuisance and trouble of emptying and depositing the whole of the contents at one time.

If a considerable area of land is available, an overflow pipe can be built into the cesspool so that the surplus liquid can be irrigated over the

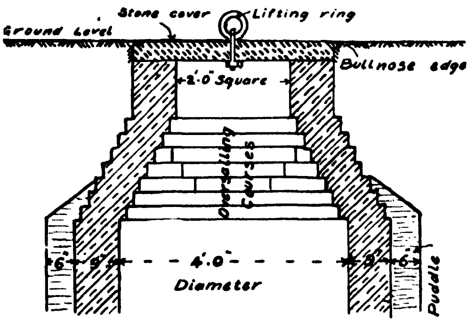


FIG. 12. SECTION THROUGH TOP OF CESSPOOL

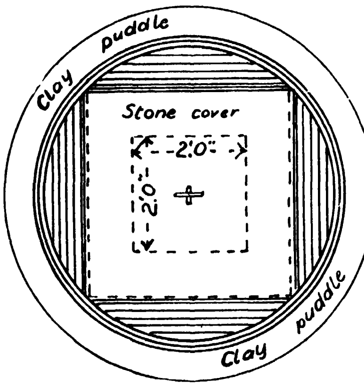


FIG. 13. PLAN OF CESSPOOL

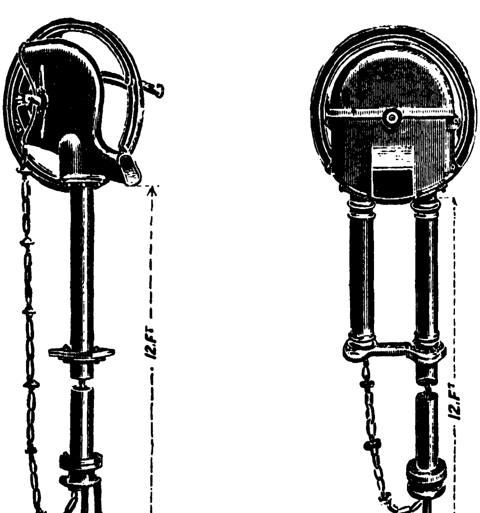


FIG. 14. CHAIN PUMP

land, or the overflow pipe can be connected to a system of underground open-jointed pipes laid a foot or so below the surface, and the sewage disposed of by sub-irrigation. Neither of these arrangements should be permitted if there is any water supply near by, and except in the special circumstances mentioned, no overflow should be attached to a cesspool.

The bricks are frequently laid in one 9-in. header ring, but this is objectionable because it

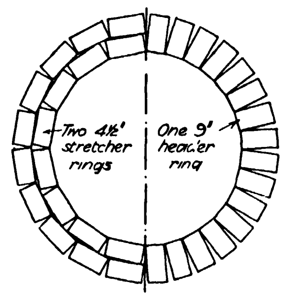


FIG. 15. ALTERNATIVE METHODS OF LAYING BRICKS IN CESSPOOLS

gives such wide joints at the back. A preferable way is in two 4½-in. rings. The relative thickness of the joints obtained can be seen from Fig. 15. Square bricks are used for the sake of economy, but in good work specially made curved bricks, known as *well bricks*, shown in Fig. 16, should be used. These can be laid with very thin joints, and a cesspool which will be more permanently watertight will be obtained.

The house drain should be disconnected from the cesspool by an intercepting trap, built into a chamber to allow of access; the sewage

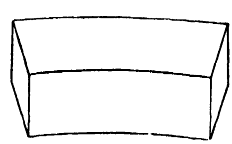


FIG. 16. WELL BRICK

passing through the chamber in an open channel. The chamber should be provided with a fresh air inlet, marked *F. A. I.* in Fig. 11, to ventilate the drain. The cesspool is also provided with a fresh air inlet, because a single vent shaft would only permit the expulsion or admission of air as the level of the liquid rose and fell in the cesspool, whereas for ventilation it is necessary to have an inlet as well as an outlet. The inlet should be at, or near, ground level, while the outlet shaft should be carried up as high as convenient, but not less than 6 ft. The shaft should be fastened to a wall or other rigid structure, and not to a tree because its swaying in the wind would break the pipe or its joints.

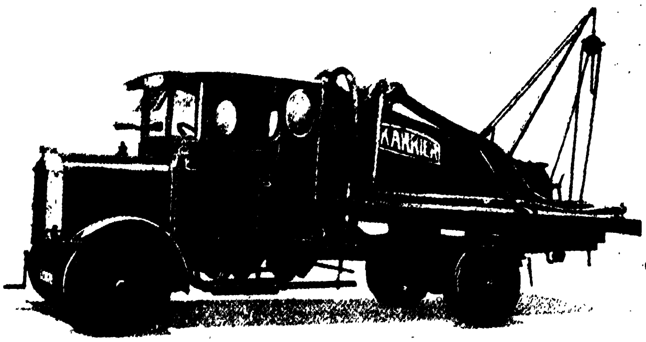


FIG. 17. VACUUM CESSPOOL EMPTYING APPARATUS

It should be noted that owing to the action of the bacteria in the sewage on the organic matter, the latter is disintegrated and a great portion of the solid matters go into solution, so that when a cesspool is emptied very little solid matter is found. When the contents are being removed, a special iron slop cart is required, so that the foul matter shall not drip on to the road dur ing its conveyance to the dumping ground. To minimize the nuisance inseparable from the emptying of a cesspool, some deodorizing substance should be employed. The most modern method of emptying cesspools is to employ a vacuum tank, as shown in Fig. 17, which represents an apparatus made by The Karrier Motors, Ltd., Huddersfield. The tank is a cylindrical one, mounted on wheels, and sealed. When about to be used the air is exhausted from the tank, creating a partial vacuum, and a hose pipe from the tank is let down into the cesspool. Upon opening a valve on the pipe, the contents of the cesspool are sucked up into the tank, so that the cesspool is emptied without any of its contents being exposed to the air.

GAS-FITTING

By R. J. ROGERS
Chief Superintendent, Fittings Department, City of Birmingham Gas Department

LESSON II

DISTRIBUTION OF GAS

Distribution Pipes. The problem of distributing the gas from the works to the consumer presented great difficulties to the pioneers, and various materials were used by them to construct conduits for the gas. The chief recognized materials used to-day for the manufacture of gas mains are—

1. Cast iron.
2. Steel.
3. Wrought iron.

Of these, cast iron and steel are mainly used for the larger underground mains, while wrought-iron pipes are used for services, internal piping, and in some cases for underground mains conveying gas at high pressures (see Fig. 2).

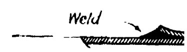
In deciding upon the size of gas pipes it should be remembered that the volume of gas which will pass through any main is proportional to the *square* of the pipe diameter, while any roughness of the inner surface, sharp elbows, or tee pieces restrict the carrying capacity of the main. Fig. 3 is a diagram giving the discharge of gas through pipes with a loss of pressure of 1-in. head of water.

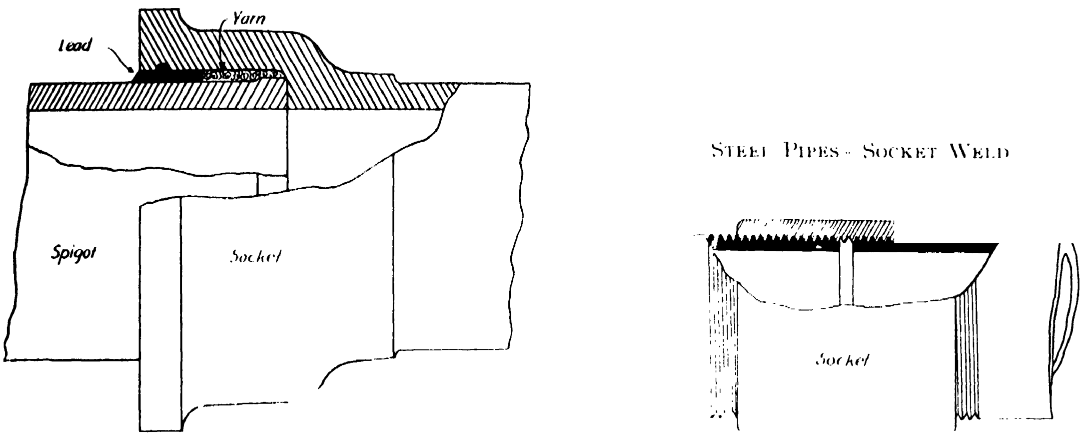
The pressure at which gas is generally distributed is only slightly above atmospheric pressure, the difference being usually equal to 3 in. or 4 in. of water column.

Gas being lighter than air (specific gravity ·4 to ·5), pressures tend to be higher at the more elevated parts of the district.

To obtain equal pressure throughout the district it is therefore often necessary to install district control governors.

A supply of gas is sometimes given to outlying districts by means of special supply mains





Cast-iron Pipes—Open Lead Joint

Steel Pipes—Socket Weld

Wrought-iron Pipes—Socket Joint

Fig. 2. Sectional Diagrams of Cast-iron, Steel, and Wrought-iron Joints

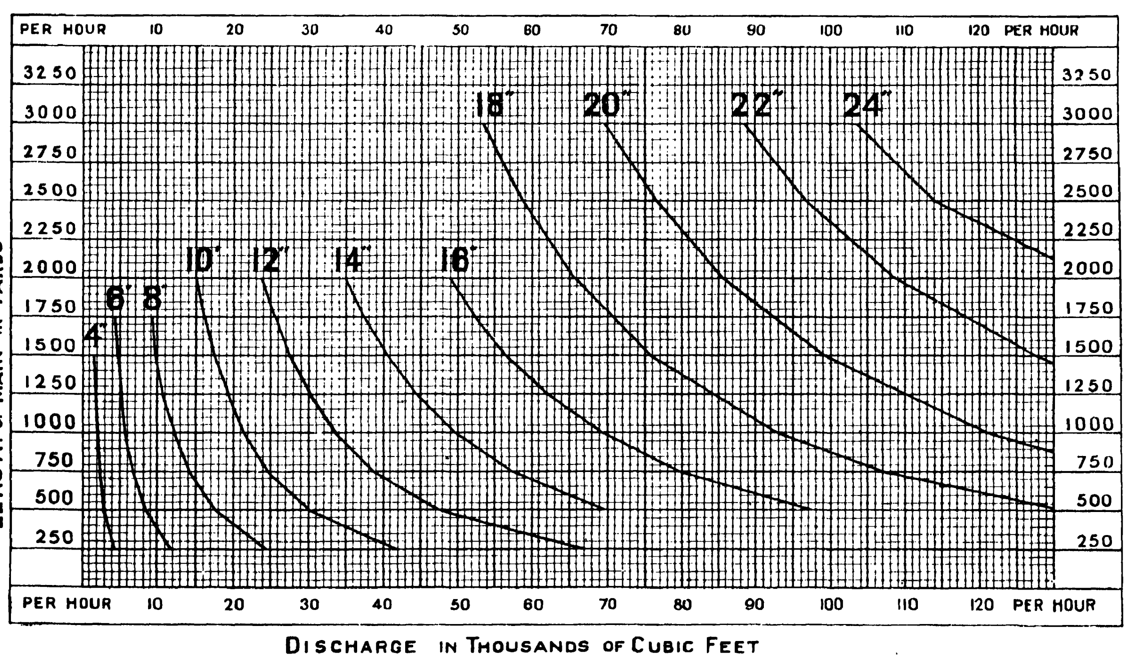


Fig. 3. Graphs showing Approximate Amount of Gas which will Pass through Various Lengths of Certain Sizes of Mains with a Loss of Pressure of 1 in. Water Column

conveying gas at high pressure (say 10 lb. or 12 lb. per sq. in.), which pressure is reduced by specially designed governors to a predetermined amount, and fed into the low-pressure distributing mains as required for use by consumers in the district.

Gas Service. The pipe conveying gas from the street main to consumer's premises is known as the " service." This service pipe should be of wrought iron (for all sizes below 3 in. diameter). It should, whenever possible, be taken off the top of the main by a bend or m. & f. elbow. It must be laid with a definite fall, preferably back to the main.

The tube used should be of steam-quality wrought iron, either specially wrapped or laid in wood troughing into which hot bitumen is poured. A connector (sometimes called a *long screw and back nut*), should be left near the main to render possible the disconnection of the pipe should this require to be done at any future date.

A *main cock* and key must be fixed on the service immediately where it enters the consumer's premises. The *gas meter* should be fixed as near as possible to the front line of the building. This minimizes the possibility of uncontrolled gas escapes and makes for safety in case of fire. On no account should a service pipe be laid under a hollow wooden floor to kitchen or back cellar ; if so laid a small escape may pass unnoticed until gas has accumulated under the building in a sufficient quantity to become dangerous.

PAINTING AND DECORATING

By Charles H. Eaton, F.I.B.D.
Member of Council of The Institute of British Decorators

LESSON II

THE PRESERVATION OF THE STRUCTURE

Trade practice appears to have resulted in the painting and decorating executed by the builder being regarded from rather a different angle of vision than that executed by the specialist firm practising the one craft only, and there is much to be said in favour of placing each branch of the industry in the hands of such specialists. The builder generally is not regarded as capable of executing decorating, but rather that he applies painters' materials for the purpose of preserving the structure and making it easy to clean, decoration being a secondary consideration.

THE CONSTRUCTION OF PAINT

Modern Materials. The student of any craft will always do well if he takes advantage of every reasonable means available to possess himself of a thorough understanding of materials, and this applies particularly to the painter and decorator. In few trades has there been such a change in the variety and type of materials, and such changes have not always been in favour of an easier understanding. Modern materials require much more technical knowledge than that which is accepted as necessary by the average craftsman. By an inefficient understanding, all the expense and care that has been bestowed on the perfecting of a formula and the production of superior materials, can be brought to nought and rendered futile in a few minutes ; in fact, it must be accepted that the poor results obtained, when really first class materials are used, are due almost entirely to a lack of knowledge and skill on the part of the operative, added to which are the very unfavourable conditions that prevail on the average job which, in themselves, make it almost impossible for even a well-trained craftsman to turn out work of which he can be proud.

It is accepted generally that all things consist of liquid and solid, and this is essentially the case in regard to paint. Paint may be said to consist of certain solid particles of varying sizes and shapes suspended in liquid or liquids that serve the purpose of allowing the material to be spread as evenly as is required over a surface : the liquid also serves to attach the particles securely to each other, and to the surface upon which the mixture is applied.

Pigments. The solids are called *pigments*, and they may be divided into two classes, *natural* and *artificial*. Pigments are regarded as materials used to give the paint density and colour ; they owe their individual colour to their ability to reflect or absorb certain rays of light, a matter of selection. Colour, being always dependent upon light, absence of light means absence of colour. The ability to absorb or reflect suitable rays of light, so as to allow the pigment to appear as of a certain colour, depends entirely upon the structure and shape of the particles, and their individual chemical composition.

Vehicle. Pigments are generally in powder form, and are ground in a medium which is called the *vehicle*. This medium may be water, or a suitable medium soluble in water, oil or spirit. The greater bulk of pigment used by the decorator is ground in oil, the oil generally used being *linseed oil*. Pigment and oil are first brought together in a mixing machine, then ground in a mill varying in size according to the quantity of pigment to be handled, the resulting mixture being a stiff paste which must be packed in an air-tight container to prevent a change taking place, due primarily to the action of air. Pigments for certain special purposes are ground in turpentine, water, or a special medium. The oil (linseed oil) acts as a binder ; that is, it binds together the particles of pigment and makes it possible to attach them to the surface under treatment. Other mediums, however, may be substituted for linseed oil, as gold size, varnish, or boiled linseed oil. Tung-oil, or Chinese wood oil, is also used by manufacturers. The type of binder varies according to the requirements of the job : in order to make the paste more fluid so that it may be spread with a brush, more oil is added, but there is a limit to the amount, this depending largely upon the purpose for which the paint is to be used ; also, paint made entirely with linseed oil and pigment would give a mixture that would dry so slowly, and be so elastic, that serious difficulties would inevitably ensue.

Thinners. Linseed oil dries by absorbing oxygen from the atmosphere, the process of oxidation of a thin film varying from 24 to 48 hours, according to the temperature. Obviously, if the oil is loaded with a pigment it would take much longer to dry or oxidize ; therefore, recourse has to be made to some other way of securing the required result. This is partially obtained by introducing a ***thinner***, that is, a material that will serve to thin the mixture and allow it to be spread more thinly, so that the oil film may take to itself the necessary amount of oxygen in a shorter period of time. Turpentine is generally used for this purpose, and *American turpentine* is the most suitable. During the last few years, ***white spirit*** has been introduced ; this is a rectified mineral spirit, and is commonly described as ***turpentine substitute***. It is being increasingly used, and is satisfactory where reliable brands are employed.

Turpentine, or turpentine substitute, dries almost entirely by evaporation. Certain difficulties and defects that develop in connection with paints have been credited to the use of turpentine substitute ; there are, however, circumstances in which it has an advantage over pure turpentine, though it should be observed that the best and most efficient thinner is ***pure*** *American turpentine*.

Driers. A normal mixture of pigment, binder, and thinner, does not, however, give all that is required. Such a mixture would frequently have serious disadvantages. The drying time of paint can be largely regulated by adjusting the proportion of binder and thinner ; the varying of the quantity of pigment may also effect an advantage in drying, but there are limits. A certain quantity of pigment is essential for a definite purpose ; if the binder is reduced beyond a certain proportion, the structure of the film will disintegrate in an unreasonably short period of time ; if the precentage of thinner be too high, the percentage of binder may be too much reduced to hold together the film. In order to correct this, and to allow for the retention of the right proportion of all the ingredients, something is necessary so that the oxidation or drying of the paint film may be secured in a sufficiently short space of time to suit industrial requirements. This is brought about largely by introducing materials which, by their action, cause the oil to oxidize in a shorter period of time, that is, they cause the oil to absorb oxygen more rapidly than it would in the natural sequence of things. The materials used for this purpose are called **driers.** The materials generally used are chiefly compounds of lead or manganese, that is, litharge, lead acetate, lead borate, lead oxide, manganese dioxide, manganese sulphate, manganese borate, manganese oxolate, and cobalt salts. These materials are, in their pure state, very powerful drying agents, and are sold to the trade in various forms known as *patent dryers*, *liquid oil dryers*, and *terebine*.

Patent dryers consist of a drying agent, as sulphate of lime, chalk, sulphate of barium, or barytes, these latter being introduced as extenders or reducing agents, the whole being ground in oil to a stiff paste. When the original package has been opened, the contents should be covered with oil to prevent a skin forming through oxidation. The pure materials are so strong in themselves that some system of reducing is necessary so that it may be possible for the craftsman to proceed with reasonable safety.

There is no standard formula for drying materials, each varying according to the knowledge and understanding, and the commercial instincts of each particular manufacturer. The absence of a standard allows the introduction of quite unreasonable quantities of extenders or reducing agents, which are far less costly than drying material itself; therefore one cannot expect to obtain a suitable material unless a reasonable price is paid, and the material is obtained from a reliable manufacturer. The use of cheap, patent driers may lead to the introduction of a greater proportion of the material than should be necessary, and this, in effect, will merely extend the basic pigment of the paint and interfere seriously with the durability of the paint; on the other hand, a too liberal use of driers of any kind will so interfere with the elasticity of the paint film that cracking will quickly result. It is wise, therefore, to become familiar with driers of a reliable manufacture and understand the particular kind suitable for various types of paint. It is unwise to use patent driers in dark paints; although it should be practically colourless, the slight colour of the reducing agent will impair the brilliancy of rich colour.

Liquid Oil Drier consists of a drying medium mixed with oil, slightly thinned with spirit; a little resinous matter is also added. The oil—the greatest volume of material in this type of drier—renders it much more safe to use, the danger from a slight excess not being nearly so great as with other types of driers. Oil, adding as it does, to the elasticity of the paint film, is more uniform and reliable in its action. Being transparent, it does not affect the colour of the paint into which it is introduced. Liquid oil driers may be regarded as the safest and most easy to use for all general purposes.

Terebine consists of the drying agent reduced chiefly with spirit; a little resinous matter and oil are, however, introduced, without which the drying agent would settle and remain solid at the bottom of the vessel whilst in store. Care should be taken to see that this has not happened, or it may transpire that, when the material is used, only spirit and a little oil is added to the paint instead of a requisite amount of drier. Terebine, in actual use, is not nearly so safe as one could wish; it tends toward increasing the risk of cracking of the paint film, and, in drying, the spirit evaporates, leaving behind the drier and resinous matter.

Gold Size consists of gum, red lead, litharge, copperas, and oil, the whole mixture being incorporated in a process of boiling. It is used chiefly as a binder and drier in flat paints. An excess of this material will cause cracking, particularly when the previous coat of paint contains much oil.

Powdered Driers. Some manufacturers prepare driers in powder form, but their use is not to be recommended. The addition of a powder that cannot be properly incorporated is bad; paint would be gritty, and in addition to this there is the greater risk of the powder falling in patches, and so causing a lack of uniformity in the film established with such a mixture. By properly balancing the ingredients, a suitable paint can be prepared for each application.

ARCHITECTURAL MODELS AND MODELLING

By Edward W. Hobbs, M.J.I.E.
Vicker's Gold Medallist; Author of "Pictorial House Modelling"

PART I

USES AND TYPES OF MODELS

Advantages of Models. The expression *architectural modelling* is applied to many different methods of representing, in miniature and in relief, the appearance of all kinds of buildings and details thereof.

Many practical men suppose that a model is nothing more than a glorified toy, scarcely worth a passing glance, and fit only for an exhibition. This attitude may be excusable, but is not tenable nowadays, when the many real merits of a good architectural model are becoming more widely appreciated.

In one respect the model has great advantages over drawings: it can be viewed from many different points, whereas the drawing is necessarily seen from one viewpoint alone, and even then does not completely represent the finished structure.

With a model, however, the building is presented in miniature exactly as it is viewed by the eye of the beholder, and every little play of light and shade, every trick of perspective, is faithfully represented, with the result that the brain receives a far more adequate conception of the structure. Moreover, a model is not affected by time, and provided the needful data are available, a model can be made of an ancient building long since demolished with the same facility as a model of an existing structure, or a new project; the models will present all of them with equal fidelity.

Typical Examples. As a case in point, the model of the celebrated Bush House, seen in Fig. 1, was made before the building was started, for the express purpose of enabling the architects and their clients to get a comprehensive idea of the finished building as then projected.

Model of Bush House Building, as Originally Projected

Those who are familiar with the actual building will see that several alterations were made in details, which emphasizes the value of a preliminary model of an important structure. The model illustrated was built from designs by the architects, Messrs. Helmle and Corbett, and was made by Mr. John B. Thorpe, of London, to a scale of ¼ in. to 1 ft.

Another interesting model of a projected structure is illustrated in Fig. 2, a model of the new buildings for the Bank of England. This is the work of Partridges Models, Ltd., of London, and is a large and handsome piece of work which gives a splendid impression of the new buildings as they will appear when finished.

Another example of a projected building is illustrated in Fig. 3, which shows a section of an interior for a cathedral. This model is the work of Berthold Audsley, of America, a well-known maker of fine scale models in the United States. This model, which is about 24 in. high, is interesting from the architectural point of view, and also as showing the perfection of detail that can be represented in a small model. As a matter of fact, it is very difficult to judge from the illustration anything of the scale of the model, but thanks to technical skill of a very high order, the picture does convey a sense of vastness and a certain massiveness of construction; in short, an air of reality.

Realism in Architectural Models. Realism is

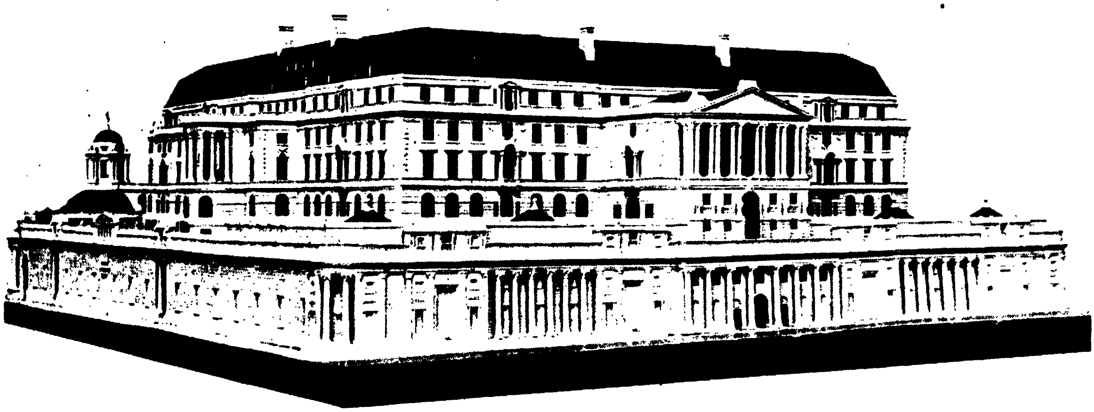


FIG. 2. MODEL OF THE NEW BUILDINGS FOR THE BANK OF ENGLAND

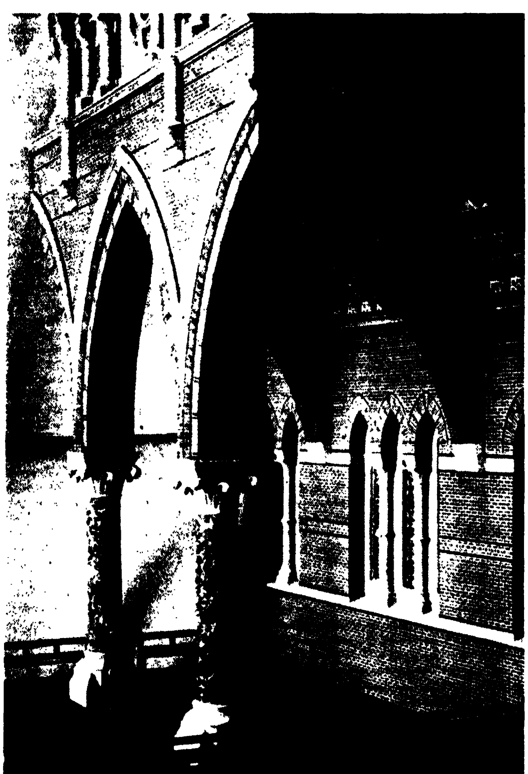


FIG. 3. INTERIOR OF A CATHEDRAL

perhaps the most important item in an architectural model with any pretensions to good quality. The model, if it is to be a good model, must have this sense of realism, or it is little more than a toy, unworthy of the builder's time and energies.

This essential quality of realism can be appreciated in all the examples illustrating these remarks, but it is necessarily a relative quality; there is no absolute standard of realism, and as a consequence can only be judged according to the purpose of the model.

In the first examples the purpose is to convey an impression of a proposed building, and each model in its own way has attained this to a very high standard. The general effect of the design, its due proportions and architectural balance, are of more importance than a meticulously accurate model—not that any suggestion of inaccuracy is imputed in the models illustrated, but the purpose was not to show exactly how many bricks or stones would be visible, but rather to get the general impression of the structure as a whole. In the third example, the atmosphere of the interior of the cathedral, rather than any details of the brickwork, is the object behind the work put into the model, and it has to be admitted that the desired result has been attained.

Accuracy and Utility of Models. For other purposes different qualities will predominate; in the example in Fig. 4, showing the Kodak

Works at Wealdstone, made by Twining Models, Ltd., of Northampton, accuracy in every detail, coupled with realism, was essential. This model is typical of a large number that are made as record models of large works and other groups of buildings, such as a garden city or an estate development scheme. The purpose is to have a graphic record of the site and every erection thereon, thus making it possible at any time to study contemplated additions and their effects on the surroundings. Such points as interference with light and air, or the best arrangement for a new roadway, can be studied on the model with an ease and celerity unattainable by any other method. For example, it is quite possible to make a rough cardboard model, showing the outer limits of a new building, and to try the effect on the other model without incurring any material expense in the preparation of elaborate plans, and without the need for a survey.

Moreover, the board of directors can study the projects on the model in the privacy of the board room, and at any time of the day, without regard to the weather conditions. What is of more importance, however, is that the effect, as seen on the model, will in all probability show up some defect of planning that can readily be overcome with little trouble when made so apparent.

To do this in a reliable manner, it is obvious that the model must be made with absolute scale accuracy, and that every detail, including the contours of the ground, must be reproduced with the utmost fidelity. This necessitates considerable time in the preparation of many photographs, the collecting of architect's plans and other data, with the result that these commercially made models cost a considerable sum of money. But it is money well spent, as such a model has an indefinite life, and can always be altered, if necessary, to keep it up to date. Students would greatly appreciate the existence of undoubtedly authentic contemporary models of wonderful buildings of the past, for instance, the Colossus of Rhodes, or the Hanging Gardens of Babylon. The art of architectural modelling was almost unknown to the ancient peoples, although there are in existence many models of early Egyptian work that are full of interest, but compared to the marvellous work turned out by modern exponents of the craft, they are but little better than the modern child's doll's house.

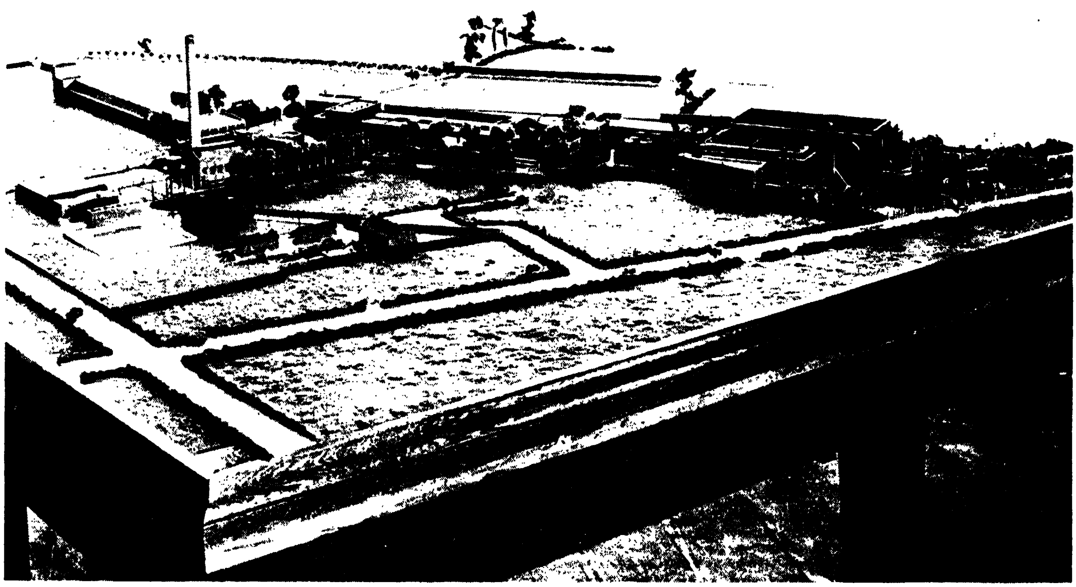


FIG. 4. SCALE MODEL OF THE KODAK WORKS, AT WEALDSTONE

Scenic Models. The foregoing examples are all of models which represent the prototype by means of miniature replicas, but there are other methods of attaining a sense of realism that can be followed for some purposes, particularly when a pictorial effect will suffice.

Take, for example, the street scene pictured in Fig. 5, built by Partridges Models, Ltd., and made on the McCorquodale perspective system. Here there are some modelled portions, and some parts are simply painted flats, or small scenes something like a miniature edition of a stage scene. But it is very difficult to detect either in the photo or on the original where the modelled parts end and the painted portions commence. Such spectacular models are generally set up in a suitable case and arranged to be viewed from a fixed point, and thus it is possible to blend the perspective or vanishing lines of the flat scene into the actual lines of the modelled parts. The latter are often modelled in perspective to further aid the illusion, as may be appreciated from Fig. 5, where the lorry and the street entrance are modelled in relief, the side walls in perspective relief, while the back portions are hand-painted flats. The effect of sunlight is attained

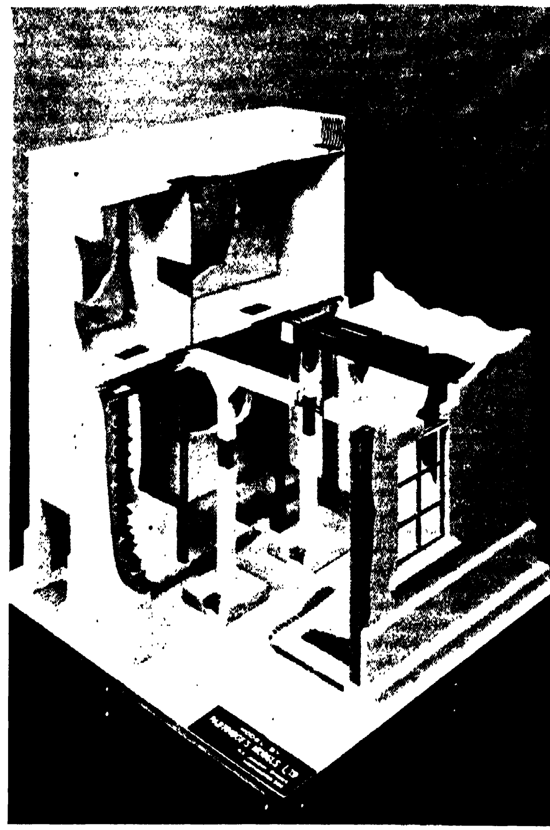


FIG. 6. SECTIONAL MODEL TO SHOW CONSTRUCTIONAL DETAILS OF A FERRO-CONCRETE HOUSE

partly by controlled artificial lighting within the model case, and partly by paintwork.

Models of Constructional Details. To the student of architecture there is a wonderful utility in the constructional scale model, such as the example in Fig. 6, which illustrates the "Expamet" system of reinforced concrete construction. The model shows sections of a simple domestic building, and how the reinforcements are arranged, parts of the walls having been shown as cut away to reveal the interior details.

Such models as these are only possible of construction by those fully equipped for the work and having the necessary training in architecture and building constructional methods, but there is a wide field for the amateur maker to explore with the greatest success.

FIG. 5. PICTORIAL OR SCENIC MODEL IN PERSPECTIVE, SHOWING A STREET SCENE

(*Elliott & Fry*)

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ARCHITECTURAL DESIGN

By T. P. Bennett, F.R.I.B.A., and T. E. Scott, A.R.I.B.A.

LESSON III

THE ELEMENTS OF ARCHITECTURE

WALLS AND CORNICES

The first and perhaps the most important element in architecture is the wall. Walls may occur as "isolated" structures or as "collective" walls; the former, such as terrace and retaining walls, are complete compositions in themselves, while the latter are essentially space enclosing elements, and must be considered in relation to the composition in the larger sense.

Isolated Walls are designed primarily to resist earth or water pressure. They are usually about one-fifth of their height in thickness, and in some cases battered, or they may consist of a thin wall with buttresses or piers at intervals.

Such features as plinths and cornices contribute to the artistic effect of isolated walls, while buttresses, piers, and "chaines" give both structural and aesthetic relief to long unbroken walls. A balustrade frequently surmounts the wall, both as a useful protective feature if the ground is high on one side, and as an architectural embellishment. All of these features will be referred to later.

Collective Walls are primarily space enclosing elements which form rooms, or collections of rooms, in a building; consequently their form and dimensions must first be determined by the requirements of the plan.

The first consideration in the design of the wall itself, as part of a composition, is its thickness. This will be determined by the requirements of *construction*, *climate*, *effect*, and *decoration*.

Construction. The study of constructional methods throughout the ages will show that in early work there was a great timidity and waste in construction, but as knowledge increased and the advance of civilization abolished slave labour, walls and other supports were decreased in thickness, thereby economizing in material, money, and space. A comparison between the Hypostyle Hall at Karnak, the church of St. Sophia at Constantinople, and any modern factory will show the respective areas of space occupied by walls and supports to be 36 per cent, 16 per cent, and something less than 10 per cent of the total area of the building.

Walls are generally built of a number of relatively small blocks bonded together; the importance of bonding is known to the most junior student of architecture.

Nothing influences the design of a wall so much as the material. Ashlar walls should have regular courses because each stone is highly finished, but a rubble or block-in-course wall will appear false if the courses are equal. In walls of different materials, such as random rubble with ashlar dressings, or brickwork with stone quoins, bond will be an important consideration. There may be vertical courses or "chaines," with filling of the rougher material, or horizontal lacing courses of brick or large stones in a rubble wall. In all cases, these variations must have some constructional significance in their position and treatment, and the two materials must be properly bonded together. Stones which are used in brick walls must equal a number of brick courses in height, and a brick dimension in length. Rustications should consist of an odd number of courses with long stones at the top and bottom.

In any one building there may be walls of varying thicknesses. External walls will usually be thickest, since, besides protecting the inside of the building, they have to resist the oblique thrust of a roof, and the eccentric loads of floors. Internally, it is necessary to distinguish between partitions and load carrying-walls. The latter will be required to resist actions which tend to crush them, such as loads from floors, and actions which tend to overturn them, such as oblique thrusts from vaults and arches. In a good plan, these oblique forces will be resisted by skilfully arranged cross walls of normal dimensions or by the balancing of one vault or arch against another. Many of the domed churches of the Renaissance show evidence of planning governed by the construction of the dome.

The actual dimensions of walls will be determined by building laws, or by scientific calculations. They must never be guessed, but as soon as the safe minimum has been settled, increases may be made to obtain effect.

Stability may be attained by the use of piers or buttresses at regular intervals. Once the general proportions of these are settled, their actual dimension, it in brick walls must be a brick dimension, in order to avoid waste and unnecessary labour.

The arrangement of external and cross walls

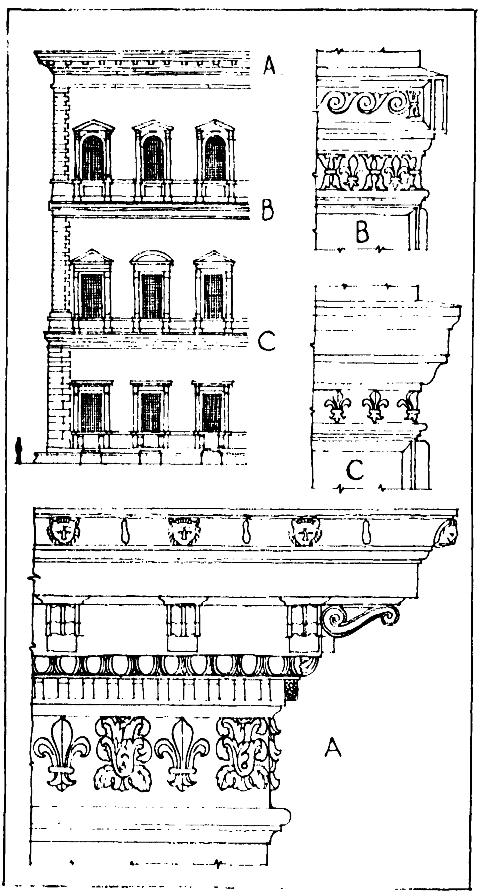

FIG. 11. FARNESE PALACE, ROME
Part elevation and details of main cornice and strong courses

must always be straightforward, in order that they may be bonded together satisfactorily.

So far, the consideration of the construction of walls has been confined, to structural walls built of brick or stone. Great emphasis must be placed upon the study of the evolution of these elements, because, as will be seen in subsequent lessons, the architectural expression, which is in general use in modern work, is the outcome of this brick and stone construction. A review of works of the past will show that the elementary basis of architecture was the building of walls, the forming of openings, and the support of the wall over the openings by a lintel or an arch. With modern materials and methods of construction, however, the process is somewhat changed. A steel or reinforced concrete frame is the fundamental basis of the design, and the problem is not to make openings in a wall, but rather to provide a stone or other protective casing around the steelwork

It will be interesting to compare the buildings of the Renaissance, such as the Farnese Palace (Fig. 11), with the modern buildings illutrated in the previous lessons.

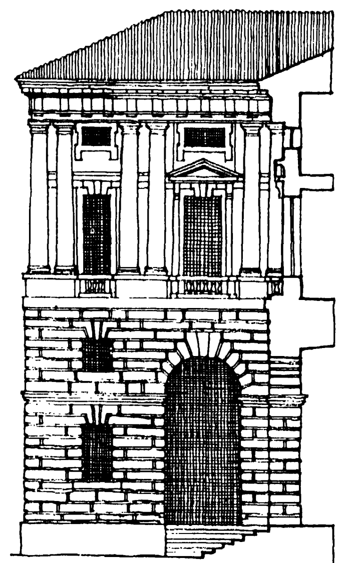

FIG. 12. GRAN GUARDIA, VERONA

The extent to which the spaces between the columns and girders are filled with walling is determined by material needs of economy and lighting and the stylistic expression desired by the architect. In some districts, the proportion of openings in a wall is controlled by by-laws.

The aesthetic aspect of this period of transition in constructional methods has been referred to in the last lesson.

The influence of climate has already been dealt with.

Effect. A thick wall is frequently required for sake of appearance. In modern steel-frame buildings, although thick walls are not usually essential for constructional purposes, they are sometimes used to give depth to door and window openings in order to create a rich and monumental feeling. This is quite legitimate when economy is not of primary importance.

Walls at the base of a building are often thicker on account of the architectural treatment of the walls above. Pilasters, or free or engaged columns in the upper part, will require considerable thickening of the wall below to support them. This point is illustrated in Fig. 12; there are typical examples in London at Somerset House, the Banqueting Hall, and

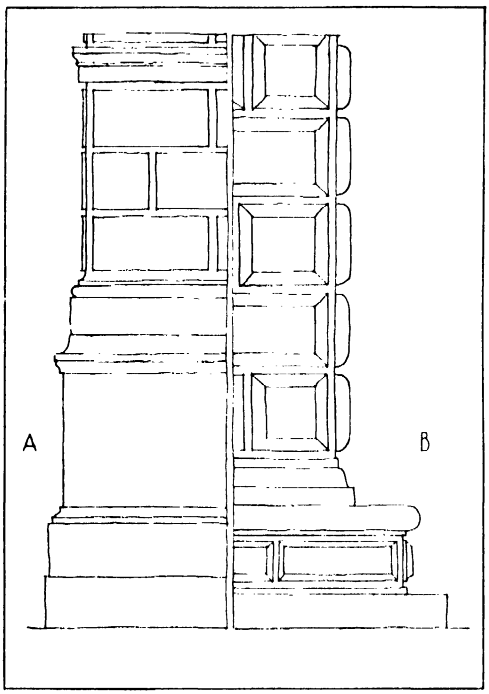

FIG. 13. PLINTHS
A = Cancellaria Palace, Rome *B* = Strozzi Palace, Florence

the Government Buildings, Whitehall. The use of steel or other hidden construction must not permit overhanging features which do not appear to be supported.

The Decoration of Walls. The basis of the decoration of walls is primarily a consideration of construction. Walls must have a foundation or base, of which the plinth is the expression, a containing part or surface proper, and a cornice or other protective crowning feature.

The plinth provides additional thickness which adds to the stability of the wall. Its function must be expressed in its treatment, which should be simple; it should have few joints and bold mouldings. There are many examples of the variety of treatment possible: the stylobate of the Parthenon, the simple deep course of the Pantheon, Paris, and the more elaborate types of the Italian Renaissance; see Fig. 13. In tall buildings, the whole of the ground floor may be treated so as to suggest a base proportionate to the height of the building, channelled joints and rustications adding to the solidity of appearance.

On the surface of the wall itself, decoration may be introduced by windows, the orders, etc., which will be discussed later.

Rusticated quoins emphasize the importance

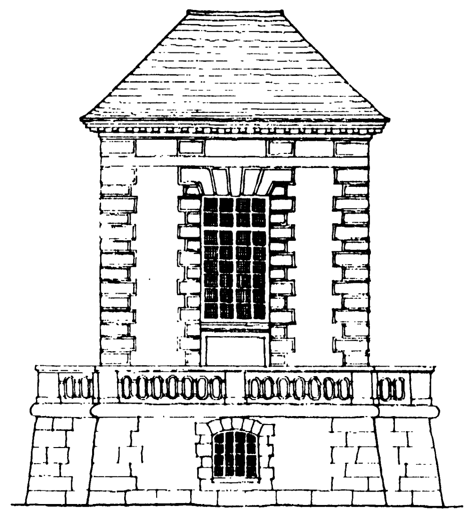

FIG. 14. THE CHATEAU OF BALLEROY
A Pavilion

of the angle, and are logical as expressions of added stability at an exposed point; see Fig. 11, and many other buildings of the Italian Renaissance. "Chaines" are of great interest when carefully handled. The finest examples may be found on some of the seventeenth century architecture in France. Fig. 14 illustrates the employment of "chaines" in a pavilion of the Chateau of Balleroy, by F. Mansart.

Horizontal emphasis is obtained by the use of string courses, which should also be used to mark changes in material or surface treatment. When used, they should locate structurally important points, such as floor or sill levels; see Fig. 11.

String courses must always be subordinated to the cornice.

THE CORNICE

The simplest form of cornice is the weathered coping. Since it is used to protect the surface of the wall as well as the top, it should project beyond the face of the wall; its essential element is, therefore, the *drip*. The cornice is the most important element in classic architecture. It will be valuable to study the refined lines of Greek examples, the rich, strong character of the Roman, and the interest and variety of the Renaissance; those on the Florentine palaces are worthy of special study.

Gothic cornices are usually shallow, because

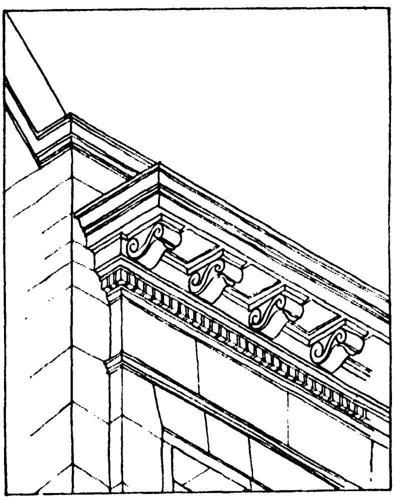

Fig. 15. A Cornice Returned and Stopped on the Face of a Street Façade

of the steep roof behind; this suggests a rule in the design of eaves in domestic work: the flatter the pitch, the greater the projection of the eaves or cornice.

Cornices may be constructed in brick, stone, wood, plaster, or metal; detail must always be adjusted to suit the material. Special points for consideration are: the position of bed and vertical joints; the relative importance of the soffit or the bed moulds, according to location of the cornice and normal point of view; the arrangement of modillions around angles. On street façades, the cornice may be returned and stopped on the face of the wall, as shown in Fig. 15.

The proportions of cornices vary in almost every example. A general rule is to make the cornice two-fifths of the entablature, or two-twenty-fifths of the height of the building.

The scale of the members of the cornice must be carefully considered in relation to environment. Interiors should usually be small in scale and may be finely carved; see Fig. 16 (*A*). The cornice of a building on a narrow street should not project as much as one on a wide street, because its projection will automatically be compared with the distance between the buildings, and its apparent size relative thereto.

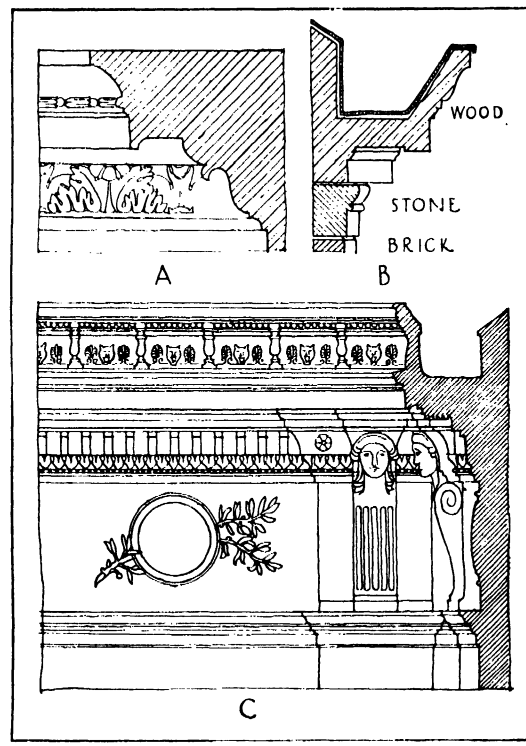

Fig. 16. Cornices

A = The Clifford's Inn Room, Victoria and Albert Museum
B = St. Benet's Church, London *C* = Palais de Justice, Paris

A cornice may not project more than 2 ft. 6 in. over the public way in London.

The treatment of the gutter has considerable influence on the form of the cornice. It may be an eaves gutter forming the top member, a decorative cast-iron, lead, or bronze gutter above the cornice as in Fig. 16 (*C*), or a lead gutter sunk in a wood cornice as in Fig. 16 (*B*).

The use of a blocking course or parapet wall above the cornice will necessitate a box gutter.

BRICKWORK

By WILLIAM BLABER
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LESSON IV

BOND

General Principles of Bonding. The arrangement of bricks when building is of great importance, as upon this depends the strength and appearance of the work. It should be systematic, and have definite principles which the craftsman can readily follow, and which will ensure the requisite strength with a minimum outlay.

If we consider the arrangement shown in

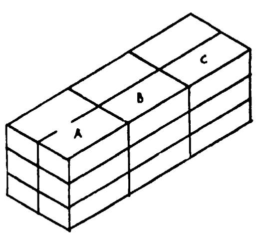


FIG. 7. WALL WITHOUT BOND

Fig. 7, it is clear that a wall built in this manner would tend to split along the continuous vertical joints if subjected to any irregular strain. The sections, *A*, *B*, *C*, etc., are entirely independent, and receive no support from each other.

If, however, the wall be built in the manner indicated by Fig. 8, the whole mass is in combination and mutually supported. The same quantities of materials have been used and the same labour expended in each case, but there is no comparison between the strengths of the two examples.

In Fig. 8 it will be noticed that the bricks in one course overlap those in the course below, forming an interlocking arrangement throughout the whole wall. The length of the lap is equal to one quarter the length of a brick, or 2¼ in. This arrangement is termed *bonding*.

There are several recognized types of bond, the two principal being English and Flemish.

If the principles of these two are thoroughly understood, the others; which are but variations of them, will present no difficulty.

A number of specimens of bonding will be illustrated, applicable to various examples of brickwork, which may at first present some difficulty to the young craftsman.

The writer's experience has convinced him of the futility of endeavouring to memorize diagrams illustrating many and complex forms of bonding, and he is convinced that a few definite rules and principles, thoroughly understood, will enable the young artisan readily to overcome many difficulties likely to be encountered during the ordinary course of events. The diagrams here given are for the purpose of demonstrating these fundamental principles.

Terms. Repeated reference to certain terms in general use will be necessary in explaining the principles of bond, so definitions are appended below.

Header. A brick laid with its 4½ in. × 3 in. end on or parallel with the face of the wall.

Stretcher. A brick laid with its 9 in. × 3 in. side on or parallel with the face of the wall.

Bat. Any portion of a brick cut or broken across its length ; for example, half bat, 4½ in. × 3 in., three-quarter bat, 6¾ in. × 3 in.

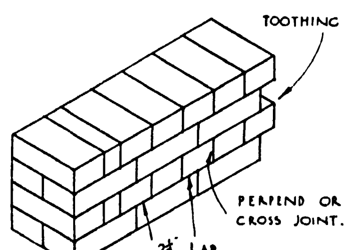


FIG. 8. BONDED WALL

Bed. The bottom surface of a brick which rests upon the mortar spread to receive it.

Frog. The indentation on one or both 4½ × 9 in. surfaces of the brick.

Arrises. The edges of the brick where its surfaces intersect.

Course. A complete layer of bricks laid on the same bed.

Perpends. The short vertical joints in the face of the wall that fall vertically over one another in the alternate courses. Instead of *perpends*, a practical term frequently used is *cross joints*.

Ensuring Good Bond. To ensure good bond, the following rules should be observed—

1. The amount by which the bricks in one course overlap the bricks in the course below should be, along the length of the wall, 2¼ in., and 4½ in. across the thickness of the wall.

2. The vertical joints in the alternate courses should fall in a plumb (vertical) line from the top of the wall to its base, whether on the face or in the interior of the wall.

3. Bats should be used as little as possible, and where used, should be evenly distributed throughout the whole of the work.

4. The bricks should be uniform in size, and the proportion of length to breadth be such that the length equals twice the width plus one joint. Good bond is impossible otherwise, as the lap would not be uniform.

5. The bricks in the interior thickness of the wall should be laid with their length across the wall, or, as it is termed, headerwise.

English Bond. In this bond the facing bricks are laid in alternate courses of headers and stretchers.

This is undoubtedly the strongest of all bonds; the arrangement of the bricks is such that no joint or part of a joint is continuous with any joint in the course below, or, as it is often stated, there are no straight joints.

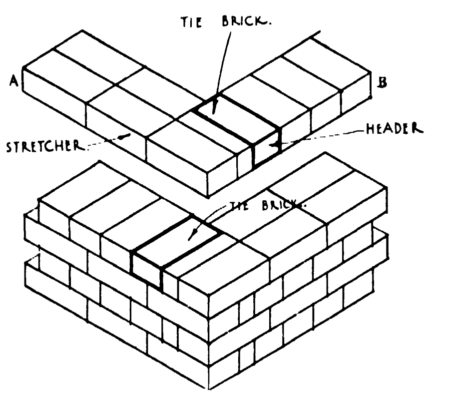


FIG. 9. ONE-BRICK WALL, IN ENGLISH BOND

Flemish Bond. The facing bricks in this bond are laid as alternate header and stretcher in the same course. It is not so strong as English bond, on account of the numerous straight joints 2¼ in. long, which occur repeatedly throughout the wall, and the greater number of bats that are used, particularly where the wall has an odd half-brick in its thickness. If the bond is carefully arranged, it is considered sufficiently well bonded for all general purposes. Careless workmanship in this respect has, however, been the cause in many instances of walls built in this bond splitting in two along their thickness.

Methods of Bonding. Fig. 9 is an isometric view of a portion of a one-brick wall built in

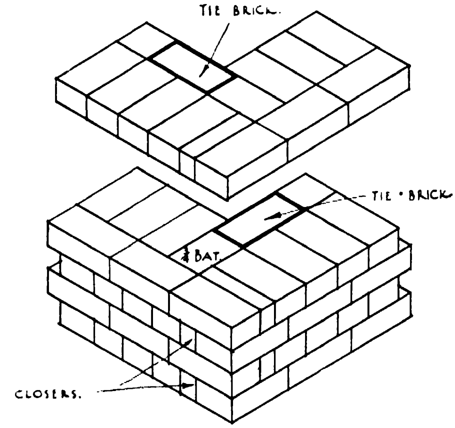


FIG. 10. ONE AND A HALF BRICK WALL, IN ENGLISH BOND

English bond, at the external angle, or, as it is technically termed, *quoin* of a building. Note that the bond on the external faces change in the same course. At *A* they are stretchers; at *B*, headers. Observe also, that the first header on the quoin is followed by a small bat, one-quarter the length of a brick. This is termed a *closer*, and its object is the commencement of the bond. It will readily be seen that the insertion of the closer moves the second header 2¼ in. along the wall, which is the necessary distance to form the lap over the stretcher below. This is consequently repeated throughout the length of the wall. Again, notice that all joints crossing the thickness of the wall pass from the exterior face to the interior in a continuous line.

We have now three definite facts to memorize—

1. Where a wall changes direction, the face bond in the same course changes.

2. That the quoin header is followed by a closer. There are exceptions to this rule, which will be explained later.

3. That all transverse joints should pass in an uninterrupted line across the wall.

Fig. 10 shows a portion of a $1\frac{1}{2}$-brick wall at the quoin of a building. Here it is noticeable that the bonds on the exterior and interior faces of the same course are different (those shown in Fig. 9 depict headers on both faces); also that the heavily outlined bricks in the interior angles (hereafter called tie-bricks) are in different positions in each case. The tie-brick in Fig. 9 has its header face parallel with the wall face, whilst in Fig. 10 the stretcher face is in that position. In both cases, $2\frac{1}{4}$ in. of the

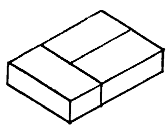


FIG. 11. UNIT OF ENGLISH BOND

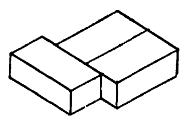


FIG. 12. WRONG ARRANGEMENT

faces bond into the return wall, and are on the opposite face of the course, commencing with a quoin header.

From the foregoing we may deduce several more facts, which should be committed to memory.

4. That where a wall has an even number of half-bricks in its thickness, the bond on the interior and exterior faces of the same course is the same, and that the tie brick in the interior

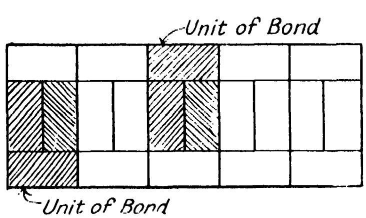


FIG. 13. TWO-BRICK WALL

angle has its header face parallel with the wall face.

5. That where a wall has an odd number of half-bricks in its thickness, the bond on exterior and interior faces of the same course is different, and the tie-brick has its stretcher face parallel with the wall face.

6. That in every case the tie-brick is in the same course as, and on the opposite face to, the quoin header.

Consider a part of one course of bricks arranged as in Fig. 11. Let us call this a *unit of English bond.* If work is proceeding correctly, this unit repeats itself along the entire length of the wall. Should the arrangement shown in Fig. 12 occur, it is apparent that the work is constructionally wrong, because $4\frac{1}{2}$ in. of the side joints of the header-bricks in the next course will fall vertically over the joints in the course below, with a resultant series of straight joints in the interior thickness of the wall. The unit shown is part of a $1\frac{1}{2}$ in. brick wall. The principle will, however, apply with slight modifications to any thickness of wall.

Consider the previous rules. The unit has

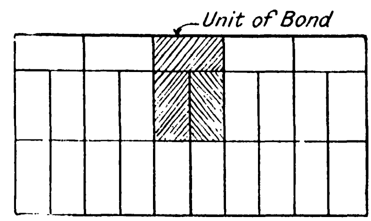


FIG. 14. ENGLISH BOND: TWO AND A HALF BRICKS IN THICKNESS

an odd half-brick in its thickness, and therefore the bond is different on each face.

Fig. 13 shows part of one course of a two-brick wall. The bond is the same on both faces; the bricks in the interior of the wall are laid headerwise, and the unit repeats itself on either face.

Fig. 14 indicates a $2\frac{1}{2}$ in. brick wall. The unit repeats itself along one face only, its thickness being insufficient to take two units. The interior bricks are laid headerwise, and the transverse joints cross the wall in a straight line, unless stopped by a face stretcher. As the wall has an odd half-brick in its thickness, the bond on its opposite faces is different.

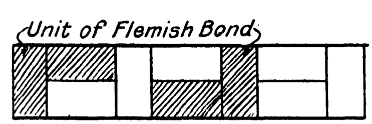


FIG. 15. FLEMISH BOND: ONE-BRICK WALL

In Flemish bond, let us consider the unit to be a face header and stretcher. In a one-brick wall, Fig. 15, this repeats on both faces. In a $1\frac{1}{2}$-brick wall, Fig. 16, the units move along on either face a distance equal to the width of the header on the opposite face. That is to say, the headers are laid side by side on the opposite faces of the same course.

In a two-brick wall, Fig. 17, the headers are arranged to be opposite each other in the same course. Now remember some of the previous rules. The bricks in the interior thickness of the wall should be laid headerwise; bats are to be used as little as possible, and distributed evenly in the interior thickness. It will be

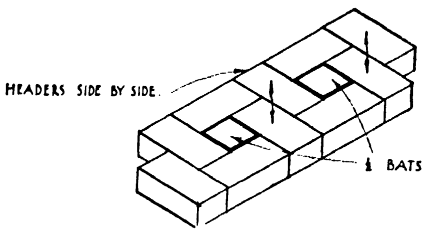


FIG. 16. ONE AND A HALF BRICK WALL IN FLEMISH BOND

seen in the arrangements shown, that in the one and two-brick walls, no bats are required. In the 1½-brick wall, a certain number are unavoidable.

Now consider Figs. 18 and 19. Two methods

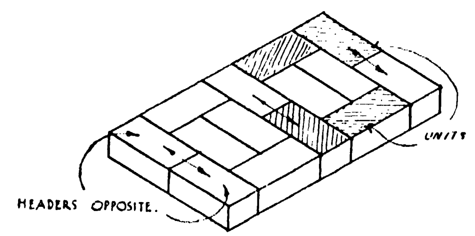


FIG. 17. TWO-BRICK WALL IN FLEMISH BOND

of arranging the bricks in one course of a 2½-brick wall are shown in plan. Where the face-headers are opposite each other, Fig. 18, a large number of bats is required. Where the face-headers pass, as in Fig. 19, the number of bats is

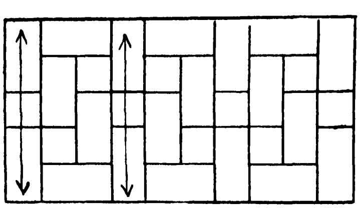


FIG. 18. INFERIOR METHOD OF BONDING
Excessive number of bats required by arranging face headers opposite each other

considerably less, and they are more uniformly distributed along the wall.

In Flemish bond, therefore, it can be assumed that where a wall has an odd half-brick in its thickness, the facing headers should be arranged to pass each other as in Figs. 16 and 18. If an even number of half-bricks in thickness, the face-headers should be arranged opposite each other, as in Figs. 15 and 17. These arrangements will usually be found to provide a more uniform bond, involving the use of the least possible number of bats, and, in consequence, producing a much stronger wall. Note that in Flemish bond, the face-headers are always placed over

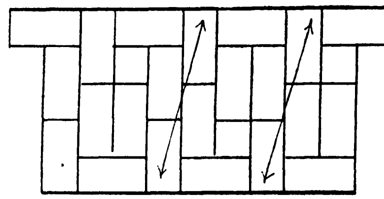


FIG. 19. GOOD METHOD OF BONDING
Number of bats reduced to the minimum by arranging the face headers to pass each other

the centre of the stretcher in the course below, and never over a perpend.

Flemish bond is frequently used as a facing bond only, the remainder of the wall being built in English bond. To put it concisely, Flemish facing with English backing, and usually termed *single Flemish bond.* The object is to obtain the greatest strength possible, where Flemish facing is desired. In this type of bonding, the

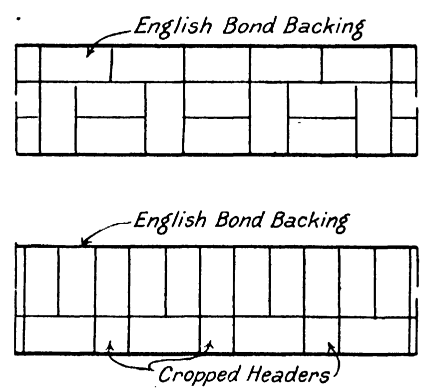


FIG. 20. SINGLE FLEMISH BOND

facing headers in alternate courses are half-bats, or, as they are termed, ***cropped headers.*** An example is shown in Fig. 20.

Window and Door Openings. In forming window and door openings, Fig. 21, some modifications of the foregoing rules are necessary, and will entail the use of several different types of closer.

The vertical sides of an opening are usually termed *reveals*, or *jambs*, the latter term being more usual when speaking of door openings. Sometimes the distinction is made that the jambs are the vertical faces of the opening and the reveals are the projecting parts of the jambs. In most cases, the reveals are recessed to receive the door or window-frame. As a general rule, where the frames are solid, such as for a door or casement frame, the recess is $2\frac{1}{4}$ in. deep. Where a cased or built-up frame is used, such as for sliding or double-hung sashes, a $4\frac{1}{2}$ in. recess is necessary. The projecting reveal on the outside face of the wall is usually termed the external reveal or jamb, and the recessed reveal on the inside face, the internal.

For fixing these frames, wooden slips, called *fixing pads,* are built into the joints of the internal reveal about every fourth course. Bricks made of breeze concrete, into which nails may be driven, are also used for this purpose. These make a better job, as there is no fear of shrinkage and loosening as in the case of the wooden slips. A number of examples are here given, showing the arrangement of brickwork in forming openings in walls of various thicknesses.

Where the recess is $2\frac{1}{4}$ in., the reveal header is mitred across its width, the outside face being $4\frac{1}{2}$ in., and the inside $2\frac{1}{4}$ in. ("mitred closer" or bat). The closer next to the reveal header is cut across its length, showing $2\frac{1}{4}$ in. on its face and $4\frac{1}{2}$ in. at the back ("bevelled closer"). Where the recess is $4\frac{1}{2}$ in. in depth, the reveal header is a half bat, and the closer is cut $2\frac{1}{4}$ in. in width on the face to $4\frac{1}{2}$ in. half-way along its length ("king-closer").

Whatever the thickness of the walls, it should be noticed that the arrangement on the face does not alter. Where the wall is over $1\frac{1}{2}$ bricks in thickness, the internal reveal is treated as a quoin, and starts with a closer next the header on the external reveal.

The examples will be found to be self-explanatory, bearing in mind the previous rules, and the student should find no difficulty in setting out the bond for any detailed door or window opening.

Intersecting Walls. Where two walls meet at an angle, the bond at the junction should be arranged, if possible, so that the *indent* is in the stretching course, and the *tie,* or projecting toothing of the joining wall, in the heading course. This rule will considerably simplify matters for the young craftsman. A number of examples are given in Fig. 22 to emphasize the rule.

Squint Quoins. Where the corner, or *quoin,* of a building is formed by two walls meeting at an angle other than a right angle, specially

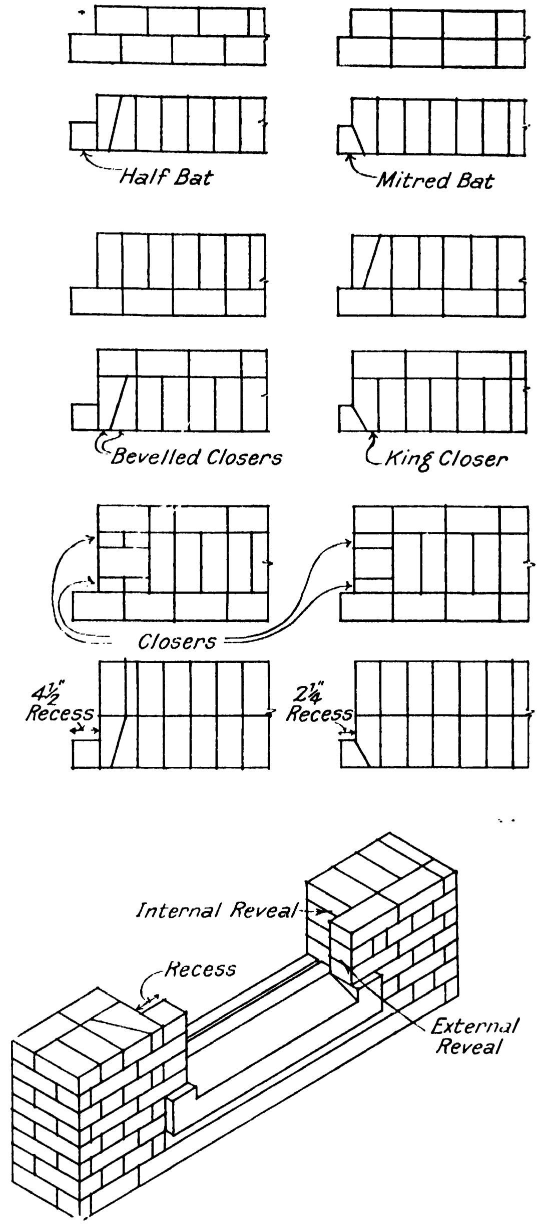


FIG. 21. WINDOW OPENINGS

shaped bricks are required at the external angle (see Fig. 23). Bricks purposely manufactured can be obtained for angles in common use, otherwise they must be cut on the job. To prepare the cutting mould where the angle is greater than a right angle, or, as it is termed,

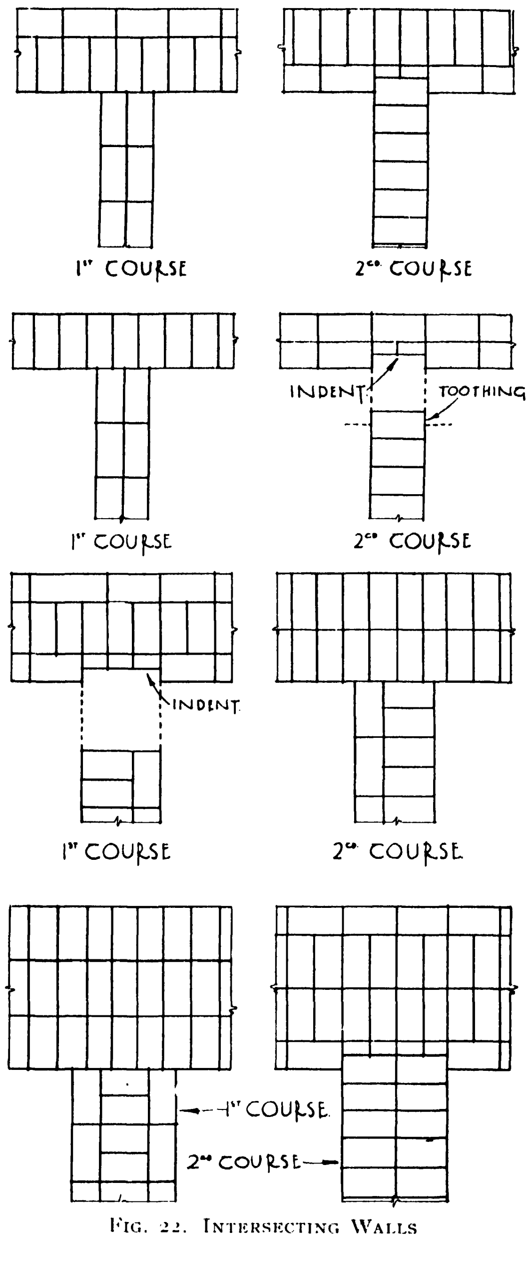


FIG. 22. INTERSECTING WALLS

obtuse, cut a piece of ½ in. pine board to the shape of a brick in plan. Mark off from one corner 2¼ in. along the stretcher face, and draw a line from this point at the required angle, say 45°. Measure 2¼ in. along this line, and square a line away from the last point. Cut away the two corners, and the result is the required mould as shown by the shaded portion in Fig. 23A.

Acute angles are treated much in the same

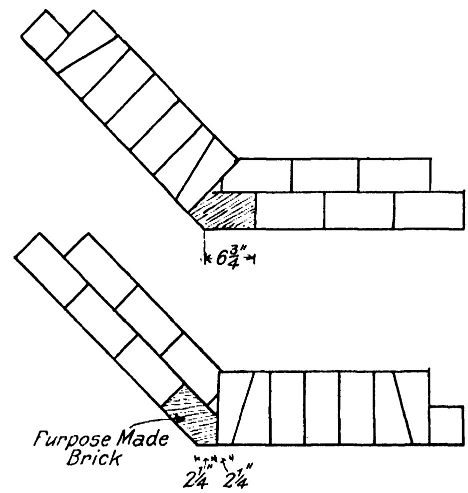


FIG. 23. SQUINT QUOIN

way as a square quoin, except that the corner brick has to be cut to the desired angle. There can be no hard and fast method of arranging the bond at these angles, but the craftsman who has

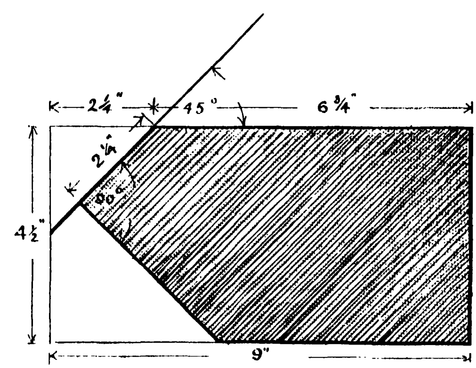


FIG. 23A. CUTTING MOULD

schooled himself in the principles previously defined and studied the given examples, should experience no difficulty in devising suitable arrangements of bond for any angle he may be required to set out.

LAND SURVEYING AND LEVELLING

By Professor Henry Adams, M.Inst.C.E., F.R.I.B.A., F.S.I., etc.

LESSON III

SURVEYING INSTRUMENTS—CHAINING

Field Work—Chain and Arrows Station Poles and Offset Staff—Throwing the Chain—Typical Chain Lines—Boundaries of Fields

Field Work in Surveying. It is now time to consider the actual work in the field. The usual complement of apparatus is *chain and arrows, pocket compass, station poles,* and *offset staff.* The chain and arrows are shown in Fig. 13, where the chain appears at *a* as done up ready for carrying away; at *b* is shown one end and exactly how a link is measured; at *c* is shown an intermediate portion of the chain with one of the brass *tallies* which are attached at every ten links. These tallies indicate to the surveyor at what part of the chain he is standing, so that he only has to count the odd links up to the ten he is nearest to. A single-pointed tally indicates 10 or 90 links; two-point, 20 or 80 links; three-point, 30 or 70 links; four-point, 40 or 60 links; and a round tally, 50 links. When done up the chain links should lie slightly diagonally, touching at their centre and the tallies hanging out. There are 10 arrows as at *d* accompanying the chain, with a little white or red flag on each so that it can be distinguished readily on the grass. Any ordinary pocket compass is generally sufficient to give the direction of the base line, but in important work special care must be taken to get the true meridian. The station poles are of fir, painted in portions alternately red, white, and black, with pointed steel shoes for driving in the ground, and a flag about 12 in. square nailed to the top. The flag is half red and half white to show up well in the distance. The offset staff is like a larger station pole; but the divisions, black and white only, are exactly one link each, ten in all; a narrow red ring painted on marks the centre. Instead of a flag at the top the termination is made by a flush hook, for use in pulling the chain through a hedge when necessary.

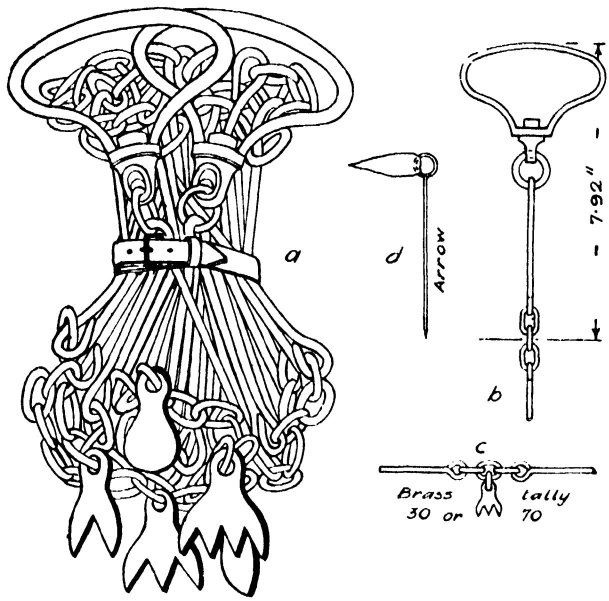


Fig. 13. Chain and Arrows

Studying the Work. Before starting a survey the surveyor walks over the ground and considers the best position for the lines, and generally makes a small sketch of them in his field book, numbering them in the order he proposes to measure them. At each point where the stations, or ends of lines and expected junctions of lines, occur the surveyor takes a pole, and, holding it lightly but firmly, drives it upright into the ground. It requires practice to do this neatly and effectively. He then takes the bearing of the base line. Not only must the field be measured out in triangles, but all the triangles must be so tied by lines crossing them, or otherwise that they are fully checked. Fig. 14 shows some typical arrangements of the main lines of a survey which mutually tie and check each other. This means that if a mistake is made either in measuring or plotting it is bound to be discovered, as the lines would not properly join up.

Method of Chaining. The surveyor is accompanied by a *chainman* to carry the poles, etc., and assist him in his work. Having removed the strap from the chain, the surveyor keeps hold of the two handles and throws the chain out, so that it lies double on the ground from the 50 tally to the handles, in the direction of the first line, preferably the base line. He then passes the arrows and one of the chain handles to the chainman, who walks forward in the direction of the line, taking care to keep the one side of the chain clear from the other. Then, holding one of the arrows vertically against the outer edge of the handle, with his thumb through the ring, he faces the surveyor, stoops down, and watches for signals. All signals should be

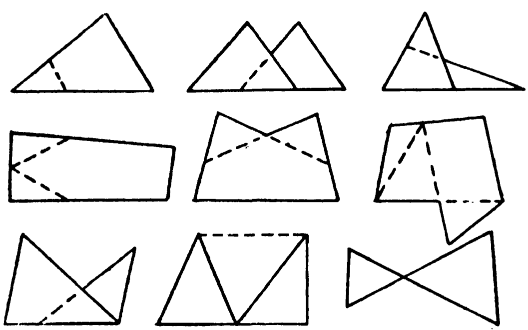


FIG. 14. TYPICAL CHAIN LINES TIED AND CHECKED

by motion and not voice. Sighting past the chainman to the distant pole the surveyor signals right, left or down, by moving only his hand, not his arm, in the required direction. The arrow being inserted, if any offsets are required they are now taken and entered in the field book. The position on the chain line is decided, and the length of a short offset measured with the offset staff. If the offset is long, the offset staff is laid down against the chain at right angles and then passed " hand over hand " to the offset point, which must be kept in view all the time to ensure a true measurement.

Boundaries. Where the field is surrounded by a hedge and ditch, the brow of the ditch is usually the true boundary, and as this is often more or less broken away, it is customary to allow 5–10 links from the centre of the hedge which is easier to measure from ; say, five links between fields belong to the same owner, 6–7 links when belonging to different owners, and 7–10 links when abutting on public lands. It is often said that the reason the owner's boundary is the brow of the ditch on the farther side of the hedge is because, in digging the ditch, he must not throw the earth on his neighbour's land and, therefore, uses it to form the bank upon which he plants his hedge. The true reason is that it is a survival of the old custom of constructing a wall and moat. When an enclosure is shut in by a fence the face of it is the true boundary, so that the owner looks on the back, or as they say, in making the fence the nails are driven " home."

There are certain signs used in the field book and on the plans in connection with the boundaries, as shown in Fig. 15, where the *T* shows the side the fence or hedge belongs to ; the brace or long *S* shows that the area of the small enclosure or building is taken along with the larger area, and the dumb-bell shows a change

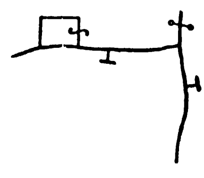


FIG. 15. BOUNDARY MARKS ON PLANS

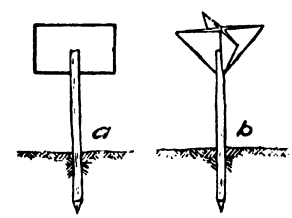


FIG. 16. WHITES FOR MARKING SUBSIDIARY POINTS

of boundary, such as the ditch changing to the opposite side of the hedge.

When the first chain length is disposed of, the chainman takes up his end of the chain and goes forward again. Upon reaching the first arrow, the surveyor verifies the direction of the chainman, who now puts down the second arrow while the surveyor takes up and retains the first, and so the work is continued.

In surveying long lines, when the whole ten arrows have been inserted, the chainman calls " tally " ; the surveyor comes up, draws the final arrow, puts his toe on the place, counts all the arrows, and then hands them to the chainman. As the end of each line is reached in the field book a line is drawn across the centre column, and when a triangle is completed some surveyors make this a double line, indicating that they can plot the work so far. When the whole survey is completed, a horizontal line is drawn right across the page. All the entries may be in pencil, but ink is better because more permanent. Subsidiary lines in a survey may be marked by " whites " to save poles, made by inserting a slip of paper in a twig with a single slit (*a*) or a double slit (*b*), as in Fig. 16.

PRELIMINARY OPERATIONS

By R. Vincent Boughton

LESSON III

SHORING

Explanation. A structure to be temporarily supported, for any of the reasons explained below, is done by means of shoring of various types, the particular type depending upon the nature or exigency of the case. Where alterations are to be made to an existing building, or a new building is to be erected adjoining and perhaps with foundations at a lower level than the existing foundations, it is necessary to inspect and make adequate provision to prevent subsidence or even overturning of existing work.

Reasons for Shoring. The most common objects of shoring are—

(*a*) To temporarily support walls that have developed such defects as to make them dangerous, as subsidency, inward or outward bulging, and leaning, and to prevent further development of defects;

(*b*) To temporarily support floors and roofs, etc., that are, under ordinary conditions, properly supported by such defective walls;

(*c*) To prevent subsidence and failure of sound walls by the removal of subjacent supports, such as may be caused during the construction of a basement next or near to a building without a basement (see later, lesson on Underpinning);

(*d*) To temporarily support a structure, or structures, which had an intermediate structure by which collateral support was given, e.g. one building of a terrace being removed might endanger the adjoining structure and necessitate shoring to prevent collapse;

(*e*) To support a floor during the demolition of its supporting wall or partition and the insertion of a bressummer or girder;

(*f*) To temporarily support the superstructure, comprising walls, floors, and roof, during the removal of a wall under them to form a large opening or for a shop front;

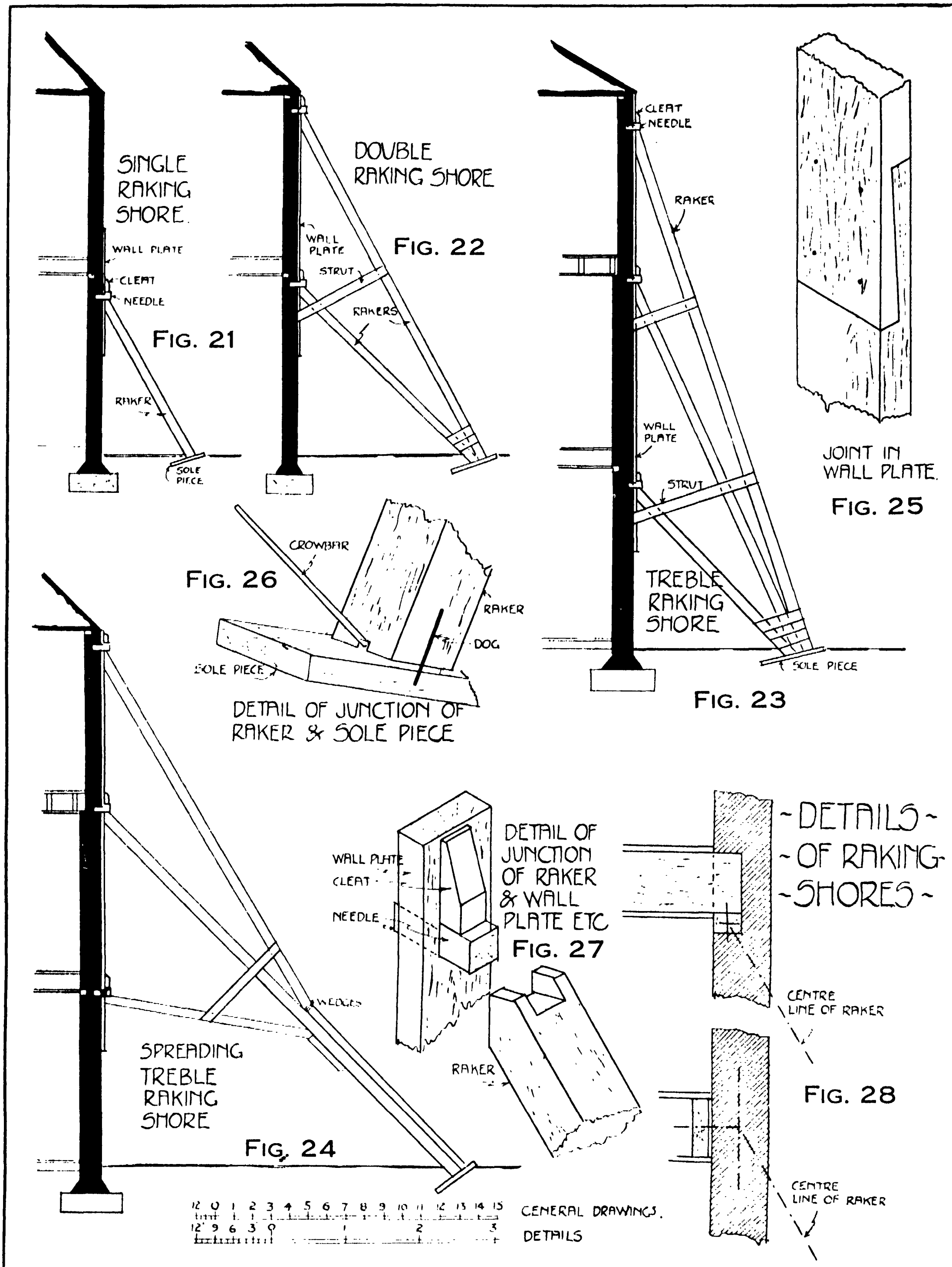
(*g*) To allow for the formation of small openings in walls.

Theories and Practice of Shoring. The stresses and thrusts caused by defects in buildings, and by, and those in, the various members of the shoring used to counteract them, are very difficult to compute, except in the case of dead shores; the forces involved are vertical, inclined, and horizontal, and induce tension, compression, and transverse stresses both in the shored work and the shores. It is, therefore, best and even safest to adopt designs and to use sizes of timber, etc., as will be given by tables later in this lesson, which have been based on judgment and experience, than risk any errors that may be made in abstruse calculations.

Types of Shoring include (1) *raking*, (2) *horizontal* or *flying*, and (3) *dead* or *vertical shoring*.

Raking Shores, sometimes called *inclined shores*, are constructed in a variety of ways, depending upon the thrusts to be borne, the height of the building, and the space available for the "spread" of the shores. Fig. 21 shows the simplest type, known as a *single raking shore*; Fig. 22, a *double raking shore*; Fig. 23, a *treble raking shore*. There may be four or more rakers in a system. Fig. 24 depicts a system of raking shores for use where there is ample room for spreading, and this method permits the use of less and shorter timbers.

In all types, except in some cases where *single* shores are required to support a "point" or concentrated load, a wall plate of 9 in. × 2 in. or 9 in. × 3 in. deal is fixed against and spiked to the wall with wall hooks, and receives and is afterwards further secured by the needles and rakers. The wall plate should extend 3 ft. above and below the top and lowest rakers, respectively, and be in one length if possible; if jointing is needed the joint should be as Fig. 25. The base of the rakers must be supported on a *sole piece*, usually of 11 in. × 3 in. deal, bedded in an inclined position in the ground and set slightly *acute*, say 85°, with the outer or top raker. The rakers should be levered up with a crowbar, operated in a notch in the foot of each raker, and securely "dogged" and cleated to the sole piece, as shown by Fig. 26. Wedges must not be used, as knocking them into position would be liable to shake the work. If the ground is soft, the area of the sole piece must be increased by forming a


SINGLE RAKING SHORE.
WALL PLATE
CLEAT
NEEDLE
FIG. 21
RAKER
SOLE PIECE
DOUBLE RAKING SHORE
WALL PLATE
STRUT
RAKERS
FIG. 22
CLEAT
NEEDLE
RAKER
WALL PLATE
STRUT
TREBLE RAKING SHORE
SOLE PIECE
FIG. 23
JOINT IN WALL PLATE.
FIG. 25
FIG. 26
CROWBAR
RAKER
DOG
SOLE PIECE
DETAIL OF JUNCTION OF RAKER & SOLE PIECE
SPREADING TREBLE RAKING SHORE
WEDGES
FIG. 24
WALL PLATE
CLEAT
NEEDLE
DETAIL OF JUNCTION OF RAKER & WALL PLATE ETC
FIG. 27
RAKER
~DETAILS~ ~OF RAKING~ ~SHORES~
CENTRE LINE OF RAKER
FIG. 28
CENTRE LINE OF RAKER
GENERAL DRAWINGS.
DETAILS

platform of timber, so that the pressure may be distributed over a sufficient area.

The top end of the rakers have to support the wall, and must be connected to the wall plate which transmits the support provided by the rakers over the wall. This is done by means of *needles* of 4 in. × 3 in., preferably of oak or other hardwood and shaped as shown by Fig. 27, which extend through the wall plate and at least 4½ in. into the brick or stone wall. The needles should be cleated to the wall plate as shown. The heads of the rakers must be notched and fitted to the needles and wall plate, as indicated. The rakers and wall plate should be strutted together at frequent intervals with 9 in. × 1 in. boards well spiked to the members; and where there is more than one raker, the feet should be well bound together with stout hoop-iron or two or three boards spiked to the struts.

The internal angle between the outer or top raker and the horizontal, or ground, should be 60° to 75°, the former being the usual for practical purposes.

The sets of shores should be normally placed 10 ft. apart, centre to centre, but this distance will vary where there are windows or other openings, which will necessitate the shores being placed against piers.

The position of the top ends of rakers should be at those points where there is an *internal resistance* to a tendency for a wall, under the *external pressure* of the rakers, to bulge inwards, and the best position is at about floor or roof levels. The actual position, where the ends of floor joists are supported by the shored wall, is given by arranging the raker so that a line drawn through its centre, and continued, would meet the centre of the wall plate or the centre of the bearings of the floor joists. If the joists run parallel to the shored wall, the best position is given by making the centre lines of rakers, wall and floor meet at a point. Fig. 28 illustrates these arrangements.

As a general rule, the shores should extend to the eaves of the roof.

Lateral or side supporting may be necessary to raking shores, to prevent side buckling; but, as a general rule, the rakers should be of sufficient size to prevent lateral bending. It is manifest that the struts considerably stiffen the rakers in one direction but not sideways, and it is, therefore, advisable to brace the sets of shores together with light scantlings or stiff boards. Owing to this lateral weakness the writer advocates the use of rectangular timbers instead of square, such as 9 in. × 6 in. or 11 in. × 6 in. instead of 7 in. × 7 in. or 8 in. × 8 in., as it is then possible to arrange the timbers scientifically with the lesser dimensions in the direction where the "strut-length" is shorter, and the greater dimensions where the "strut-length" is greater.

MASONRY

By E. G. Warland
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LESSON IV

QUARRYING (*contd.*)

Norwegian Granite Quarrying

Quarrying in Norway and Sweden is very different from quarrying in England and Scotland. In Scandinavia no quarry is sunk below the surface level, as huge masses of rock are exposed free from soil and rubbish.

The quarryman therefore sees at once what his quarry is like and how it can be developed, and he has not to engage in the speculative work of exploring and developing in the way the British quarrier must do.

The *ice period*, which left huge deposits of boulders, clay, and sand on Scottish quarries, performed a wonderfully important work for the quarries in Norway and Sweden, where the movement of the glaciers scoured off the disintegrated rock on hill tops and left the sound rock below fully exposed.

This explains why many of the quarries are free from " top-rock," and why the term " deep quarry rock " found in many building specifications has not much significance in Norway.

Though almost the whole of Norway is Granite and Syenite, not a millionth part of the rock is suitable for commercial purposes. About 90 per cent of all exported granite comes from the south-east side of the Christiania or *Oslo* fjord, in the county of Ostfold.

The most famous quarry in Norway is *Bakke* on the Iddefjord, a few miles from the town of Fredrikshald. This property has 400 acres of exposed rock, and the principal quarry lies down by the edge of the fjord where steamers up to 4,000 tons can load direct from the quarry cranes. A photograph of Bakke quarry, Norway, is given in Fig. 7.

The beds of this rock lie parallel, averaging 20 ft. deep, and the face now being worked is 65 ft. high. Blocks of almost any size can be obtained; in fact, the sizes of the quarried blocks are only restricted by the loading and discharging facilities.

In three successive blasts in this quarry over 9,000 tons of whole and unfractured blocks wer secured, so that an ample and continuous supply is to be relied upon for generations to come. The quarry is electrically equipped, the current being obtained from a waterfall. All drilling is done by compressed air, though this is not general in other neighbouring quarries.

Blasting and splitting of the rocks is carried out in the same way as in Scottish quarries, but naturally all the expense of *tirring* (removing overburden) and pumping of water is obviated.

This quarry produces the well-known granite called *standard grey*, and its fine grain, purity, and freedom from mica spots, has made it the most popular grey granite on the market where large blocks are required quickly for building purposes. It is what masons call a *safe* stone, and because of this reliability in working it is greatly used for carving and fine mouldings, and very few fractures happen during the masoning. The popularity of this granite and variety of purposes for which standard grey is used, have caused several substitutes to appear, but no stone equals it in texture, freedom from black spots, and safe working.

It is almost chemically free from iron, and this fact has led to its use for modern paper rolls, some of which are 16 ft. in length, and 2 ft. in diameter. It is also used for rolls for cocoa grinding, and for grinding of various chemicals. Fig. 8 shows the *rock face* of a granite quarry in America. The marketable stone is quarried at the surface, as in Norway. In Fig. 9 the drill is seen at work boring, preparatory to blasting. The effects of a recent blast are seen on the right of the picture.

Quarrying Forest of Dean Stone

The colours are grey, blue, and red. Grey and blue are generally to be obtained from the same quarry, but some quarries yield a preponderance of grey, others of blue.

In the red stone quarry there is sometimes an admixture of grey stone, the two colours being mingled in the same layer of rock. This stone is known as *wilderness*.

The first operation is the excavation and

FIG. 7. NORWEGIAN GRANITE : BAKKE QUARRY

By kind permission of Messrs. A. & F. Manuelle, Ltd.

clearing away of the top soil and loose rubble, which is termed "ridding"; the depth of the "rid" varies, but is chiefly made up of a top

FIG. 8. WINNSBORO BLUE GRANITE QUARRY FACE, RION, SOUTH CAROLINA

layer of vegetable soil, peculiar to a forest district, then a layer of sandy soil and loose rubble.

The situation of a quarry is usually chosen so that the "rid," which is of no commercial value, can readily be disposed of with the minimum amount of labour. The quarries are thus usually situated upon a hillside, and it is here that the accessible rocks are to be found. The "rid" having been removed, some thin layers of stone are obtained, but of low value. The layers vary from 2 to 8 in. thick, and are used for paving, cover stones for manholes, etc. The thickest stones, if of suitable grit, are often used for the manufacture of grindstones. These layers are readily quarried; the chief instrument used for so doing is the *crowbar* for dislodging them from their beds. The faces of these thin slabs are fairly true and require very little dressing when used for pavings, etc., hence the term, *self-faced*, by which they are known in the trade. After the thin layers have been quarried the thick beds become accessible; they are from 5 ft. to 6 ft. thick. Usually the lower the position of the bed in the quarry, the better the quality of the stone. The depth to which a quarry may be worked is usually limited by the cost, and also by the presence of coal in the stone, indicating the close proximity of coal measures or strata.

For quarrying the larger beds, explosives are necessary, especially for clearing the tight corners to allow freedom of movement of the large masses. High explosives are used as a lifting agency to dislodge heavy benches of stone, but this method requires great experience and judgment, for an unwise use of high explosive would result in the shattering of the rock, rendering it unsuitable for masonry work of importance.

When the top of the large beds of stone have been laid bare and the freedom of movement obtained, the quarrymen begin to cut up the rock into convenient size blocks, the sizes being determined by the lifting capacity of the crane, and the purposes for which the blocks are intended. The large beds of stone are now converted into blocks with the aid of drills driven by compressed air. The old method of splitting the rocks by working a V-shaped groove and inserting plugs is now discarded, owing to up-to-date improvements. Drill holes about 5 in. apart are put in to a depth of 9 in., with every twelfth hole bored to the bottom of the bed of stone. Into all the holes are driven plugs and feathers with a sledge hammer, which causes the stone to split in the desired direction.

The blocks are then conveyed to the masonry works, which are all situated close to the railway tracts and station. These works are

FIG. 9. WINNSBORO BLUE GRANITE, RION, SOUTH CAROLINA, DRILLING FOR BLASTING AT QUARRY FACE
Position of latest blast can be seen on the right

equipped with machinery suitable for dealing with stone of this structure and are capable of the production of wrought-stone to meet all requirements.

STRUCTURAL ENGINEERING

By W. ARNOLD GREEN, M.A., B.Sc., A.M.Inst.C.E., M.I.Struct.E.

LESSON II

LOADS ON STRUCTURES

Materials of Construction. The number of materials available for the use of the structural engineer is yearly increasing. The use of stone and timber was probably known to man in his remotest savage state. The employment of metals for general building construction was made practicable by the introduction of rolling mills, one for sheet-iron being first used in 1728, though it was not till 1783 that Cort, the inventor of the puddling process for converting pig-iron into malleable metal, produced iron bars by means of grooved rolls.

To the introduction between 1860 and 1870

TABLE I

SUPERIMPOSED LOADS ON FLOORS

Comparison of London Practice with Practice in 109 American Cities

Use of Floor	Present Practice in London	Average of 109 American Cities	Proposed for London
	Superimposed Weight in lb. per sq. ft.		
Attic Floors in Dwellings	70	49·7	40
Dwelling (Ground Floor)	70	52·2	50
Dwelling (above Ground Floor)	70	49·7	50
Tenements (Ground Floor)	70	55·8	50
Tenements (above Ground Floor)	70	50·6	50
Hotel Bedrooms	84	57·3	60 av.
Assembly Halls with Fixed Seats	112	95·9	80
School Classrooms	112	69·9	80
Offices (above Ground Floor)	100	69·7	80
Hospital Wards	84	61·0	80
Assembly Halls where Crowds may be Closely Packed . .	112–150	110·3	100
School Corridors, Stairs, and Landings	112	92·5	100
Halls in Schools	112	99·5	100
Hotel Corridors	112	87·7	100
Hospital Corridors	112	83·6	100
Retail Shops	112	119·4	120
Offices (Ground Floor)	100	114·0	120
Factories for Light Loads	112	121·8	120
Drill Rooms	150	137·0	140
School Halls in which Drilling may take place	150	137·0	140
Playgrounds on School Roofs	150		140
Ballrooms (and other Floors Subject to Rhythmic Vibrations) .	150	115·9 av. 250·0 max.	140
Retail Shops for Heavy Goods		162·8	160
Factories for Medium Loads	150	177·0	160
Warehouses	224 min.	184·2 av. 450·0 max.	200 min.

of the manufacture of mild steel, by the Bessemer and open-hearth processes, the present extensive use of structural steel is mainly due.

Bricks, at first sun-baked and later produced in kilns, are of remote antiquity. The use of lime for mortar and for concrete was known to the Romans, but it was not till a century ago that the invention of Portland cement made possible the extraordinary growth in the use of concrete and reinforced concrete that is being witnessed to-day.

Structural materials may be classified under three heads—timber, masonry, and metals.

Before attempting to describe the properties of structural materials, it is necessary to have some idea of what properties concern the structural engineer, so beyond the matter of weight, which is dealt with in Table III, further detailed description of structural materials is postponed.

Live and Dead Loads. The designer of a structure often has to work to regulations which specify the loads to be used in the calculations, as *live loads* to be added to the *dead load* of the structure and finishes. These loads may often appear to be excessive. Thus a particular schoolroom floor with desks may never be called upon to support a load of people averaging more than 20 lb. per sq. ft. of floor area, but it should be remembered that during construction, floors are often loaded with building materials more severely than they would ultimately be even if the design load were realized.

Allowable Loads. Design loads are specified in the steel-frame clauses of the London Building Act and in the London County Council's regulations for reinforced concrete construction, both of which the student is recommended to study.

Table I, page 171, from the "Report on the

TABLE II

APPROXIMATE WEIGHTS OF STORES

In Lb. per Cubic Foot of Space Occupied

Building Materials		White Lead Paste, in cans	174
Cement, Natural	59	White Lead, dry	86
Cement, Portland	73	*Hardware*	
Lime and Plaster	53	Hinges	64
Groceries and Wines		Locks, in cases, packed	31
Beans, in bags	40	Sash Fasteners	48
Canned Goods, in cases	58	Screws	101
Coffee, Roasted, in bags	33	Sheet Tin, in boxes	278
Coffee, Green, in bags	39	Wire, Insulated Copper, in coils	63
Dates, in cases	55	Wire, Galvanized Iron, in coils	74
Figs, in cases	74	*Textiles, etc.*	
Flour, in barrels	40	Cotton, in bales, compressed	18
Rice, in bags	58	Cotton, Bleached Goods, in cases	28
Soda, in barrels	46	Cotton, Flannel, in cases	12
Salt, in bags	70	Cotton, Sheeting, in cases	23
Soap Powder, in cases	38	Cotton Yarn, in cases	25
Starch, in barrels	25	Hemp, Italian, compressed	22
Sugar, in barrels	43	Hemp, Manila, compressed	30
Sugar, in cases	51	Jute, compressed	41
Tea, in chests	25	Linen, Damask, in cases	50
Treacle, in barrels	48	Linen Goods, in cases	30
Wines and Liquors, in barrels	38	Linen Towels, in cases	40
Drugs, Paints, etc.		Tow, compressed	29
Alum, Pearl, in barrels	33	Wool, in bales, compressed	48
Blue Vitriol, in barrels	45	Wool, not compressed	13
Glycerine, in cases	52	Wool, Worsted, in cases	27
Linseed Oil, in barrels	36	*Miscellaneous*	
Linseed Oil, in iron drums	45	Glass and Chinaware, in crates	40
Red Lead and Lithage, dry	132	Hides and Leather, in bales	20
Rosin, in barrels	48	Hides and Leather, in bundles	37
Shellac, Gum	38	Paper, Newspapers, and Strawboards	35
Soda, Caustic, in iron drums	88	Paper, Writing and Calendered	60
Soda, Silicate, in barrels	53	Rope, in coils	32
Sulphuric Acid	60		

Construction and Control of Buildings in America," gives the result of the L.C.C. Chief Architect's investigations on floor loads specified in America, and the revised loads he proposes for London.

In warehouses it is sometimes possible to form a close estimate of the actual loads the floors will have to carry, but often the choice of a suitable design load is bound to be a guess in the dark aided by experience, the designer being supported by the consciousness of margins of safety necessitated by ignorance.

Weights of Materials. The approximate weights, shown in Table II, of stores per cubic foot, are given in the Carnegie Steel Co.'s handbook. Knowing the probable height of the pile or stack, the suitable design load can be readily obtained by multiplying height and weight.

Most engineering handbooks give tables of specific gravities and weights per cubic foot of various substances. The latter is not necessarily $62\frac{1}{2}$ times the former, as a cubic foot of coals or stones, for instance, contains varying amounts of air space. Nor does it necessarily follow that a cubic foot of damp material is heavier than a cubic foot of the same material dry, as the greater cohesion of the damp material may result in a greater amount of air space more than compensating for the additional weight of water.

The lists of weights, given in Table III, are taken from R. A. Skelton & Co.'s Handbook, No. 16. The values given are rough averages, the weights of many substances showing considerable variation; thus a cubic foot of one sample of granite may weigh as much as 187 lb.

TABLE III

WEIGHTS IN POUNDS PER CUBIC FOOT

	lb.
Liquids	
Acid, Hydrochloric 40%	75
Acid, Nitric 91%	94
Acid, Sulphuric 87%	112
Alcohol	49
Benzine	46
Gasoline	42
Mercury	849
Oils	58
Paraffin	56
Petrol	55
Petrol, Refined	50
Water, Fresh	62
Water, Salt	64
Metals	
Aluminium	165
Brass	520
Bronze	510
Copper	550
Gold	1205
Gun-metal	540
Iron, Cast	450
Iron, Wrought	480
Lead	710
Nickel	530
Platinum	1342
Silver	655
Steel	490
Tin	460
White-metal	460
Zinc	440
Soils, etc.	
Chalk	170
Clay	135
Earth, Loose	75
Gravel	110
Mud, Dry	100
Mud, Wet	120
Sand, Dry Loose	100
Sand, Wet	130
Shale	160
Stones, Masonry, Aggregates, etc.	
Brick, Pressed	150
Brick, Common	125
Brick, Soft	100
Brickwork	112
Cement	90
Concrete	140
Concrete, Reinforced	150
Concrete, Coke Breeze	90
Flint	160
Granite	170
Lime	60
Lime Mortar	105
Limestone, Compressed	170
Limestone, Granular	125
Limestone, Loose Broken	95
Limestone Walls	165
Marble	170
Plaster of Paris (Gypsum)	140
Rubble Masonry	140
Sandstone	150
Sandstone Masonry	140
Slate	175
Timber	
Ash	50
Beech	50
Cedar	35
Cherry	42
Chestnut	41
Cork	15
Cypress	37
Ebony	76
Elm	35
Elm, Canadian	45
Greenheart	70
Hickory	53
Jarrah	63
Larch	34
Mahogany, Spanish	60
Mahogany, Honduras	35
Oak, English	60
Oak, American	53
Pine, White	25
Pine, Yellow	35
Pine, Red	40
Pine, Pitch	45
Plane	40
Poplar	25
Spruce	30
Sycamore	37
Teak	50
Walnut	40
Miscellaneous	
Anthracite, Broken, Loose	54
Asbestos	187
Asphalt	88
Coal, Bituminous	85
Coal, Broken, Loose	50
Coke	45
Coke, Loose	30
Flour	40
Glass, Window	160
Glass, Flint	190
Grain, Wheat	48
Grain, Barley	39
Grain, Oats	32
Hay and Straw in bales	20
Ice	59
Salt	45
Sulphur	125
White Lead	197

per cub. ft., and another sample as little as 162 lb. The weight of porous materials and of timber varies with the moisture content.

The approximate weights of roofing materials are given in Table IV.

Concentrated Loads. A beam carrying only a small floor area may be called upon to bear a concentrated weight much greater than the product of the floor area and the design load.

To guard against this contingency, every beam (except closely spaced floor beams, which will share with their neighbours any concentrated load above one of them) should be strong enough to carry the greatest concentrated load likely to come on to it. Thus Mr. Robins Fleming[1] recommends the following design loads for garage floors --

Garages	Floor Load, lb. per sq. ft.	Point Load, lb.
Of Area Less than 600 sq. ft.	60	2,000
Of Area 600 sq. ft. and More	90	3,000
For Storing Lorries 1 to 3 tons Capacity	150	8,000
For Storing Lorries 3½ to 5 tons Capacity	200	12,000

[1] *Engin* *ord*, 27th June, 1918.

The above point loads are approximately equal to eighty times the floor load, less 4,000, with a minimum of 2,000 lb.

Impact. Design loads are treated as stationary loads, which should include an allowance for impact, when moving loads or machinery with reciprocating parts are to be carried.

A great divergence of opinion exists as to what percentage addition to the actual weight of the moving load is suitable.

For highway bridges the Ministry of Transport specifies a 50 per cent addition to the assumed total weights of traction engine and trucks.

For crane runways 50 per cent or even 100 per cent is sometimes asked for, but in view of the fact that the cranes themselves are often designed for an impact of only 10 per cent of the load lifted, 20 per cent of the wheel load is probably a sufficient impact allowance.

The impact effect due to the rapid starting or stopping of a loaded lift-cage will depend on the rate of acceleration (or retardation). The lift makers usually specify the equivalent dead loads to be used in designing the floor for the lift machinery.

TABLE IV

APPROXIMATE WEIGHTS OF ROOFING MATERIALS, ETC.

In Lb. per Square Foot of Surface

Asphalt per 1 in. thick	7–13	Lead with Laps and Rolls	9
Asphalted Felt	½	Plaster, Ceiling, per 1 in. thick	9
Boarding per 1 in.	3½	Slates, 3 in. lap, with nails	8½
Corrugated Sheeting, 18G	2½	Wood Purlins	2¾
Purlins	1¾	Tiles, Plain, 10½ in. in. × ½ in. with Mortar for Pointing—	
Glass, ¼ in. thick	3¼	8 in. gauge	16
Glazing Bars	1½	7 in. gauge	18½
Putty	⅜	6 in. gauge	21
Purlin		Angle Purlins	3¼
Lead (net)			

ANSWERS TO EXERCISE I

1. $R_1 = 16$ tons, $R_2 = 2$ tons.
2. 9 tons.
3. 50⅝ ft.-tons.

JOINERY

By T. Corkhill, F.B.I.C.C., M.I.Struct.E., *Double Medallist*

LESSON IV

BORING TOOLS

Bradawls. The bradawl, or *sprig-bit,* Fig. 56, is the simplest form of boring tool. The steel blade may be obtained in many sizes; it is fixed in the handle by a tang. In the better varieties a pin passes through the ferrule and tang to

Fig. 56. Bradawl

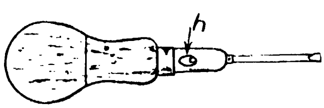


Fig. 57. Bradawl with Removable Blades

prevent the blade from pulling out when in use. The blade should cut across the grain when being used, with a half-turn to-and-fro motion. This applies specially to boring near the end of the

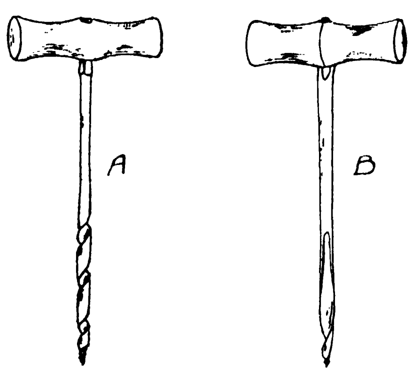


Fig. 58. Gimlets

stuff—otherwise the bradawl will split the wood. The blade is shaped like a chisel but is sharpened on both sides. Fig. 57 shows a useful type in which the blade can be removed. The blade is held in position by friction only and can be levered out at the hole *h*. Several sizes of blades are provided with the one handle.

Gimlets. Two different types of gimlet are shown in Fig. 58, a twist gimlet at *A* and a *Swiss* gimlet at *B*. The blade is fixed in the head by a tapered square, riveted at the top. The gimlet is useful for boring in corners, or where it is not convenient for the brace and bit.

There are many forms of combinations of bradawls and gimlets usually called *toolpads*. The principle is the same in all of them, a number of interchangable blades being provided to one handle. In some types the blades fit in the hollow handle when not in use. Some varieties contain bradawls, gimlets, screwdriver, countersinks, saw and chisel. Generally they are more favoured by the amateur than the joiner.

Brace and Bits. The most useful brace for the joiner is the *ratchet brace* as shown in Fig. 59. The ratchet enables the brace to be turned through a small arc instead of through a complete circle, that is, the brace only turns the bit in a clockwise motion. When the brace is turned backwards the bit remains stationary. This enables the joiner to bore holes in corners or near the wall whilst keeping the brace bit upright. The brace is also useful for driving in screws with the screwdriver bit, because there is a greater *purchase* on the brace, especially on

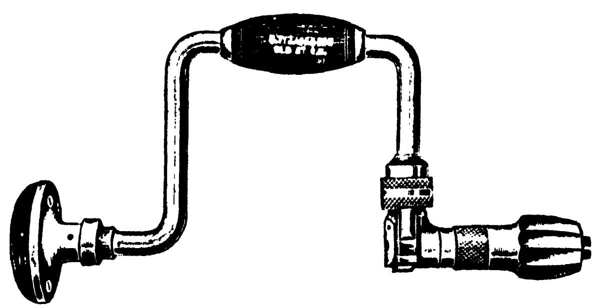


Fig. 59. Brace

the downward stroke when used horizontally. The jaws of the brace are serrated to grip the bit. The main parts of the brace are of hardened steel, nickel plated, with ball bearings; the wooden parts are usually of rose-wood.

Twist Bits. These are the most satisfactory bits for easy and clean boring, but they are easily damaged. There are many varieties. Fig. 60 shows a "Russell Jennings," Fig 61 an "Irwin," and Fig. 62 a "Gedge" pattern; the "Jennings" bit is very similar to the "Russell Jennings." All these makes, except the "Gedge," bore a very clean hole across the grain, but are not very good for boring with the grain, i.e. in the end of the stuff. The "Gedge," bit is specially adapted for boring with the grain. It also bores very quickly across the grain, but it is not so clean cutting because of the difficulty in keeping it sharp. All these bits may be bought separately; or a full set may be had, as shown in Fig. 63, which ranges from $\frac{1}{4}$ in. to 1 in. diameter, rising in $\frac{1}{16}$ in. The action is very similar in all the twist bits except the "Gedge." The bit, Fig. 61, is drawn into the wood by the screw point *b*, the cutters *a* strike out the circumference of the hole, and *c* removes the waste wood. It is very important that the cutters *a* are only sharpened on the inside.

A *depth gauge* is shown in Fig. 60. The thumb screw *n* fixes the gauge to the stem of the bit. The revolving steel ball *f* prevents any marking of the stuff when the required depth has been reached.

Centre Bits. These are the most serviceable bits; they are cheap, easily sharpened, bore a very clean hole, and can be obtained from $\frac{1}{4}$ in. to 2 in. diameter. The centre point *a*, Fig. 64, fixes the position, and *b* cuts out the circumference of the hole, whilst the lip *c* removes the waste wood. The diameter of the hole is twice the distance from *a* to *b*. The cutter *b* must stand prominent from the lip *c*, and must be sharpened on the inside only. The lip *c* is also sharpened on the inside only, so that it acts like a chisel.

Small Bits. Three very useful bits are shown in Fig. 65. A *shell* bit is shown at *A*, a *nose* bit at *B* and a twist bit at *C*. These bits are only used for small holes, such as screw and bolt holes, and for *pinning*. They can only be obtained up to $\frac{1}{2}$ in. diameter. The shell bit is a favourite bit because it is easily sharpened and not easily damaged. The nose bit is specially useful for boring in end grain.

Counter Sinks. These are not boring tools, but are used in conjunction with boring tools to prepare the holes to receive screw heads, etc. Fig. 66 shows three different varieties; *A* is used for timber, *B* for metal, and *C* for brass or hard wood.

Rimers. This type of bit is used for increasing the size of holes, or for preparing conical shaped holes. Fig. 67 illustrates three different kinds; *A* is used for wood and is useful for preparing the tapered holes in ladder sides to receive the rungs. For metal we use a similar shape, but it is solid in section as shown at *B*. Another type, for metal, is square in section as shown at *C*.

MISCELLANEOUS BITS

Expansion Bits, Fig. 68, are very convenient because they can be adjusted to small variations. The screw *a* is loosened to adjust the cutter *c*, which can be fixed to the required size at once by reason of the graduations on the cutter. Various sizes of cutters may be obtained, and the largest size of bit will bore from $\frac{7}{8}$ in. to 5 in. diameter. There are several variations of the expansion bits; the illustration shows a Clark's Bit. Another good make is the Steer's Bit, but Anderson's Bit is a cheaper and inferior type.

Forstner Bit. This bit has no centre point to fix the position, but the whole circumference *a*, Fig. 69, is sharpened to fix itself immediately in the required position. The cutter *b* removes the waste wood. It is a very useful bit for sinking holes, panels, etc., which are seen and do not go through the stuff; it is also useful for parts of holes on the edge of the material.

Augers. For heavy work and deep borings it is necessary to lengthen the stem of the twist bit as shown in Fig. 62. This illustration shows a *Gedge Auger*. A wooden handle is placed through *a* to give the required leverage. They are usually about 2 ft. long, but the stem may be made longer for any particular job which may require it.

Screwdriver Bits. These are extremely useful for driving in screws quickly. Fig. 70 shows the usual type. Another type has a slot in the end to use on the screw rivets in saw handles. The chief advantage of the screwdriver bit is the increased leverage afforded by the brace.

There are many other forms of bits, but they are not often possessed by the joiner. Amongst them may be mentioned the *dowel* pointer, the spoke trimmer, the screw and plug bit which prepares the screw hole for plugging to cover up the screw head, and the adjustable countersink.

Care of Bits. It is usual to keep the bits in good condition by carrying them in a *roll*, or *case*. Fig. 71 shows the usual type; the material may be leather, green baize, or moleskin. The last named is the most satisfactory, considering the cost and wear. The bits must be

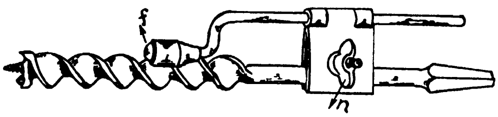


FIG. 60. BRACE BIT WITH DEPTH GAUGE

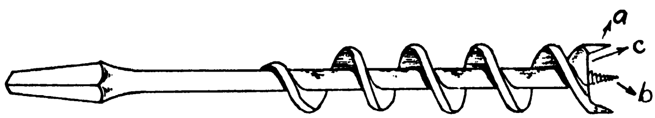


FIG. 61. TWIST BIT

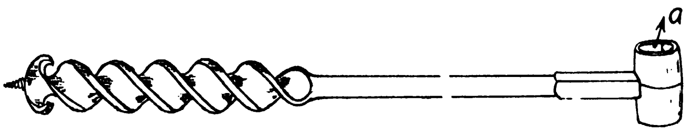


FIG. 62. AUGER

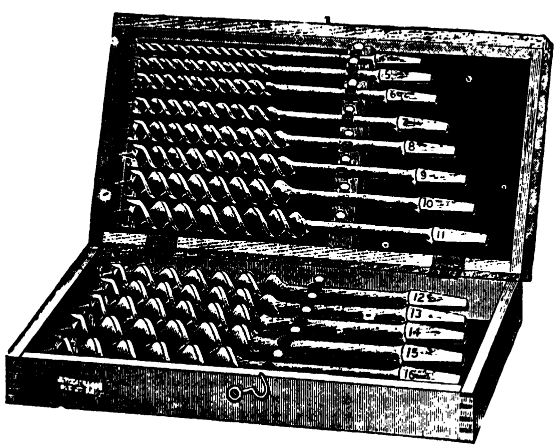


FIG. 63. SET OF TWIST BITS

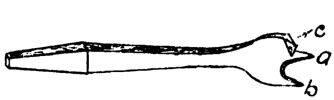


FIG. 64. CENTRE BIT

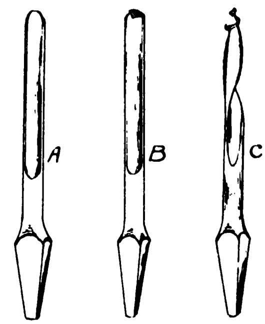


FIG. 65. SMALL BITS

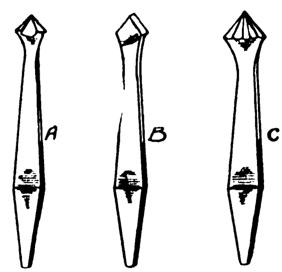


FIG. 66. COUNTERSINKS

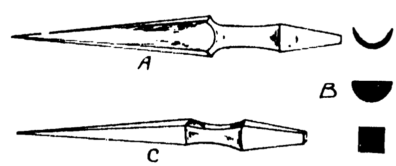


FIG. 67. RIMERS

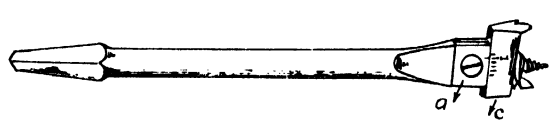


FIG. 68. EXPANSION BIT

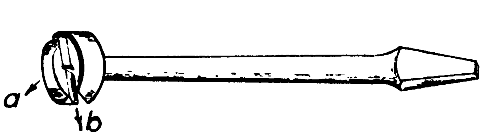


FIG. 69. FORSTNER BIT

FIG. 70. SCREWDRIVER BIT

kept sharp, or the strain on the bit will be increased so that it will probably break. It cannot be emphasized too strongly that all the bits which have outer cutters, for describing the circumference of the hole, must be sharpened on the inside. If not, the bit will not clear itself, and will require a much greater effort to turn,

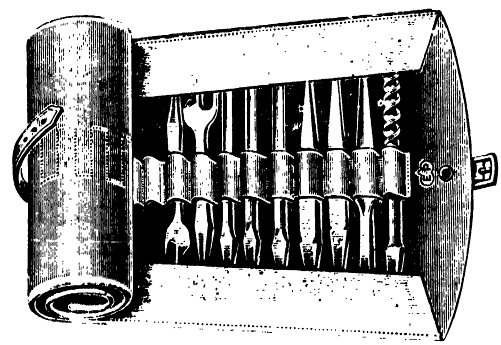


FIG. 71. BIT ROLL

besides making a ragged hole; this applies especially to the twist bits.

Boring. The beginner often finds a difficulty in boring vertically or horizontally, as the case may be. Sometimes an assistant advises him with regard to the position of the head of the brace. The best method is to square the centre line over the face of the stuff, and to fix a thin straight edge in the vice with the stuff, so that the straight edge coincides with the squared line, and projects about 6 in. above the stuff. The operator then watches the stem of the twist bit to see that it is parallel with the edge of the straight-edge in both directions. For horizontal end boring, the stuff is laid on the bench with the straight-edge resting on the top, and the stem of the bit resting on a small block. The stuff should be fixed to the bench by a bench cramp. If the holes are not at right angles to the edge of the stuff, the straight-edge is arranged to suit the direction of the boring.

Boring Machines. For heavy work on roof trusses, floors, etc., a hand boring machine is often used. This consists of a base, upon which the operator sits to steady the frame, a vertical frame which holds the bit, and two handles, so

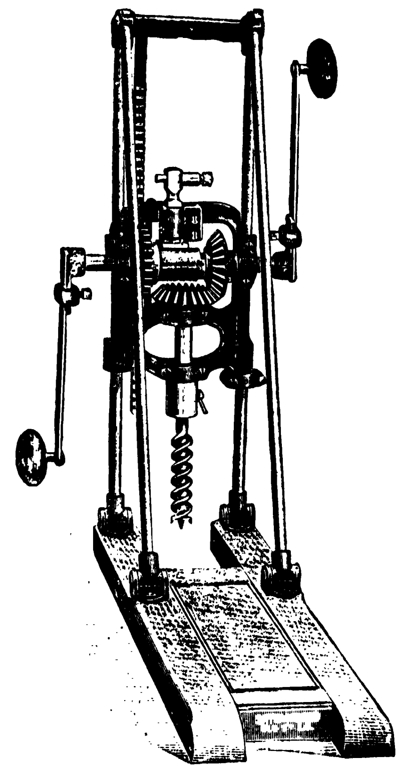


FIG. 72. BORING MACHINE

that the operator uses both hands for turning the bit. The vertical frame is adjustable for boring to different angles, and for closing the machine for compactness when not in use. Fig. 72 shows an improved type of boring machine, the usual wooden fittings being replaced by steel rods.

ARCHITECT'S OFFICE AND ROUTINE

By HERBERT J. AXTEN, A.R.I.B.A., A.I.STRUCT.E.
Chartered Architect

PART III

ACCOUNT BOOKS AND ACCOUNTING

A MEMBER of the clerical staff is also responsible for keeping the account books, and for preparing and issuing accounts for fees. For this purpose the following books are necessary

1. **Petty Cash Book.** Entries in this book are of small expenditures, each usually under 20s., for which it is unnecessary to draw a cheque, such as travelling expenses, postage stamps, adhesive stamps for contracts, forms of contract, and the many minor articles required in an office from time to time.

2. **Journal.** This book is now chiefly used for the opening entries when a new set of books is commenced, and for closing entries when the books are balanced. It is also used for entries other than cash transactions.

The journal is a book of original entry; that is, if an entry is to be made in the books and it does not involve the receipt or payment of cash, the entry must first be made in the journal. If, however, the entry is a cash transaction it may be entered direct into the cash book, and posted from there to the ledger. Fig. 6 gives the form of ruling for this book

Date	Particulars	Fol.	*Dr.* £	*Dr.* *s.*	*Dr.* *d.*	*Cr.* £	*Cr.* *s.*	*Cr.* *d.*

FIG. 6. RULING FOR JOURNAL

3. **Cash Book.** This book, as its name implies, is a record of cash transactions, but strictly it is a ledger account which, for convenience only, is usually kept in a separate book. It also partakes of the nature of the journal, inasmuch as all cash entries are made direct into the cash book without first passing through the journal.

Dr. CASH BOOK *Cr.*

Date	Details	Fol.	£	*s.*	*d.*	Date	Details	Fol.	£	*s.*	*d.*

FIG. 7. RULING FOR CASH BOOK

Receipts and payments are entered in this book—on the *debit*, or left-hand, side if a receipt, and on the *credit*, or right-hand, page if a payment.

At stated intervals, usually of one month, the bank pass book should be examined and checked with the cash book; and all charges made by the bank, e.g. for cheque books, etc., should be credited to the cash book and debited to a suitable ledger account headed "Bank Charges." The balance of the pass book will then equal the balance of the cash book. Fig. 7 is the usual form of cash book.

4. **Ledger.** The ledger contains particulars of all business transactions with other persons, and of all charges against the business. A summary of the ledger accounts will reveal the exact position of a business or practice on a given date. The ruling of the ledger is identical with that given for the cash book.

SPECIMEN ACCOUNTS

To illustrate the use of these accounts, a typical example is given, showing how the various items are entered in the books—

1. Feb. 1. 1925. A B instructed to act as architect for C D; on this date the builder signed the contract for the erection of a building for the amount of £40,000.
2. Feb. 10. C D (the client) pays two-thirds of the architect's fee, i.e. two-thirds of £2,400 = £1,600.
3. Feb. to August. Architect's out-of-pocket expenses chargeable to his client (C D) amounted, during this period, to £150.
4. Feb. to August. Architect's expenses, chargeable to the practice, amounted, during this period, to £28 10s.
5. August 31. Maintenance period ends; it is found that extras on the contract amounted to £1,000.
6. Sept. 3. Architect sends in his account, amounting to £825.
7. Sept. 10. Client offers architect £750 in full settlement, which is accepted, and paid on this date.

These items will be found entered in the various accounts in Figs 8 and 9.

Commencing with item No. 1, the first entry is in the journal, because though no cash passes, the client (C D) becomes liable, upon the signing of the contract, for the payment of two-thirds of the architect's fee. Thus, in the journal, the entry will be—

Feb. 1. C D . . . . *Dr.* £1,600
To Professional Services . £1,600

The reason for this entry is that the architect is giving his services, and the client is receiving them; therefore the account which *gives* must be credited, and the account which *receives* must be debited.

On 10th February (item No. 2) this amount is paid; consequently the account which gives (i.e. C D) must be credited, and that which receives (i.e. cash) must be debited.

JOURNAL

Date	Particulars	Fol.	*Dr.* £	*s.*	*d.*	*Cr.* £	*s.*	*d.*
1925								
Feb. 1	C D . . . . *Dr.*		1,600	–	–			
	To Professional Services					1,600	–	–
	Being two-thirds of fee for building at Enfield.							
Aug. 31	C D . . . . *Dr.*		800	–	–			
	To Professional Services					800	–	–
	Being balance of fee for building at Enfield.							
Aug. 31	C D . . . . *Dr.*		25	–	–			
	To Professional Services					25	–	–
	Being $2\frac{1}{2}$% on £1,000 extras on building at Enfield.							
Sept. 3	Professional Services . . . . *Dr.*		75	–	–			
	To C D					75	–	–
	Being agreed deduction from total fee.							

FIG. 8. JOURNAL WITH SPECIMEN ENTRIES

CASH BOOK

(A Ledger Account Kept in a Separate Book)

Dr. *Cr.*

Date	Details (of *Receipts*)	Fol.	£	*s.*	*d.*	Date	Details (*of Payments Made*)	Fol.	£	*s.*	*d.*
1925						1925					
Feb. 10	To C D (two-thirds of Fee) .		1,600	–	–	Feb. – Aug. 31	By C D (being Sundry Expenses) . . .		150	–	–
Sept. 10	,, C D (Agreed Balance of Fee) . . .		750	–	–	,,	,, Office Expenses . .		28	10	–
						Dec. 31	,, Balance . . .		2,171	10	–
			£2,350	–	–				£2,350	–	–

LEDGER ACCOUNTS

C D (the Client)

Dr. *Cr.*

Date	Details	Fol.	£	*s.*	*d.*	Date	Details	Fol.	£	*s.*	*d.*
1925						1925					
Feb. 1	To Professional Services A/c		1,600	–	–	Feb. 10	By Cash		1,600	–	–
Feb. – Aug. 31	,, Cash (being Sundry Expenses) . . .		150	–	–	Sept. 3	,, Professional Services A/c		75	–	–
,,	,, Professional Services A/c		800	–	–	10	,, Cash		750	–	–
,,	,, Professional Services A/c		25	–	–	10	,, Cash (Expenses) . .		150	–	–
			£2,575	–	–				£2,575	–	–

OFFICE EXPENSES

Dr. *Cr.*

Date	Details	Fol.	£	*s.*	*d.*	Date	Details	Fol.	£	*s.*	*d.*
1925						1925					
Feb. – Aug. 31	To Cash		28	10	–	Dec. 31	By Balance . . .		28	10	–

PROFESSIONAL SERVICES ACCOUNT

Dr. *Cr.*

Date	Details	Fol.	£	*s.*	*d.*	Date	Details	Fol.	£	*s.*	*d.*
1925						1925					
Sept. 3	To C D (Agreed Reduction of Fee) . . .		75	–	–	Feb. 1	By C D (two-thirds of Fee) .		1,600	–	–
Dec. 31	,, Balance . . .		2,350	–	–	Aug. 31	,, C D (Balance of Fee) .		800	–	–
						,,	,, C D (Fee due on Extras)		25	–	–
			£2,425	–	–				£2,425	–	–

FIG. 9. CASH BOOK AND LEDGER ACCOUNTS

Item No. 3. The amount of £150 would be entered in small amounts, covering the period in question, but for the sake of brevity it has been entered here in one sum. The principle, however, remains the same. Payments out must be credited to cash, and debited to the account which is liable for these payments, or the goods or services which such payments represent. This sum, therefore, must be debited to the client and credited to cash.

Item No. 4 represents a sum of money which is not chargeable to the client, but to the practice. The entry, therefore, will be—

Office Expenses .	*Dr.* £28 10 –		
To Cash . . .		£28 10 –	

Item No. 5. At the end of the maintenance period it is found that extras amount to £1,000, on which the architect is entitled to charge 2½ per cent, i.e. £25. The cost of the building, therefore, amounted to £41,000 ; on this sum the architect is entitled to £2,425, i.e. 6 per cent on £40,000, the amount of the accepted tender, plus 2½ per cent on £1,000, being the amount of the extras. He has, however, received £1,600, and so there is a balance due of £825. There must, therefore, be a journal entry, as follows—

Aug. 31.	C D	*Dr.* £800	
	To Professional Services .		£800
	C D	*Dr.* 25	
	To Professional Services .		25

On 3rd September (item No. 6) the architect sends in his account. The client thinks this is rather large, and they talk over the matter, and eventually agree to a payment in full settlement of £750. This means, in effect, that professional services account has not given services represented by £2,425, but only £2,350 ; consequently this account must be debited with £75 (the amount which the architect has agreed to forgo) and the client must be credited with a similar sum, as if he had actually paid it. This adjustment must be made by means of the journal.

On 10th September the client pays the £750, and the entry in the books, therefore, will be—

Debit Cash
Credit C D.

SUPERINTENDENCE

By P. J. Luxton
Member of the Incorporated Clerks of Works Association

PART III

ENGAGING A CLERK OF WORKS

(*contd.*)

QUALIFICATIONS

There are some fundamental qualifications. The applicant will have little chance of success if his age is under thirty at least. Unless he is a very exceptional man, or can exert private influence, it will be assumed that his experience is too short to qualify him for a post of authority. He should be proficient at a skilled building craft. Most clerks of works have been either carpenters, bricklayers or masons, usually carpenters. The plumber will have to find scope for his ability in other directions. There may have been instances where a plasterer or painter has filled the position—on purely decorating work the latter may have been employed—but they have been very few. Carpenters are preferred because they are accustomed to setting out. Their training has taught them to be careful and exact, and as a rule their general education is higher than that of the other craftsmen mentioned.

The applicant will usually be expected to present evidence of experience as a foreman, or in a similar supervising capacity. The son of a builder who has assisted in the management of his father's business is a case in point. As the clerk of works will have to be of equal status on the works to the foreman, this factor of previous superintendance is regarded as important. The exception would be small jobs in country districts.

Technical Training. Young men should be able to prove that they have spent a considerable time in studying building construction, and some of the sciences connected therewith, such as geometry. This means the production of certificates from recognized authorities, the Board of Education, the City and Guilds of London Institute, the Worshipful Company of Carpenters and others. The subjects which should be studied are building construction, and the trades—carpentry and joinery, brickwork, masonry, plumbing, etc.—and sanitary science, geometry, mechanics, elementary chemistry and physics as applied to building construction, and builder's quantities. Where possible, classes should be attended; personal contact with a good teacher who will explain the many difficulties that arise is preferable. Failing an opportunity for attending a technical institute, the would-be superintendent should take some recognized course of instruction by corrsepondence. But even then he should endeavour to pass one or more of the examinations mentioned; the Worshipful Company of Carpenters, Carpenters' Hall, London Wall, E.C., hold one at their Hall each November, which is specially designed for prospective clerks of works and foremen.

He should read works dealing with the various subjects, and study them, particularly the drawings. The information conveyed in such volumes will be far too extensive to be retained in the memory. What will happen will be that the student will gradually absorb a lot of knowledge, which will be retained in outline, and he will be able easily to find and understand the specific details when occasion arises for their application to actual work. Such matters as the gauges of metals, sizes of pipes and pipe fittings available, various formulae, and standard sections of rolled steel are remembered only by men who are constantly using them The superintendent should be able to obtain these facts without difficulty; more than that will not be required.

A great deal of valuable information appears in building periodicals, particularly papers read before professional and other societies. These usually represent the latest practice in any particular direction, and even if the reader has no immediate use for innovations, a knowledge of their existence is desirable.

General Education. A fair general education is necessary, so that the clerk of works can meet other people on a level. He should write a legible hand, be able to explain his meaning clearly, and be acquainted with the general economic and other conditions underlying building work. His duties will carry him into all sorts of places, where he will have to grasp the principles on which the use of the completed building is based, such as hospitals, schools, factories, and public buildings. The buildings will be designed to meet the requirements of the occupiers; they will not be intelligible to the superintendent unless these requirements are understood.

One other point deserves mention. The applicant for a post must look like a superintendent, and his general character must bear the fullest investigation. This should not require emphasis; it applies to a position of trust in any occupation.

Where these qualifications exist, practical experience, including as a supervisor, technical knowledge gained by study in addition to that acquired by experience, a fair general education implying adaptability, and a good address and character, their possessor can consider that he has a fair chance of success in applying for the position of clerk of works.

Form of Application. He will, in making the application, state his age, occupation, experience and general qualifications. These should be expressed concisely— the people who wade through the applications are usually busy men.

An important point is that of salary; this may be stated in the advertisement, or the applicant may have to say what he requires. Generally speaking, it is not less than a skilled mechanic's pay plus two-thirds. On any important job it will be from seven to eight guineas a week, and more on the largest jobs. The applicant will be taken at his own valuation—if he asks for pay below the average he will be regarded as a superintendent below the average.

Typed copies of references should be sent with the application, the originals being retained until required.

An appointment being obtained, the applicant receives a formal notice to that effect which he acknowledges—he may have to sign a short agreement—and on a specified date he takes up his duties. Before dealing with these duties, the other types of clerks of works will be mentioned in so far as their job differs from the man who is employed on new buildings.

ROOF COVERINGS

By John Millar, P.A.S.I., M.I.Struct.E.

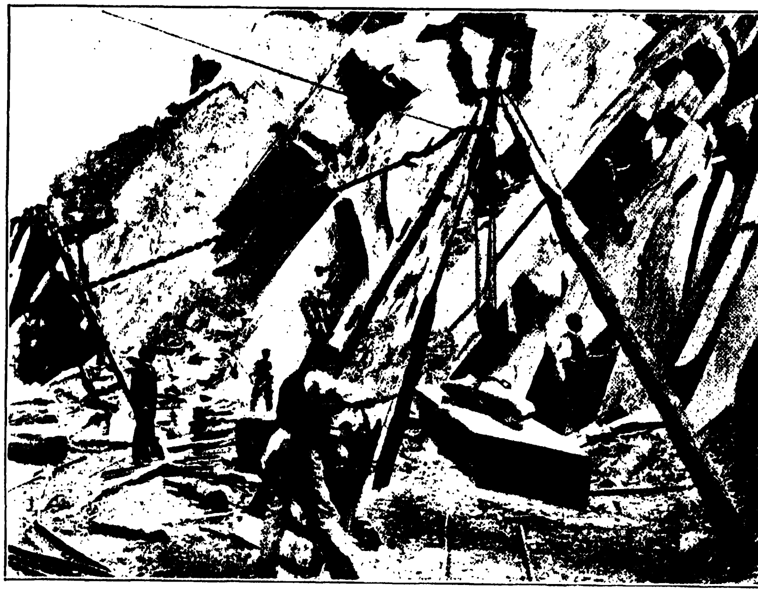
LESSON II

QUARRYING OF SLATES

Quarrying. Slate is obtained by open quarrying or by mining, and in certain quarries is obtained in both ways, according to the dip of the strata. The open workings generally run in galleries, and the underground workings in chambers. In both systems the slate is worked in descending order, commencing at the top.

In the Oakeley quarries, North Wales, the workings are partly open (see Fig. 4) and partly underground (see Fig. 5). The latter sections are approached through the mountain side by driving level shafts into the various slate veins, which are then worked out in chambers 50 ft. to 70 ft. wide and 50 ft. or 60 ft. high. About 50 per cent only of the rock is removed, the remainder being left in the form of walls to support the masses of rock above.

There are five veins, which dip into the mountain at an angle of 45°.



Oakeley Quarries, Ltd.

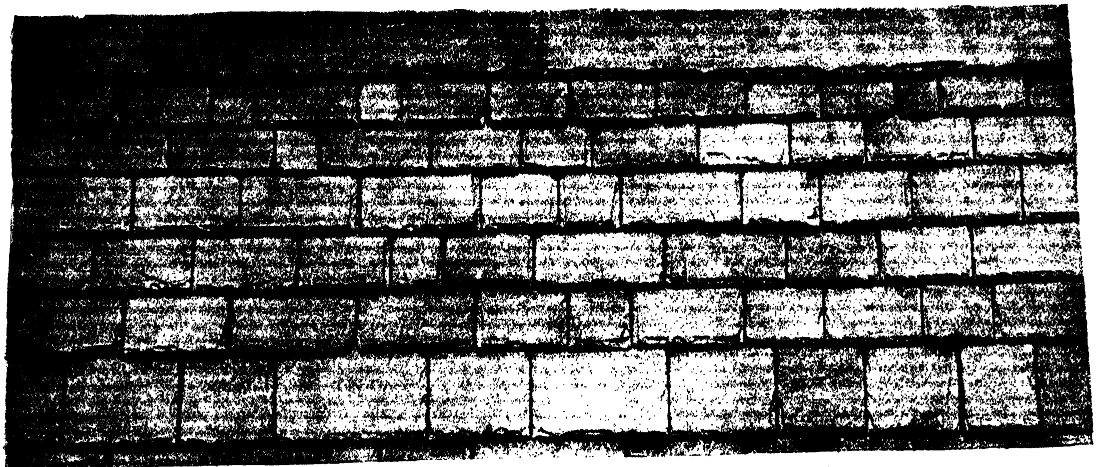
Fig. 4. Quarrying Old Vein Slate in Open

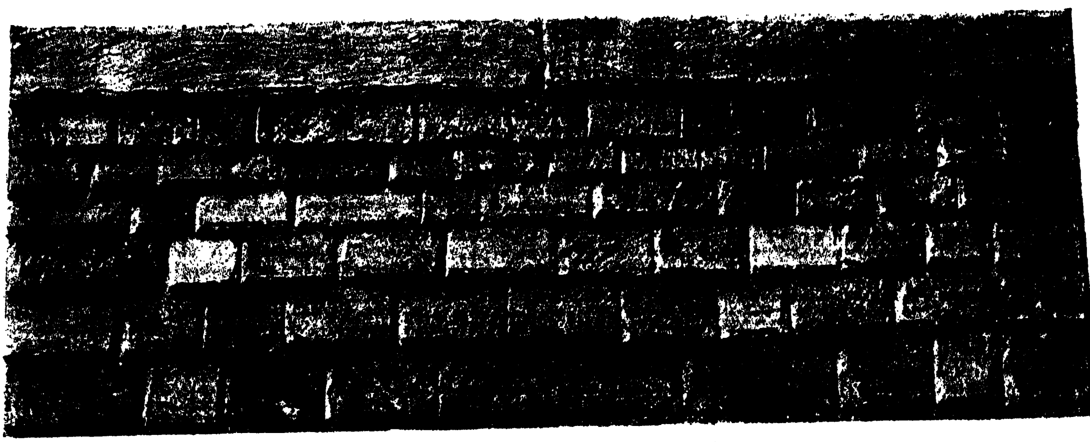
Owing to the dip of the slate veins into the earth, it is worked underground, as the expense of exposing the slate veins for quarrying in the open, by the removal of the superincumbent masses of rock, would be too great, and would make it impossible to work the slate at a profit. All five veins are now worked simultaneously, and are known as, in descending order: *north vein*, consisting of a band of slate 200 ft. thick; the *back vein* (40 ft. to 70 ft. thick); the *small*, or *stripy, vein* (30 ft. thick); the *main*, or *old, vein* (200 ft. thick); and the *new vein*. This last vein produces the best slates.

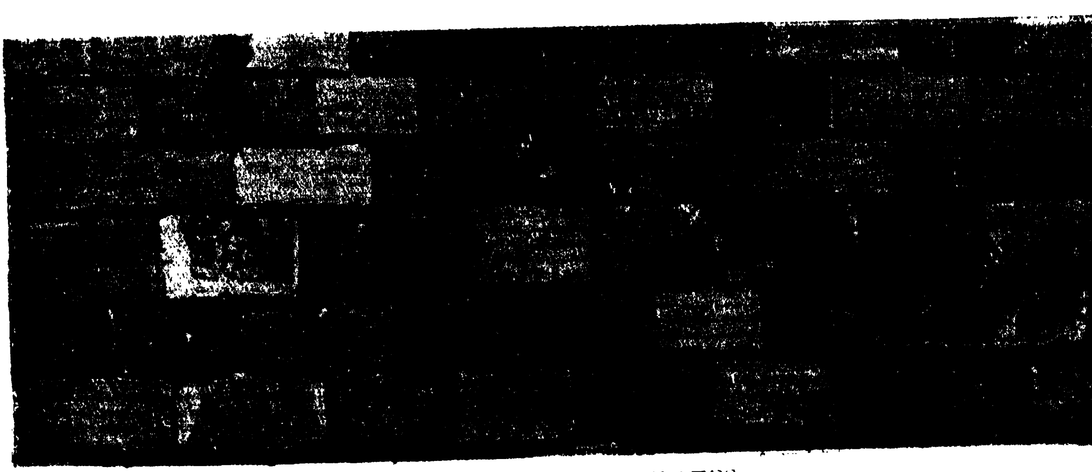
Blasting. Whichever of the above systems is employed for reaching the slate, the process of obtaining it is by blasting. In the removal of the rock advantage is taken of any natural joints that may occur, and also of the tendency of the rock to split in certain directions. Where natural joints do not conveniently occur, it is necessary to obtain a free bottom and a free side before the rock can be quarried. For this purpose, a chanelling machine is used for cutting free bottom (see Fig. 6). The arrangement of the chambers and floor, in a typical Welsh quarry is shown in Fig. 7.

After a free bottom and a free side have been obtained, holes 1 in. to $1\frac{1}{4}$ in. in diameter, and varying from 1 ft. to 10 ft. in depth, are drilled or "jumped" by hand and fired with a blasting cartridge, containing from a few ounces up to a few pounds of gunpowder. In some cases two men are employed in drilling, one holding the drill while the other one strikes it with a light sledge hammer. In the large quarries hand drills have been superseded by drills worked by compressed air or electricity.

Between each blow the drill is slightly withdrawn, turned slightly, water being added from time to time to assist in the cutting of the hole.


PRECELLY GREEN ROOF IN MIXED SHADES


PRECELLY RUSTIC SLATES


"VRONLOG" RUSTIC SLATES

(See the article on "Roof Coverings" facing this page)

These holes, when driven along the planes of cleavage, are termed "splitting holes," and when driven at right angles thereto, "pillaring holes." Mechanically drilled holes vary from $1\frac{1}{4}$ in. to $2\frac{1}{2}$ in. in diameter, and up to 15 ft. in depth.

After the drilling, these holes are thoroughly cleaned out before the blasting cartridge is inserted for firing. The charges are fired in turn electrically by a safety time fuse.

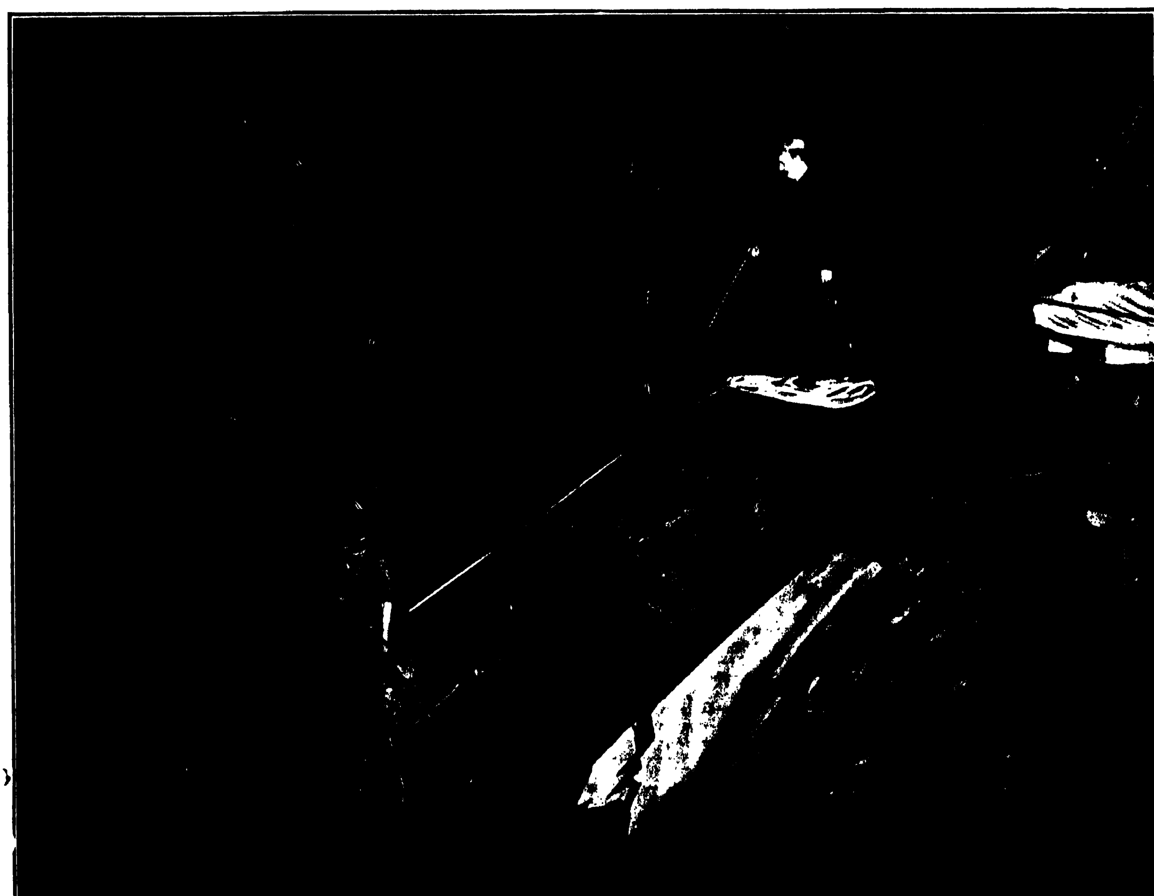
The blocks of rock when quarried vary greatly in size, and weigh anything up to 40 or 50 tons, or even more. To facilitate handling and removal on trolleys up the incline to the surface of the quarry, the blocks have to be reduced in size. This reduction is done by using a mallet and chisel, and plug and feathers, thus dividing the block along the cleavage and pillaring.

Splitting. These small blocks are then taken to the splitting and dressing sheds at the surface, where they are further reduced to slabs about 3 in. in thickness before being placed on the saw tables.

The rough slab is next sawn across one end to give it an even square face for the splitter, who with a broad-edge chisel and mallet carefully splits the reduced slab into sheets (see Fig. 8), which are then cut into slates by a circular dresser.

The slates are now divided into sheets of the required thickness, and sorted according to size and colour into heaps which are termed *bests*, *mediums*, and *seconds*. These are comparative terms and do not always imply that the bests and mediums are better than the nominal seconds. They have reference to texture, thickness, and uniformity of cleavage.

The rule laid down for the splitters in the best Welsh quarries is that for *best* quality slates,



Oakeley Quarries, Ltd.

FIG. 5. QUARRYING SLATE ROCK, UNDERGROUND CHAMBER

size 22 in. by 12 in., or 22 in. by 11 in., there should not be a greater number than eighteen in 3 in.

Medium quality slates run eleven, twelve, and thirteen to the 3 in., that is, $\frac{3}{16}$ in. for *best* quality and $\frac{1}{4}$ in. for medium quality slates.

The method of splitting or riving the slate in the Westmorland area differs from that employed in the Welsh area. In the Welsh area the splitters sit at their work and, resting the block against the side of their legs, divide and subdivide the block into the required thickness, with a broad, thin chisel and wooden mallet. This is termed "chisel riving." In the Westmorland area hammer riving is generally adopted. In this method the splitters or rivers stand at their work. They use a hammer, one end of which has a cutting edge, and, holding the block with one hand, they apply a series of blows with the other along the cleavage plane until the block splits.

Dressing. After the block has been split to the required thickness, the irregularly shaped pieces are next dressed into roofing slates. The method of doing this varies slightly in different quarries. Some use a machine which is worked by a foot treadle, others use a circular dressing machine with two knives fixed diagonally, and driven by electricity. Along one side of the machine is a notched measuring gauge, into which the slates are placed. The knife, descending or revolving, cuts them to the required size. The edge on the face of the slate which is first struck with the knife shows a clean cut, while the under edge breaks or spalls, giving a rough splayed edge to the slate. This rough splayed edge is on the side of the slate which is termed the "back" when laid, except in the case of the under-eaves slate, which is reversed in order to obtain a close joint along its lower edge, and so lessen the risk of the slates being stripped off by the wind. The punching or drilling of the nail holes is usually done on the building.

Oakeley Quarries

FIG. 6. CUTTING FOOT JOINT WITH ROCK CHANELLER, UNDERGROUND FLOOR

Sizes of Slates. Table III gives the names and sizes of the various slates obtainable, also their covering capacity.

TABLE III

SIZES, NAMES AND COVERING CAPACITY OF SLATES

Name	Size	Covering of One Mi[illegible] Slates, L[illegible] 3[illegible]	Actual No. Required One Squa[illegible] ft.) 3[illegible]
Princesses .	[illegible] in. × 14 in.	136 yd.	98
Duchesses .	[illegible] in. × 12 in.	117 ,,	115
Marchionesses	[illegible] in. × 11 in.	97 ,,	138
Countesses .	[illegible] in. × 10 in.	78 ,,	169
Viscountesses	[illegible] in. × 9 in.	62 ,,	213
Ladies .	[illegible] in. × 8 in.	48 ,,	277
Headers .	[illegible] in. × 12 in.	61 ,,	218
Doubles .	[illegible] in × 6 in.	25 ,,	533

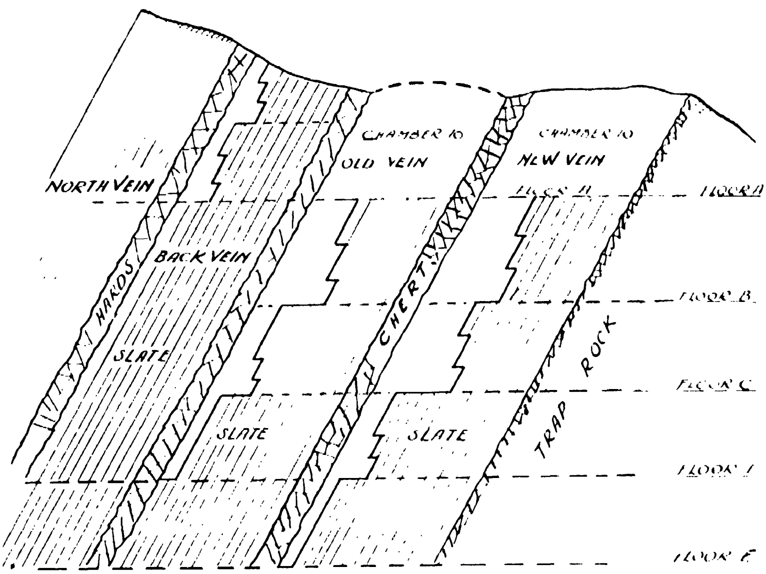


FIG. 7. TYPICAL SECTION OF A WELSH SLATE QUARRY

VARIETIES OF SLATES

Slate Areas. The principal sources of supply are North Wales, Westmorland, Cumberland, Lancashire, Cornwall, and South Wales.

North Wales. The largest quantity of slates are obtained from this area in bests, mediums, and seconds. The sizes run from 34 in. by 14 in. down to 10 in. by 6 in. They are sold to the trade in thousands of 1,200 plus 60 extra, making a total of 1,260 slates per 1,000, with the exception of sizes 36 in. by 24 in., which are sold by weight. Slates sold by weight are called "ton" slates.

The colours of slate from this area are purple-grey, grey-blue, and blue, and all are excellent metal.

Westmorland and Cumberland. This area produces a slate of a green colour of various shades, among which are light green, dark sea-green, and olive green. The colouring of these slates is derived from the presence of ferrous oxide and magnesia. They are thicker and coarser than Welsh slates, averaging $\frac{3}{8}$ in. in thickness, and are more expensive, but they make a more pleasing roof. The above area embraces North Lancashire which produces an excellent slate in random sizes for graduated work. The material which forms the slate in this area is not a marine clay, but is largely made up of volcanic ash, and these slates do not possess such a good cleavage as the clay slates.

Cornwall. The slates obtained from Delabole, Cornwall, are very durable, and the quarries are among the oldest in the country. Sized slates

Oakeley Quarries, Ltd.

FIG. 8. SLATE SPLITTING

are chiefly produced, the colour of which, after a few years' weathering, mellows down to a silver-grey. Thick *randoms* and *rustics* of a green colour can also be obtained. Randoms are slates supplied in mixed sizes. Rustics are slates that have taken on a stained appearance, due to chemical changes along the cleavage planes, which have become slightly open as a result of weathering. They are approximately ⅜ in. in thickness and are used for diminishing work.

South Wales. This area produces slates of various shades in light, dark, bright, and olive green. Two well-known varieties are Precelly and Vronlog. The former are produced in rustics and randoms, and the latter in standard sizes from 24 in. by 12 in. down to 10 in. by 6 in., and also in randoms and rustics.

Peggies are small slates which vary in length from 9 in. to 14 in.

Good slates are also obtained from Scotland and Ireland, but owing to difficulties of transport they are used locally only.

Foreign Slates. Other countries producing slates are France, America, Germany, and Norway. Many of these slates are of an inferior quality, and careful discrimination should, therefore, be exercised in their choice.

SLATING

Technical Terms. The following terms are employed by the slater –

The *back* is the upper surface of the slate when laid; the under surface is called the *bed*. The part of each course exposed to view is termed the *margin*; and the length of the margin, or the distance between the nail holes of each course, is called the *gauge*.

The top of each slate is termed the *head*, the lower edge the *tail*.

A *course* is one horizontal layer of slates.

The *lap* is the amount that one slate covers the next but one below it; but when the slates are head-nailed, the lap is measured from the nail hole instead of the top of the slate.

The *bond* is the arranging of the slates on the roof, so that no vertical joint of one course is less than half a slate in width from the vertical joint in the course above and below; this is accomplished by introducing a half-slate or a slate and a half-slate at the commencement of every alternate course.

The *eaves* (Fig. 9) is the name given to the lower edge of the roof; and the upper edge, or the line formed by the intersection of the roof surfaces, is called the *ridge*.

The *verge* is the edge of the roof plane at a gable end.

The *hip* is the line of intersection of two roof planes containing an angle greater than 180°; the *valley* the line of intersection of two roof planes containing an angle of less than 180°.

A *hipped end* is the sloping end of a roof and is generally triangular in shape.

A *double eaves course* is the first course of slates laid on the roof, not exposed to view, and equal in length to the slate to be used minus the gauge. It is introduced to fulfil the condition that, wherever a vertical section is taken through the slates, there shall be two thicknesses of slates, and three thicknesses if taken through the lap.

The *double ridge course* is the last course of

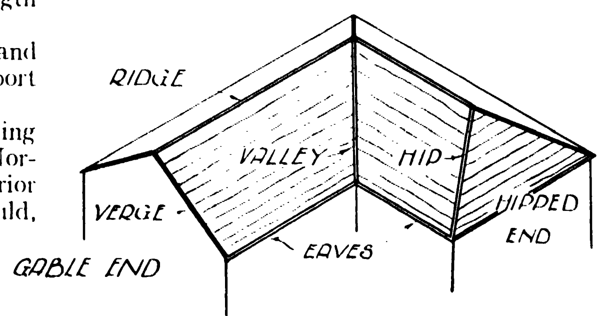


Fig. 9. Terms Used in Roof Work

slates laid at the ridge, and is of the same length as the double eaves course.

Where battens only are employed, and where greater protection is required, the joints are pointed in cement or hair mortar, to prevent wind and rain from penetrating the roof. This is termed *torching*.

Shouldering is the term applied to the bedding of the top of the slates in hair mortar for about 2 in. wide where the situation is an exposed one.

Rendering is the application of hair mortar to the underside of the slates when laid on battens, to prevent snow or driving rain from entering at the crevices. The disadvantage of this method is that the bedding tends to attract moisture rather than repel it, and for this reason this method fails in its object

When the building is in an exposed situation, it is preferable to give a steeper pitch and a greater lap than would ordinarily be employed, and to adopt a slate with a rough face.

Slaters' Tools. The slaters' tools are few in number. They consist of a *cutting-iron*, about

2 in. by $\frac{1}{4}$ in. in section and about 1 ft. 6 in. long, with the ends shaped and sharpened for fixing into the block of wood; a *pick-hammer*; an ***axe***, or ***zax***; a ***slate-ripper***; and a *chalk line* (see Fig. 10).

The ***axe*** is used for dressing the edges of the slate; it consists of a steel blade about 12 in. long with a spike. The blade is fixed to a wooden handle. The slate is placed on the dressing or cutting iron, projecting over the edge by the amount it is desired to trim off. The axe is then taken in hand, and by a series of sharp blows the slate is trimmed off to the required size. The spike on the back of the blade is used for punching the holes in the slate, the positions of which are marked with a gauge.

The ***gauge*** is usually a piece of batten with two nails driven through it, at a distance apart, to give the position of the nail-holes from the tail of the slate. One nail projects sufficiently to score a line across the slate to mark the level of the nail holes; and then with a sharp blow the holes are punched with the spike. One end of the hammer is used for driving nails; the other end is pointed and used for punching holes in the slate, if necessary, while the work is in progress on the roof. On the side of the hammer there is a claw for removing bent or defective nails.

The ***ripper*** is used to remove broken slates by cutting through the nails by which they are held; it consists of a long thin steel blade with a wooden handle at one end, while the other end is widened out sufficiently to form a hook on each side of the blade, so as to grip the nail which it is desired to cut. The tool is passed up below the slate and round the nail, and then

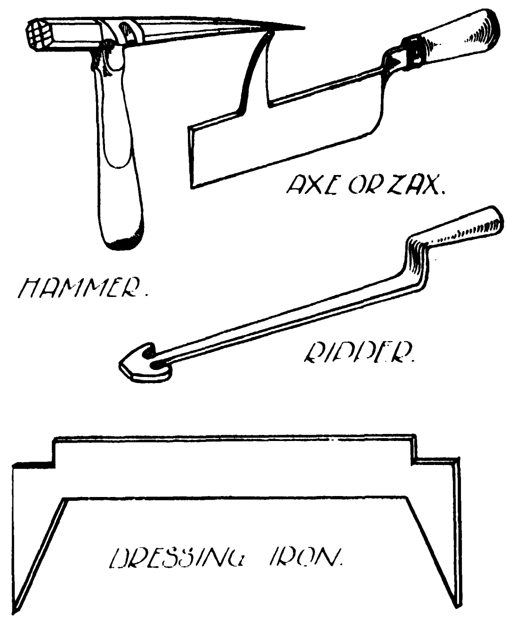


Fig. 10. Slater's Tools

with a sharp pull the nail is forcibly cut and the slate withdrawn.

The *chalk line* is employed for setting out the position of the battens, when used on the roof, and also as a guide in fixing the slates.

PLUMBING

By Percy Manser, R.P., A.R.S.I.
Honours Silver Medallist

LESSON III

MATERIALS (*contd.*)

ZINC

Properties and Uses. Chemical symbol Zn. Melting point 773° F. Specific gravity 7·2.

Chief ores of zinc: *Blende*, a zinc sulphide; *calamine*, a zinc carbonate. These are found in Gloucestershire, Cumberland, and in Belgium and Spain.

Zinc is a hard metal, bluish white in colour, crystalline in structure, and very malleable when heated to 260° F., but at ordinary temperature it is brittle. If heated to above 390° F. it is again brittle and can be crumbled. It will also burn, giving a bright bluish-white flame. Zinc is not affected by ordinary dry air, but soon tarnishes when exposed to a moist atmosphere, and becomes coated with an oxide of zinc, which acts as a protective coating and prevents further action. It is largely used for roof coverings and for coating cisterns, pipes, and various fittings used by the plumber in the form of *galvanized iron*.

Manufacture. The ore is treated somewhat differently to that of lead and copper, the metal being obtained by distillation. The ore is heated in a current of air, then mixed with crushed coke, and again heated in large crucibles till the metal volatilizes at red heat. The vapour given off is collected in a series of condensers, from whence it is cleared out. After cleansing it is cast into ingots and is termed *spelter*.

TIN

Properties and Uses. Chemical symbol Sn. from *stannum*. Melting point 442° F. Specific gravity 7·3.

The chief ore is *tinstone*, tin and oxygen, SnO_2. It is found chiefly in Cornwall; also found in Australia and Mexico.

Tin is a soft metal, yellowish white in colour, low in tenacity, but very ductile and malleable. It possesses a bright metallic lustre, and does not tarnish when exposed to dry or moist air. Pure tin when bent emits a cracking sound. It is largely used for coating iron plates, which are commonly known as *tin plates*; it is a poor conductor of heat and electricity.

Manufacture. The ores are first carefully sorted, crushed, and washed. The ore is then placed into a reverberatory furnace and mixed with finely-crushed charcoal and lime; after heating, the molten metal is run out into ingots. Sometimes the metal is again melted down to further purify it before being placed ready for dispatch for commercial purposes.

ALLOYS

An *alloy* is a mixture of two or more metals and is obtained by fusing these metals together. A proper alloy is an intimate mixture but not a chemical compound. Although metals can be made to combine, they can again be separated. When melted down and mixed together, if they are allowed to stand, the metals will separate owing to their different specific gravities, the heavier metal sinking to the bottom of the pot and the lighter rising to the top. It is for this reason that the plumber should always stir the solder well before taking out a ladleful to wipe a joint. In Tables I, II, and III are given lists of the chief alloys that are of interest to plumbers.

Uses of Solders. The *soft solders* are those chiefly used by the plumber for jointing lead pipes, tinning brasswork preparatory to wiping to lead pipe, making fine solder seams with the copper bit, etc. The zinc worker and tinsmith use copper-bit solder for making their seams and joints.

The pewterer uses a solder with a very low melting point for joining the seams when covering draining boards, bar counters, etc., the heat being applied by means of a small blow-pipe.

The *hard solders* require a very much higher temperature to melt them, and a brazing lamp or blow-pipe with foot bellows is required. They are used for brazing copper, brass, and iron tubes and fittings. The coppersmith solders or brazes the dovetail joint used in making sheet-copper articles with hard solder, the copper requiring to be brought to a red heat during the process of brazing (jointing). The apparatus generally used is known as a *brazing hearth*.

On referrring to the list of alloys it will be seen that *gun metal* is composed of copper and tin. This metal is used for making valves, cocks and fittings for use in water and steam-fitting works. Copper alone would be too soft to stand

TABLE I

ALLOYS

Alloy	Copper	Zinc	Tin	Lead	Iron	Nickel
Brass, Ordinary .	2	1				
,, Turning .	3	1				
Pot Metal . .	2½			1		
Bronze Cocks .	88	10	2			
Gun Metal . .	90½		9½			
Bell Metal . .	4		1			
Muntz Metal .	3	2		$\frac{1}{100}$		
Gedge's Metal .	60	38·2			1·8	
Babbit's Metal .	4	9	96			
White Brass .	3		90			
German Silver .	8	3·5				3
Pewter . .			4	1		

TABLE II

SOFT SOLDERS

Tin	Lead	Bis-muth	Melting Point, F.	Solder
1	2		441°	Plumbers
2	1		340°	Tinmen and zinc-workers (copper bit)
1	1		320°	Blow-pipe
1	1	2	203°	Pewterers
1	1	1	254°	Very fine

TABLE III

HARD SOLDERS

Copper	Zinc	Silver	Brass-wire	Solder
2	1			Spelter (hardest)
3	2			,, (hard)
1	1			,, (soft)
2	2	$\frac{1}{4}$		,, (fine)
1		3		Silver (hard)
		2	1	,, (soft)

the wear and tear of continual use, but by alloying the copper with tin we get a much harder substance more suitable for the purpose. By alloying two parts copper and one part zinc, we get brass of a second quality, whilst the better quality is a mixture of three parts copper and one part zinc.

Plumbers' Solder. This is an alloy of lead and tin in the proportion of two parts lead and one part tin. It is usually cast into bars of eight, and weighs approximately 56 lb. per cast.

The characteristics of good plumbers' solder are briefly: The ends of the bars should have a bright appearance; there should be several white spots about the size of peas. It should work somewhat like butter, so that fat edges do not work up on the joint or tears form on the underside of a horizontal joint. When solder contains an excess of tin it will be found to stick to the cloth.

TEST. The best method of testing solder is to wipe a joint and note how it works. It often happens that a pot of plumbers' solder becomes *poisoned*. This may be due to the presence of zinc and renders the solder useless. It can be remedied by heating the solder in the usual way over a fire and stirring in a handful of powdered sulphur; a thick crust will form on the surface of the solder, and this crust should be carefully removed, if possible in one piece. This is termed *burning out the solder*, the sulphur cleansing it and bringing the poisonous substance to the surface. Care should be taken when cleansing a pot of solder to have an open flue to the fire-place, as sulphur fumes are given off in the form of sulphur dioxide.

Tinman's and Zinc-worker's Solder is cast into sticks, each weighing approximately ½ lb. If a stick is held close to the ear and bent, a slight cracking should be heard, indicating the presence of a fair proportion of tin in the solder.

FLUXES

A **Flux** is a substance used to prevent the oxidation of metals to be soldered, and also to assist in the flowing of molten metals and the adhesion of the solder to the metal. Without the aid of a flux, oxidation, or *tarnishing*, would

TABLE IV

FLUXES

Material	Flux
Lead with Fine Solder .	Resin and Tallow
Lead with Coarse Solder .	Tallow
Tin and Zinc . . .	Chloride of Zinc
Brass and Copper with Soft Solder . . .	Resin
Brass and Copper with Hard Solder . .	Borax
Pewter	Galipoli Oil

occur; the result would be a faulty joint or seam, as the case may be.

Table IV gives a list of the fluxes in general use.

In addition to the above list, there are now on the market several good fluxes in paste, liquid, and powder form; among these may be quoted Fluxite, Baker's Fluid, and Boron Compound. The latter is used for brazing with hard solders.

Chloride of zinc (more commonly known as *killed spirits*) is obtained by adding zinc to hydrochloric acid, the hydrogen being given off and leaving chloride of zinc. This may be used as a flux for soldering brass, copper, and iron, but should not be used for tinning brass or copper unions and fittings previous to wiping joints, owing to the presence of the zinc (see note on poisoned solder).

BUILDER'S GEOMETRY

By Richard Greenhalgh, A.I.Struct.E.
Honours Medallist in Geometry

LESSON IV

CIRCLES AND ARCS

Circle Through Three Points. Let *A*, *B*, and *C*, Fig. 37, be the three points, which may be placed anywhere except in a straight line. Bisect *AB* by the line *DE*; then any point on *DE* is equidistant from *A* and *B*. Similarly,

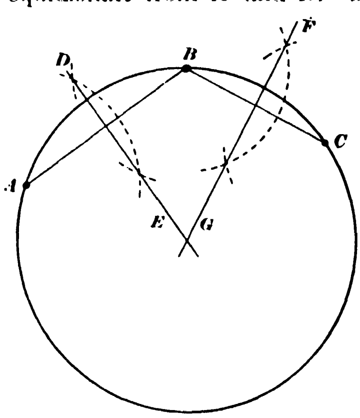


Fig. 37. Drawing Circle through Three Given Points

bisect *BC* by *FG*, and any point on *FG* must be equidistant from *B* and *C*. The intersection of the two bisectors will thus be equidistant from all three points and must therefore be the centre of the required circle.

The above problem is really the same as circumscribing a triangle by a circle, and is also identical with the problem of completing a circle when only an arc is given. For example, let the given arc be as shown in Fig. 38. Choose any three points as *A*, *B*, and *C* on the arc. Then bisect the lines joining the points, as already explained.

Segmental Arch. An application of the previous problem is when a segmental arch has to be drawn to a given span and rise. Let the span be 3 ft. and the rise 6 in., as shown in Fig. 39. Set out the dimensions to a suitable scale, say, 1 in. to a foot. Join the top of the rise with one end of the span, and bisect the line so formed. Where this bisector cuts the

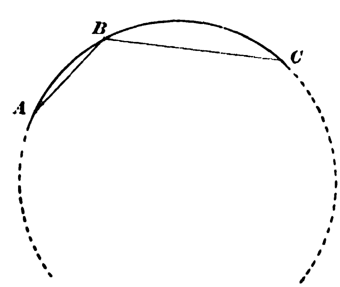


Fig. 38. Given an Arc, to Complete the Circle

centre line of the arch will be the centre from which the arch curves are struck. Of course, if the centre line was not available, a bisector could be drawn at the other side of the arch, and the required centre would be at the intersection of the bisectors.

The above result can be checked by calculation, using the following rule: *If two chords intersect, then the product of the two parts of one* *chord is equal to the product of the two parts of the other chord.* Thus, in Fig. 40, $A \times B = C \times D$. It follows from this that, if any three of the lengths are known, the other length can be

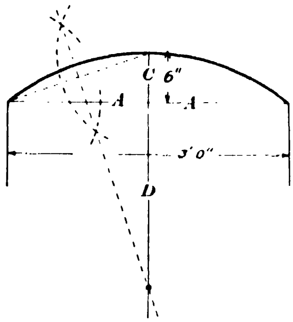


FIG. 39. OBTAINING RADIUS OF SEGMENTAL ARCH

calculated. Thus, if A is 2 in., B is 3 in., and C is 1 in., then

$$D = \frac{A \times B}{C}$$

therefore,

$$D = \frac{2 \times 3}{1} = 6 \text{ in.}$$

In the case of an arch, one chord is divided into two equal parts A, Fig. 39, and therefore

$$D = \frac{A \times A}{C} = \frac{A}{C}$$

When D is obtained, the diameter can be obtained by adding C; the radius is found by halving the diameter.

This method of obtaining the radius of an arch when the span and rise are given, is often summed up in the following rule: *Square half the span, divide by rise, add rise, and divide by two.*

Apply this rule to the arch given in Fig. 39.

Squaring half rise	.	$\frac{3}{2} \times \frac{3}{2} = \frac{9}{4}$
Dividing by rise	.	$\frac{9}{4} \div \frac{1}{2} = \frac{18}{4} = \frac{9}{2}$
Adding rise .	.	$\frac{9}{2} + \frac{1}{2} = 5$
Dividing by 2	.	$5 \div 2 = 2\frac{1}{2}$ ft.

The radius of the soffit is therefore 2 ft. 6 in., which length may be checked by measuring Fig. 39 to scale.

Drawing Flat Arcs. Sometimes an arch has a very "flat" curve, that is, its rise is small compared to its span. In this case, the radius is very long, and in some cases the centre may be so far away as to be inaccessible. Under

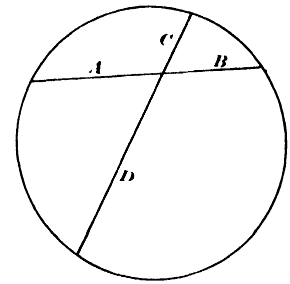


FIG. 40. INTERSECTING CHORDS

these circumstances, the flat curve can be drawn, as shown in Fig. 41, by means of a triangular frame. The principle of this method is that the angles in the same segment of a circle are always equal.

Suppose a curve has to be drawn through the three points A, B, and C on the board shown in

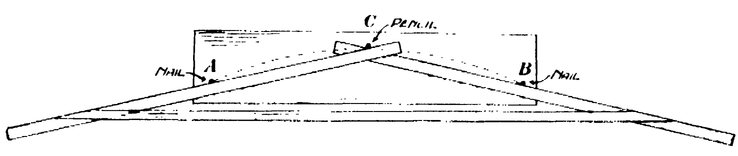


FIG. 41. DRAWING "FLAT" ARC

Fig. 41. Drive nails a little into the board at A and B. Make a triangular frame as shown from three strips of wood, the angle at the apex being equal to the angle ACB. Then, holding a pencil against the apex of the frame, glide the legs of the frame against the two nails. The required curve will thus be traced on the board.

Drawing Circle in Triangle. Let ABC, Fig. 42, be a triangle in which it is required to inscribe a circle. Bisect one of the angles, as BAC. Then, any point on the bisector AD must be equidistant from the sides AB and AC. Similarly, any point on the bisector BE must be equidistant from AB and BC. Therefore the point of intersection F of these two bisectors must be equidistant from the three sides of the triangle, and must consequently be the centre of the required circle. If desired, the radius of the circle may be obtained by dropping a perpendicular (as FG) from the point F on to any side of the triangle.

Of course, the above explanation is not necessary merely to solve the problem, but is necessary to understand and remember the

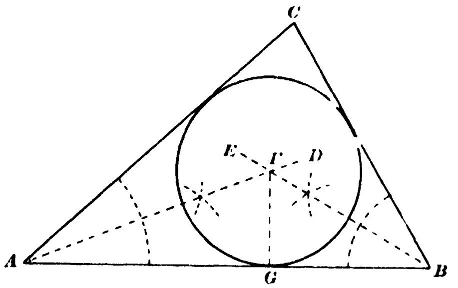


FIG. 42. INSCRIBING CIRCLE IN TRIANGLE

construction, and to apply the same method to other problems.

Drawing a Trefoil, etc. A trefoil is shown in

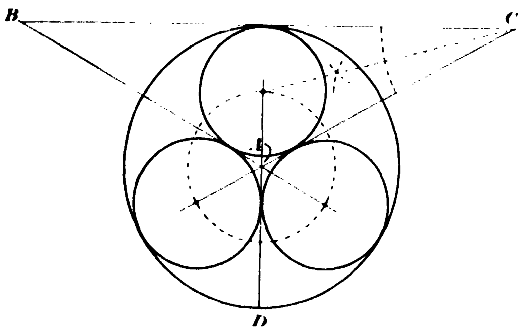


FIG. 43. CONSTRUCTING A TREFOIL

Fig. 43 and consists of three equal and tangential circles, circumscribed by a larger circle. Each small circle will clearly occupy a sector equal to one-third of the circle and having an angle of 120°. Draw *AB* and *AC* with the 30° set-square, and draw *AD* vertically. The centre of the top circle clearly lies on *DA* produced. Complete the triangle *ABC*, and bisect an angle, as *ACB*. The bisector will cut *DA* produced in the centre of the required small circle. The

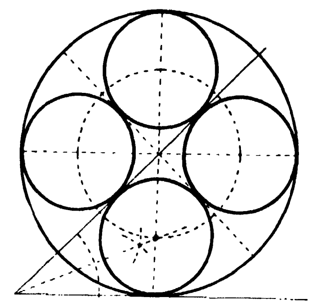


FIG. 44. CONSTRUCTING A QUATREFOIL.

other two centres are then easily obtained and the trefoil completed.

It should be observed that this problem chiefly consists in drawing a circle in the triangle *ACB*, as already explained in connection with Fig. 42.

A *quatrefoil* is shown in Fig. 44. It is drawn by first dividing the large circle into four sectors. A small circle is then inscribed in one sector by first drawing the surrounding triangle. The quatrefoil is completed in the same manner as for the trefoil.

Similar figures with a larger number of small circles can be drawn out in the same way.

ARCHITECTURAL MODELS AND MODELLING

By Edward W. Hobbs, M.J.I.E.
Vicker's Gold Medallist; Author of "Pictorial House Modelling"

PART II

MAKING THE MODELS

Materials Required. Perhaps a brief review of the methods that may be followed by the amateur will be of assistance to those students and architects who wish to study some detail of a structure, or to solve a constructional problem.

Primary consideration has to be given to two main points; first, the scale of the proposed model and, secondly, the materials to be employed in its construction. The latter to some extent will govern the amount of detail that can be reproduced.

Dealing first with materials suited for the novice, there is no doubt that good grade cardboards, particularly Bristol boards, are the very best for all-round use. Practically anything can be modelled with cardboard, with such obvious exceptions as trees and shrubs, and the amount of detail that can be represented is astonishing. Those without experience might be excused for supposing that cardboard would have only limited application, but practical work will speedily demonstrate the truth of the claim that cardboard is the ideal material for architectural modelling. For some of the work it is desirable to employ a fine and regular grained wood, such as high grade pine or limewood.

For the baseboard of a large model, a wooden framework is needed, and should be faced with a good quality of three-ply board.

Sundry other materials are used from time to time, but the student who provides himself with a selection of Bristol boards, ranging in thickness from two-ply to five-ply, will have ample to commence with.

The chief tools are a really keen and free-cutting pocket knife, and a steel straight-edge for a guide while cutting. *Seccotine* is the most convenient form of adhesive, although some workers favour the old-fashioned gum; the writer, however, prefers seccotine, and has proved it excellent for the purpose.

Suitable Scales. Considerations of scale for the model are based on various items, but chiefly the purpose of the model. Students who wish to study the constructional details involved in various phases of building work will find that a scale of ½ in. to 1 ft. is as practical as any, and has the advantage that most architectural details are drawn to this scale, and consequently it is a saving of time and trouble to adhere to this scale for the model work.

Little models, made to a scale of ⅛ in. to 1 ft., are very fascinating, and are particularly appropriate for architects desirous of submitting a model of a proposed building to a client.

Such models of the average domestic building can be made without difficulty, and are small enough to permit the elimination of much unnecessary detail work, but large enough to give a capital idea of the proposed structure. These models can well be considered as plastic pictures rather than scrupulously detailed and accurate models; they have, however, just the right character for their purpose, which is chiefly that of arousing and concentrating interest on the design as a whole. Models of estates and large factories are frequently and conveniently made to a scale of 32 ft. to 1 in., but models of individual buildings, intended as window displays in an estate agent's office, are customarily made to a scale of ¼ in. to 1 ft., a scale that permits accurate modelling of such details as rain-water fittings.

Elaborate models are often made with glazed window openings, and may be illuminated from within to give a night effect or for accurate determination of problems concerning lighting, either indoors or exterior. The novice is, however, advised to commence with a modest model, say of a small domestic building to a scale of 8 ft. to 1 in., and to represent the windows by paintwork.

Details and Methods. As an example of the procedure to follow in the construction of such models, suppose it is desired to represent a house with an L-shaped plan and a flat roof.

The first requirements are the full working drawings or plans of the building, which will probably be to the desired scale of 8 ft. to 1 in., but if not they will have to be enlarged or reduced accordingly. The first step is to make an elevation drawing of each separate outside wall, and to show thereon every window opening, doorways, the details of such things as revealed lintels, and the principal coursing of the masonry or brickwork. These outlines are best drawn in water-proof Indian ink, and must, of course, be

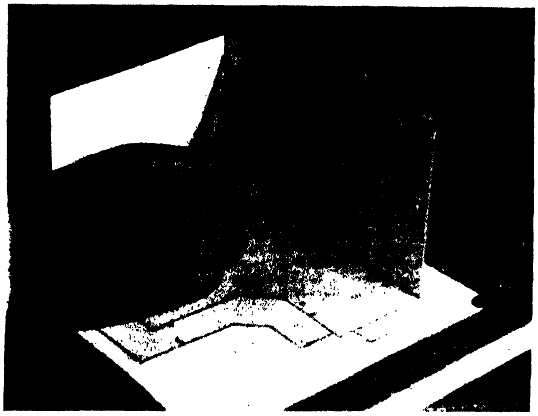


Fig. 7. Preliminary Stages in Making a Simple Model

accurate in every particular, but more especially so as regards the squareness of corners, and correctness of length and height. What is wanted is an accurate outline of the walls, from a horizontal base line to the plate in the case of a building with an ordinary roof, or to the top of the cornice in flat-roofed buildings.

Next prepare a smooth piece of board large enough to support a stout cardboard base for the model proper. Cut the piece of card for this base, which should be at least four-ply in thickness, and draw thereon the outline of the walls in plan, and any other features, such as a projecting bow window.

Then fasten this card to the base with drawing pins at the corners, as seen in Fig. 7. The various wall sections should have been drawn on two-ply or three-ply card, and have next to be cut accurately to shape with the knife, using a free decided cut that should completely sever the card with one stroke.

Guide the knife blade with the straight-edge and take care to keep it upright to ensure a square cut. All edges that form vertical corner joints, or quoins, should then be mitred neatly by careful sand-papering, or by the use of a bevel-print trimmer as used by photographers.

The next proceeding is to coat carefully, completely, but lightly, the edges with seccotine, and then to place the lower edge in contact with the line of the plan on the baseboard card. Now erect the next wall as shown in Fig. 7, and strengthen the corner with a triangular web-shaped piece of card as there shown. Leave this to set for a few minutes, and then continue by erecting the other walls.

The internal angles of outer walls can be made without severing the pieces from the walls themselves, if they are drawn as one wall and the junction marked by a vertical line. This is half cut through with the knife, or scored as it is termed, and the card bent to the proper shape. It is then set up in place as shown in Fig. 8. The remaining wall sections are placed, and finally a roof card cut to fit within the walls and stuck in place with seccotine. To support the flat roof it is best to fit stretcher pieces of card across the major openings, allowing them to set before fixing the roof card.

Bow windows and similar projections are modelled separately, and can usually be scored at the angles and bent to shape as previously mentioned. They then have web pieces stuck inside to stiffen them, and the flat portion that will abut the main part of the walls is rubbed gently on a piece of very fine sandpaper, to make a perfectly flat surface for the junction with the main walls.

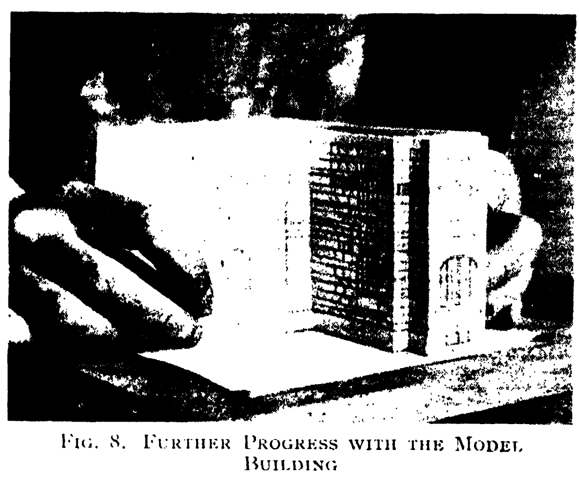


Fig. 8. Further Progress with the Model Building

These pieces are now placed in position and separately roofed. No matter what the shape of the building, it can be modelled by one of these methods. The first, which is known as "building up," is to draw separate elevations for each wall surface, and to build them up as described; the other plan is to draw an expanded elevation of the several walls in their correct order, and to score the joints and fold the card to shape. As a rule, the best results are to build up the main structure and make such things as bow windows, chimney stacks, and the like by

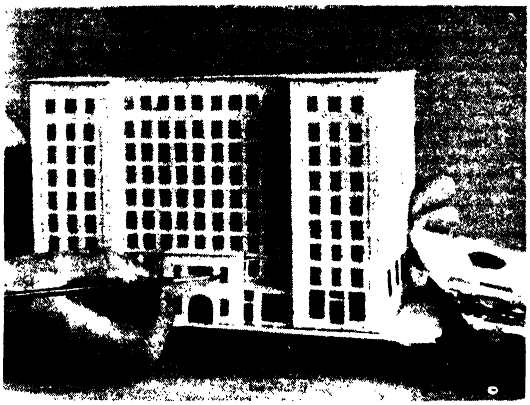


FIG. 9. PAINTING THE WINDOWS OF A MODEL DWELLING

the folding method. Roof work is particularly interesting, but is carried out in exactly the same way, by preparing expanded plans of each roof section, placing them in position, and sticking them together with seccotine. The usual plan is to take the chief roof surface from the ridge, and to draw the expanded roofs on each side of the ridge. This card is then cut to shape, scored along the ridge line, and folded. A stiffening web or two is then stuck into the angle, and when dry the whole stuck to the walls. Afterwards, the other sections are added until the whole is complete.

Painting the Model. The next step is the painting of the model, and this is best done with ordinary water colours, as shown in Fig. 9. It gives great scope to artistic expression, and when well done adds greatly to the effectiveness of the model. In some cases it may be desirable to paint the wall surfaces before they are erected, but the writer finds by experience that the happiest results are derived from the final painting of the model as a whole, as a better judgment of the effects is then obtained, and the relative colour values and strengths can better be controlled. During this time the model remains on the wooden base, as this prevents the card buckling and so distorting the model; but when all is finished the wooden base is abandoned, and the card base embellished with grass or shrubs, according to its purpose.

Representing Grass, Trees, Water, etc. The best way to represent grass is to use some of the wonderful green flock papers made by Sanderson & Sons, of Berners Street, London, W. This has simply to be cut to the desired shape and pasted to the base; it gives a perfect representation of a well tended lawn.

Commercial model makers use other materials, but the flock paper is by far the best for the novice. Most small domestic models appear to the best advantage when set in a small garden, with a few trees and shrubs in the background. They are, however, the most difficult items to model in a realistic manner, but that it is possible is well shown by the magnificent work of Twining in the model illustrated in Fig. 4, where the different kinds of trees are apparent and also the treatment of the hedges. There is no wonderful secret method for making tree models; it is simply a matter of personal skill, and the novice can with care make a tolerable model from ordinary "loofah" as used for bath purposes. This is first cut or broken into small pieces of appropriate shape, and then teased with a small pair of tweezers as shown in Fig. 10, gradually fraying out the fibres and making them as fluffy as possible. The pieces are then dipped into Batik or similar green dye, and when dry are again teased and worked up as fluffy as

FIG. 10. FASHIONING THE LOOFAH PREPARATORY TO MAKING MODEL TREES

possible. These pieces are then built on a twig of suitable shape, and stuck thereon with a trace of adhesive. When finished the tree is pushed into a hole in the base and secured with adhesive. Shrubs and hedges are dealt with in the same way, and finally the whole is relieved with little touches of other greens and yellows, to avoid the monotony of the uniform green imparted by the dyeing process.

Conventional and practical methods for the representation of other common features are the following. To model a roadway, first make a card base with a curvature to represent the camber, paint it a dull brown, and apply a sprinkling of very fine sand. Tar paving is well modelled by a strip of fine emery paper, pasted in position, and edged with grass or a strip of card painted to represent a curb.

Water is modelled in several ways, small ponds and ornamental water by the use of mirror, edged with representations of rockwork and reeds, the latter made from thin dry grass suitably dyed.

Another effective treatment is to set a piece of plain glass over a recess in the model, the latter sanded and modelled to represent the bottom of a river. Sometimes a few smears of paint on the underside of the glass add to the general effect.

Rough casting is shown on small models by stippling with nearly dry process white, and on larger models by coating the surfaces with oil colours, and sprinkling with Fuller's earth or finest plaster.

Window sills, cornices, and other projecting parts are best built up with strips of thin cardboard of appropriate widths, and then fashioned as necessary with the point of a sharp knife or a specially prepared plane.

One of the great charms of architectural modelling, as a hobby or pastime, is that it opens a new field for self-expression, and enables the devotee to retain a delightful and permanent memento of constructive skill and ability.

SPECIFICATIONS AND QUANTITIES

By Wilfrid L. Evershed, F.S.I.
Chartered Quantity Surveyor

LESSON III

SPECIFICATIONS (*contd.*)

TYPICAL PARAGRAPHS

The student can now commence the actual work of writing a specification, and will head it thus

SPECIFICATION OF WORKS required to be done in the erection and completion of a house, at John Street, Smithtown, for A. B. Cee, Esq., in accordance with the drawings prepared by and to the satisfaction of

Messrs. Dee and Ese, Esq., F.F.R.I.B.A.,
900 Fore Street,
January, 192 .. Smithtown

PRELIMINARIES AND GENERAL

Contract. The form of contract will be that agreed between the Royal Institute of British Architects and the National Federation of Building Trade Employers of Great Britain and Ireland, dated, 192 .

Site. The site is situated in John Street, Smithtown, and adjoins the property known as "Brookwood"; the road is a public highway and the nearest station is Smithtown, about one mile away.

Possession of the site will be given immediately upon signing the contract.

The soil is believed to be gravel, but the contractor is advised to visit the site and satisfy himself upon this.

If approved by the architect the gravel and sand excavated may be used by the contractor.

Completion. The whole of the works must be completed and handed over within 26 weeks of the order to commence, or pay the building owner the sum of £5 per week as ascertained and liquidated damages.

Drawings. The drawings comprise

No. 1	¼ in.	scale	plans.
,, 2.	¼ in.	,,	sections.
,, 3.	¼ in.	,,	elevations.
,, 4.	½ in.	,,	details.
,, 5.	in.	,,	block plan of site and drains.

And such other details as will be supplied from time to time.

Tools, Tackle, etc. The contractor is to supply all tools, tackle, and plant required for the due and proper completion of the work, and remove same at the finish of the contract.

Sheds, etc. The contractor is to provide all necessary storage sheds, mess rooms for workmen, and all attendance in connection therewith, and remove and make good any damage at the completion of the work.

Sanitary Conveniences. The contractor is to provide proper sanitary convenience for the use of workmen and others engaged upon the work, keep same in clean and sanitary condition, and remove and make good any damage on completion of the work.

Hoarding. Erect a close board hoarding along the front of the site next roadway, provide all necessary access doors, fans, planked footways and railings, all to the satisfaction of the local authorities, and remove and make good any damage on completion.

EXCAVATOR AND CONCRETOR

Clear Site. Allow for clearing the site of all shrubs, trees, or bushes, properly grubbing up the roots, and carting away or burning rubbish.

Surface Digging and Filling. Remove vegetable soil 6 in. deep, and wheel and deposit it at spot where marked on site plan. Use earth for filling where required to make up finished levels, and cart away superfluous earth; made-up soil to be well rolled with a heavy roller to finished surface.

Trench Digging. Excavate for trenches to the depth shown on drawings, and of the following widths: for 9 in. walls, 2 ft. 6 in. wide; for 14 in. walls, 3 ft. 3 in. wide. Level and consolidate earth at bottom.

The bottoms of foundations are to be approved by the architect before the concrete is laid.

Filling-in. All trenches to be filled in as soon as walls are above ground level. All filling is to be well punned in layers, and watered when so directed.

Pipe Trenches. Excavate for all water and drain pipes, and fill in and pun over same as before directed.

Surplus Earth. All surplus earth from trenches is to be removed and carted away.

Cement. The cement is to be British of approved manufacture, and to comply with the requirements of the latest specifications of the British Engineering Standards Committee, and if required by the architect a certificate to this effect is to be supplied with each consignment.

Lime. The lime is to be freshly burnt grey stone lime, from an approved manufacturer, finely ground, and free from impurities.

Aggregate. The aggregate is to be clean, hard-broken bricks, stone or ballast, to pass 2 in. ring.

Sand. The sand to be clean and sharp, and either fresh water or pit sand. No other sand will be allowed to be used. It must be free from clay, loam, dirt, and impurities, and washed or screened as necessary.

Concrete. The concrete is to be mixed on a clean boarded platform, by measure. That for foundations to be in the proportion one part of cement to three parts of sand and six parts of ballast, with a sufficient quantity of water; and the whole to be thoroughly incorporated and tipped into trenches.

BRICKLAYER

Mortar. The mortar to be composed of one part of lime to three parts of sand, to be mixed and prepared in quantities sufficient only for one day's consumption. Cement mortar to be prepared as required in small quantities, and to be mixed in proportion of one part of cement to two parts of sand.

Brick Walls. Build all walls throughout of the various heights and thicknesses shown and figured on the drawings, with all the projections, recesses, openings, etc., shown, in their proper positions. The footings of all walls to be of the number of courses shown, each course projecting 2¼ in. beyond the face of wall or footing immediately above same. To be built perfectly level, not to rake with the ground, but to be stepped up where the levels vary, as may be directed by the architect.

Brickwork in Cement. All brickwork in chimney stacks above roof level, all brickwork erected as piers standing alone, and such parts of the walls as are shown hatched on plans to be built in cement mortar.

Hollow Walls. The hollow walls shown on plans to be built in two half-brick thicknesses, with a 2 in. cavity, bonded together with wrought-iron galvanized ties, every 18 in. in height and 2 ft. 3 in. apart. The hollow and ties to be kept free of mortar droppings by haybands or battens lifted as work proceeds. The damp course to hollow walls to be laid at two levels, that over inner thickness one course above that over remainder. The perpends of bottom course to be left open.

Facings and Pointings. The facings to be carried out in English bond, the perpends carefully kept, and the joints pointed at completion with a neat struck weather joint in grey-tinted mortar.

MASON

Rubble-walling. The walls of .... to be built of local Kentish Rag from .... quarry, squared and brought up to level courses not more than 2 ft. apart, and with not less than one through stone to each superficial yard. The face of stones to be left natural face, and joints pointed with V-joint in mortar.

SLATER

Roofs. Cover the roofs with best Portmadoc slates, 20 × 10 size, of first quality, laid to 3 in. lap on battens specified in "Carpenter," and nailed with two 1½ in. copper nails to each slate.

Ridges. Cover the ridges with 2½ in. rubbed slate bird's-mouth roll and 6 in. by ½ in. sawn slate wing, all bedded and jointed in oil cement, and secured with brass screws.

TILER

Roofs. Cover the roof with hard, well-burnt, approved red tiles of local manufacture, entirely free from fire cracks and all other defects, laid to a 2½ in. lap, with two stout cast-iron tile pins to each tile and (bedded in hay) hung to battens; put tile and a half where required at edges and cuttings to assist the use of closers.

Hips and Valleys. Lay all valleys and cover all hips with purpose-made hip and valley tiles to course, and bond with roof tiling.

CARPENTER

Materials. The timber generally is to be good quality, sound, bright, Baltic or White Sea red (or as is generally termed, yellow), and to hold the full sizes specified.

It is to be free from shakes and large, loose or dead knots, waney edges and other defects, and to be properly seasoned; no discoloured sap and only a small proportion of bright sap will be permitted.

Roofs. If the roofs are fully and clearly shown on the drawings, it may be sufficient to say

Construct the roofs of buildings and the trusses of the sizes figured on the drawings. The rafters to be notched down upon purlins and cut true at the edges, and securely spiked thereto.

Gutters. Lay the gutters with 1¼ in. gutter boards and framed bearers to a fall of 1½ in. in 10 ft. with 2 in. cross rebated drips not more than 9 ft. apart. The gutters to be 9 in. wide at the narrowest part. Form deal dovetail cesspools, 8 in. by 8 in. and 6 in. deep, for outlet of gutters, with proper dished and rebated perforation for 4 in. pipe.

JOINER

Materials. The timber for joinery is to be selected first or second quality Swedish yellow or first quality

Petrograd, and is to be of approved brands, sound, clean, free from shakes, large, loose or dead knots, properly seasoned ; no discoloured sap will be allowed and only a small proportion of bright sap.

The oak is to be of English growth.

[*Note.* Japanese oak is sometimes allowed, but American oak is only considered as equal to good quality yellow deal.]

The oak for internal joinery is to be Austrian wainscoat.

The mahogany is to be either Honduras or Tabasco.

The teak is to be Moulmein or other approved East Indian.

[*Note.* For large panels in joinery American whitewood, basswood, or Columbian pine may be specified.]

Windows. The windows numbered .... on plans to have deal cased frames, having 6 in. × 3 in. sunk, weathered, and check throated sills grooved on underside, and to have 1½ in. × ¼ in. galvanized iron water bar bedded in white lead and let into groove in stone or brick sill, 1¼ in. pulley stiles, 1 in. inside and outside linings, ⅜ in. back linings tongued together, and the parting beads tongued to frame with 2 in. double-hung ovolo-moulded sashes in six squares each, with sash bars 1¼ in. wide. Sashes to be double-hung with brass-faced axle pulleys, Austin's flax lines, and iron weights.

All double-hung sashes to have strong brass sash-fasteners, p.c. .... each. Each lower sash to have a pair of brass sash-pulls, p.c. .... each. Sashes to have moulded horns, and deep bottom rail, with a beaded draught piece 4½ in. × 1 in. in place of bottom bead.

Doors. All doors numbered .... on plans to be 2½ in. folding doors, each leaf four panelled, the top and bottom panels to have raised panels, and all to be moulded both sides. The frames to be 4½ in. × 4 in. rebated, chamfered, and moulded, and the doors to be hung thereto with one and a half pairs of 4 in. wrought-iron butts to each leaf. Put two 9 in. wrought-iron barrel bolts and a night latch, p.c. 10s. each. These doors to have 6 in. × 2½ in. architrave moulding, splayed at back for plaster. The pediment over door to be out of 2 in. stuff with moulded scrolls, as shown on detailed drawing.

Stairs. The stairs to have 1½ in. treads with rounded nosings and inch risers glued, blocked, and bracketed on two 3½ in. × 2 in. fir carriages, 1½ in. moulded outer string, 1½ in. moulded wall string, inch beaded apron linings, curtail step and veneered riser, 4 × 4 square framed newels, moulded handrail out of 3½ in. × 3½ in. selected wainscoat oak, 1½ in. deal turned balusters housed to string and handrail. The newels to be wrought below landings, and turned as pendants 6 in. long. The wainscoat to be twice oiled with linseed oil at completion.

FOUNDER AND SMITH

Eaves Gutter. The eaves gutter to be properly bolted together in red-lead and fixed with galvanized mushroom-headed screws to the woodwork. All eaves gutters to have outlets cast on, and such stopped ends, angles, and other fittings as may be required. All outlets in eaves gutters to have strong galvanized iron wire domes.

Rain-water Pipes. The rain-water pipes to be placed where shown on the drawings, and to be 3 in. internal diameter, fixed to stand 2 in. clear of walls with clips and bolts. The heads of rain-water pipes to be of selected patterns, p.c. 10s. each. Each rain-water pipe to have any necessary offset or plinth bends, and shoe at foot.

HOT-WATER FITTER

Hot-water Supply. The domestic water supply is to be fitted up on the cylinder system in accordance with the following details, and is to be tested to the satisfaction of the architect before being approved.

Boiler. The boiler is to be a welded wrought-iron boot boiler .... in. metal, to hold .... gallons, properly set at back of range on firebricks to form flue under and at back of same, and is to be provided with manholes having cast-iron plates and screws. Particular care is to be taken that the manhole covers are absolutely water-tight.

Cylinder. The cylinder is to be a galvanized wrought-iron hot-water cylinder to hold .... gallons, of .... in. plate, with wrought-iron manhole plate bolted over the manhole with gunmetal bolts, tapped and screwed with inside strengthening plate. The cylinder to be fixed in kitchen in position where directed on strong T-iron brackets, built into the wall. It is to be covered with an approved asbestos composition lagging, finished smooth and prepared for painting, and having necessary dishing to manholes.

Pipes. All the pipes for hot-water work to be wrought-welded, galvanized steam pipes, fixed 1 in. free from wall with steel clips screwed to deal, provision being made for expansion and construction. No elbows but bends only are to be used.

The primary flow and return between boiler and cylinder to be 1½ in. pipes, the main circulation pipes 1¼ in. ; the supply to bath to be 1 in., and to the lavatory basins and sinks ¾ in.

The cold-water supply to be brought from storage tank in 1 in. water tube.

In fitting pipes to boiler and cylinder, special care is to be taken that the boiler is fixed level, and that no pipes project into the interior of either the boiler or cylinder. The boiler is to be tapped and screwed for pipes, which are to have back-nuts screwed on outside.

(F. R. Yerbury)

CHURCH AT SALAMANCA

HISTORY OF ARCHITECTURE

By Thomas E. Scott, A.R.I.B.A.

LESSON IV

GREEK ARCHITECTURE

CONSTRUCTIONAL METHODS

One of the finest qualities of Greek architecture is its truthfulness. The Greek builders accepted the limitations of the materials available, and set out to use them faithfully, making each feature do that which it appeared to be doing; never was there any deception.

Materials. The materials used by the Greeks were marble, stone, timber, bricks, and terra-cotta. Of these, the timber has decayed, and

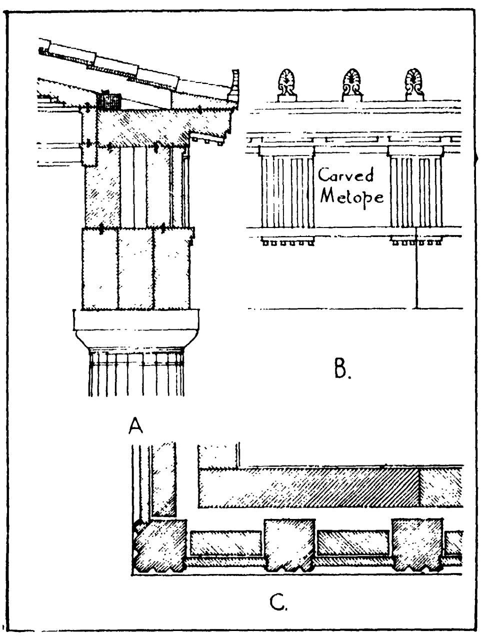


Fig. 19. The Construction of the Greek Doric Entablature
A = Section through Entablature. B = Elevation
C = Plan through frieze

the bricks, which were sun-dried, have not stood the test of time; terra-cotta ornaments have been found, and are to be seen in many museums.

Most of the temples in Greece were built of marble, the best known being Pentilic from Mount Pentilicus, near Athens. A grey marble was frequently used for paving and the stylobate, also as a foil to the sculpture in friezes.

In the colonies, a type of limestone was generally used. Here, in order to produce a fine surface consistent with the delicate mouldings in which the Greek delighted, important

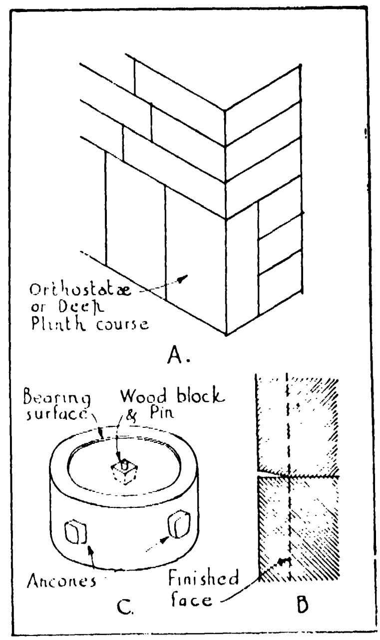


Fig. 20. Masonry Details

surfaces were usually covered with a thin layer of marble dust stucco. The resultant finish was hardly distinguishable from marble.

Walls. These were usually built of big blocks of stone without mortar. The bottom course was usually higher than the remainder (Fig. 20, A). Joints were finely worked, but there does not appear to have been any real bond; metal cramps were sometimes used in thick walls. It appears from remains that surfaces were not finished until the walls were built, when the last $\frac{3}{8}$ in. or so was dressed off, but many buildings never had this final finish (Fig. 20, B).

Columns were sometimes monolithic (of one stone), but usually consisted of a number of drums, or sections. These were first roughly shaped, with *ancones*, or projections, left on for hoisting. The inner part of the bed was sunk, and the drums were revolved on one another or on sand so as to produce a fine joint (Fig. 20, C). Flutes were worked afterwards when the column was built.

The Lintel. This was usually a single stone, but in larger temples two or three stones were used side by side. It will be appreciated that the spacing of columns was determined largely

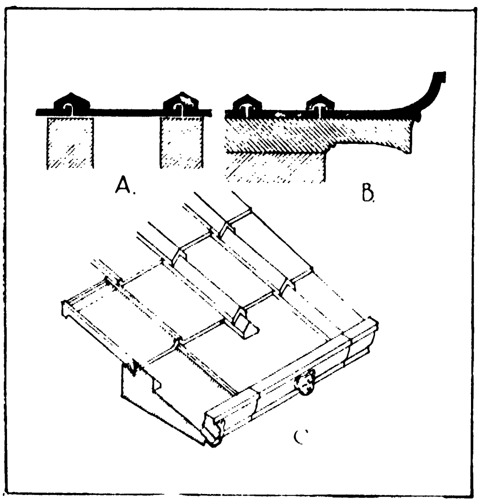


Fig. 21. Details of Roof Tiling
A — From Bassae. B — The Parthenon. C — Diagram showing arrangement of gutter

by the spans over which stone lintels could be used with safety.

The Frieze. This was the middle member of the entablature. In the Doric order, the triglyphs carried the cornice, and the carved metopes were loosely fitted so as to avoid cracking in case of settlement.

The Cornice. This was sometimes of a harder stone, and was built up as shown in Fig. 19.

Roofs. These were probably constructed of timber, of which no traces remain. The roof covering consisted of terra-cotta and marble tiles (Fig. 21). These were stopped at the eaves by *antefixae* (Figs. 22 and 27), which were carved or painted. In some cases, a gutter was formed, as in Fig. 21, C, with carved gargoyles, through which the rain-water ran off.

Ceilings over the outer passages, or ambulatories, were of stone or marble, and were deeply coffered, while those inside the building were of similar design, but constructed of timber, and painted.

THE GREEK ORDERS

Those forms of construction which were evolved out of the use of the simple column and lintel are known as the *orders*; they were

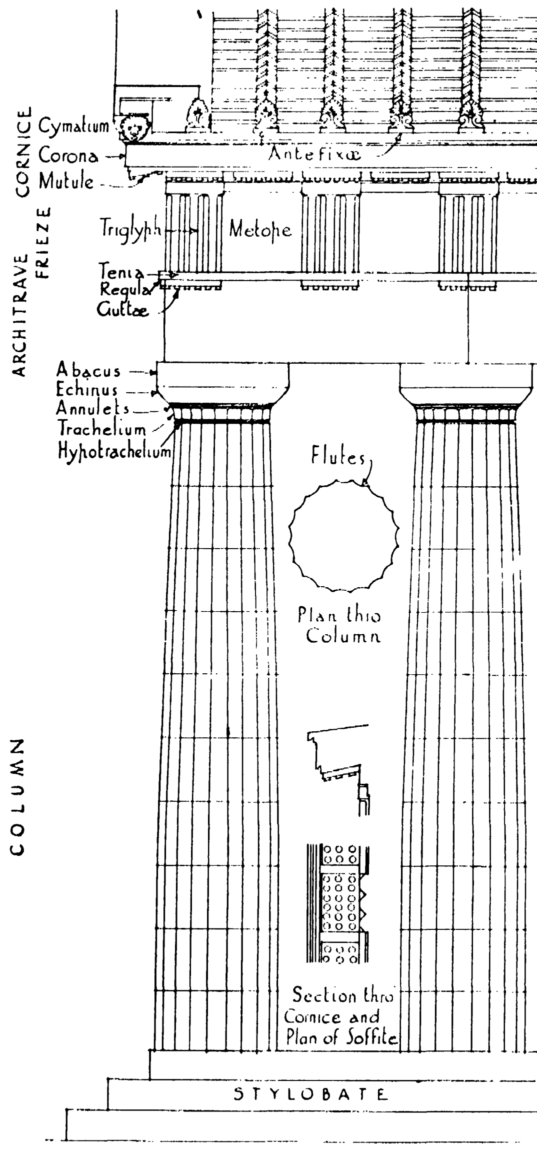


Fig. 22. The Greek Doric Order

developed to a state approaching perfection by the Greeks. The oldest was the Doric order, which many authorities have attempted to trace back to an Egyptian prototype, while others ascribe its form to the influence of timber origin. These theories are interesting, but it appears probable that the Doric order was the result of the normal development of building in stone, with the refinements of which it is known that the Greeks were capable.

The Doric Order. This is essentially the typical Greek order (Fig. 22). The column, which is from four to six-and-a-half diameters high, has no base, but stands upon a platform, usually of three steps, called a *stylobate*. There are a number of channels in the length of the column, known as *flutes*, ranging from twelve to twenty-four in number, twenty occurring in

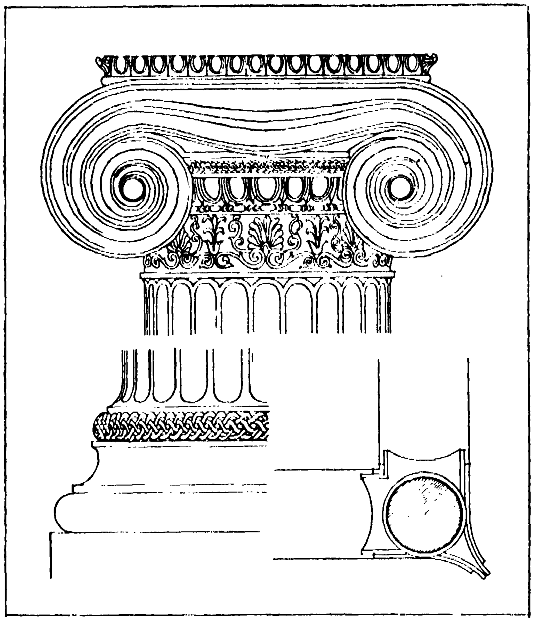


FIG. 23. CAPITAL AND BASE
From the North Porch of the Erechtheion at Athens. The diagram shows the method of treating the angle capital

the best examples. The column is tapered, diminishing to about two-thirds or three-fourths of its diameter at the top. The sides are usually curved in a convex manner, known as the *entasis*. This is a correction of an optical illusion which makes straight sides appear to curve inwards. At the top of the column is a *capital*, consisting of an *echinus* and an *abacus*. The former is circular on plan, boldly curved in profile in early examples, tending to be straighter in later work. The abacus is a square slab upon which the lintels rest. At the lower part of the capital are a number of fillets, known as *annulets*; below, on the lower edge of the block of stone forming the capital, is a splayed groove called the *hypotrachelium*, and the band between, the *trachelium*.

The **entablature** is about one-third the height of the column, and consists of three parts—*architrave*, *frieze*, and *cornice*. The architrave is the lintel proper, and has one vertical face with a flat moulding at the top called the *tenia*; a small member known as the *regula*, with six small *guttae*, occurs at intervals under each triglyph.

The **frieze** contains *triglyphs* and *metopes*, regularly spaced, the former occurring over the columns and the centres of the bays; at the corners of the building the frieze ends with a

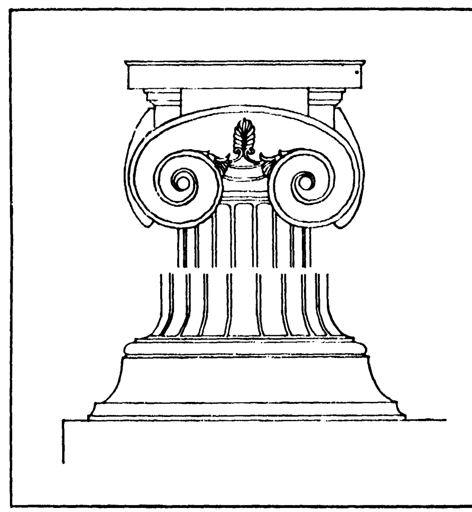


FIG. 24. CAPITAL AND BASE
From the Temple of Apollo Epicurius at Phigaleia

triglyph, the end columns being consequently more closely spaced than the remainder. The metopes usually contain sculpture.

The **cornice**, or crowning part, consists of a projecting stone, forming an eaves, on the underside of which are flat projections known as *mutules*, usually decorated with rows of guttae.

The Ionic Order. This order is chiefly distinguishable by its scroll or volute capital (Figs. 23 and 24), which seems to have some connection with the spiral forms which were used by the Egyptians and Assyrians.

Columns are usually about nine diameters high, including the capital and base, and as a rule have twenty-four flutes. These are separated by fillets, and not by arrises as in the Doric order. Bases are moulded, and consist usually of an upper and lower torus separated by a scotia and fillets; examples are shown in Figs. 23 and 24. Capitals consist chiefly of a pair of spirals or volutes, with a shallow abacus. They were, in many cases, beautifully enriched with carving.

The **entablature** consists of three members, as does that of the Doric order; it varies in height, but is usually about one-fourth of the height of the column. The architrave is usually subdivided into three parts, with an enriched moulding at the top. The frieze is usually plain, but in some cases is decorated by a continuous band of sculpture.

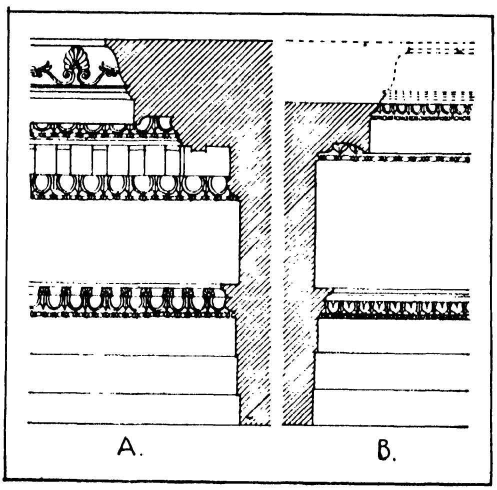


FIG. 25. GREEK IONIC ENTABLATURES
A = Temple of Minerva Polias, Priene. *B* = The Erechtheion, Athens

The **cornice** has no mutules, but rests upon a bed mould, which frequently includes a series of square projections known as *dentils* (Fig. 25).

The Corinthian Order. This order was not developed to the same extent as those previously referred to. The chief characteristic is the capital, which is an elaboration of the Ionic order, but deeper; see Fig. 26. An interesting variation from the Temple of Winds is illustrated in Fig. 10.

PEDIMENTS

An important feature which was evolved by the Greeks is the **pediment.** This is the name given to the gable at the end of the building, which is formed by carrying up the cornice to conform to the slope of the roof. An additional member—the *cymatium*—is included in the pediment, and returned round the angle and stopped, as in Fig. 21. In some cases, this member was formed by the end tile (Fig. 21, B).

The triangular space enclosed (the *tympanum*) was the focal point in the design, and frequently contained sculpture, those on the Parthenon being particularly interesting examples.

The **anta** (plural, *antae*) is a form of pilaster, used at angles, and against walls, to support the end of an entablature. The proportions, bases, and capitals are usually different from

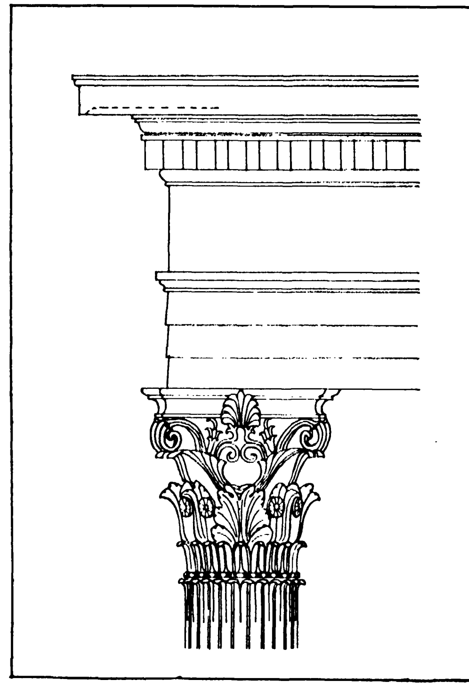


FIG. 26. THE GREEK CORINTHIAN ORDER
From the Choragic Monument of Lysicrates, Athens

those of the orders; an anta capital from the Erechtheion is shown in Fig. 27.

GREEK MOULDINGS AND ORNAMENT

Mouldings. Greek mouldings were refined and delicate, possible in a country with a sunny climate, where every subtle curve had its effects of light and shade, and capable of execution in the fine-grained marble which was generally used. The profiles of the mouldings were usually free curves approximating to conic sections, such as ellipses. Typical mouldings and their enrichments are given in Fig. 27.

Ornament. This was very refined in character, and was based chiefly on the acanthus leaf and the scroll. The former was derived from a plant which grows wild in Southern Europe; there are two varieties, one with a very pointed leaf, and the other much broader. The former is the one used in Greek work, while the latter found favour with the Romans. A very much used ornament was the *anthemion*, which was employed on the antae at the Erechtheion. Among other enrichments used were the *guilloche*, which decorates the base in Fig. 23, the *bead and reel*, and those shown in Fig. 27.

Sculpture. Greek sculpture was undoubtedly the finest ever produced. Perhaps the best was that by Phideas at the Parthenon. The extreme thoroughness of the work is illustrated in the groups in the pediments of this building, where the figures, though seen only from the front, are almost detached, and are perfectly modelled all round. Words cannot adequately describe the beauties of this work; it represents Greek art at its best, and has never since been equalled. There are many fragments and restorations in the British Museum which should be studied by all who desire to understand the wonderful perfection of Greek art.

Colour. From the few traces which remain, it seems certain that the Greeks decorated many of their buildings with colour. Mouldings and enrichments were painted, and coloured backgrounds provided for sculpture; sometimes whole buildings were painted, the colours used being strong hues of green, blue, red, and yellow.

The Greeks not only exercised great care in the execution and detail of their work, but showed great ingenuity in adjusting proportions so as to correct optical illusions. *Entasis*, to which reference has been made; the raising of the entablature and stylobate towards the centre to prevent the appearance of sagging; the close spacing of end columns, producing an added appearance of stability, and the inclining of columns inwards in a pyramidal form for the same reason; the slight thickening of angle columns because they would appear slender

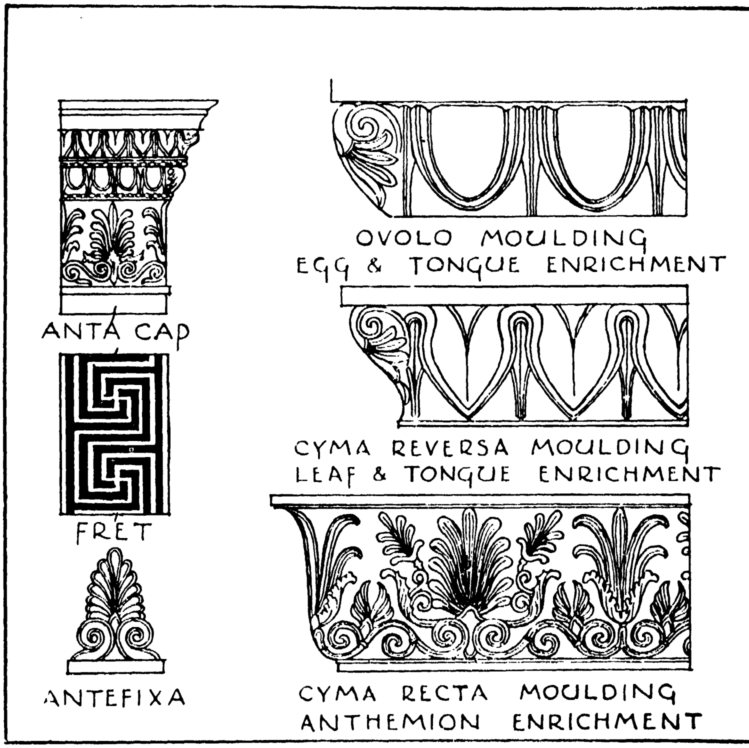


Fig. 27. Greek Mouldings and Enrichments

when silhouetted against the sky; these were typical refinements which, in the hands of such skilled designers, produced an architecture which is the perfect expression of a nation's ideals.

For sincerity and culture it has never been surpassed, but admiration must be tempered with a discreet appreciation of the conditions which produced it, and the realization that although the great works of the Greeks may inspire all who see or study them, they are not models suitable for reproduction *en masse* in this twentieth century.

JOINERY

By T. Corkhill, F.B.I.C.C., M.I.Struct.E., *Double Medallist*

LESSON V

MEASURING AND SETTING-OUT TOOLS

No matter how carefully the joiner may finish a job, it is useless unless it is accurate with regard to size and shape. To this end it is necessary to have accurate tools for setting-out. A square which is not true will upset the most careful calculations, and a "blind" or inferior rule will get the owner into trouble sooner or later.

Rules. A *four-fold* rule is shown in Fig. 73. The advantage of this type of rule is that it is convenient for the pocket, and is not so liable to to be broken as the *two-fold*. The latter is only jointed once, hence it is 12 in. long, which makes it inconvenient for the pocket. The bench joiner generally prefers a two-fold because it is better for using, and usually more accurate for measuring distances above 6 in. long. The usual length is 2 ft., but many joiners, especially outside hands and foremen, prefer a 3 ft. rule, which is always a four-fold. It is very convenient for door openings, etc.

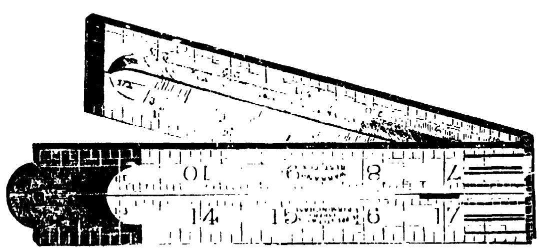


Fig. 73. Rule

All joiner's rules are subdivided into $\frac{1}{8}$th and $\frac{1}{16}$th inches, on the outer edges. The better type of rules have the inner edges graduated, as in Fig. 73, for the scales common to the building trades. The knuckle, or middle joint, is marked for setting the legs of the rule to various angles. Many rules have brass lined edges, this strengthens the rule and prevents it from going "blind," or difficult to read so quickly.

Subdivisions less than $\frac{1}{16}$ in. are not used by the joiner. He usually refers to a measurement which varies from $\frac{1}{16}$ in., as *bare* or *full*. If the measurement were not quite $3\frac{5}{16}$ in. he would say $3\frac{5}{16}$ in. full, or bare, as the case may be; or *three and five and a half sixteenths* if it were $3\frac{11}{32}$ in.

The Use of the Rule. For accurate measuring the rule should be applied on its edge, to avoid *parallax*, as shown in Fig. 74. This illustration also shows the method of dividing a board into several equal parts. If the board has to be divided into five equal parts, and it is less than 10 in. wide, the 10 in. mark on the rule is placed to one edge of the board, and the end of the rule to the other edge. The board is then marked every two inches of the rule to divide it into five equal strips. If the board is more than 10 in. wide the rule is opened and the 15 in. mark placed on the board edge, then 3 in. divisions are pricked off. The method can be applied to any width of board and any number of divisions. When the divisions have been found the rule is used as a gauge, by applying a pencil to the end of the rule, and using the fingers as the head of the "gauge."

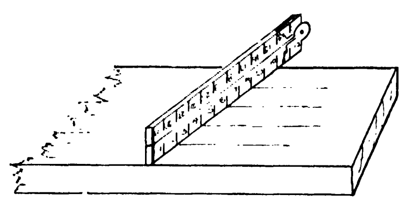


Fig. 74. Use of Rule

Try-square. Fig. 75 shows the usual type of joiner's *try-square*. It consists of a steel blade *b* securely riveted in an ebony stock *s*, which has a brass face to prevent wear. A brass plate *r* on each side of the stock receives the rivet ends. It is essential that the square be perfectly accurate, and it should be tested occasionally. The best way of testing the square is by applying it to a board with a straight edge, and squaring lines with both the inner and outer edges of the blade; then by turning the square over, the accuracy is proved if the two edges of the square coincide with the lines. If the square is not quite *true*, it is better to file the edges square to the stock, rather than to attempt to force the blade into accuracy.

The usual sizes of squares are 4 in., 6 in., 9 in., and 12 in. The joiner, however, very often requires a larger size, and usually makes a mahogany one with a blade about 2 ft. by 3 in.

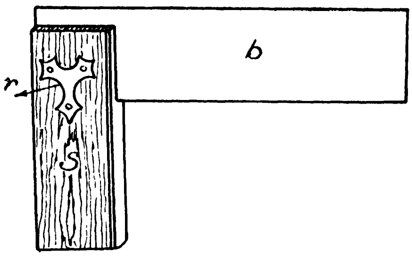


Fig. 75. Try-square

by $\frac{5}{16}$ in. and a stock about 1 ft. 6 in. by $2\frac{1}{2}$ in. by $\frac{3}{4}$ in. Fig. 76 shows the usual method of making a wooden square; the blade is glued in the stock and fixed square by the wedges *w*. Any variation afterwards should be corrected by planing the edges of the blade.

There are several variations from Fig. 75. The *mitre square* has the end of the stock cut to an angle of 45° so that the blade will register either 90° or 45°. The *adjustable square* has a

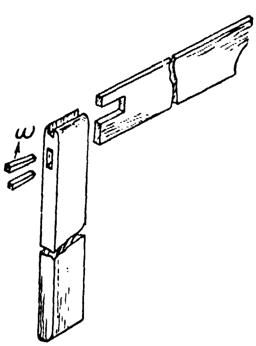


Fig. 76. Wooden Square

sliding blade, and some squares have their blades graduated as rules. None of these squares, however, are popular with the joiner, who usually prefers the type shown.

Bevels. These are used for setting out angles other than right angles. Fig. 77 shows the usual type, which consists of a sliding blade *b*, a stock *s*, and a screw *a*. The screw is to fix the blade after adjusting it to the required angle. The materials are the same as those used in the try-square.

Gauges. The most common form of gauge is the *marking* gauge shown in Fig. 78. It consists of a stem *a*, a head *b*, a marking point, or spur, *s*, and a thumbscrew *t*. The stem and head are usually made of beech, and the screw of boxwood. The spur is filed to a pin point and projects out of the stem about a full $\frac{1}{16}$ in. The

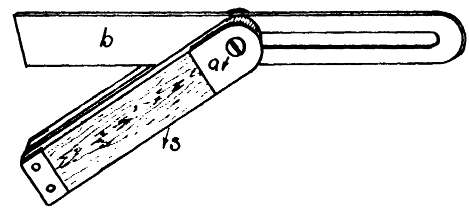


Fig. 77. Bevel

head is adjusted to the required position and then fixed securely by the screw.

To make a good line with the gauge, it is necessary to press the head firmly to the edge of the stuff, and to let the corner of the stem, as well as the marking point, rest on the stuff. The gauge is then pushed away from the operator to make the gauge line. Unless the gauge is used in this way, the point is apt to follow the grain instead of keeping parallel to the edge of the stuff. It is advisable to make a light mark on the first stroke and to repeat the operation if a heavy gauge mark is required. The gauge

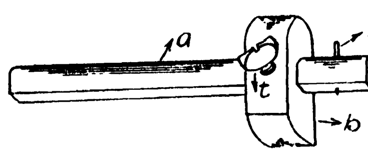


Fig. 78. Marking Gauge

mark can be made more visible by running a pencil along it. To *set* the gauge to the centre of the stuff, first loosen the screw and set the head approximately to the correct position, then loosely tighten the screw. The point is lightly pricked into the stuff from one side, and then the gauge is applied to the other side. If the point coincides with the first mark it is in the centre, and the stuff can be gauged. If there is a variation, the stem is tapped on the bench to adjust for the variation and then the screw is tightened up.

Mortise Gauge. There are many varieties of mortise gauges, but the essentials are the same in all of them. Fig. 79 shows a common type;

the chief variation from the marking gauge is the double spurs *c*. The outer spur is fixed, but the inner one can be adjusted by the screw *a* in the end of the stem. Very often this is a small thumb screw projecting from the end of the stem. The spurs are set to the thickness of the mortise. The head *d* is then adjusted in the same way as for the marking gauge, for the position of the spurs on the stuff. The screw *b* fixes the head to the stem. A projection on the

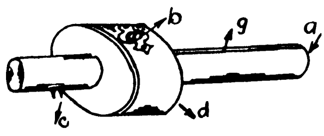


FIG. 79. MORTISE GAUGE

head runs in the groove *g* to prevent the head from turning round. To set the points to the centre of the stuff, proceed as described for the marking gauge. In this case the two points have to coincide. The illustration shows a gauge in which the stem is cased in brass, and the ebony head is faced with brass.

Cutting Gauge. The cutting gauge, Fig. 80, is very similar to the marking gauge, except that the spur is replaced by a cutter. An enlarged view of the cutter *c* is shown separately. It consists of a piece of steel about $1\frac{1}{2}$ in. by $\frac{3}{16}$ in

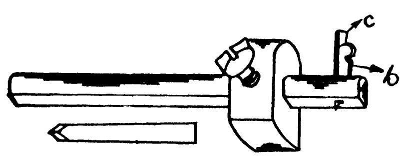


FIG. 80. CUTTING GAUGE

by $\frac{1}{16}$, sharpened on both sides to a point, and fixed in the stem by a wedge *b*. The cutting gauge is very useful for cutting through thin stuff, and for making small rebates. It requires careful handling to prevent the cutter from running with the grain.

Other Gauges. In many cases, such as chamfers, the sunk marks made by the spur of the marking gauge are not permissible; so the joiner usually bores a hole in the stem, at the opposite end to the spur, to receive a pencil. An alternative method is to cut a rebate in the end of a small piece of wood, to the required size, for a pencil gauge. This is not convenient except for small widths; and it also requires both hands, one to run the piece of wood and one to use the pencil. It is very convenient to round one face of the head of the marking gauge for gauging concave circular work. When this is done the head is taken off and reversed, to suit whichever side is required. There are many combinations and variations of the gauges described above, but they are not favoured by the joiner. A *grasshopper gauge* has a long fence and is used with a pencil for gauging in hollows for circular work. It is mostly used in handrailing.

Marking Knife. This is a very useful tool for accurate setting-out. The pointed end, Fig. 81, is used for pricking off distances and is more accurate than a pencil. The knife end is sharpened on both sides to a cutting edge, and is used for *cutting in* the shoulders of rails for framing, and for stair treads, etc., for accurate sawing. The use of the cutting edge is one of the points of controversy amongst joiners. It certainly assists in accuracy, but it can be very

FIG. 81. MARKING KNIFE

destructive in the hands of a careless setter-out. Once the mark is made it is very difficult to remove, except by planing a large amount of stuff away; hence the joiner must be sure of the position before using the knife.

MISCELLANEOUS TOOLS

Screwdrivers. The usual pattern of joiner's screwdriver is shown in Fig. 82, although many prefer the *cabinet*, or spindle, screwdriver. Neither has any advantage over the other for utility, except that the one shown in the illustration is stronger than the spindle type. To prevent the blade turning in the handle, the shoulders *g* are let into the ferrule, and the tang is wider than for the chisel.

The American *spiral* screwdriver is becoming very popular in this country. The blade *b*, Fig. 83, is made to revolve in either direction by simply pushing down the handle. It is removable, three different sizes of bits being supplied with the tool. The slide *s* is adjusted so that the blade may turn right or left handed, or remain rigid as an ordinary screwdriver. It is extremely useful for driving in a quantity of light screws; but it is hardly suitable for heavy work.

The *ratchet* screwdriver shown in Fig. 84 can be made to turn right or left hand or remain rigid, by adjusting the slide *s*.

Hammers. The *Warrington* pattern, Fig. 85, is most common amongst joiners, but the *claw* hammer shown in Fig. 86 is a favourite with the carpenters. The *cross pane*, or peen, *p* in Fig. 85, is useful for working in corners and for using as a lever, especially for levering back a nail which has bent over. The claw *c* in Fig. 86 is useful for withdrawing nails, and as a lever.

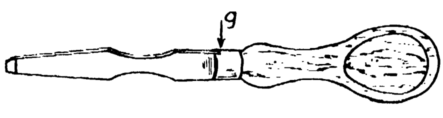


FIG. 82. SCREWDRIVER

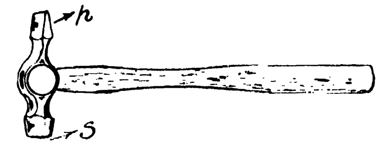


FIG. 85. WARRINGTON HAMMER

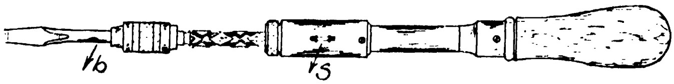


FIG. 83. SPIRAL SCREWDRIVER

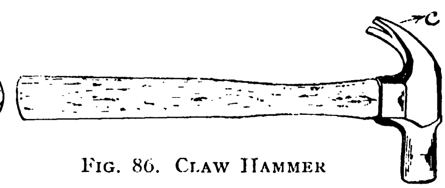


FIG. 86. CLAW HAMMER

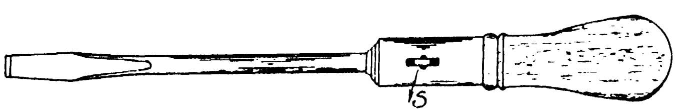


FIG. 84. RATCHET SCREWDRIVER

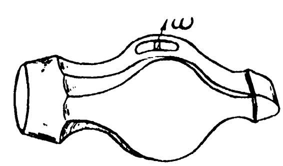


FIG. 87. HEAVY HAMMER

Fig. 87 shows the type used for heavy work, such as flooring, driving up framing, etc. They are sold by weight and may be obtained up to 3 lb. The shafts are made of ash or hickory, and are wedged as shown at *w* in Fig. 87. The shaft hole in the head is larger on the outside, so that when the head is wedged it will not fly off.

Using the Hammer. The shaft is about 10 in. to 12 in. long and it should be held as near to the end as possible to get the greatest effect from the blows. When using the hammer near glass or mouldings it is usual to slide the head along a try-square blade to prevent breaking the glass or bruising the moulding. This applies specially to nailing in panel mouldings, or glass beads to rough glass. If the glass is smooth the head can be slid along the glass. When driving up framing with the hammer, it is usual to place a piece of waste wood between the framing and the hammer to avoid bruising the stuff.

Pincers. The *Lancashire* pattern, Fig. 88, is the usual type. A convenient size is 8 in. or 9 in. long, because the easy withdrawal of a nail depends upon the length of the pincers. The action, when being used, is that of a lever, with the rounded part *f* acting as the fulcrum. If *pf* is eight times *nf* then the pull on the nail is eight times the power exerted on the handle. The surface of the stuff should be protected by a try-square blade or a waste piece of wood, to prevent the fulcrum from damaging the stuff.

Mallets. These are usually made of beech, Fig. 89, and are chiefly used for striking chisels and for knocking framing together. The head is mortised to receive the shaft, the mortise being bigger on the outside so that the shaft is passed through the head from the top. This prevents the head from flying off when being used. The striking faces taper a little towards the handle; theoretically they should taper to the axis of rotation when being used. The head is usually about 6 in. by 4½ in. by 3 in. thick. Many joiners prefer the metal head; this is a cast-steel head made to receive hardwood blocks for the striking faces, which can easily be replaced. The chief advantage of this kind is that it is less bulky, and at the same time it is heavier.

Compasses. Fig. 90 shows a pair of wing compasses generally used by the carpenter.

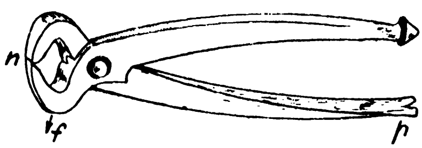


FIG. 88. PINCERS

They are chiefly intended for heavy work such as scribing mouldings to walls, and skirtings to floors. The wing *w* is riveted to the leg *a* and gives rigidity to the movable leg *b*, which is mortised to slide on the wing. It is then fixed in position by the screw *s*. This type is not suitable for bench work, where they are required

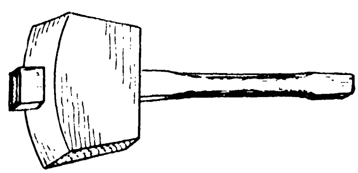


FIG. 89. MALLET

more as dividers than as compasses. A more useful type for the joiner has a sensitive spring adjuster, so that the " fixed " leg can be adjusted (within small limits) after fixing the movable leg with the thumb screw.

Trammel. When it is required to draw circular arcs, or to set out divisions, greater

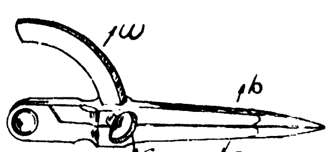


FIG. 90. COMPASSES

than the compass will allow, it is usual to employ the *trammel heads* shown in Fig. 91. The rod *c* may be any length, and it is usually made of hardwood. The *heads* are fixed on the rod at the required radius by the milled screws *a*. A piece of brass *b* prevents the screws from *biting* into the rod. One head is provided with a socket *p* to receive a pencil for describing arcs, etc. The heads may be obtained in a large range of sizes. They are usually about 6 in. long for joiner's work. A good substitute for the trammel is a wooden lath fixed at one end by a bradawl, or nail, with a pencil applied at the free end for describing circular arcs.

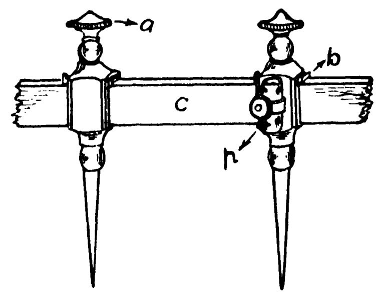
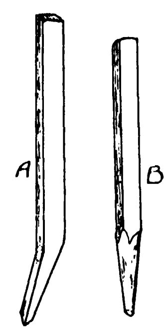


FIG. 91. TRAMMEL

Punches. A *handrail punch* is shown in Fig. 92, A; this is used for turning the round nut of a handrail bolt, when it is in position for joining together two pieces of wood. Fig. 92, B, shows a *nail punch* which is used for driving nails below the surface of the wood preparatory



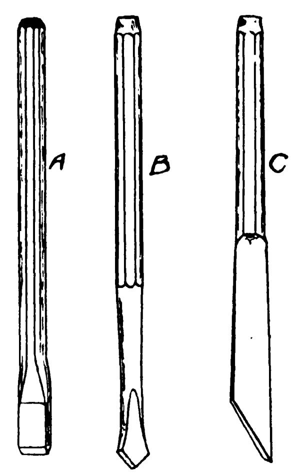


FIG. 92. PUNCHES FIG. 93. CHISELS AND DRILL

to *stopping* the holes. They may be obtained in various sizes, and may be square, octagonal, or circular. The latter variety is knurled so that it may be held securely.

Iron Chisels. Fig. 93, A, shows the usual type of *cold chisel*; it is made of octagonal steel and is used for cutting bricks, stone, concrete, iron, etc. A *plugging chisel* is shown at C;

this is used for raking out the mortar from the joints of brickwork, preparatory to driving in plugs.

Drills. The usual form of drill for making circular holes in brickwork, stonework, etc., to receive wooden plugs, is shown in Fig. 93, B. There are many other types, one of which is shown in Fig. 94. This is a *pipe drill* and is

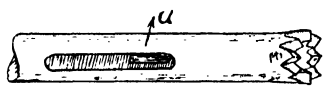


FIG. 94. PIPE DRILL

hollow for part of its length. The serrated, or jagged, cutting point enables it to cut rapidly into brickwork, if it is sharp. The slot *a* is to allow the dust to escape as it works up the hollow tube. The method of using the drill is to give it a circular motion whilst driving it with the hammer.

Spirit Level. Fig. 95 shows the usual type of carpenter's level. It is generally about 9 in. or 10 in. long for convenient carrying, but the

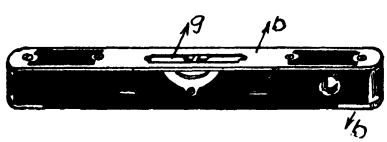


FIG. 95. SPIRIT LEVEL

longer it is the better it is for levelling. It is usually made of ebony, and well protected with brass, *b*. The glass tube *g* is *nearly* full of spirits so that a small air bubble shows through the glass. This air bubble rises to the highest point; and because the glass tube is slightly convex it shows in the middle of the tube when the tube is perfectly level. The purchaser should see that the bubble has a quick movement, is easy to see, and is not too big to register clearly.

When using the level, it is advisable to turn it *end for end* after taking one reading, and see if it registers the same. The level shown in the illustration has a small secondary tube at one end, at right angles to the levelling tube. This small tube enables the level to be used as a plumb rule. An ordinary level may be used as a plumb rule by resting it on the stock of a foot square, whilst the blade edge acts as the rule.

Plumb Rule. This is a straight and parallel piece of yellow pine, with a gauged line down

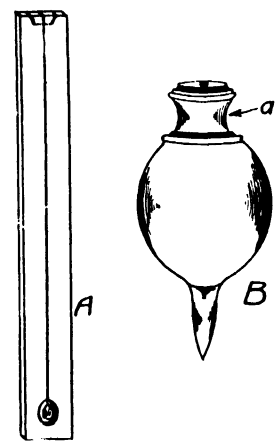


FIG. 96. PLUMB RULE AND BOB

the centre as shown in Fig. 96. The line is terminated by a hole sufficiently large to allow a *plumb-bob* to swing freely without touching the sides of the hole. The string which carries the bob is fixed at the top of the rule. Fig. 96, B, shows a brass plumb-bob; the top *a* is threaded so that it may be removed to pass the string through. The carpenter, however, generally makes his own. He makes a plaster mould round an existing bob and saws the mould in half. He then makes a pouring hole and an air vent hole, puts the two halves together, and pours molten lead in the mould. A piece of wire should be passed through the mould first, to leave a hole in the bob for the string.

BUILDER'S OFFICE AND ROUTINE

By R. F. Galbraith, B.Sc.

PART III

GENERAL OFFICE DUTIES

(contd.)

Costing Contracts. The cost of a particular contract is usually recorded in a special journal having columns for the following charges: Plant, general charges, materials, sacks, wages, sub-contracts, manufactured goods from the builder's works (see Fig. 3).

Date	Particulars	Fa	Plant	Sacks etc.	General	Wages	Materials	Sub.Contrs.	Manf. Goods	Total
	Factory London	B.7	107 10 -	231 4 -	127 - -	7,081 10 2	10,721 3 7	3,721 2 5	107 10 2	22,097 0 4
1926 June 6th	Davis & Co.	P.J. 59					1 5 11			1 5 11
" "	Cement Mark. Co	" 59		77 - -			221 - -			298 - -
" "	Wages	W.B. 20				237 16 3				237 16 3
" 10th	Brinsdown Join. Co	P.J. 60					46 7 6			46 7 6
" 11th	District Iron & S. Co	" 60					577 10 4			577 10 4
" 12th	Job 65	R.C.J. 27							79 8 5	79 8 5

Fig. 3

A small section at the foot of each page should be ruled in red and used to credit items removed from the job. The following points should be noted in using the above form of journal.

Only "plant" of a permanent character, such as ladders, poles, scaffold boards, machinery, etc., should be entered in the "plant" column. Shuttering, nails, wire, and such-like consumable stores should be listed under materials.

The value of sacks and other returnable packages should be entered under "sacks," and the credited value entered in the credit section when returned.

Insurance and special expenses should be entered under "general charges"; manufactured goods, such as joinery and stores, are entered from the prime cost journal.

Telephone Messages. The telephone plays an important part in a builder's office. Messages from outside jobs are frequently coming in, materials are missing here, a question there, a message from an architect, or some other matter that requires prompt attention. All messages should be recorded accurately, in a special telephone call book, showing the time received, and should be dealt with as soon as possible by the man dealing with the matter.

Postage Book. A record of all letters and telegrams dispatched should be kept in a postage book, the amount paid on each, together with a note as to the nature of the correspondence, e.g. letter, inquiry, O.H.M.S., etc., should be entered. The above are the main duties to be undertaken by the general office staff, but there are numerous other small items that must be carried out in addition to the typing of correspondence and other work. Insurance cards of workmen have to be stamped, list of workmen, with names and addresses prepared, unemployment returns to answer, etc.

SURVEYORS AND ESTIMATING

The duty of the surveyor and estimator consists of the preparation of estimates, the adjustment of variations, the preparation of valuations for payments and accounts, and the final adjustment of the contract price.

Estimates. When an estimate is required, bills of quantities should be sent to the builder in order to place all firms tendering on the same basis. The habit of sending drawings and specifications of work required to several builders and obliging them to expend money on preparing bills of quantities should be discouraged by refusing to tender for such work, unless the value is, say, less than £1,000, and only one or two firms have been invited to tender.

On the receipt of a set of bills of quantities, inquiries should be sent out for materials required and for work that is usually sub-let, such as structural steelwork, granolithic work, etc. The specifications clause detailed in the preambles of each bill should accompany each inquiry where they affect the quality of articles required, and an exact copy of the specifications and schedule should be sent when prices are required for sub-let work. The bills of quantities are then priced and the value of each item worked out and totalled. Each extension and cost should be checked; special care should be taken to see that a total which is transferred to a summary is not also carried forward to next page.

Variations. All variations on a job, whether additions or omissions, are measured and adjusted by the builder's surveyors in conjunction with the surveyors appointed by the building owner or architect. Normally, all variations would be ordered in writing by the architect, and care should be taken that written orders are obtained in cases where the contract provides " that no alterations or additions shall be made without a written order from the architect."

Day Work. Small jobs, such as alterations and repairs and certain items on large contracts, are done on a " day-work " basis. That is to say, the actual cost of labour and materials is charged with the addition of an agreed percentage to cover cost of tools, supervisors, profit, etc.; the percentage will vary from 10 to 20 per cent, according to the nature of the work.

Day work on a large contract should only be adopted when the work is of a very difficult nature, and where it would be impossible to arrive at a fair price without having the actual cost available. Generally, it pays better to " measure " a job and price the items than to execute it " day work."

Usually the time spent on day work is entered on a special sheet and vouched for by the owner, architect, or his representative.

Valuations for Payments of Accounts. On a large job, payments are usually required on account from time to time. A valuation, or statement, of the value of work executed is usually prepared by the surveyor, often in conjunction with the owner's surveyor. The bills of quantities should be used as the basis and the amount executed noted on the side. Extra work can be valued approximately, but no payments on account affects the final settlement of the job.

BRICKWORK

By William Blaber
Lecturer in Brickwork at the Northern Polytechnic, London

LESSON V

VARIOUS BONDS

Stretching Bond. This bond, Fig. 24, applies to walls a half-brick thick, such as sleeper or partition walls, and also to chimney stacks, where it is frequently termed *chimney bond.* The lap in this bond is 4½ in.

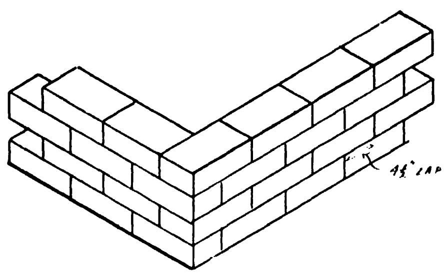


Fig. 24. Stretching Bond

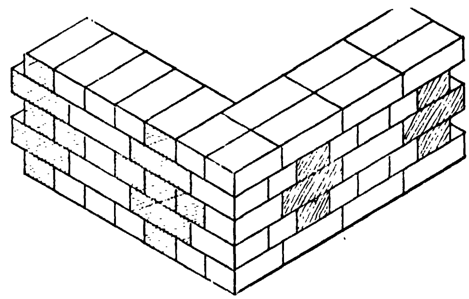


Fig. 25. English Cross Bond

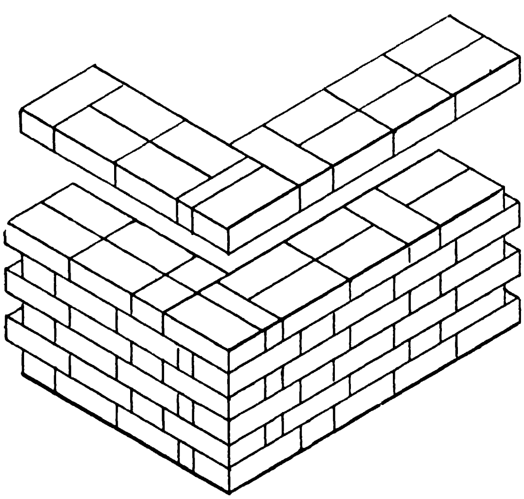


Fig. 26. Flemish Garden Wall Bond

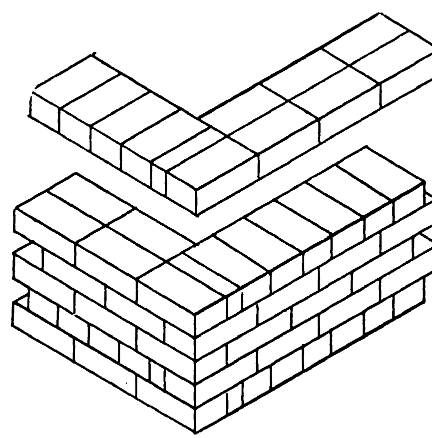


Fig. 27. English Garden Wall Bond

English Cross Bond. This is practically the same as English bond proper, except that in the stretching course a three-quarter bat is used on the quoin and the closer omitted, Fig. 25, or a header placed next to the quoin stretcher in every alternate stretching course. This arrangement with variations can be seen in many of the older examples of brickwork, where darker facing-bricks have been used to form diamond or trellis patterns. This is frequently known as *Dutch bond.*

Garden Wall Bonds. Where two fair faces are required in a 9 in. wall, a greater proportion of stretchers is used than in the recognized bonds. The types in general use are called English and Flemish *garden bonds,* but are sometimes given local terms, such as "Scotch" or "Sussex" bond.

Flemish Garden Wall Bond. Three stretchers are laid between the headers in each course, as shown in Fig. 26. As in Flemish bond proper, the header should come over the centre of a stretcher in the course below.

English Garden Wall Bond. Three courses of stretchers are built to every course of headers, the stretching courses being arranged with a $4\frac{1}{2}$ in. lap as in stretching bond, Fig. 27.

Both of the above bonds are deficient in strength, particularly the latter, which is likely

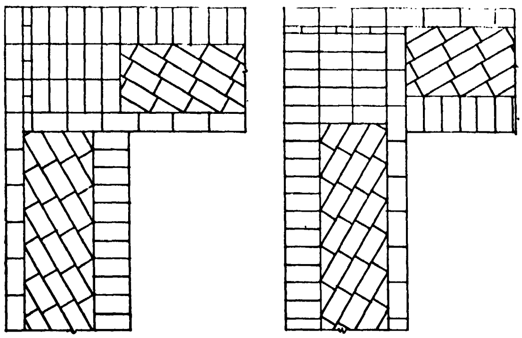


Fig. 28. Raking Bond

to bulge at the stretching courses, these having no tie across the thickness of the wall.

Raking Bond. This bond is used to strengthen thick walls longitudinally. The bricks in the interior of the wall are laid diagonally across the wall at an angle of about 30°, Fig. 28, or laid herringbone fashion, Fig. 29, the quoins being built in the usual manner. The angle of rake should be arranged to give the greatest number

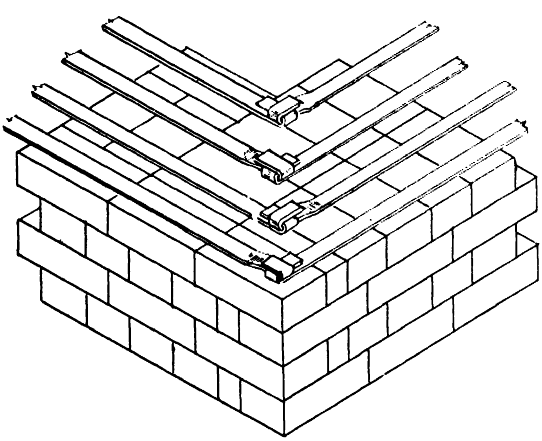


Fig. 30. Hoop-iron Bond

of full stretchers across the wall, with the minimum amount of cutting. These raking courses are arranged at intervals of from three to eight courses.

Herringbone courses are not generally used for walls less than four bricks in thickness.

Hoop-iron Bond. To reinforce walls in their length pieces of hoop-iron are built in between the courses at certain intervals lengthways along the wall, as shown in Fig. 30. Their ends are jointed to make them continuous. This system

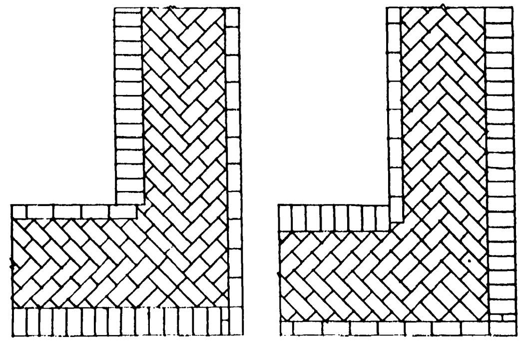


Fig. 29 Herringbone Courses

was introduced by Brunel, a civil engineer, about 1835. It is not much used at the present time, unless to strengthen the connection where a toothing has been left in a wall for future extensions.

Heading Bond. This bond, Fig. 31, is used for circular sweeps where stretchers would give the curve an irregular appearance, or, as the craftsman would say, " make the work hatch and grin."

Cavity Walls. In bleak and exposed situations subject to driving rain and snow, the external walls of bu'ldings are frequently built with a space in their thickness, usually $2\frac{1}{4}$ in. wide, to prevent penetration of dampness into

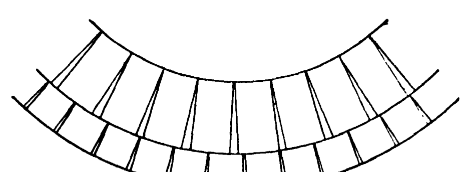


Fig. 31. Heading Bond

the interior of the building, Fig. 32. Near the sea, the spray carried by the wind deposits salt on the face of the walls, and this permanently attracts moisture from a humid atmosphere. A cavity ensures a more uniform temperature inside the building, and protects from decay any woodwork in contact with the wall.

In constructing hollow walls, the outside

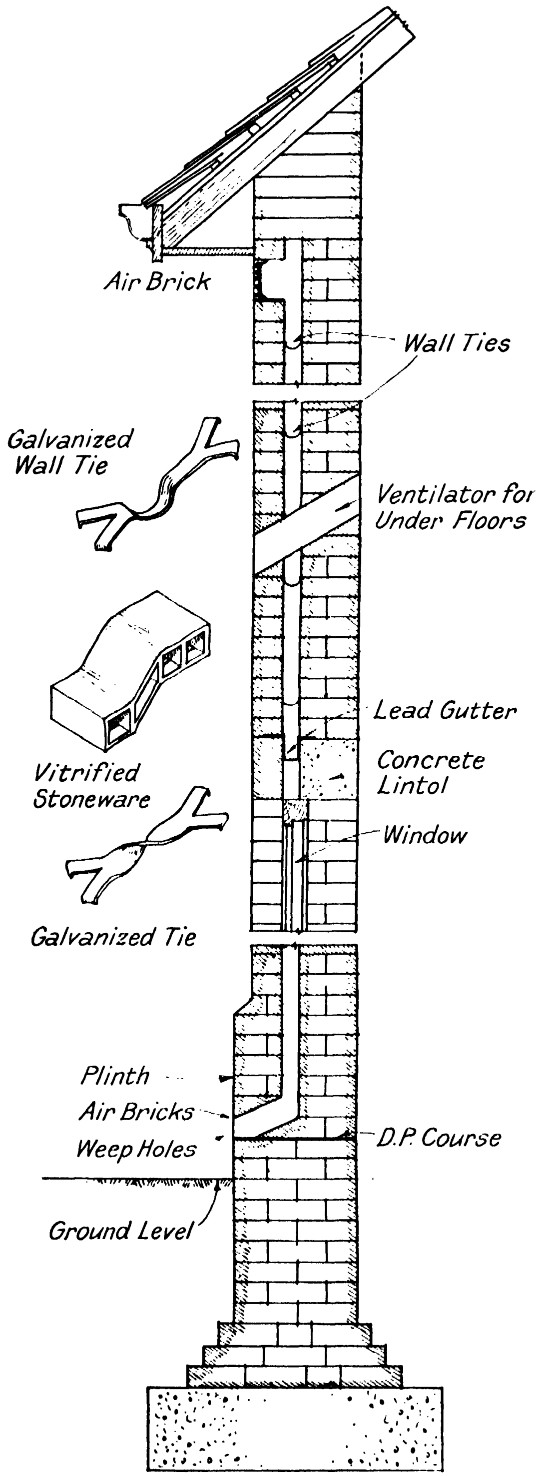


Fig. 32. Cavity Wall

portion should only be considered as a protecting skin, and not as any part of a load-supporting structure. The inside wall should be of sufficient thickness to carry the weight of floors and roof. The outer wall actually receives support from the inner, by the bond ties which are built in as the work proceeds. These may be specially made vitrified bricks, or cast-iron, wrought-iron, or wire-shaped ties as shown in Fig. 32, placed in rows about 1 ft. to 1 ft. 6 in. apart vertically, and about 3 ft. apart horizontally. Each row is set centrally between the row below, or, as often described, "chequer-wise."

The cavity must be well ventilated by inserting sufficient air-bricks just below the eaves of the roof, and at the base of the wall just below ground level. Provision must also be made for drainage of any accumulated condensed moisture, by leaving small weep-holes at the bottom of the cavity just above the damp-proof course. Gratings should be fitted to exclude vermin.

All floors should be ventilated direct from the atmosphere and not from the cavity. The usual method is to build in short lengths of pipe through the thickness of the walls, and sloping towards the outer face so as to convey no moisture to the inner wall. All window or door frames must be protected from falling moisture by building in a strip of lead in the shape of a small gutter, and extending sufficiently beyond each side of the frame so as to allow any water to drip clear of the woodwork.

The cavity must be closed at the top to prevent access of vermin, and to ensure uniformity of temperature in the building.

When building hollow walls great care is required to keep the cavity clear of falling mortar. The writer has, on more than one occasion, been called in to ascertain the cause of dampness showing on the inside of a cavity wall. The stains were, in one case, in patches, and nowhere near a down-spout or water-pipe of any description. On cutting an opening in the outer wall near one of the patches, it was found that mortar droppings had accumulated on the wall-ties until a fair sized part of the cavity was practically solid. The accumulated mortar was saturated with condensed moisture. To prevent this occurring, when building cavity walls, lay battens bound with hay along the wall-ties as the work proceeds. These battens catch falling mortar, and are drawn up when the wall reaches the height of another row of ties, the process being repeated throughout the building of the wall.

BUILDER'S GEOMETRY

By Richard Greenhalgh, A.I.Struct.E.
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LESSON V

POLYGONS

A polygon is a plane figure bounded by a number of straight lines. A triangle may be considered to be a three-sided polygon, and a *quadrilateral* is a polygon with four sides.

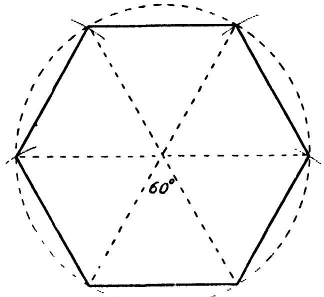


Fig. 45. Drawing a Hexagon

Usually, the term is only applied to figures of five or more sides, as follows

Pentagon has 5 sides.	Octagon has 8 sides.
Hexagon ,, 6 ,,	Nonagon ,, 9 ,,
Heptagon ,, 7 ,,	Decagon ,, 10 ,,

Polygons may be either *regular*, that is, the sides (and angles) are equal; or *irregular*, that is, with unequal sides and angles.

Regular Hexagon. Suppose it is required to draw a regular hexagon of $1\frac{1}{4}$ in. side. Describe a circle of $1\frac{1}{4}$ in. radius, Fig. 45, and then step off the radius round the circle. If this is done accurately, the compasses will just go round six times. Join the points thus obtained.

If diagonals are drawn, it will be seen that the angle between them at the centre are each 60°, and another method of finding the points on the circumference would, therefore, have been to use the 60° set-square.

To Draw any Regular Polygon. Assume that pentagon of $1\frac{1}{2}$ in. side is required. Draw AB $1\frac{1}{2}$ in. long, Fig. 46. Now, the triangle between AB and the centre of the circle contains 180°, and the apex angle is $360 \div 5 = 72°$; therefore the base angles at A and B must be $(180 - 72) \div 2 = 54°$. Set out these angles at A and B, thus locating the centre of the circumscribing circle. Draw the circle, and step off AB round the circumference. If the draughtsmanship is accurate, the length AB will just go round five times. Join the points thus obtained, and the pentagon is completed.

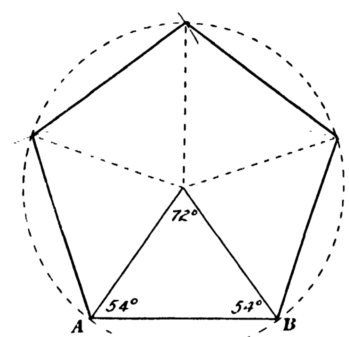


Fig. 46. Drawing a Polygon

Octagon in Square. A woodworker often requires to convert a square length of timber to octagonal form. Let $ABCD$, Fig. 47, be the

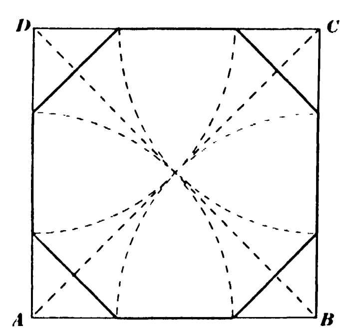


Fig. 47. Drawing Octagon in Square

square section. Draw the diagonals. With each corner of the square as centre, and a half diagonal as radius, describe arcs as shown. Draw across each corner to the points thus obtained on the sides.

CONIC SECTIONS

The Four Sections. A cone may be cut by a plane in four ways: (1) by a plane parallel to the base, when the section is a *circle*; (2) by a plane at a less inclination than the generator, when the section is an *ellipse*; (3) by a plane parallel to the generator, when the section is a *parabola*; (4) by a plane of greater inclination than the generator, when the section is a *hyperbola* (see Figs. 48, 49, and 50).

Of the three latter sections, the ellipse is the most used in building work; the parabola is used to a slight extent for arches, moulding, and in structural mechanics; the hyperbola is sometimes used in the outline of Greek mouldings.

The conic sections will now be dealt with from the point of view of plane geometry, but will be dealt with later as the sections of solid bodies.

True and Approximate Ellipses. There are at least a score of different methods of drawing ellipses, these methods being divided into two classes, those for drawing *true* ellipses and those for drawing *approximate* curves. A true ellipse has a different curvature at every point, whereas an approximate ellipse is made up of a number of circular arcs joined tangentially.

Axis and Foci. An ellipse has two diameters, or *axes*, the larger one being called the *major axis* and the smaller one being termed the *minor axis*. If half of the major axis is taken in the compasses, and this distance is then struck off from one end of the minor axis on to the major axis, Fig. 51, two points, known as *foci*, are obtained. The lines from the foci to any point on the curve are known as *focal lines*. If the angle between the focal lines is bisected, the bisector is said to be *normal* to the curve.

Drawing an Ellipse—String Method. A practical method of drawing a true ellipse is by means of a piece of string, as shown in Fig. 51. This method depends on the following well-known property of the ellipse: *The sum of any pair of focal lines is constant and is equal to the length of the major axis.*

Let it be required to draw an ellipse having a major axis of 4 in. and a minor axis of 2½ in. Draw the axes as shown in Fig. 51, and obtain the foci by striking off 2 in. from A on to the major axis. Insert small nails or drawing pins at F, F_1, and A. Tie a piece of thin string to F, pass the string over the top of A, and bring the string down to F_1, where it is again tied. Now remove the pin at A and, pressing a pencil against the inside of the loop of string, glide the pencil round. An ellipse will thus be traced.

It will be seen, in this method, that the length of string represents the sum of the focal distances and is constant. This is the reason why half the major axis is struck off from A to obtain the foci; these two radii must together equal the major axis.

Geometrical Method. Fig. 52 shows a geometrical method of drawing an ellipse, the principle being the same as for the string method. Draw the axes AB and CD, and find the foci F and F_1. Divide the major axis into two parts, as at the point e. Take one part, as Ae, in the compasses, and strike out arcs with the foci as centres. Now take the remainder of the major axis in the compasses, and again describe arcs with the foci as centres. Four points on the ellipse are thus located, and further points on the curve can be located by repeating the process for other points, as g, on the major axis.

In this method it will be observed that the sum of the two lengths taken in the compasses is equal to the length of the major axis.

An Easy Method. Perhaps the easiest geometrical method of drawing an ellipse is that shown in Fig. 53. Describe circles on the major and minor axes. Draw a number of radial lines. Where each radial line cuts the outer circle draw a vertical line, and where the radial line cuts the inner circle draw a horizontal line to intersect the vertical line. The intersection is a point on the elliptic curve required. A number of such points are obtained, and the curve is then drawn freehand through them.

Ellipse in Rectangle. Fig. 54 shows another method of drawing an ellipse when the two axes are given. The containing rectangle $ABCD$ is first drawn through the extremities of the axes EF and GH. Divide EA into a number of equal parts, and divide EO into a similar number of equal parts. Draw radial lines from G to the division points on EA, and draw other radial lines from H through the points on EO to intersect the first radial lines. Two points on the quarter curve are thus given. The construction is repeated for the other quarters.

Trammel Method. This practical method of drawing an ellipse depends on another property of the ellipse. Take a piece of paper, at least equal to the length AB of half the major axis, as shown in Fig. 55, and mark on it the length BC of half minor axis. Now move the paper so that point A glides on the minor axis while point C glides on the major axis. The point B

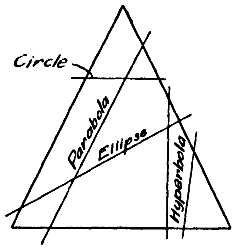


FIG. 48. SECTIONS OF CONE

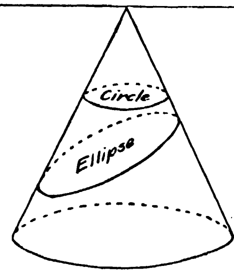


FIG. 49. CIRCLE AND ELLIPSE

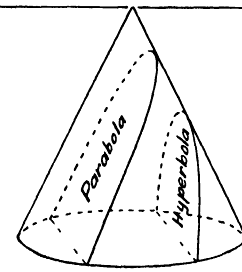


FIG. 50. PARABOLA AND HYPERBOLA

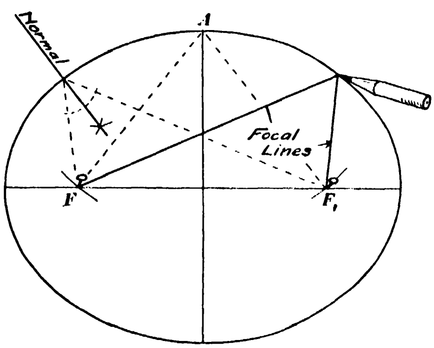


FIG. 51. STRING METHOD

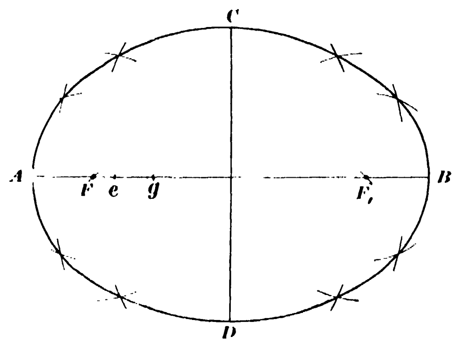


FIG. 52. GEOMETRICAL METHOD

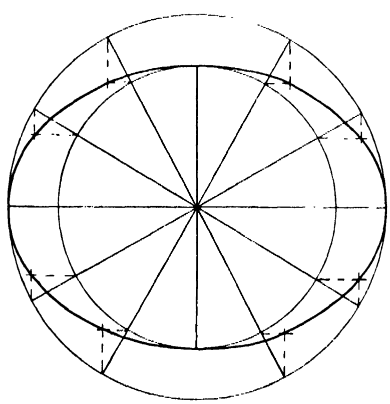


FIG. 53. THE EASIEST METHOD

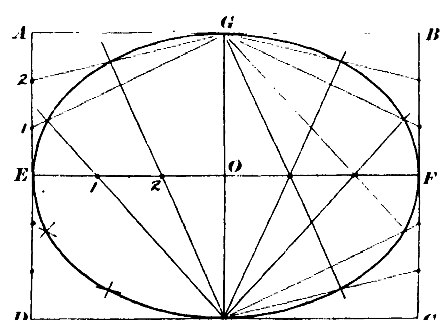


FIG. 54. ELLIPSE IN RECTANGLE

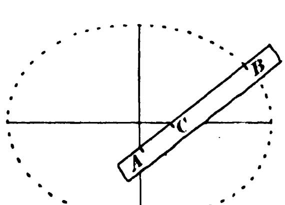
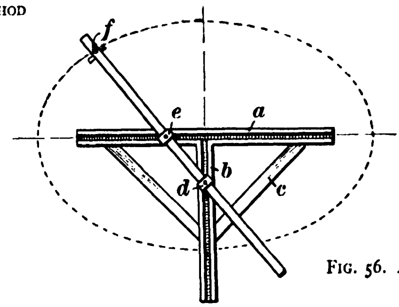


FIG. 55. TRAMMEL METHOD



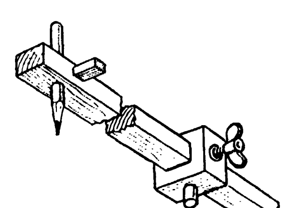


FIG. 56. A SIMPLE TRAMMEL

will thus describe the ellipse. It is usual to mark against B in a number of positions, and then draw a freehand curve through the points thus obtained.

The Trammel. The *trammel* is an instrument for drawing ellipses, and can either be purchased or home-made. A type that can be made by any woodworker is shown in Fig. 56. Two pieces of grooved wood, *a* and *b*, are halved together at the centre, the joint being stiffened by means of four angle braces *c*. The *trammel bar* is a strip of wood arranged so that two pegs, *d* and *e*, can be adjusted along its length and secured where desired. The end of the bar is arranged to carry a pencil *f*. Part of the trammel bar is shown enlarged at the left-hand side.

To use the trammel, the peg *d* is set at a distance from the pencil equal to half the required major axis, and the peg *e* is similarly set for the half minor axis. The trammel bar is then moved so that the peg *d* slides along the minor axis, and the peg *e* travels along the major axis, the pencil thus tracing out the ellipse.

This method of striking an ellipse can also be used by the plasterer to run an elliptical moulding, say on an arch, the mould, or *horse*, taking the place of the pencil.

PAINTING AND DECORATING

By Charles H. Eaton, F.I.B.D.
Member of Council of The Institute of British Decorators

LESSON III

PIGMENTS

Having now obtained a general understanding of the construction of paint, it is desirable, before proceeding with the question of the application of paint, that something further should be understood about pigments. It has already been seen that the subject of pigments falls into two main classes: natural, and artificial. Further, some pigments definitely co-operate with the vehicle, or binder, whilst others are quite inert, and a few appear actually to retard or delay the process of oxidation.

The various white pigments may be regarded as the most important, because amongst these are found those which most favourably co-operate with the vehicle, and also form the basis of many coloured paints. All of the white pigments may be regarded as having individual qualities that render them particularly suitable to individual types of work, as some afford a means of providing, either in themselves or in co-operation with other pigments, adequate protection against decay; others are proof against an atmosphere laden with chemical fumes; others are of great value because their great density affords a means of easy obliteration when a change is to be made in the colour of a surface; whilst others combine, in part, all three qualities, that is, they offer reasonable resistance to weather and foul atmosphere, and they obliterate quite satisfactorily.

There is a large class of materials which should be included in the list of white pigments; these materials, of themselves, have little body or even durability, but are used as extenders to render the physical condition of paint more suitable, or to act as reducing agents or adulterants, in order to bring the material within a certain limit of cost. The builder, however, may not consider it necessary to know too much about these things, his main concern generally being confined to the question of the description being a fitting one for the material. If he wishes to know more, adequate safeguards are likely to become available as a result of the work of the British Engineering Standards Committee, who have drawn up set formulae for paints suitable for almost every class of work, thus enabling the architect to specify that the paint shall conform to the British Engineering Standards specification, and the builder to see that the material conforms to this specification, failing this, to risk having to execute the work again.

MANUFACTURED WHITE PIGMENTS

The names of the principal white pigments are white lead, zinc oxide, lithopone, titanium dioxide, and antimony oxide, all of which are produced by chemical means. Barytes, whiting, terra alba, French chalk, China clay, and white earth, occur in nature in a more or less pure state, requiring little preparation by the manufacturer to render them suitable for his purpose. It is these latter pigments that are used as extenders; they are all practically inert, but each has a special function to fulfil when introduced with other materials into paint, and should not always be regarded as adulterants.

White Lead is probably the oldest of the white pigments: reference to it is found in an old bill, dated in the year 1271, for materials used to decorate the "painted chambers" of Edward I. The white lead used was referred to as *albi plumbi*, and previous to this date it is frequently referred to under the Roman name of *Cerussa* or *Ceruse*. White lead is obtained as a result of treating, by various processes, the metal lead, and is a double compound, *carbonate and hydrate of lead*. It is a colourless substance of very considerable opacity. For centuries there was only this white pigment, and but one method of manufacture, commonly known as the *Old Dutch Process*. Other methods were, however, introduced, their chief advantage being a great saving of time.

White lead is regarded as poisonous, and, when introduced into the human system, acts cumulatively, causing, in the first instance, *colic*, commonly known as *painters' colic*; this, if neglected, develops into a type of paralysis known as *plumbism*, which is a notifiable disease. Generally, it may be stated that poisoning by white lead is caused by dust being allowed to polute the atmosphere during the process of rubbing down painted surfaces, or by personal neglect such as dirty hands and clothing, the finger nails frequently secreting particles of lead which get transferred into the system with food, etc. Efforts have been made to improve matters by making it compulsory to do all rubbing down by first damping the surface with a sponge of water, then rubbing down with a *waterproofed glasspaper*, thus controlling the particles of lead that are cut off by the abrasive material. This method also obviates the fouling of the atmosphere with particles of abrasive material that become detached from ordinary glue bound glasspaper; such particles, entering the respiratory organs, act as an irritant to the delicate membranes.

White lead, as originally produced, is in the form of a dry powder which, after various washing processes, is dried and ground in linseed oil and sold to the trade, usually in the form of a stiff paste. When the keg is opened, the material should be covered with oil or water; but if the latter is used, care should be taken to see that the pigment is free from all trace of water before making it into paint. If oil is used, it may be difficult to make paints that dry without gloss (i.e. *flatting*), from which oil, except the grinding oil, is excluded.

The pigment, if properly prepared and mixed with a suitable vehicle, as linseed oil and turpentine, is wonderfully durable, and may be mixed with other pigments with but few exceptions, these being pigments that contain sulphur or similar compounds. In a foul atmosphere, for example, a sulphur-laden atmosphere, as in the neighbourhood of gas works, the pigment quickly changes from white to grey. Its opacity, or hiding power, is very good, due largely to its high specific gravity, which is about 6·47. It weighs about 175–180 lb. per cub. ft, and when ground to a stiff paste absorbs 8 or 9 per cent of oil. Its covering power, that is, the area covered by a given quantity, is not so good as that of other materials, this being due to its weight. White lead made by some processes appears to require more oil than when made by other processes. White lead co-operates well with the oil, and actually assists in its oxidation.

Zinc Oxide, or oxide of zinc—frequently called *zinc white*—is made from metallic zinc (*spelter*). It was first brought to prominent notice in France by Courtois of Dijon, about 1781. Sorrol, in 1834, while carrying out experimental work in connection with the galvanizing of metals, made certain discoveries which resulted in the commercial production of the pigment, and in 1841, extensive furnaces were erected at Grenelle for further developing and exploiting the process.

The metal vulcanizes at a temperature a few degrees higher than that at which it melts, and vapours are evolved which, in the presence of air, rapidly oxidize and solidify in the form of a white powder, frequently known as *philosophers' wool*. There are two methods of obtaining the desired result, known as the *direct* and the *indirect processes*. The first method is practised chiefly in America, and the latter in France, the direct process being the most simple; other processes have been tried, but have not been a success.

Zinc oxide is a fine, brilliant, white powder, much lighter than white lead when ground—in oil—to a stiff paste, the form in which it is usually sold. It absorbs about 20 per cent of oil—a much larger quantity than in the case of white lead. If of good quality, it is not affected by sulphur-laden atmosphere; therefore it retains its purity of colour for a long time. If it is of low quality, it contains a percentage of lead. Its opacity, or hiding power, is not good, but owing to the fineness of its particles, its covering power is excellent. All attempts to improve its opacity have failed. It makes an excellent paint, specially suitable for use as a finishing over white lead, and is used largely in the making of enamels.

Zinc oxide, if pure, is non-poisonous; its main defects are lack of density, and a failure to combine satisfactorily with oil. The film established with this material becomes excessively hard, resulting in cracking, and there is a lack of freedom in working under the brush. The material should be kept covered with oil after opening the package. On no account should it be covered with water. The best method with practically all such materials is to level the material and cover carefully with a piece of greaseproof or oiled paper; special care is necessary regarding the use of driers, an oil drier being considered best.

Lithopone. This material consists of *zinc sulphide* in combination with *barium sulphate* (barytes, or *blanc fixe*), and was first introduced in 1874, by J. B. Orr, under the name of Charlton White, Zinkolith, or Orr Zinc White. The process of manufacture is still carried on at Widnes. Similar pigments were introduced by Griffiths in 1875, and by Knight in 1876.

The process of manufacture varies considerably; there are immense quantities produced in England, the United States, Belgium, Holland, and Germany.

Lithopone should be very white, and its texture soft. Properly prepared, it has a greater opacity than any other white pigment, but it has the disadvantage of going off colour, which detracts from its value. When exposed to strong sunlight, it becomes grey; the cause of this defect is not known. The higher the proportion of zinc sulphide, the greater the body and covering power.

It is used chiefly as an undercoating for inside work, the material being generally unsuitable for outside work. Its chief advantage lies in its density, or obliterating power. It has fair covering power and generally dries without gloss, having a flatting effect. It makes an excellent flatting for application prior to enamelling, but if it is used for this purpose the binder should be gold size. When mixed with oil, Lithopone should not be allowed to come into contact with water, and brushes used in this material should be kept free from water also. It requires considerable experience before a satisfactory job can be made; this is on account of its rapidity in drying, making it difficult to apply.

Titanium White, or **Titanium Dioxide,** was first discovered by a clergyman, the Rev. William Gregor, in Menachan, Cornwall, in 1791. He called this element "Menachin." In 1795, Klaproth made a similar discovery, and called the element Titanium. It was found later that the two discoveries were identical.

Titanium is found combined in three minerals, *rutile*, *brookite*, and *anatase*, in each case in a different crystalline form. It appears to occur most abundantly distributed in the minerals ilmenite, sphene, or titanite, and titaniferous iron ores. It is manufactured as a white pigment from the mineral *ilmenite*, which is a compound of iron oxide and titanium dioxide. Vast deposits of the mineral are found in Norway, though there are deposits in many other parts of the world. The English deposit, found chiefly in Cornwall, is unsuitable for use.

Briefly, the principal process of manufacture is as follows. Finely powdered ilmenite is mixed with concentrated sulphuric acid, and the mass heated. A violent reaction takes place under the coagulation of the mass, transforming the titanium and iron contents into titanium and iron sulphates. The coagulated mass is then dissolved in water, and freed from undecomposed minerals in a settling vat. The clear solution, containing the sulphates, is brought to a boiling temperature by the use of indirect steam, causing the *titanium* to precipitate *titanium hydrates*. The precipitates obtained are washed, to free them from iron, but they still contain absorbed sulphuric acid and basic sulphates of titanium, in small quantities, which are, however, neutralized by adding barium carbonate. The neutralized precipitate is calcined to convert the *dioxide* into a *crypto* to *micro-crystaline state*.

In the finished material, which is a beautifully white pigment, there is a very small percentage of barium sulphate. By precipitating the titanium dioxide on a barium sulphate base, composite pigments are made. Titanium is a brilliant white in colour, and its texture is very fine.

When ground into a stiff paste, it absorbs about 23 per cent of oil. The pigment is quite inert, that is, it does not assist or retard the oxidation of the oil, and it is not affected by heat, acid, or sulphur fumes. The pigment has very good body and covering power, and its opacity or obliterating power is nearly twice that of white lead. *It is absolutely non-poisonous.*

The paint film established by this pigment is rather soft, rendering it liable to pick up dust, etc., but this can be largely overcome by the addition of 10–15 per cent of zinc oxide, which hardens the film. Titanium is probably the most valuable addition to the long list of painters' materials that has been made for a generation; and when its use and limits are really understood, it will no doubt largely displace certain other pigments.

Antimony Oxide is another new pigment, though it does not appear to have attracted quite so much interest and attention as titanium. The raw material used is *stibnite*, or *grey antimony*; alone or mixed with iron, the stibnite, as it occurs naturally, is roasted in the presence of air or oxygen. The fume or vapour created is antimony oxide, which is collected in a series of chambers, the finest particles being found in the chambers which are the greatest distance from the source of operation. If carefully prepared, antimony oxide is of a very pure white, and when ground into a stiff paste, requires about 10–12 per cent of oil. The paint film is soft and very similar to titanium, but it becomes yellow on exposure to sulphuretted hydrogen. Exposure to light and pure air restores it to its original colour. It does not change colour quite so quickly as white lead.

Antimony oxide has no action upon linseed oil, it being quite inert. It is slow drying, but this may be corrected if the material is used in conjunction with zinc oxide. Its opacity and covering power are very similar to titanium.

NATURAL WHITE PIGMENTS

In the foregoing, the student will find sufficient information to assist him to make the best use of the white pigments that are manufactured. The use of the naturally occurring pigments is more a matter for the manufacturer than for the painter, but some points about a few of them may be of use.

These whites are regarded as colourless bodies, they are used chiefly because of their cheapness. In actual practice their use is primarily to give bulk and to maintain weight rather than to give opacity. Generally they have very little opacity when mixed with oil, but the reverse is the case when they are mixed with water.

The names of the principal, naturally occurring, white pigments are—*Barytes*; *Blanc fixe*; *Whiting*, or *Paris White*; *Gypsum*, or *Terra Alba*; *China Clay*; *Strontian White*; *Satin White*; *Magnesite*; *Silicine*; *Asbestine*; and *Alumina*.

Barytes, or **Barium Sulphate**, is the most important and most widely used. It occurs in a crystalline condition, and is known as *heavy spar*, or *cawk*. It is also prepared artificially. This material occurs in large quantities in various parts of England, e.g. Derbyshire, Devonshire, Cornwall, Cumberland, and at various places in Wales and Ireland. It is generally white in colour, but when iron is present it is a pale yellow. It requires but little preparation, beyond separating from impurities, grinding very carefully, washing and grading. It is in the form of a very heavy white powder, almost as heavy as white lead, and it is claimed that it has a distinct function to perform in paint. The decorator, however, will find it necessary to doubt the utility of this material except in a limited number of cases. Its chief function is as an extender.

Blanc Fixe is, chemically, exactly the same as barytes, and it is made by precipitating solutions of barium salts by means of sulphuric acid.

Whiting, or **Paris White**, popularly known as *Gilders' whiting*, or *chalk*, needs but little description. After quarrying, it is put through a series of washings, levigated, and dried. Its chief use is in connection with distemper and with size, or for putty with linseed oil. When ground in oil, it has no opacity.

Gypsum, or **Terra Alba**, is found plentifully throughout this country. It is a brilliant white, and rather heavy. It has little body in oil. It is used as an adulterant.

China Clay, found largely in England, France, and Germany, occurs almost ready for use, requiring only washing, etc. It is very bulky and transparent in oil. Its chief function is to prevent settling out of pigments in paints made for dipping. It is also used extensively as a base upon which to strike or precipitate certain colouring materials. It plays an important part in the manufacture of ultramarine blue.

In the above there will be found sufficient information to enable the student to glean the general utility of these various adulterants or extenders.

MASONRY

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LESSON V

TECHNICAL TERMS AND STONE FINISHINGS

Fig. 10 is the sketch of the angle of a building indicating the terms used for the various stones.

The term **Face** is applied to the surface of the stone exposed to view, and is usually the vertical surface shown on elevation.

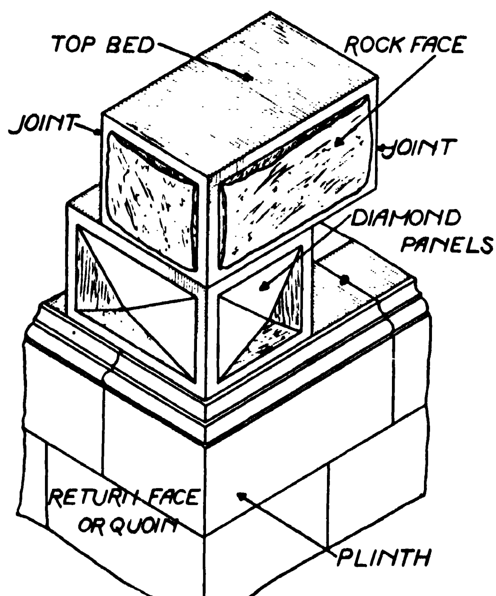


Fig. 10. Sketch of Angle of Building, showing Moulded Plinth and Quoin Stones
Finished with diamond panels and rock face chisel drafted

The **Return Face** is the vertical surface exposed to the side elevation, and is generally at right angles to the face.

Beds are the lower surface upon which the stone rests, and the upper surface which supports the stone above. They may be either horizontal or inclined.

Joints are the surfaces prepared to receive other stones butting against them.

Back, or Rough Back, is the term applied to the vertical surface entirely hidden in the thickness of the wall, and the surface is usually left from the punch or saw.

Clean Back is the term used for the inside vertical surface of stones extending through the thickness of the wall, and forming a face on the inside.

Quoin Stone is a block of stone placed at the angle of a building, the faces being finished in several forms. Fig. 11 shows the *quoin stones* finished alternately with *rock-faced chisel-drafted margin* and *diamond panels* with *chisel-drafted margin*.

Plinth is the lower courses of stonework

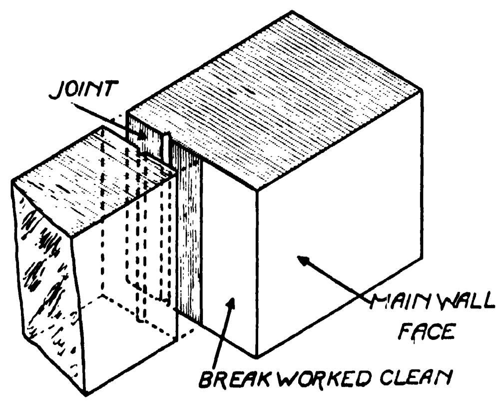


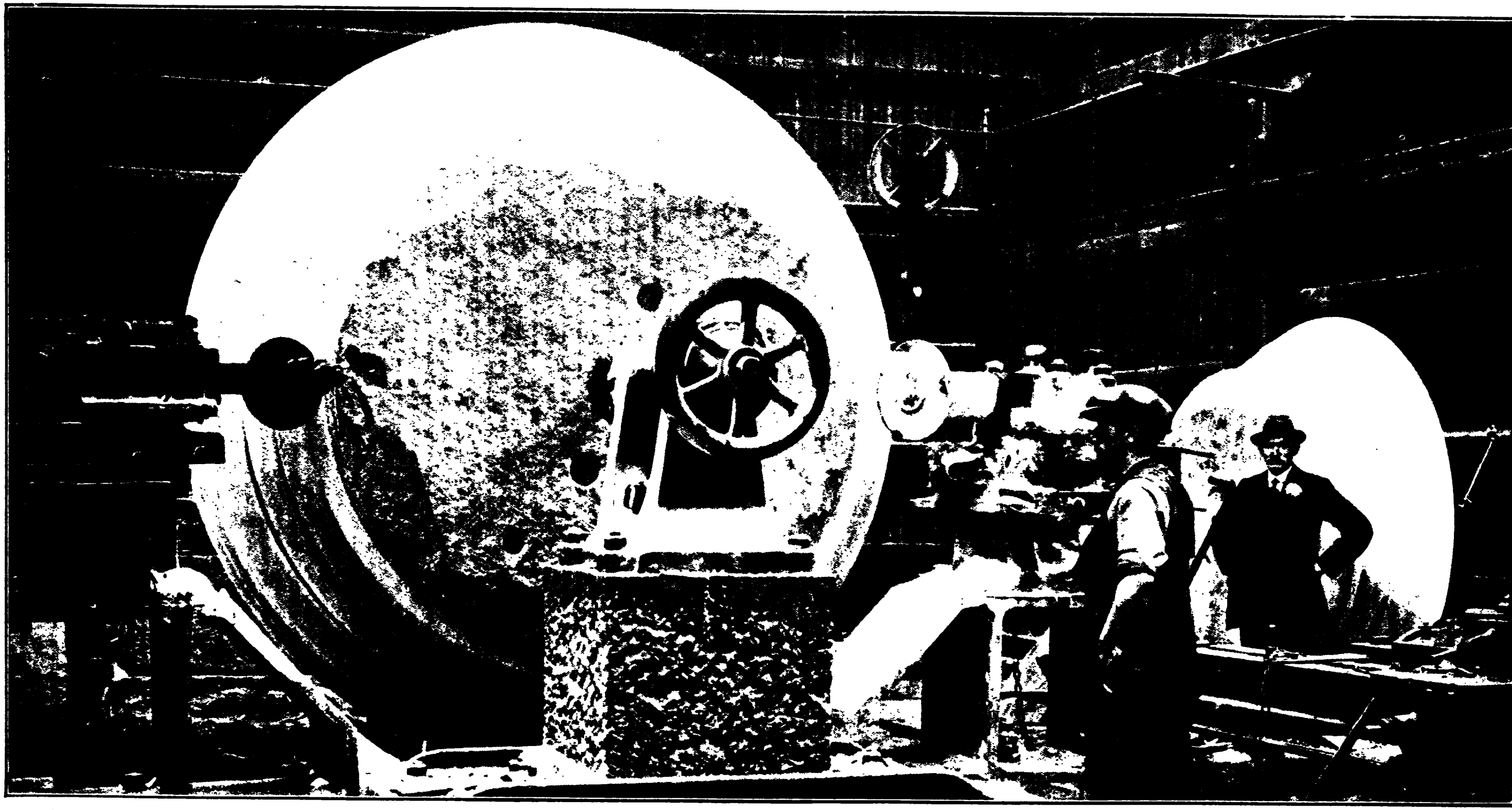
Fig. 11 Break Stone

projecting from the main wall face. The top course is usually moulded.

Break (Fig. 11). This term is usually applied to a recess from the main wall face. When a joint is in line with the *break*, the stone is worked clean for the depth of the break, and a hard line is marked on the stone, showing the face line of the recessed wall, the remainder of the surface being worked as a joint. In the sketch the abutting joint is kept away from the joint for clearness.

The **Arris** of a stone is the edge made by the intersection of two surfaces forming an external angle.

A **Closer** is the last stone to be placed in a course, being jointed to the correct length so as to close or fill the gap exactly.



By kind permission of *Messrs. A. & F. Manuelle, Ltd.*

FIG. 12. TURNING GRANITE BASE FOR BUSH HOUSE, LONDON

External Mitre, Fig. 13, is the line formed by the intersection of two mouldings at an " external angle " of a building.

Internal Mitre, Fig. 13, is the line formed

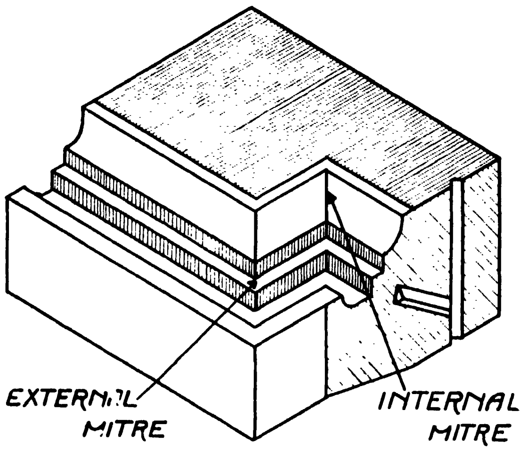


Fig. 13. External and Internal Mitre

by the intersection of two mouldings at an " internal angle " of a building, the moulding making an angle less than 180°.

Ashlar Stop (Fig. 14). The moulding is mitred and returned on to an ashlar face, forming an abrupt finish to the moulding.

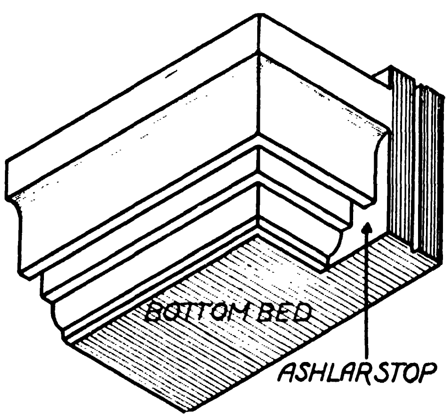


Fig. 14. String Course with Ashlar Stop

Ashlar is the term applied to finally dressed stone worked to fit in the general face of the wall, either projecting from the *wall line* or *flush*, and is described according to the finish of the face of the stone.

Plain Ashlars are stones with rubbed, dragged, or polished plain surfaces.

Boasted Surfaces, Fig. 15, are finished with a 2 in. *boaster* in fairly even tool marks. The regularity and angle of the chisel marks depend upon the style of the craftsman.

Tooled, or Batted, Surfaces, Fig. 16, are left with regular chisel marks vertically across the face of the stone, cut with a " batting " or

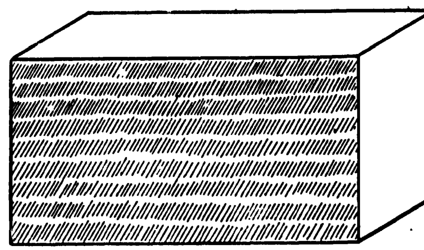


Fig. 15. Boasted Ashlar

" broad " tool after the surface has been rubbed true. The " bats " are usually specified so many bats to the inch. The faces of York stone used as *padstones* (*templates*) are usually batted, or tooled.

Rusticated Ashlars are the courses of stone-work projecting from a wall and finished in several ways. The back of the " rustication " should always be the face line of the wall. The following are some methods of treating the rustication : *chamfer*, Fig. 17 ; *chamfer-fillet*, Fig. 18 ; *rebated*, Fig. 19.

For **Rustic Work in Granite** the faces are left

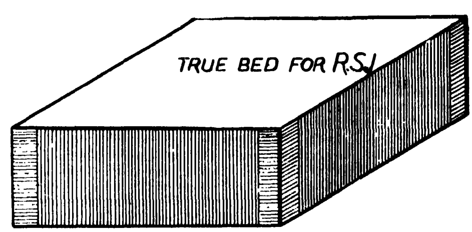


Fig. 16. Tooled, or Batted, Template

rough and should be entirely free from punch marks.

Pitched Faced Ashlar. Fig. 20. The beds and joints are worked true and the lines for the face of the wall marked on both beds and joints. The lines are then " pitched " with a hammer and " pitching tool." The rough surface of the stone should extend over the surface, no punch or chisel marks being shown.

Punched, or Broached, Ashlar, Fig. 21, is left from the punch in furrows across the surface, usually between chisel-drafted margins.

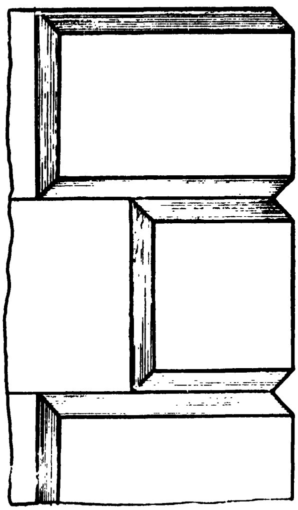


FIG. 17. CHAMFERED JOINTS

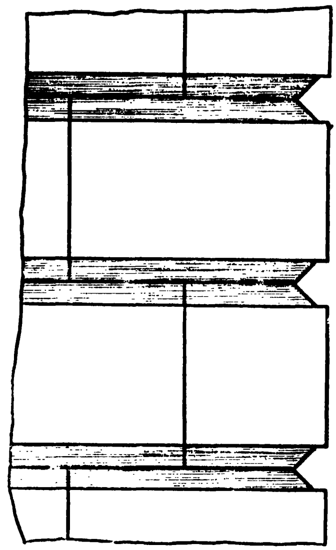


FIG. 18. CHAMFER-FILLET JOINTS

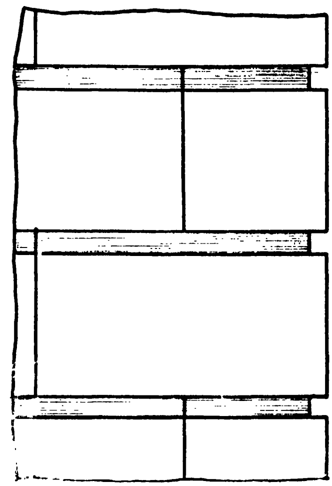


FIG. 19. REBATED JOINTS

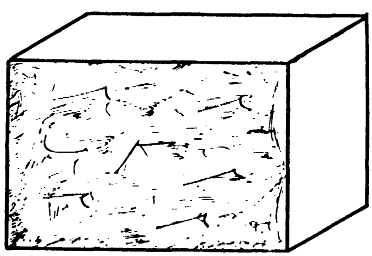


FIG. 20. PITCHED-FACE ASHLAR

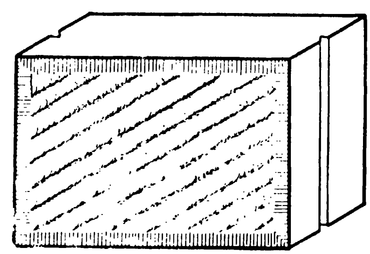


FIG. 21. PUNCHED OR BROACHED

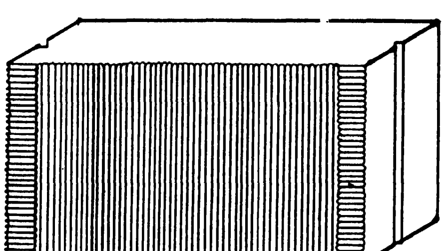


FIG. 22. FURROWED SURFACES

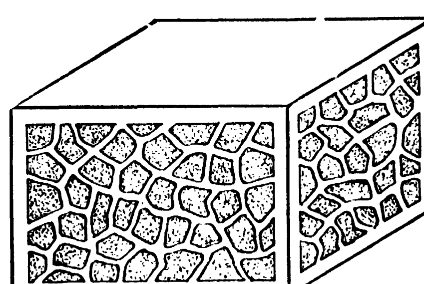


FIG. 23. RETICULATED ASHLAR

Furrowed Surfaces, Fig. 22, consist of small *flutings* either horizontal or vertical across the

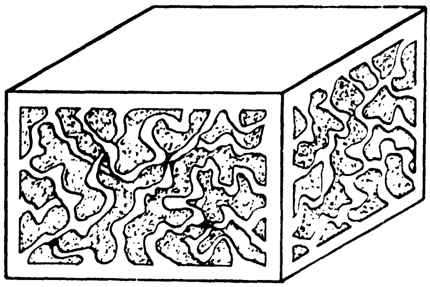


FIG. 24. VERMICULATED ASHLAR

face of the stone, the "flutes" being $\frac{3}{8}$ in. centre to centre.

Reticulated Ashlar (Fig 23). The surface is worked true with a series of sinkings about $\frac{3}{8}$ in.

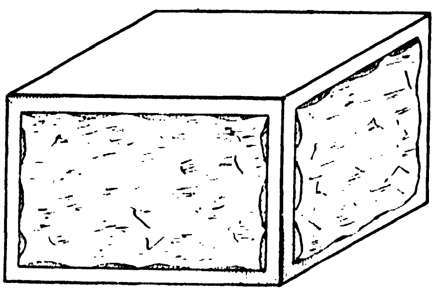


FIG. 25. ROCK-FACE, CHISEL DRAFTED MARGINS

deep, cut into the stone, the sinkings being separated by bands of regular width. The sinkings should be worked true to a gauge, and "picked" with a fine *mallet-headed point.*

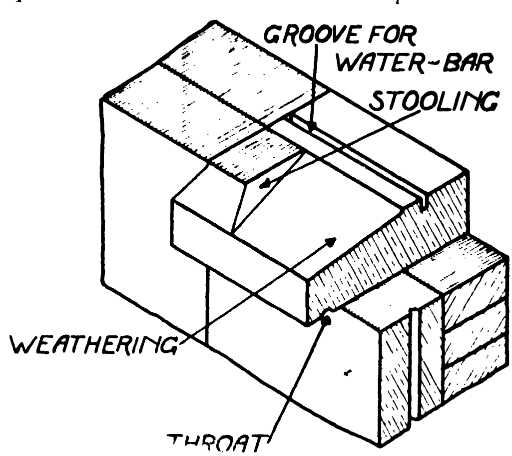


FIG. 26. PLAIN STONE SILL, SHOWING WEATHERING, THROATING, STOOLING AND GROOVE FOR WATER-BAR

Vermiculated Ashlar (Fig. 24). This style of finish is different from the former. The bands separating the sinkings are irregular in width

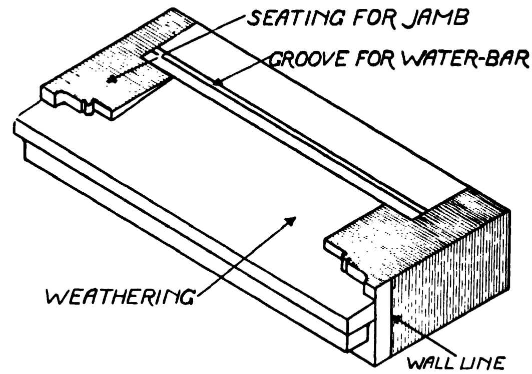


FIG. 27. SKETCH OF MOULDED WINDOW SILL
Showing moulded jambs worked direct on to weathering

and form. They are often worked to interlace, giving a worm-eaten appearance.

Chisel-drafted Margins (Fig. 25). True drafts are worked around the face of the stone, and the

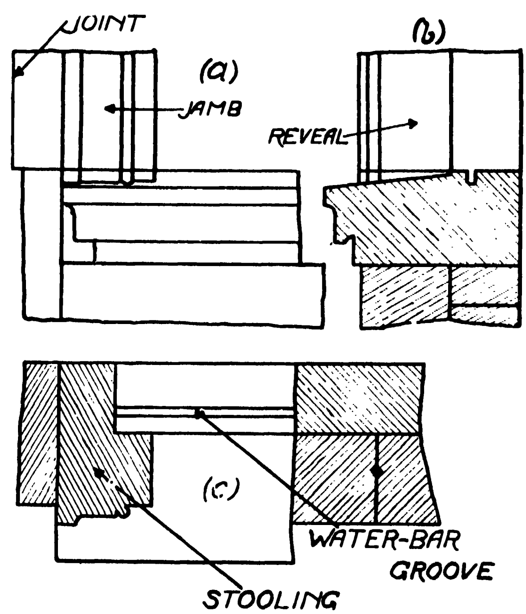


FIG. 28. (*a*) ELEVATION, (*b*) SECTION, (*c*) PLAN OF MOULDED SILL

centre is either left "rough," "punched," or "picked."

WINDOW OPENINGS

Sills. The term applies to the lower horizontal member of a window or door opening.

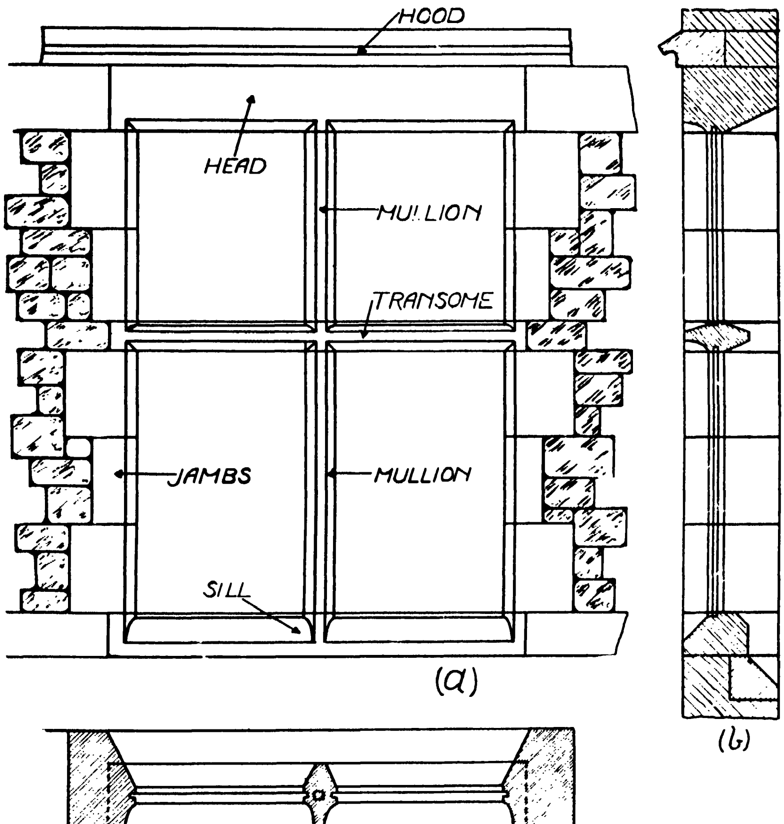


FIG. 29

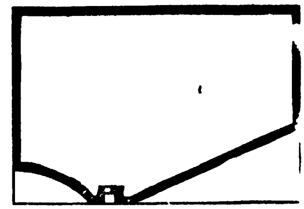


FIG. 32

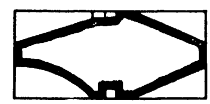


FIG. 31

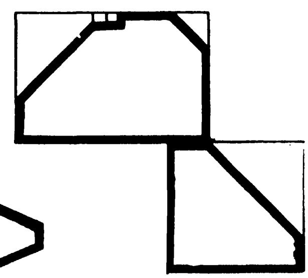


FIG. 30

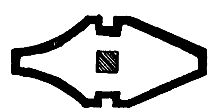


FIG. 34

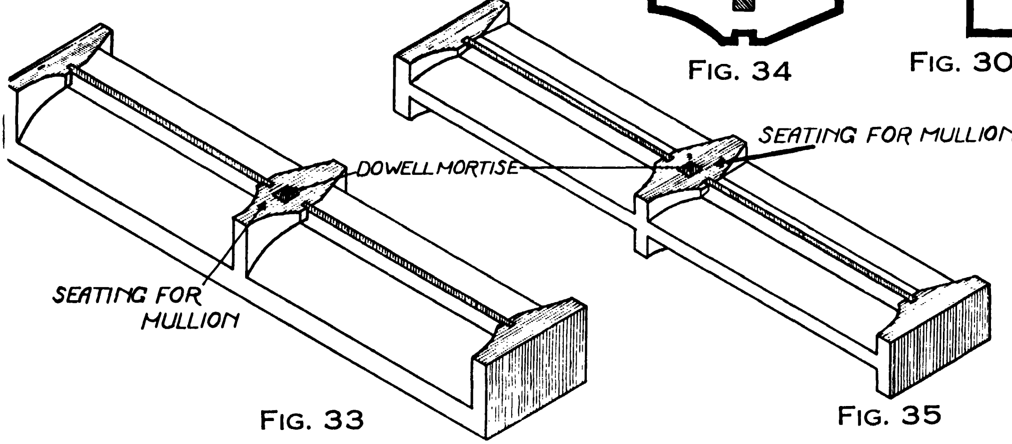


FIG. 33

FIG. 35

FIG. 29. (*a*) ELEVATION, (*b*) SECTION, (*c*) PLAN, SHOWING TREATMENT OF FOUR-LIGHT WINDOW
FIG. 30. DETAIL SECTION THROUGH SILL AND SUB-SILL
FIG. 31. DETAIL SECTION THROUGH TRANSOME
FIG. 32. DETAIL SECTION THROUGH HEAD
FIG. 33. ISOMETRIC SKETCH OF SILL
FIG. 34. DETAIL SECTION THROUGH MULLION
FIG. 35. ISOMETRIC SKETCH OF TRANSOME

Window Sills, Fig. 26, are constructed to throw the water clear of the wall, and keep the moisture from penetrating under the wood sill which is attached to the frame. To meet these requirements they should be *weathered, throated,* and *grooved.*

The **Weathering** is the exposed top surface, and should be worked inclined to the horizontal, the angle depending upon the projection of the sill and the *reveal* of the window jambs.

Stoolings. Horizontal portions should be left at each end of the sill, forming seatings for the jambs to rest on; the weathering is usually mitred away from the stoolings, or the jamb moulding is cut direct down to intersect the slope of the weathering.

A horizontal seating should also be left under *mullions* where the window has two or more "lights."

Throat. Sills should have a projection from the wall line, thus allowing an undercut groove to be worked, forming a *drip* so that the water from the sloping surface is allowed to drop clear of the wall.

Water-bar Groove. A groove should be cut in the top bed of the sill behind the back edge of the weathering, and carried past the reveal line of the opening, to receive a *metal strip,* 1 in. × ¼ in. in section, which should be bedded in red lead, half in the *stone sill* and half in the *oak sill,* to prevent the water percolating through the joint between the two sills. Sills should not be allowed to run under the jambs too far, as they are then liable to fracture, owing to unequal settlements of the building.

The throating should not be worked right through the length of the sill but returned to the wall, forming a drip at each end.

Fig. 27 is a sketch of a moulded sill; the moulded jambs are cut direct on to the weathering.

Fig. 28 shows the sill in (*a*) elevation, (*b*) section, (*c*) plan.

Jamb Stones are the stones employed at the sides of openings, forming the reveals to the openings. They should be well bonded through the wall and on the face.

Fig. 29 shows the treatment of a four-light window, (*a*) elevation, (*b*) section, (*c*) plan; with detail sections through the *sill,* and *sub-sill,* Fig. 30; *transome,* Fig. 31; and *head,* Fig. 32. The sill in this case has no projection, but usually a moulded *drip stone* is provided under the sill, in separate course. Fig. 33 is a sketch of the sill showing the rebate instead of a glazing groove.

Fig. 34 is a section through the mullion (*vertical bar,* or *post*), dividing the window into several lights.

A sketch of the transome is shown in Fig. 35; this is a *horizontal bar* separating a window into two lights in height. The top portion of the transome is worked as the sill with weathering, rebate, etc., but the underside is worked as a head, or *lintel*; this is shown clearly in detail section of *transome.*

Dowells. Either copper or slate is used in the beds of *jambs, mullions, columns,* etc., to prevent lateral movement of the stone. They should not be more than 2 in. long for this purpose, but for *finials, terminals,* etc., as long as the individual case requires.

A **Joggle** is the indentation made in the joints of stones to prevent sliding, the cavity so formed being filled with *liquid cement,* or *grout.* Sometimes an indentation is cut in the joint to receive a projection on the next stone.

ESTIMATING

By Henry A. Mackmin, F.S.I., M.R.San.I., M.I.Struct.E.

LESSON III

BRICKLAYER—(*contd.*)

Mortar. In our calculations for mortar we will assume the proportions to be 1 to 3, as mentioned in the last lesson, and working on the prices given therein, we find that the price per bushel will amount to 3s. 3d. for Portland cement, and 1s. 10d. for grey stone lime. Quotations for sand are usually per yard cube, and for this purpose we will assume the price at 15s., including delivery. The materials diminish in bulk when mixed, and it takes 1 yd. of sand to make 1 yd. (cube) of mortar, in the proportions given above, and about 6¾ bushels of cement or 7 bushels of lime are required. For the labour in mixing, we will take 12 hours if in cement, and 8 hours if in lime; but, of course, these figures must be amended in accordance with the plant available, and the quantity to be mixed at one period. For large quantities these periods could be reduced considerably. Working upon the data given it will be found that the cost of cement mortar (1 to 3) is £2 13s. 5¼d., and for lime mortar £1 18s. 10d., assuming labourer's rate is 1s. 4½d. per hour.

Bricks. The standard size of a brick (known as the R.I.B.A. standard) for the South of England is 9¼ in. in length including joints, measured from centre to centre, and in height four courses, including joints, should measure 1 ft. Owing to differences in the sizes of bricks, an amendment was made in the year 1919 to apply to the North of England. The difference is in height only, and four courses should measure 13 in.

In the Midlands seven courses are often taken to equal 2 ft.

Unit of Measurement. The unit adopted for the pricing of brickwork varies in different parts of the country, and requires careful consideration. In London and the south all brickwork is reduced to a standard rod of 272 ft. super of 1½ bricks in thickness; and any walls less or greater in thickness have to be "reduced" to this standard. In the Midlands and the North of England the work is reduced to a standard of 1 yd. super, but one brick in thickness. In certain Government schedules and upon some engineering works the brickwork is billed per yard cube or per foot cube. These different units have a considerable bearing upon the calculations for materials required.

Materials Required (*per Rod reduced*). Space does not permit the inclusion of the mathematical calculations necessary to find the number of bricks and the quantity of mortar required. It is not a very difficult task for the student to work out the quantities himself, but for the purpose of these lessons it will be assumed that one rod super of reduced brickwork will require 4,398 bricks and 2⅛ cub. yd. of mortar. The actual number of bricks per rod is really 4,290, but an allowance for waste must be made, and in the above number 2½ per cent has been taken for this.

Materials Required (*per Yard reduced*). With northern bricks and working to the 1919 standard, 90½ bricks are required, if 2½ per cent is allowed for waste; and, for mortar, 1$\frac{1}{10}$ ft. cube should be allowed.

Scaffold. The use and waste of scaffolds is a serious item, especially as this kind of plant requires constant renewal. In addition, there is the cost of erecting and taking down to allow for, as well as the cartage. This item does not appear to have received the attention it deserves, for many estimating surveyors simply deal with the cost on a percentage basis. From careful data acquired with several jobs, the writer is of opinion that the use and waste is equal to about 10s. per rod, and the labour erecting and striking is worth about 15 hours per rod. For the purpose of these lessons the total cost of scaffolding per rod reduced will be taken as £1 10s., and per yard reduced, as 8d.

Labour. We now come to the most vital as well as the most difficult factor. The quantities and prices of materials can be analysed and calculated, but the cost of the labour is affected by very many things: all men cannot work at the same speed; the state of the weather affects the progress of the work; the nature of the job; and the class of bricks used—all contribute to make the task of the estimating surveyor a difficult one.

The following calculations will be based upon the assumption that one bricklayer and one labourer will lay 65 bricks per hour, but the student must remember that this must be varied according to circumstances. In some parts of the country, and on some kinds of work, it is often possible for one labourer to assist more than one bricklayer; this will affect the cost considerably. If the work is pierced by many openings additional time must be allowed, as their formation delays the work. If the work is to be executed during the winter months longer time must be allowed, owing to the weather. If the job is some distance away from a town, and lodgings are difficult to obtain, additional time must be assumed, because the most skilful bricklayers can always obtain work near their own homes. This factor also applies to other trades, especially that of the plasterer. From the above remarks, the student will at once appreciate the difficulties of the estimating surveyor, and he will also see how it is necessary to know the conditions of each job as well as each neighbourhood.

Water. For wetting the bricks and preparing the mortar, water is required, but the cost is not allowed for in the following prices, as great variation occurs in different districts. In some places water can be obtained free; elsewhere a charge is made by the water authority, as a percentage upon the whole job (often 7s. 6d. per £100 of work); or it is sometimes sold per gallon. Local inquiries are necessary, but the following quantities may assist the beginner—

Per Rod reduced, about 300 gals.
Per Yard reduced, about 6¾ gals.

Cartage. In the following items it is assumed that the prices of the materials include delivery, but if it becomes necessary to obtain prices for cartage or haulage, the quotations given will usually be weights; therefore the following must be allowed—

Bricks, per thousand		3 3⅛ tons
Sand per yard		3 tons
Cement, 11 sacks		1 ton
Stone lime per yard	about	2 tons
Mortar, per yard	about	1½ tons

Detailed Exaples

Brickwork in Lime Mortar (1 to 3), Southern Practice—

	£	s.	d.
4,400 bricks, at £3 10s. per 1,000 delivered	15	8	–
2⅛ cub. yd. lime mortar, at £1 18s. 10d.	4	2	6
Scaffold: use, waste, and labour	1	10	–
Bricklayer and labourer, 68 hrs. at 3s. 2d.	10	15	4
	31	15	10
Profit and Establishment, 12½%	3	19	6
Price per Rod super Reduced	£35	15	4

Brickwork in Cement Mortar (1 to 3), Southern Practice—

	£	s.	d.
4,400 bricks at £3 10s. per 1,000 delivered	15	8	–
2⅛ cub. yd. cement mortar at £2 13s. 6d.	5	13	8
Scaffold (as before)	1	10	–
Bricklayer and labourer, 70 hrs. at 3s. 2d.	11	1	8
	33	13	4
Profit and Establishment, 12½%	4	4	2
Price per Rod super Reduced	£37	17	6

Brickwork in Cement Mortar (1 to 3) in Cavity Walls, in Two Half brick Thicknesses and 2¼ in. Cavity—

	£	s.	d.
Cost of brickwork, two-thirds the amount of previous item	22	9	–
Extra labour in forming cavity. Bricklayer and labourer, 7½ hrs. at 3s. 2d.	1	3	9
Wall ties (galvanized) ½ cwt. at 26s.		13	–
	24	5	9
Profit and Establishment, 12½%	3	–	8
	£27	6	5

As this item is usually priced per foot super, it is necessary to divide by 272, which gives the price of (say) 2s.

Brickwork in Cement Mortar (1 to 3) in Half-brick Walls—

	£	s.	d.
Cost of brickwork, one-third of the cost of 1½ brick wall	11	4	5
Extra labour in forming fair faces both sides. Bricklayer and labourer, 7 hrs. at 3s. 2d.	1	2	2
	12	6	7
Profit and Establishment, 12½%	1	10	10
	£13	17	5

This item is priced per foot super; so if the above cost is divided by 272, the amount per foot super will be (say) 1s. If the work is in the formation of sleeper walls or other work which will not require scaffolding, the cost of this must be deducted.

Brickwork in Lime Mortar (1 to 3), Northern Practice—

	s.	d.
90½ bricks at £3 10s. per 1,000 delivered	6	4
1$\frac{1}{10}$ cub. ft. of lime mortar at £1 18s. 10d. per yard cube	1	3
Scaffold (as described earlier)		8
Bricklayer and labourer, 1½ hrs. at 3s. 2d.	4	9
	13	0
Profit and Establishment, 12½%	1	8
Price per Yard super Reduced	14	8

Brickwork in Cement Mortar (1 to 3), Northern Practice—

	s.	d.
90½ bricks at £3 10s. per 1,000 delivered	6	4
1$\frac{1}{10}$ cub. ft. of cement mortar at £2 13s. 6d. per yard cube	2	2½
Scaffold (as described earlier)		8
Bricklayer and labourer as last item, but plus 10%	5	2½
	14	5
Profit and Establishment, 12½%	1	9½
	16	2½

ARCHES

The formation of arches is priced separately from the other brickwork, as "extra only" over the cost of ordinary brickwork. This means that the item is priced as an addition to the cost of building the wall in the ordinary way, and if a superior brick is used, it is necessary to find out the cost over and above the price of the ordinary brick used. Rough relieving arches are numbered, but gauged arches, axed arches, and segmental arches are priced per foot super "extra only." In the quantity surveying articles in this work, it will be noted that the measurement of the latter class of arches is taken to every exposed face, and this fact must be kept in mind in preparing prices.

Rough Relieving Arch. For a typical opening to a span of 3 ft. allow for extra time, bricklayer and labourer, 1¼ hours, and for ten extra bricks.

Gauged Flat Arch. For an opening similar to the above, and assuming that the arch is 4½ in. in the wall, about 25 special facing bricks will be required and 12 ordinary bricks will be displaced. Allow for extra time for bricklayer and labourer 1¼ hours per foot super, and for jointing material about 4d. per foot super.

Axed Arches and Segmental Arches. These can be worked out in a similar manner to the above.

ITEMS PRICED PER FOOT OR PER YARD SUPER

Damp-proof Course (Slate). Allow for labour one-tenth of an hour and two slates, and for cement (about) 3d. per foot super.

Breeze Slab Walls. To the cost of the slabs, which is usually 2s. to 3s. per yard super, allow for labour one hour, and for mortar ¼ ft. cube per yard super.

Brick Paving. Allow per yard super 34 bricks; 1 ft. cube of mortar; and for labour, one hour.

ITEMS PRICED PER FOOT RUN

Brick on Edge Copings. Allow four bricks; extra mortar (say) 1d.; and for labour, 6 ft. per hour.

Cuttings. For fair cuttings allow about 6 ft. per hour, and for rough cuttings 3 ft. per hour.

NUMBERED ITEMS

Bed and Point Frames. Allow for labour 1–2 hours each, according to the size; and for mortar ½–1 ft. cube for each frame.

Core and Parge Flues. Allow 10 ft. per hour, and material about 2d. per foot.

Setting Stoves and Kitcheners. Allow for labour 4–8 hours; for bricks 10–40, in accordance with the size of stove; and for mortar 2–9 ft. cube.

FACINGS

Facing bricks are priced "extra only" over the cost of ordinary bricks (every exposed face being measured). If ordinary bricks cost £3 10s. per 1,000, and the special facing bricks £11 per 1,000, obviously the extra cost is £7 10s.

DETAILED EXAMPLE

"Extra Only" over Ordinary Brickwork for Picked Red Facing Bricks. Prime Cost £11 per 1,000 (delivered), including Pointing in Cement with Struck Weathered Joint—

	s.	d.
8 facing bricks at £7 10s. "E.O." per 1,000	1	2½
Extra cement mortar		¼
Bricklayer and labourer, extra time 5 mins. at 3s. 2d. per hour		3¼
	1	6
Profit and Establishment, 12½%		2¼
Cost per Foot super "extra only"	1	8¼

Glazed Brickwork. This work is measured "extra only" in a similar manner to the ordinary facings, and the price can be compiled as detailed in the last item. There are, however, extra items per foot run for plain angles and for bull-nosed angles; but as the manufacturers will quote for these special bricks separately, it is a simple matter to compile the price.

EXERCISE III

1. Using the data given in the preceding lessons, find the cost per foot super for a cavity wall with one 9 in. and one 4½ in. wall and 2¼ in. cavity. Assume that one labourer can attend upon two bricklayers. Mortar, cement and sand, 1 to 3.

ANSWER TO EXERCISE II

Portland cement 3s. 3d. per bushel. Grey stone lime 1s. 10d. per bushel.

DRAINAGE AND SANITATION

By Henry C. Adams, M.Inst.C.E., F.R.San.I., etc.

LESSON III

WATER-CARRIAGE SYSTEMS

Principles of Design. The essential principle of the water-carriage system is the introduction of a sufficient quantity of water into the drains which, in flowing through them, will carry with it all the foul matters from the premises. The water is used as the transporting agent, and to enable it to flow the drains must be laid with a falling gradient from every point at which the sewage is admitted down to the junction with the main sewer. It is not merely necessary for the water to flow, but it must flow with a velocity which will carry the foul matter along. Experiments and observation have shown that flowing water will transport material as follows. A velocity of 0·25 ft. per second will move semi-fluid mud; 1 ft. per second will move sand and gravel the size of beans; 2·2 ft. per second will move 1 in. rounded shingle; and 3·25 ft. per second will move angular shingle the size of a hen's egg. A greater velocity is required to pick up and transport any matter deposited on the bottom of the pipes than is necessary to carry it along when once it is on the move.

The ideal at which to aim is rapid and complete removal of the foul matter. Fresh sewage is comparatively harmless, but after a short time putrefaction, that is, the decomposition of the organic matter, sets in, and this is accompanied by the emission of foul-smelling gases. Sewage consists of the waste-water from the house containing grease, soap, and foul matter from the washing and cleansing of the house, the body and clothes, together with urine and faeces. The impurities are partly in suspension in the water and partly in solution; the proportion of solid matter in suspension is very small, amounting only to about 40 parts per 100,000, or one-twenty-fifth of 1 per cent. Of these solid matters some float, some are carried along in the body of the liquid, while others tend to sink to the bottom. This is due to the varying specific gravity of the matter. *Specific gravity* is the ratio of the weight of any substance to the weight of an equal volume of water. Thus, as substances with a smaller specific gravity than water are lighter than water, they float; those of the same specific gravity remain promiscuously in the body of the water; those of greater specific gravity tend to sink. The transporting power of water varies with the sixth power; that is, if the velocity is doubled, the transporting power is increased 2^6, or 64 times. It is, therefore, apparent that a very small variation in velocity is of considerable importance. The velocity must at all times be sufficient to prevent the heaviest matter in the drains from settling to the bottom.

Velocity of Flow. When a volume of liquid is flowing through a conduit it does not move forward as a homogeneous mass, but the velocity varies in different parts of the cross section, so that the particles are continually changing their position relative to each other. This variable velocity is shown in Fig. 18. The surface velocity in the centre is 25 per cent greater than the mean, while at the sides and bottom the velocity is reduced by friction between the flowing water and the conduit to about 25 per cent less than the mean. In order, therefore, to give a "self-cleansing" velocity at the bottom of the pipe, arrangements must be made for a mean, or average, velocity one-third greater.

The mean velocity depends upon the slope or gradient of the drain. The particles of a liquid move very freely among themselves, and the surface of a liquid at rest is always horizontal, consequently liquid in an inclined pipe slides down in an endeavour to take up a horizontal position at the lowest level, and the steeper the pipe the more readily the particles of water slide over each other and the quicker the velocity. A simple formula to find the mean velocity of flow in a pipe is—

$$V = 4\tfrac{1}{2}\sqrt{fs} \text{ (Eytelwein)}$$

when V = mean or average velocity in feet per second, f = fall in inches per yard, s = hydraulic mean depth in inches.

The *hydraulic mean depth* is the ratio of the cross sectional area of the flowing water divided by the length of that portion of the perimeter of the pipe which is in contact with the liquid, or briefly—

$$\frac{\text{Area}}{\text{Wetted perimeter.}}$$

In the case of a pipe flowing full, the hydraulic mean depth (generally written H.M.D.) will be—

$$\frac{\text{Area}}{\text{Circumference}} = \frac{\pi r^2}{2\pi r} = \frac{r}{2} = \frac{d}{4}$$

where r = radius, d = diameter, and π = ratio of circumference to radius of a circle = 3·1416 or $\frac{22}{7}$.

For a pipe flowing half-full it will be found that the H.M.D. is also $\frac{\text{diameter}}{4}$. It therefore follows that the average velocity of flow is the same whether the pipe is full or half-full, but it varies for any other depth of flow. If the average velocity of a pipe flowing full or half-full is taken as unity or 1, the average velocity at one-fourth full will be 0·75, at one-sixth full it will be 0·5, and at four-fifths full it will be 1·15, which is the maximum obtainable. Calculations are made on the basis of the drain flowing full or half-full, but allowances must be made when the quantity of liquid is insufficient to fill the pipe to this extent, as is invariably the case with house drains. The discharge is given by multiplying the cross-sectional area of the flowing liquid by its mean velocity.

Size of House Drains. The usual size for house drains is 4 in. diameter, but where a number of houses are drained through a single pipe, or in the case of institutions, then a 6 in. pipe is generally used, and is ample for the purpose.

Fall of Drains. House drains are generally laid with a fall, or gradient, of 1 in 40 for 4 in. pipes, and 1 in 60 for 6 in. pipes, which gives velocities when full or half-full of 3·75 and 4 ft. per second respectively. This apparently excessive velocity is required because of the extreme fluctuations in the flow through the pipes. It is undesirable to lay pipes more steeply than will give an average velocity (when half full) of 8 ft. to 10 ft. per second, as in such case there is a risk of the liquid draining away, and leaving unbroken solid matter behind in the pipes. Also, running water has the power to erode and wear away the hardest materials; this power varies with the square of the velocity, or double the velocity gives four times the eroding power. The wearing out of the house drain by the flowing water is, however, more an academical than a practical possibility.

It should be noted that there are a large number of formulae giving the velocity of flow in pipes, and that they all give slightly different results. The explanation is that each formula is based on a limited number of experiments under similarly limited conditions, and is not necessarily correct under other conditions.

Separate and Combined Systems. There are two systems of drainage, the *separate system*, where two entirely separate sets of drains are laid to a single property, one of which carries the rain-water and the other the sewage; and the *combined system*, in which one drain only is laid to carry off everything which comes from the premises. The determination of the system to adopt depends, in towns, upon the system employed for the public sewers. In many instances of town sewerage a compromise is effected. A "storm water sewer" is laid to collect and convey the rain falling on the streets and the front roofs and gardens of houses, and the "foul water sewer" receives the sewage from the houses and the rain which falls on the back roofs and yards; this is known as the *partially separated system*. In such case the houses would be drained on the "combined system." So far as the house owner is concerned, a separate system practically doubles the cost of the drainage. It also has the disadvantage that during dry weather the mud left behind in the storm water drain decomposes, and gives off foul gas, which may escape into the air.

When there are no public sewers, and the sewage has to be disposed of by the owner within the boundaries of his own property, it is desirable that the flow of rain-water to the outfall, or purification plant, should be reduced as much as possible, and it may be practicable in many cases to discharge the greater part of

TABLE I

QUANTITIES OF WATER (ALSO FOR SEWAGE) FOR DOMESTIC PURPOSES

	Gal. per Head per Day
Cooking	0·7
Drinking	0·3
Total for Dietetic Purposes	1·0
House Cleansing	3·0
Clothes Washing	3·0
Personal Ablutions	3·0
	10·0
If Water Closets are installed, add	5·0
If Baths are installed, add	5·0
Total for Domestic Use	20·0

the rainfall on to the garden without it entering the drains at all. When providing for rainfall in single house drains, allowance should be made for a fall at the rate of $1\frac{1}{2}$ in. to 2 in. per hour over the area occupied by the house, out-buildings, and paved yards. This rate would not probably continue for more than a few minutes at a time, but the drains should be large enough to carry the maximum quantity they may receive.

The quantity of sewage derived from a single house varies with the character and occupation of the residents, but the figures in Table I give an approximately correct average flow.

SUPERINTENDENCE

By P. J. Luxton
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PART III

OTHER CLERKS OF WORKS AND SUPERVISORS

The Estate Clerk of Works superintends building works, and to that extent his duties do not vary from those of the other types. But he has to know a lot about farm buildings, their construction and equipment, the special points to be observed in connection with stables, cowsheds, piggeries, barns, silos, stores for grain, roots, and other foods, and buildings containing farm machinery. There are problems connected with drainage and water supply that do not arise on new buildings in towns, and the use of local materials is also an important factor.

He will probably have to know something about forestry, the upkeep of paths, by-roads, hedges, gates and fences. Maintenance work on structures as widely different as the mansion and the cottage will be his business, and he may have to collect rents, superintend a fire brigade, organize functions, and even play a church organ. Much of the work done under him will be by direct labour, and as far as possible such materials as timber, stone, sand, ballast, and perhaps slate will be obtained on the estate.

He is provided with a house, and is often a person of importance in his district. He does a considerable amount of designing of farm buildings and cottages, and generally is a combination of architect, builder and superintendent. Posts of this kind are fewer now than they were a few years ago, because of the breaking up of large estates, farms having been sold to their occupiers or an investor. The estate clerk of works is usually responsible to the estate agent, as far as the non-technical side of his work is concerned, or to his employer direct.

Vacancies are infrequent. They may be advertised in a paper like *The Field*, filled privately, or through the Society of Estate Clerks of Works. Sometimes, on a large estate, an assistant succeeds to the vacancy. Salary would depend on a number of considerations, extent of estate, size of house occupied, supply of fuel and farm produce, and other things.

The general qualifications are those already mentioned for the new building clerk of works, plus a knowledge of agricultural and similar matters. Books dealing with farm buildings are obtainable, and the Board of Agriculture and Fisheries supplies pamphlets gratis which contain much valuable information. As the estate clerk of works buys materials and pays wages, he has to have a knowledge of business methods which would be somewhat akin to those adopted in a small builder's office. On an extensive estate he is supplied with a clerk, who has to be a fair draughtsman.

The Establishment Clerk of Works is in a position which is a cross between the man on new buildings, and the man on the estates. The word " Establishment " is used as meaning places like hospitals, asylums, poor law institutions, ecclesiastical and public buildings, not directly concerned with agriculture. On military buildings a particular type of superintendent known as a military foreman of works is employed, whose status and duties will be explained later.

The duties on establishments include the occasional supervision of new structures, but more particularly the maintenance of extensive existing buildings. This clerk of works employs direct labour, buys materials, and takes his instructions from an architect, and probably an engineer. He is concerned with the renewal of damaged or worn parts, with internal alterations—which may be frequent—with periodical re-painting and cleaning, the keeping in wholesome condition of drains and sanitary fittings, the inspection of hydrants and fire extinguishing appliances, renewal of lighting defects, and the upkeep of heating and similar apparatus. Often he makes fittings and appliances which cannot be conveniently obtained from outside sources. On cathedrals and similar buildings the clerk of works usually is a man who has been a stonemason; on other kinds of establishments the carpenter is most frequently met with.

The qualifications do not vary from those already detailed. The pay will depend upon several circumstances, such as the use of a residence, the right to a superannuation allowance or pension, meals on the premises, and other things. Generally speaking, the establishment clerk of works is as well off as the man on a new building, but like the one on estates, he has the advantage of holding a position which is permanent and not lost when a building is completed. Much tact and patience is necessary, one difficulty sometimes being the number of persons in authority connected with the establishment. The number of such posts is not large, consequently vacancies are infrequent. They are usually filled privately.

Public authorities employ a clerk of works whose position is somewhat similar, although usually he does not employ direct labour. He is found, for instance, in the service of county education committees, where he acts under the committee's architect on works connected with the upkeep of, and addition to, school buildings and premises. In addition to inspections of structures, drainage, etc., he measures up and checks accounts for final approval, makes surveys for proposed alterations or additions, interviews people to obtain a report on their views, and prepares drawings of existing and proposed work. In a large county there is a considerable amount of travelling involved by or in this position.

City and Town Councils owning a considerable amount of property sometimes have a clerk of works, and this man may have to include in his duties the inspection of public conveniences, highways and paths. Public authority positions are usually filled through advertising. On civil government buildings the establishment clerk of works is an officer of H.M. Office of Works. He has probably been promoted from a subordinate position, after passing examinations, and the permanent man is entitled to a pension, if he lives long enough. In addition, the Office of Works has a temporary staff. The London County Council also has permanent and temporary staffs. Particulars of the requirements and conditions of appointment under both the Office of Works and the L.C.C. can be obtained on application to these authorities.

The Military Foreman of Works. The only other separate type that will be dealt with is the previously mentioned military foreman of works, who is a non-commissioned officer of the Royal Engineers. With the exception of large new premises in Great Britain, the military foreman of works supervises, under Royal Engineer officers, the erection and maintenance of military buildings in all parts of the British Empire. He joins the Engineers as a sapper, already possessing some capacity in the practice of a skilled craft. After he has, at his craft, attained the standard of "very superior," obtained a certificate respecting his general education, undergone military training and received promotion, he is accepted by examination for a course of instruction lasting twelve months at the School of Military Engineering, Chatham. Practically his whole time is occupied by this course, which covers building construction, sanitation, surveying, and electrical work. At its conclusion he sits for an examination, and, if successful, is given an appointment as an assistant M.F.W. for a probationary period of six months. If, at the end of that period, he has been proved efficient, he becomes a fully qualified M.F.W.

QUALIFICATIONS AND APPOINTMENT OF FOREMAN

The office of clerk of works, as has been explained, varies considerably in its character. That of the foreman is different; his employer is nearly always the builder or contractor.

General qualifications are obviously very similar to those of a clerk of works. But there is this distinction between the two occupations. Most building operations require a foreman;

for the larger ones only is the cost of employing a clerk of works entertained. So the number of openings for a foreman are greatly in excess of those for a clerk of works. The majority are for the working foreman, and an ambitious building operative will, if he watches his opportunity, find one of these without a great deal of difficulty. He must be a responsible person, energetic in looking after his employer's interest, competent at a skilled craft, and able to get other men to work under him.

But it is not so easy to get an appointment as a general foreman. Most men in this position are on the wrong side of the forties, and have not been given the responsible post they hold until they have had considerable experience, and shown capacity above the average. The cost of the buildings on which they are employed will probably be not less than £8,000, and may be at any figure between that and a £1,000,000. Jobs costing £100,000 are not by any means uncommon, and the contractor has much at stake in undertaking to do work involving such a sum. The possibility of loss is usually present. Consequently his chief man on the works, the general foreman, is not selected at random.

The general foreman usually has a more regular job than the clerk of works, in that if satisfactory to his employers, he moves from one job to another; few architects have a practice sufficiently large to enable them to retain the services of a clerk of works for a long period. In comparing the remuneration of the two, the advantage probably lies with the general foreman. There would not be much difference in salary, but the latter often receives a bonus if his management produces a profitable result. The clerk of works receives his salary only; occasionally his employers may give him a present on parting, but he has nothing whatever to do with profits.

An appointment as general foreman is obtained by promotion, by private recommendation, by direct application to contractors, by advertising in trade journals, and through the various builders' foremen's associations. Of these there are three in London, and some in Bristol, Birmingham, and other large cities. The position of working foreman is usually filled by promotion, or by direct application to contractors. Deputy foremen, who superintend particular trades under a general foreman, are usually appointed by him, and not by the contractor.

In applying for these kinds of positions, the general particulars previously given in connection with clerks of works' appointments hold good. Trade, age, experience, general qualifications and salary required should be stated, and references supplied.

BUILDING SCIENCE

By Raymond R. Butler, M.Sc., A.I.C., F.C.S.

LESSON III

WATER

Pure natural water should be clear and transparent, free from taste and smell. A classification of drinking waters (Table VI) based on their degree of purity is a fairly satisfactory one.

Spring Water. This water is frequently calcareous (hard) and often chalybeate, due to dissolved iron. The brown incrustation frequently found around the spot from which the water is issuing consists largely of oxide and hydroxide of iron (Fe_2O_3 and $Fe(OH)_3$).

Deep Well Water. This is a very satisfactory source of supply, particularly in sandstone areas. The water may be hard, due to the presence of

TABLE VI

Classification of Drinking Waters

Degree of purity	Origin of water	Nature of water
1. Wholesome	(a) Spring water (b) Deep well water (c) Upland surface water	Very palatable
2. Suspicious	(d) Stored rain water (e) Surface water from cultivated land	Moderately palatable
3. Dangerous	(f) River water (g) Shallow well water	Palatable

dissolved salts, but its passage through the strata of rock effectively filters it from undesirable substances. Water from wells more than 100 ft. deep is considered safe for drinking purposes (due to the filtering effect of the rock strata), provided the well is efficiently lined and contamination by surface water prevented. Artesian wells, named after the village of Artois, France, at which the first well of this kind was constructed, tap an underground reservoir under pressure, and as water tends to "find its own level," the steady flow from a well of this nature often assumes large proportions.

The deep well must not be confused with the shallow well, frequently only 20 ft. in depth, which merely collects subsoil water, often of very doubtful purity.

Upland Surface Water. To-day it is not uncommon for the authorities in a large city to trap, by means of a masonry dam, large quantities of clean mountain and upland water, and to convey such water across country by means of cement conduits, for the use of the city.

For example, the Dartmoor reservoir at Burrator provides Plymouth with upland water, and the Birmingham Corporation, by trapping water in the Elan Valley in Mid-Wales, supply Birmingham with some 75,000,000 gals. of good water per day.

Such water is frequently comparatively soft, due to the absence of dissolved calcium compounds. The standard "degree of hardness" in water is the solution of one grain of calcium carbonate per gallon of water, and it has been agreed that water containing six grains or less per gallon (6° hardness) shall be considered *soft* water, while more than six grains per gallon constitutes *hard* water.

The solution of calcium carbonate ($CaCO_3$) in water is rendered possible by the presence of carbon dioxide (CO_2). Thus—

$$\underset{\text{(chalk, insoluble in water)}}{CaCO_3} + \underset{\text{(carbon dioxide)}}{CO_2} + H_2O \longrightarrow \underset{\text{(calcium bicarbonate, soluble in water)}}{CaCO_3.H_2CO_3}$$

The substance calcium bicarbonate is colourless and soluble in water. It is usually spoken of as ***temporary hardness***, because on boiling the water it decomposes, carbon dioxide escapes, and white insoluble calcium carbonate is precipitated. This is the origin of boiler incrustation, and of the "fur" in the kettle. *Permanent hardness* is due to dissolved calcium and magnesium sulphates, which are not removed in the same way on boiling the water.

Several methods of softening water are employed to-day. *Clark's method* consists of adding to the water 1 oz. of quicklime per 700 gals. of water for every degree of hardness present in the water. The quicklime combines with the loosely combined CO_2 in the calcium bicarbonate, and is precipitated as $CaCO_3$; in doing so this action decomposes the bicarbonate, so that the calcium in that is precipitated as insoluble $CaCO_3$ also.

Other ways are: (*a*) by the addition of sodium carbonate (Na_2CO_3) to the water. This, however, causes frothing and pitting of the boiler plates when employed in boilers, and therefore (*b*) barium carbonate ($BaCO_3$) is sometimes employed for a similar purpose; (*c*) by the modern *Permutit* process, in which complex silicates precipitate the temporary and the permanent hardness together. For further details on this important subject the student should consult standard textbooks.

It should be noted that one important difference between hard and soft waters is their effect on lead. Hard waters coat lead pipes with a kind of protective skin of lead sulphate, whereas soft water dissolves lead progressively and continuously. The reactions are probably complex, but it is suggested that dissolved oxygen and carbon dioxide in the water may account for the action. The chemical equations may possibly be of this nature—

(*a*) $\underset{\text{(lead)}}{2\,Pb} + \underset{\text{(oxygen)}}{O_2} \longrightarrow \underset{\text{(lead monoxide)}}{2\,PbO}$

(*b*) $PbO + H_2O \longrightarrow \underset{\text{(lead hydroxide)}}{Pb(OH)_2}$

(*c*) $Pb(OH)_2 + CO_2 \longrightarrow \underset{\text{(lead carbonate)}}{PbCO_3} + H_2O$

The lead carbonate so produced is not an adherent skin on the surface of the pipe, but is loose and may be carried along by the flow of water. The action of lead on the human system is cumulative.

The purification of drinking water, and the problems arising in connection with the disposal and treatment of sewage are beyond the scope of this section.

BUILDING CALCULATIONS

By T. Corkhill, M.I Struct.E., M.Coll.H.

LESSON II

DECIMALS

7. It has been shown that each succeeding column of a number *increases* in value by multiples of 10 from the units column. Similarly, in the opposite direction each column *decreases* in value by subdivisions of 10.

When we continue decreasing below the unit, we have parts of a unit, which are called *decimal fractions.* A decimal "point" is placed after the units column, to distinguish between the whole number and the fraction. We call the whole number the *integral* part, and the remainder the *fractional* part.

Consider the number 342·423, (the number reads, three hundred and forty-two, point four two three). To the right of the decimal point, the figure 4 represents 4 tenths of a unit, the figure 2 represents two hundredths of a unit, and the 3 represents three thousandths of a unit; that is, the fraction equals

$$\frac{4}{10} + \frac{2}{10 \times 10} + \frac{3}{10 \times 10 \times 10},$$

which equals $\frac{423}{1000}$.

8. **Addition and Subtraction of Numbers with Decimals** are worked in exactly the same way as previously described for whole numbers, keeping the decimal points under each other.

Addition	Subtraction
723·564	723·564
214·376	214·376
937·940 *Ans.*	509·188 *Ans.*

9. **Multiplication.** If we move the decimal point one place to the right, the value of the number is *increased* tenfold; thus -

$$346·23 = 34·623 \times 10$$
$$3462·3 = 34·623 \times 100$$

To multiply a number by 99 we move the decimal point two places, and then subtract the number.

Multiplication is the same for decimals as previously described for whole numbers; but the fixing of the decimal point in the answer may give trouble to the student; if so, the decimal point may be ignored until the result is obtained, and then found by the *approximate* method.

Example. Multiply 652·34 by 273·26.

Solution.

```
      652·34
      273·26
   130468·
    45663·8
     1957·02
      130·468
       39·1404
  178,258·4284  Ans.
```

Explanation. The first operation is to multiply 652·34 by the left-hand figure in the multiplier. That is, we commence with 4 × 2, which is $\frac{4}{100}$ × 200, hence the result is 8 *units*: place the 8 in the units column. Complete the multiplication of the top line by 2. Proceed in the same way for the next multiplier, which is 7; but we do not require to consider the decimal point, because each succeeding line of working starts one place farther to the right. Note that the number of decimal places in the product equals the number of decimal places in the factors.

Rough check for fixing the decimal point—

$$600 \times 300 = 180,000,$$

therefore, the decimal point comes after the sixth digit.

The student should apply the "rough check" method in every case. Take the nearest round numbers, then the multiplication can be done mentally. If we had taken 700 × 200 it would have given 140,000, which would again give the decimal point after the sixth digit.

10. **Division.** If we move the decimal point one place to the *left*, the value of the number is *diminished* to one-tenth of its original value.

$$34·623 = 346·23 \div 10$$
$$3·4623 = 346·23 \div 100$$
$$0·034623 = 346·23 \div 10,000.$$

Example. Divide 17·646 by 6.

Solution. 6|17·646
2·941 *Ans.*

Example. Divide 1346·7672 by 12·24.

Solution.

```
Divisor Dividend  Quotient
1224)134676·72(110·03 = Ans.
     1224
      1227
      1224
         3672
         3672
```

TABLES

Weight (Avoirdupois)

16 drams = 1 ounce (oz.).
16 oz. = 1 pound (lb.).
14 lb. = 1 stone.
28 lb. = 1 quarter.
4 qs. (112 lb.) = 1 hundredweight (cwt.).
2,240 lb. = 20 cwt. = 1 ton.

Capacity

4 gills = 1 pint.
2 pints = 1 quart.
4 quarts = 1 gallon.
2 gallons = 1 peck.
4 pecks = 1 bushel.
8 bushels = 1 quarter.

Length

12 inches = 1 foot.
3 feet = 1 yard.
$5\frac{1}{2}$ yd. = 1 rod, perch, or pole.
220 yd. = 40 poles = 1 furlong.
1,760 yd. = 8 furlongs = 1 mile.
100 links = 22 yd. = 1 chain.
10 chains = 1 furlong.

Area

144 sq. inches = 1 sq. foot.
9 sq. feet = 1 sq. yard.
$30\frac{1}{4}$ sq. yards = 1 sq. pole.
40 sq. poles = 1 rood.
4 roods = 1 acre.
4,840 sq. yards = 1 acre.
10 sq. chains = 1 acre.
640 acres = 1 sq. mile.
(Note local differences; Cornwall acre = 5,760 sq. yards.)

Angles

60 seconds = 1 minute.
60 minutes = 1 degree.
90 degrees = 1 right angle.
360 degrees = circle.
57·3 degrees = 1 radian = length of radius stepped round circumference.

Volumes

1,728 cub. inches = 1 cub. foot.
27 cub. feet = 1 cub. yard.

METRIC SYSTEM

Multiples			Unit	Sub-multiples		
Kilo	Hecto	Deca	Gramme.	deci	centi	milli
1,000	100	10	Litre.	$\frac{1}{10}$	$\frac{1}{100}$	$\frac{1}{1000}$
Km.	Hm.	Dm.	Metre.	dm.	cm.	mm.

The Metre is the unit of length.
The Litre is the unit of capacity.
The Gramme is the unit of weight.

Are = unit of area.
Stere = unit of volume.

1 cm. = $\frac{1}{100}$th of a metre. 1 Hm. = 100 metres.

The Are and the Stere are only used by surveyors and timber merchants, otherwise we use the square metre and cubic metre —

1 Are = 100 sq. metres = 10 m. × 10 m. = 100 m^2 = unit of land measure.
1 Stere = 1 cub. metre = m. × m. × m. = m^3 = unit of timber measure.

APPROXIMATE ENGLISH AND METRIC EQUIVALENTS

A metre = $1\frac{1}{11}$ yards = 3 ft. $3\frac{3}{8}$ in.
A sq. metre = $10\frac{3}{4}$ sq. feet.
4,000 sq. metres = 1 acre.
An are = 100 sq. metres = 119·6 sq. yards = $\frac{1}{40}$ acre.
A stere = 1 cub. metre = 1 cub. yard 8·32 cub. feet.
A litre = ·213 gallons.
A kilogram = 2·205 lb.

CONVERSION TABLE

To Convert	To	Multiply by
Acres	Hectares	0·4047
Centimetres	Inches	0·3937
Cub. centimetres	Cub. inches	0·061
Cub. metres	Cub. yards	1·308
Cub. feet	Gallons	6·23
Cub. inches	Cub. feet	0·00058
Metres	Feet	3·281
Ounces (Av.)	Grammes	28·35
Pounds (Av.)	Kilograms	0·4536
Pounds per sq. inch	Kilograms per sq. centimetre	0·07031
Sq. centimetres	Sq. inches	0·155
Sq. metres	Sq. feet	10·76
Sq. inches	Sq. feet	0·007
Sq. yards	Acres	0·0002067
Tons per sq. inch	Kilograms per sq. centimetre	157·5
Yards	Miles	0·000568

Note. To reverse the conversion, divide column (2) by column (3) to give column (1), i.e.—

$$\frac{\text{Hectares}}{0{\cdot}4047} = \text{Acres.}$$

Explanation. (1) Move the decimal point to the end of the divisor, and the same number of places in the dividend. (2) Proceed as previously described for long division. (3) When the decimal point is reached in the dividend, place a decimal point in the quotient. In this example, when the 6 is brought down from the dividend, we ask how many times will 1224 go into 36, the answer is 0, therefore, we put 0 in the quotient. The same thing occurs when we bring down the 7, but the decimal point has intervened.

When all the digits in the dividend have been used and we still have a remainder, we can still continue the process by adding cyphers to the remainder, because 134676·72 has the same value as 134676·72000.

We often find that the decimal part of the quotient does not work out, but repeats itself; it is then called a *recurring decimal*, which will be considered in "fractions."

CONTRACTED METHODS

11. In building calculations we often require approximate values; for instance, when finding the area of a floor, in squares of 100 sq. ft., we do not generally consider anything below ·01, or 1 sq. ft.

When using logarithms we usually work to four figures; the slide rule will only give accurate results to three figures; and generally, in building calculations, if we are correct to four figures, the answer is satisfactory.

The student should be clear as to the meaning of significant figures. For example—

347963	= 348000	to 4 sig. figures.
0·078543	= 0·07854	,, ,, ,,
6534·976	= 6535·	,, ,, ,,

When we remove the unnecessary digits, if the last digit to be removed is more than 4, we *add one* to the last remaining digit. Hence, in the first example above, when we cut off the 6, we had to add one to the 9, which gave the answer as 348000.

12. **Multiplication.** Find the product of 341·625 × 542·26 to 4 sig. figures.

```
                          341·63
                          542·26
                         170815
                          13665
                            683
Rough check :                68
300 × 600 = 180,000.         20
                         185251
```

Therefore, the answer to 4 sig. figures is 185300.

Explanation. (1) Use five digits in both multiplicand and multiplier. (2) Multiply 341·63 by 5. (3) Fix the decimal point by considering $500 \times \frac{3}{100} = 15·$; or fix the decimal point at the end, by the "rough check" method. (4) Cut off the right-hand digit, and multiply 3416 by 4, but take into consideration the figure we *should have carried forward* if we had used the right-hand digit. (5) Repeat the process for each digit in turn, of the multiplier; but for every new digit of the multiplier cross off a digit of the multiplicand.

Example. Find the number of squares contained in a floor 123·25 ft. by 35·75 ft., using contracted multiplication. A square = 100 sq. ft.

Solution.

```
 123·25
  35·75
  36975      Rough check,
   6162      100 × 40
    862      -------- = 40 squares.
     61        100
  4406·0     44 squares, 6 sq. ft.  Ans.
```

13. **Contracted Division.** Divide 3214·8 by 84·71, approximately.

```
8471·)321480·(37·95  Ans.
      25413
       6735          Rough check :
       5930            3000
        805            ---- = 30.
        762             100
         43
         42
```

Explanation. (1) Arrange the divisor with the decimal point *at the end*, and move the decimal point in the dividend correspondingly. (2) Proceed as in ordinary division for the first digit in the quotient. (3) Cut off the last digit in the divisor; then try how many times 847 will go into the remainder 6735; place 7 in the quotient. (4) Repeat the process, each time cutting off another digit from the divisor.

Example. Solve approximately $\frac{3·2981 \times 7·4382}{0·093724}$.

Solution. 261·75 *Ans.*

EXERCISE II

1. A load of timber contains 600 ft. super of 1 in. boards. How many loads will it take to floor 16 rooms 12¾ ft. by 11¼ ft.?

2. The area of windows for habitable rooms must equal at least $\frac{1}{10}$th of the floor space, and half of the window space must open. Find the minimum size of the opening casements for a room 18¼ ft. by 15½ ft.

3. Evaluate, by contracted methods $\frac{2328· \times 59·27}{28·361}$

Answers to Exercise I

(1) The hall is 136 ft. × 65 ft. × 23 ft.

(2) 1557 squares and 60 sq. ft.

(3) 3996 sq. ft. and 3996 panes.

CIVIL ENGINEERING

By Professor F. C. Lea, D.Sc., M.Inst.C.E.

LESSON I

INTRODUCTION

The civil engineer, according to Telford's classic definition, is one who " directs the sources of power in nature for the use and convenience of man " ; but in these days the work of the civil engineer is principally confined to providing means of transport—which involves roads, railways, harbours, bridges, and other structures—

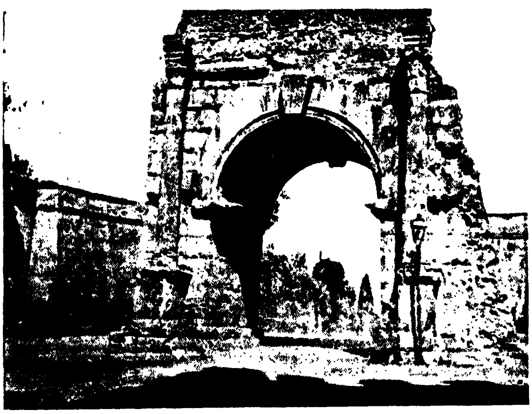

Fig. 1. Outer Entrance Gate to Rome
From the Appian Way

controlling and supplying water, dealing with sewage, and other communal engineering problems.

For some thousands of years before Christ, in Mesopotamia and Egypt, canals for irrigation and transit purposes, and splendid buildings, principally in brick and masonry, had been constructed. The Romans, centuries before the dawn of the Christian Era, made excellent roads, of which the famous Appian Way (Fig. 1) is so well known. They built splendid aqueducts for carrying water to their cities, the finest example of which is probably that still existing at Nimes (Fig. 2). They also erected noble buildings, of which the Colosseum (Fig. 3) and the ruins of the baths of Caracalla are deservedly famous, and which have withstood the ravages of time better than the destructive acts of men. They designed and arranged their cities so that not only business, but the discussion of public affairs could be carried on in surroundings made beautiful by the engineer, the architect, and the sculptor.

Fig. 4 shows a view of the Roman Forum, with the arch of Titus and the Coliseum in the background. The three columns of the Temple of the Vestal Virgins are clearly seen. The Palatine Hill, on which were built the famous palaces, is seen to the right.

Arch bridges, which they frequently threw across streams to facilitate commerce and military operations, still carry roads over swift

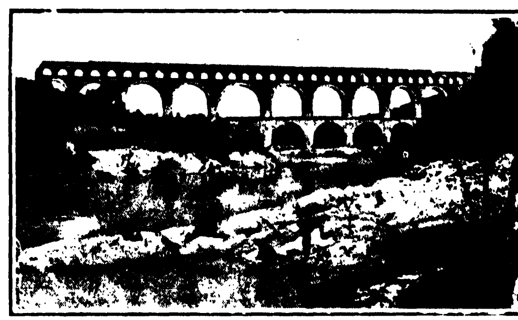

Fig. 2. Nimes Aqueduct, Pont du Gard

running rivers. Fig. 5 shows the only remaining arch of the Pons Aemulius, built probably in the time of Augustus, but there are many Roman bridges still intact. They not only constructed, before the time of Christ, elaborate water-works and splendid aqueducts, many miles in length, to bring water to Rome, but also made main drains, which still bring surface water to the Tiber. Fig. 6 shows, just above the surface of the water, the arch exit of the Cloaca Maxima (Greatest Sewer), the main sewer of ancient Rome. This was made in the time of Tarquinus Priscus to drain the marshy land between the Capitoline and the Palatine. Very little progress, however, in civil engineering was made from early Roman times until the dawn of the nineteenth century.

It was only in 1778 that the first iron bridge (Fig. 7) was built by Wilkinson and Darby over the river Severn, an arch of 100 ft. span strangely like a wooden structure that Trajan threw over the Danube for military purposes, about the end of the first century A.D., and very nearly equal in span to the longest arch the Romans built. This first iron bridge was soon followed, however,

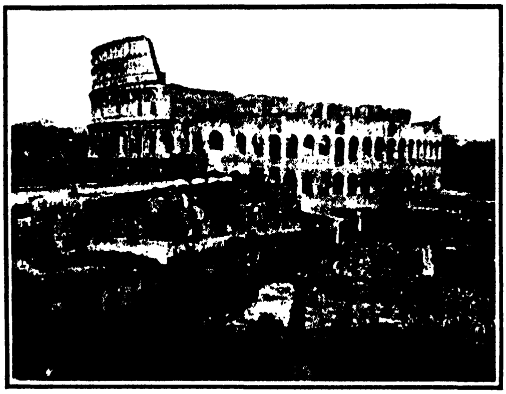

FIG. 3. COLOSSEUM, ROME

by many others of much greater span, and during the last hundred years numerous bridges have been constructed in iron and steel, many of

FIG. 4. THE ROMAN FORUM
with the Colosseum and Arch of Titus in the background and ruins of the Temple of the Vestal Virgins on the right

great span, the famous cantilever Forth Bridge (Fig. 8) having a main span of 1,700 ft., and the new Quebec cantilever bridge a span of 1,800 ft.; suspension bridges of 2,000 ft. span have been made, and the new bridge to be erected across Sydney harbour is to be a steel arch of 1,600 ft. span. This wonderful progress has been very largely possible for three reasons: the development of the art of casting in iron, the production and fabrication of wrought iron and steel, and last, but not least, the development of theory, allied with experiment, that has made it possible to control the choice of materials, and to predict with very considerable precision the performance of new and larger types of structures.

It can hardly be said that corresponding progress has been made in the design of earth works and masonry structures, but the development of reinforced concrete on a theoretical and experimental basis has led to the economical construction of great buildings, retaining walls,

FIG. 5. PONS AEMULIUS, NOW CALLED PONTE ROTTO
The remaining arch of a bridge built, probably, 50 B.C.

dams, and other structures. The Roman engineers were able to construct channels and other works for the control of the flow of water, but again it was not until the eighteenth century that the modern developments in the knowledge of the laws governing the flow of water could be said to have commenced.

The art of road making in this country, at least, had almost died out from the Roman occupation until the beginning of the nineteenth century. In 1803, Telford, the first president of the Institution of Civil Engineers, reported to the Government upon the state of the roads, and subsequently made the famous Liverpool and Great North roads and the road from London to Holyhead, in connection with which he designed and erected the splendid suspension bridge across the Menai Straits. Railways and light railways have been developed within the last hundred years. At the present time road making is advancing very rapidly in this country, and it forms a most important part of the work of the civil engineer.

The growth of large towns that has taken place so remarkably during the last century, has made it increasingly necessary to consider the important problems of water supplies and sewage disposal; and in the future the civil engineer, along with the architect, will be called upon more and more to assist in the solution of problems of public health and transit, to design and improve towns and cities, and to conserve and convey the available sources of water to our large industrial areas. He will also be called upon to assist the mining engineer, the mechanical and electrical engineer, to utilize as far as possible the sources of power in our coal beds, in our streams, and possibly in the tides.

FIG. 6. PONTE EMILIO, OVER THE TIBER
Beneath the right arch is seen, near the water surface, the arch of the Cloaca Maxima, the "great sewer" of Rome

In carrying out these works he has many difficulties to face, but the large body of practical experience that has been codified, and the body of theory that has been gathered together by many patient workers, makes it possible for the young engineer to face with considerable confidence the task.

Training of the Civil Engineer. In the articles that follow it is hoped to deal with some of the fundamental problems that underlie the work of the civil engineer, not by any means completely; upon most branches of civil engineering special treatises have been written, and for more complete knowledge the reader will consult standard works. It is essential that any serious student of the subject should have a satisfactory knowledge of the fundamentals of mathematics, physics, and chemistry, and for a good many problems a knowledge of geology is desirable. On the basis of these, engineering theory is founded, and for the rest experiment and practical experience must be relied upon. The best

FIG. 7. THE FIRST IRON BRIDGE
It was built over the River Severn in 1778, and is still in use

training is to follow a complete course at a recognized technical college or university for three or preferably four years, to be supplemented by two or three years' practical and methodical training in the office, and some training in workshops and experience before going to the university, and during the long vacations, is of great value. Civil engineering is, however, a school in which those of the widest experience are always learning, and every fresh piece of work brings new problems and new interests.

FIG. 8. FORTH BRIDGE
The two main spans are each 1,700 ft.

The only possibility of solving many of these with assurance is by the aid of a sound knowledge of fundamental principles, common sense, and intuition born of observation and a wide experience.

GAS-FITTING

By R. J. Rogers
Chief Superintendent, Fittings Department, City of Birmingham Gas Department

LESSON III

METHODS OF MEASURING GAS

Gas Meter. For safety and convenience it is desirable that the meter should be fixed in a light, accessible and well-ventilated position.

For accuracy of registration it is essential that it should be fitted perfectly level and in a position which is not subjected to extremes of heat or cold. Trouble and inconvenience may be avoided if a position for the meter is arranged when the house is planned.

The gas meter, though a much maligned machine, is one of the most accurate measuring instruments in general use to-day. Its accuracy is vouched for, not only by the meter makers and by the gas undertaking, but by Statutory Gas Inspectors working under the jurisdiction of a panel of Justices of the Peace appointed by the local authority. By law the maximum of error of a meter must come within the limits of 3% slow—that is, against the gas undertaking, and 2% fast—that is, against the consumer.

The *wet meter* is the oldest type, and in suitable positions, such as cellars or basements, it has much to recommend it.

This meter depends for its registration on the revolution of a drum divided by oblique vanes into three or four chambers which consecutively fill with gas over a water seal and then discharge to the meter outlet.

The *dry meter* is a much commoner type to-day. This is made of tinned plate and is divided horizontally into a shallow upper compartment and a larger measuring chamber below.

This measuring chamber is again completely divided by a central vertical plate. To each side of this vertical plate are attached bellows of Persian sheep skin, prepared and tanned to a specification. By suitable slide valves and ports gas is fed alternately inside and outside both these bellows, thus giving four discharge chambers to outlet, the inflation and deflation of the leather diaphragm ensuring a steady flow of gas to the outlet. By means of flag wires, tangent and train of wheels each motion of the diaphragm is recorded on the index of the meter.

Fig. 4 shows the internal construction of a dry meter. From the inlet of the meter the gas enters, through the orifice H, the triangular chamber C, a portion of which has been cut away to show the valves V_1 and V_2. The bottom portion of the meter is divided into halves by the vertical partition P. In each half is a cylindrical chamber, A_1 and A_2, the end of which is formed by a disc K attached to the rim of the cylinder by a flexible leather diaphragm D. The meter is actuated by the pressure of the gas. The function of the valve (which resembles the slide valve of a steam engine) is to admit gas alternately to the inside and outside chambers, both being used for measuring purposes. Whilst the inside chamber is filling, the valve allows the gas displaced from the outer chamber by the movement of the disc K, to pass to the outlet of the meter, and in the same way allows the gas from the outer chamber to pass to the outlet whilst the inside chamber is filling. It is necessary to have the chambers and valves in duplicate so that the action of the meter shall give a continuous supply of gas at the outlet.

As shown, the valve V_2 is admitting gas to the outer chamber M_2, and is allowing gas from the inner chamber A_2 to pass to the outlet. This is shown more clearly in the enlarged section through the valve.

The registration is accomplished through the tangent arms T_1 and T_2, which are moved to and fro by the rods R_1 and R_2. These rods are rotated first one way and then the other by the in-and-out movement of the discs K. By means of the links L_1, and L_2, the pendulum motion of the tangent arms is converted into a rotary motion in one direction at the worm wheel W, and this by means of a pinion and shaft is made to actuate a train of spur wheels and pinions, attached to which are the index fingers. Motion is given to the valves by connecting rods working on cranks on the worm wheel shaft.

The *prepayment*, or *slot meter*, is exactly the same in construction as the ordinary meter, except that suitable mechanism, actuated by the engaging of the coin in the necessary cog, enables a gas valve to be opened, which valve is gradually closed again as the gas is consumed.

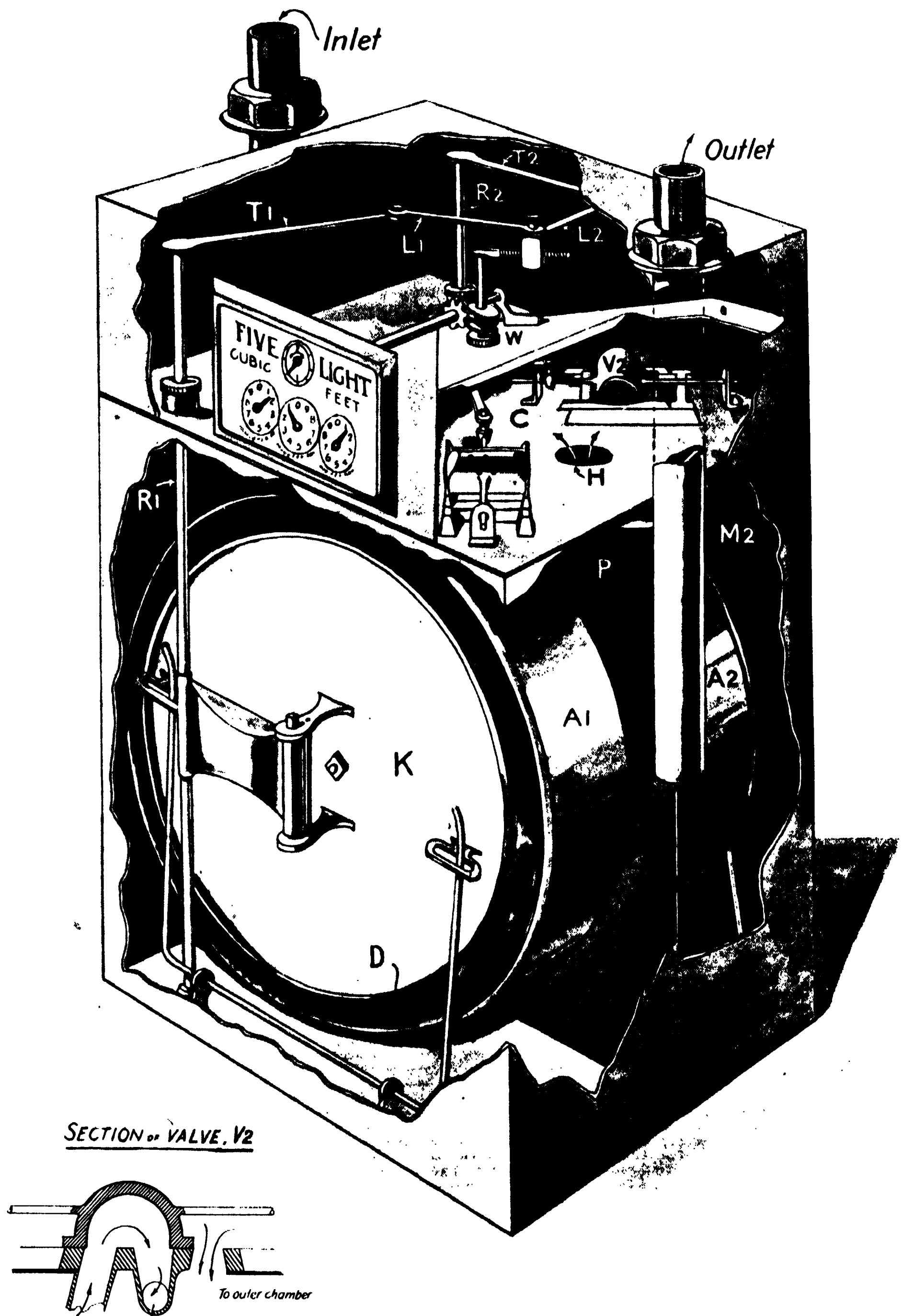

FIG. 4. VIEW SHOWING INTERIOR CONSTRUCTION OF DRY METER

It should be remembered that the gas registered on the index of the prepayment meter is not affected by any inaccuracy or breakdown of the automatic mechanism.

Sizes of Meters. The size of meters from their inception up to a few years ago was designated in "lights." Each "light" represented a nominal capacity of six cubic feet of gas per hour, so that a 5-*light* meter had a normal capacity of 30 cubic feet per hour. This nomenclature is a relic of the days when gas was used almost entirely for the flat flame or bat's-wing burner, the approximate hourly consumption of which was 6 cubic feet.

In recent years a series of *standard* size meters has been adopted by the gas industry, and Table 1 gives the capacity of both *light size* and *standard size* of meters.

TABLE I

SIZES OF GAS METERS

Standard size	Size in lights	Capacity in cu. ft. per hr.	Size of service In.
1	5	30	¾
2	--	40	¾
3	10	60	1
4	20	120	1¼
-	30	180	1½
5	--	210	1½
--	50	300	1½
--	60	360	2
6	--	420	2

System of Charging for Gas. Although we have spoken of gas being measured in cubic feet, it is now charged in many districts at a price per *Therm.* The reason for this is plain. Not only does the consumption of gas in cookers, gas fires, etc., depend upon its heating value, but, as will be seen in a later lesson, the illumination received from an incandescent mantle is also dependent on flame temperature derived from the heat in the gas.

As the consumer of gas requires to purchase *heat*, the basis of charging for gas supplied has been arranged on the calorific, or heating, quality, in place of charging on the volumetric measurement, which does not take into account the heating quality of the gas.

Under the Gas Regulation Act, 1920, all gas undertakings are required to declare the calorific value of the gas they undertake to supply, and the local authority will test and certify that the gas, as supplied, is up to the declared standard. The consumer then pays for the heat content or *therms* in the gas he uses.

The unit of heat measurement is known as the *British Thermal Unit.* This is the amount of heat required to raise the temperature of one pound of water 1° Fahrenheit.

The calorific value of a gas is the number of these heat units in one cubic foot of the gas.

The therm is equal to 100,000 of these British Thermal Units. Thus, if gas has a

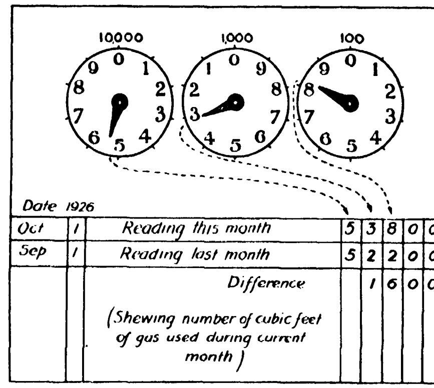

FIG. 5. HOW TO READ THE GAS METER

calorific value of 500 British Thermal Units per cubic foot, one therm would be contained in—

$$\frac{100{,}000}{500} = 200 \text{ cubic feet}$$

Or if its calorific value were 475, then $\frac{100{,}000}{475}$, i.e. 210·5, cubic feet of the gas would equal one therm.

To Read a Gas Meter (see Fig. 5). Write down the figures next behind the pointers, beginning at the left-hand dial, and then add two ciphers. Whenever the hand lies between two numbers the lesser number is read. It will be noted that whereas the two outside pointers rotate in a clockwise direction, the order of the figures on the middle dial is reversed and the pointer rotates anti-clockwise.

From the number obtained in accordance with these instructions deduct the previous reading of the meter. The difference between the two represents the quantity of gas consumed in the interval.

MAISONS LAFFITTE — THE CHATEAU

By W. [illegible]

See the article on "Architectural Drawing" which faces this page

ARCHITECTURAL DRAWING

By Walter M. Keesey, A.R.I.B.A., A.R.C.A.

LESSON I

INTRODUCTION

Draughtsmanship Yesterday and To-day. The training of the architectural draughtsman has received very considerable attention of recent years, and the impetus given to it by the growth of the large architectural schools and the establishment of new centres all over the country has been very marked. Formerly, draughtsmanship was mainly dependent on the carefully executed drawings which came from the chief architect's hands, and which received the flattery of imitation by the younger men. Fortunately, architects have, generally speaking, always been excellent draughtsmen of the "essentials" of their work, but the expense of reproduction was a considerable hindrance to freedom in method, and consequently the ink line drawing was most necessary. Another factor was the general simplicity of construction, which needed but few differences of representation, brick, stone, and wood being the chief items, with occasional steel girders appearing only on the sections.

The new age of concrete and steel has, however, acted very healthily upon the requirements of architectural draughtsmanship, and a whole new series of clean cut, decisive, and easily read methods have been evolved. This evolution has been gradual, of course, but a comparison of an average set of plans of 1900, with those of the present day, would reveal many salutary changes both in formal expression and artistic treatment. The progress of reproduction generally, but particularly in "true-to-scale" prints and pencil reproductions, has affected the standard considerably; both methods are capable of showing the true workings of the mind of the various well-known men at all the stages before the "inking in" by an assistant, however competent, inevitably destroys to some extent the personality of the designer present in the original work.

It will be recognized, then, that architectural draughtsmanship is something more than a mere recording of facts on paper; it can be made to display a personality of treatment, which, apart from being intriguing, can, and usually does, express all the varieties of thought and well-considered design which the architect desires to convey to the actual constructor.

This is very evident in a highly decorative scheme containing sculptured forms, when the drawings compare very remarkably with the finished building. A notable case in point would be, for example, the Central Hall, Westminster, designed by Lanchester and Rickards, and bearing on its stone surface an unmistakable likeness to the actual drawings, though having passed through the hands of the builder and sculptor. Such fluidity of thought and pencil must be the envy of most architects, but the present-day training endeavours to compete with the problem with a very great measure of success.

One is inclined to believe that the decorative work in such an architectural scheme as that of Maison Lafitte, shown in our frontispiece, must be due to the ability of the architect and the sculptor combined. It is generally understood that the architect decided in a broad way what was to be the general position and type of decoration, and that the sculptor carved his own interpretation of these plans. Most old work gives the impression of personal character in the various treatments of stone, wood, or plaster, and such study as can be given to decorative work is amply repaid by the observation of these characteristics.

This water-colour drawing by Mr. Cyril Fasey is an excellent example of his methods of work and should be referred to during the later lessons on "Rendering." Note the simplicity of the washes and the concentration on certain parts of the scheme of colour.

Basis of Draughtsmanship. What, then, is to be the basis of study? A capacity and inclination for drawing is obvious; and drawing, from the point of view of an architect, can only be considered as a means to one end, and that end is *expression.* The chief means of expression on paper is *line*, and this may be considerably amplified by the use of *tone*, either in light and shade, or *colour.* The student, in this purely technical side of his training, is faced with the problem of the expression of the surface and volume of objects both in plan and elevation.

Surface we know to be the result of the

composition of many underlying elements, and a knowledge of these is essential before positive expression can be described or illustrated. No two surfaces of different material, or two surfaces of the same material on different planes, or under different conditions of light and shade, should be drawn in an exactly similar manner. The powers of the draughtsman must therefore be infinitely varied and flexible, and in addition they must be directed and controlled by the capacity of the artist to visualize or imagine an object under the various conditions which will affect the attempt to render it in a drawing.

These various factors make it almost impossible to standardize any type or manner of line or tone in draughtsmanship; and such methods as the comparatively recent "architect's" method, in which the principal masses of a building were emphasized with an outline stronger than the general mass, merely serve to prove that such a simple formula is applicable only to the treatment of the most elementary surfaces and planes. The student appreciates at an early stage the importance of being able to express general planes, both in plan and elevation, but the artistic facility which is necessary to such expression is not easy to acquire.

The methods by which the teaching of architectural draughtsmanship may be approached are probably as varied as are the personalities of the teachers; but a brief outline of routine work is suggested, which, in lieu of the extensive training of a modern school, might be entered upon with little previous experience. It must be borne in mind that individual labour is usually hard, and as much additional knowledge as is possible should be gained from constant study of contemporary work. There are many exhibitions open in the various centres from time to time, and every school has one at the year's end; several publish their work, and the Architectural Press frequently reproduces representative work. All types of work become grist to the student's mill. The syllabuses of the various schools make illuminating reading, and consultation with the bibliography given would explain very quickly the reasons for the methods adopted. For the benefit of the novice, a summary of the progressive stages of study is given, and this is amplified in the later lessons on the particular subjects.

Suggested Course. It is impossible to divorce draughtsmanship from architectural education, and it is assumed that the student is desirous of entering the profession. For this reason all suggested experimental work has a twofold purpose—a training in the artistic and architectural appreciation of the objects studied, and also a training in facility of pure draughtsmanship, which is essential to representation.

The more easily and readily this is achieved the more quickly is the brain enabled to think, the eye to perceive, and the hand to obey and produce on paper.

A good general education is essential, and students must be advised to obtain the necessary qualifying examinations as laid down by the Royal Institute of British Architects, otherwise acute discomfort and wasted effort will result when the time comes for practice. Too much stress cannot be laid on this; but it may also be pointed out that a bias towards a future occupation could easily be arranged during the last years of general school education. Geometry and mathematics are essential, and historical architectural reading an advantage. Freedom in drawing should be cultivated, particularly analytical, and the memory faculty trained to the highest degree.

The further subjects of study should include geometrical pattern, solid geometry and projection, model drawing and perspective, use of scales and general precision, museum work of all sorts, lettering, measured drawings in various materials, constructional drawings and requirements, sciography or shadows, rendering in tone and colour, holiday sketching, competition drawings, and finally, working drawings for the job. It will be readily understood that as the above necessarily omits all reference to the more technical branches of the profession—such as architectural design, planning and construction, materials and hygiene, colour decoration, and professional practice the province of the architect becomes a very wide one. It is now considered that apart from all these many and varied branches of his technical education, he should be acquainted with a general sense of the importance and suitability of all decorative features, fittings, and details; he should have a reasonable knowledge of the various periods and styles of decoration and furnishing; and he should have a vast amount of common sense and imagination in the application of the schemes of his own brain or those of his clients.

ARCHITECTURAL DESIGN

By T. P. Bennett, F.R.I.B.A., and T. E. Scott, A.R.I.B.A.

LESSON IV

THE ELEMENTS OF ARCHITECTURE

DOOR AND WINDOW OPENINGS

Openings in walls are of two distinct types rectangular and arched—evolved from the constructional use of the lintel and the arch. In historic architecture, these methods have been employed for small and large openings respectively, but modern methods permit square-headed openings of greater span than is possible with the natural usage of stone as a constructional material.

In the earliest times the lintel was the only method employed in spanning openings. Its limit was soon reached, and this was one of the controlling features in Egyptian and Greek architecture.

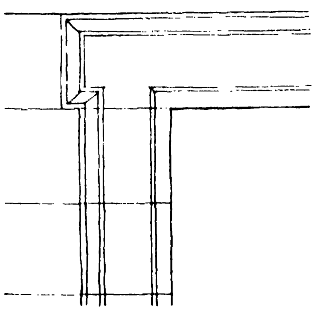

Fig. 17. The Theoretical Arrangement of the "Crossette"

There have been many attempts to overcome this difficulty: the heavy abacus of the Greek Doric Order, the battered jamb in Egypt and Greece, and the corbel under the lintel in Gothic work. None of these methods increased the size of the opening appreciably, and, in the two latter cases, seriously interfered with the hanging of a door and the framing of a window.

They all serve to illustrate the enormous freedom given to architecture by the discovery of the arch, the origin of which is not known, but is an interesting subject for speculation. It will be well to consider these two types separately, since their construction insists upon different architectural decoration.

Rectangular Openings. In primitive architecture it is not uncommon to find the sill, jambs, and lintel of cut stone, while the surrounding walling is in rubble. The subsequent decoration of those features provides what is known as an *architrave*, the most logical decoration which can be applied to a door or window opening. The need for a wide bearing for the lintel introduces the *crossette* (see Fig. 17). The next step is the introduction of a cornice to prevent rain from running on to the window. There are windows of this type at the Temple of Vesta at Tivoli, and an interesting variant is shown in Fig. 18, in which the importance of the lintel is accentuated by ornament. Between the architrave and cornice, a frieze may be added, giving a composition capable of many variations. Fig. 19 is one of countless examples.

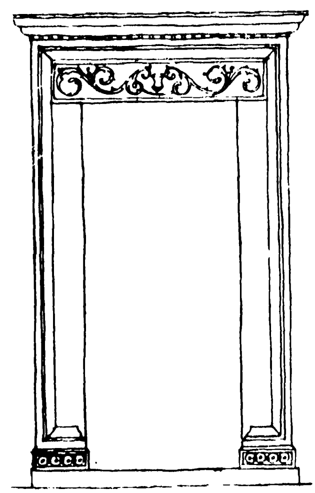

Fig. 18. Doorway at Corneto

The subsequent introduction of a pediment may be open to criticism in point of fitness, but since it serves to throw off the rain to the sides of the opening, its use may be accepted as sound. In any case its decorative effect fully justifies its employment (see Figs. 12, 21, and 22).

Greater effect will be given to the cornice by prolonging it beyond the architrave and supporting it on consoles, Fig. 20. It is essential that (1) the console shall be far enough away to allow for the bearing of the lintel; (2) the console must not descend below the underside of the lintel; if it does, the lintel itself will rest upon a small unbonded stone; (3) the cornice must project equally beyond the face and side of the consoles; (4) if the bed moulding is deep, the upper member only need run around the console, the remainder stopping against the side, as in the famous doorway of the Erechtheion.

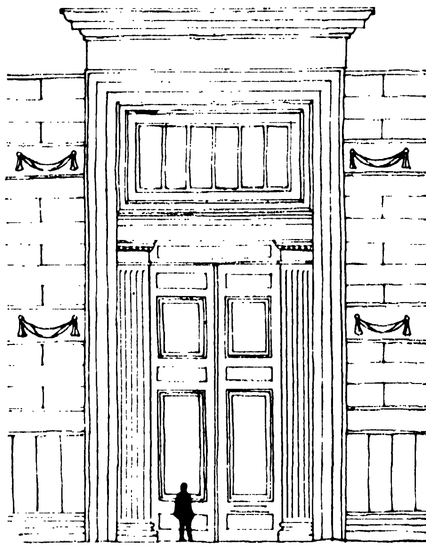

FIG. 19. DOORWAY OF THE PANTHEON, ROME

The console may be supported on a plain band or architrave of the same width as the console, thereby establishing a link between it and the wall.

Door and window openings may also be decorated by the use of the orders. There are many excellent examples to be found in the work of the Italian Renaissance.

Rectangular openings with flat arches, having radiating or joggled joints, have been used with much success since the Renaissance (see Fig. 14). The underside should be slightly cambered to prevent the appearance of sagging.

In modern work wide rectangular or square window openings are possible, using a steel girder encased with stone. The aesthetic considerations have been referred to in Lesson II.

Arched Openings. The arch has one drawback: it is not, in itself, in equilibrium, but exerts a thrust which must be resisted to prevent the collapse of the arch. This may be effected by means of a pier, or may result from the balancing of one arch against another in an arcade, in which case the end bay only will require lateral support. Fig. 12 illustrates the arrangement of the end bay of an arcaded façade.

Although good proportions and an appearance of stability are the chief considerations in ordinary cases, and usually ensure safety, the strength of arches in important or unusual positions should be calculated.

The arch has been used in many forms—semicircular, segmental, semi-elliptical, pointed, and horseshoe, each of them sometimes stilted.

In all cases there are three essential constructional elements: *voussoirs, keystone*, and *imposts*. These should generally be used as the basis for

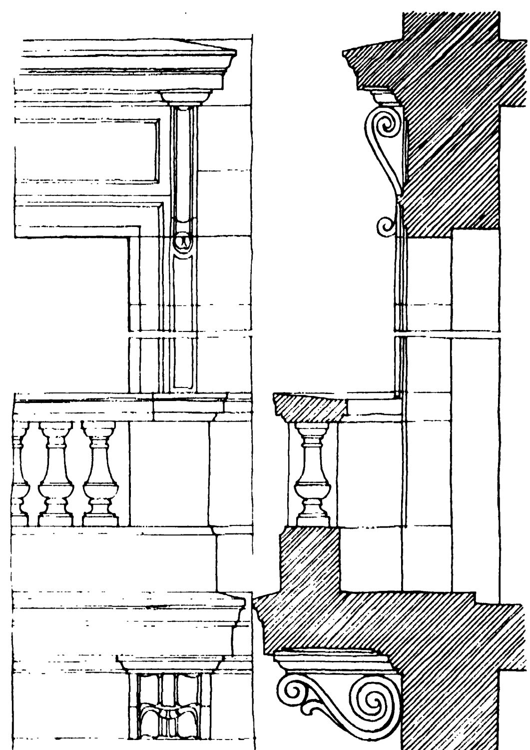

FIG. 20. THE CORRECT ARRANGEMENT OF THE CONSOLE UNDER AN ENTABLATURE, AND OF BRACKETS SUPPORTING A BALUSTRADE

decoration. An exception is the decoration of the spandril, when a semicircular headed opening is enclosed in a rectangle, but here the ornament will serve to emphasize the strength of the bold, simple arch.

Some of the earliest examples of the arch show the use of a simple label mould around the extrados or outer edge of the voussoirs; this was probably the origin of the moulded archivolt, or arch-ring.

The keystone should be emphasized by ornament, and the impost marked by a simple moulding, although there are several beautiful examples in which the springing of the arch is

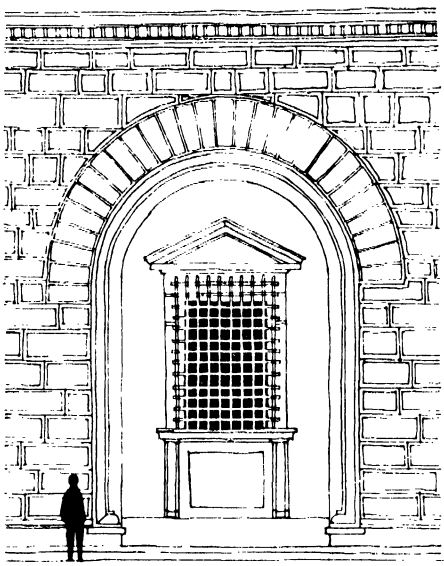

FIG. 21. WINDOW FROM PALAZZO RICCARDI, FLORENCE

not marked, but the archivolt carried right down to the plinth. See Fig. . I, and also the work of Brunelleschi at Florence.

Arches should, if seen from below, be slightly stilted to allow for distortion in perspective.

The decoration of arched openings by a surrounding order, and the setting of a rectangular opening in an arched recess, provide rich and beautiful compositions (see Figs. 21 and 22).

The arch without mouldings but strongly marked joints gives an appearance of strength; richness may be added by a decorated keystone. The channels or chamfers to the joints should be parallel, the surfaces proper only being wedge shaped.

It has been pointed out that the use of the arch permits wide spans; in many buildings openings are so large that they can hardly be classed as windows, although exigences of climate may require them to be glazed. Such openings may be required for purposes of lighting large open halls or spaces, such as railway stations or churches, or may be the expression of scale, combining many ranges of windows in commercial or other buildings. There are many fine examples in the Roman baths and basilicas, and, more recently, the Gare du Nord in Paris, and railway station at Helsingfors (see Fig. 23).

They cannot be filled with a single piece of joinery, but must have stone or metal subdivisions, which will be important elements in the design. Special consideration will have to be given to means of opening for ventilation, and to accessibility for cleaning.

In the architecture of the French Renaissance there are many examples of the linking up of windows in a vertical direction: by pilasters, as at Chambourd, by "chaines" at Balleroy and elsewhere, and in later work by the use of an

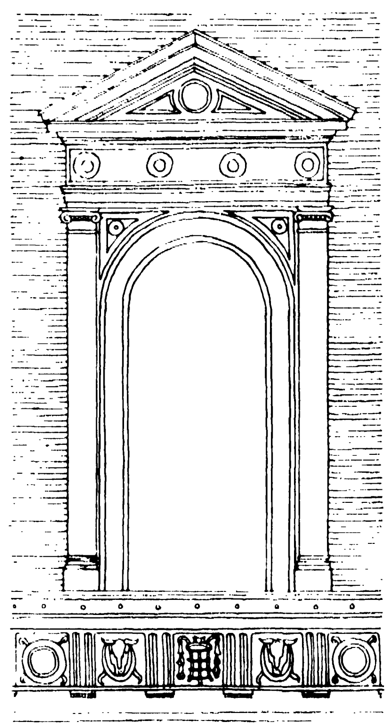

FIG. 22. WINDOW FROM PALAZZO ALBERGATI, BOLOGNA

architrave. This resulted in the first place from the national tendencies towards vertical emphasis; but in the design of modern buildings which are many floors in height, the use of "combined" windows is a valuable expedient, both for the creation of suitable scale and in the relief from monotony which may occur with constantly repeated windows of similar size and shape. Two of the many types are illustrated in Figs. 24 and 25.

There are many examples of combined shapes

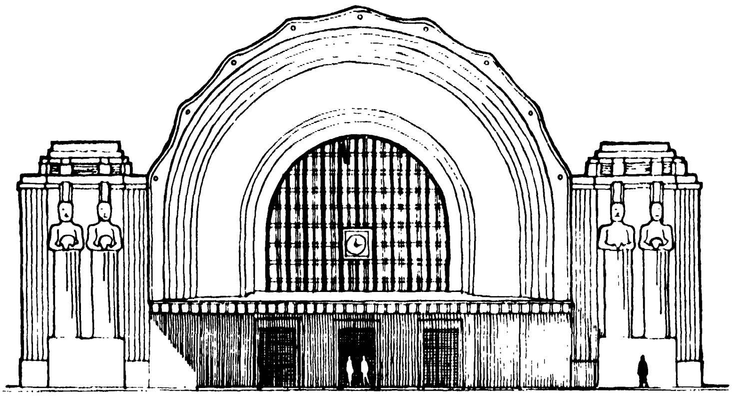

FIG. 23. THE STATION ENTRANCE, HELSINGFORS

in window openings, such as the one at Wilton by Inigo Jones while the possibilities of a continuous range of similar openings will intro-

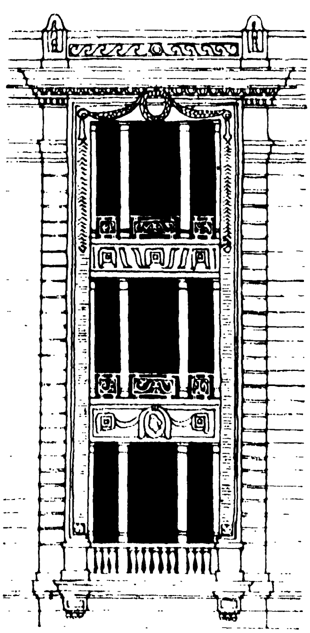

FIG. 24. "COMBINED" WINDOW PLACE, VICTOR HUGO, PARIS

duce the *portico*, which will be dealt with in the next lesson.

Besides decoration, there will be special considerations in the design of door and window openings.

If doors are approached by means of steps, they should have a landing immediately outside. Double doors will be natural at important approaches, and are useful in other positions for the moving of furniture. Door openings, with curved heads, will lead to difficulties in the hanging of doors, because the door will " bind " in the reveal. This may be overcome by raising the arch, as was common in Gothic work, or by inserting a fanlight in the upper part, and making the actual door square-headed. This latter method, however, requires additional height to the opening, and is one of the many reasons for the general use of rectangular door openings in ordinary work.

Window openings are generally similar to doors, but the additional element, the *sill*, is of importance. It should be a single stone, loosely

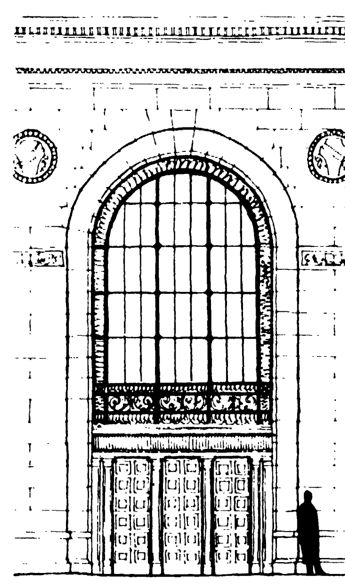

FIG. 25. AN INTERNAL OPENING, THE LIBRARY, DETROIT

inserted and fixed when the building has settled, and must have a drip. The height of the sill is of importance in general work, and should not be less than 2 ft. 9 in. above the floor in upper stories. The use of the long, low casement window, in domestic work, will sometimes call for a high sill level in order to secure good appearance, but it should never be so high that a seated person cannot see out of the window.

In a thick wall the portion under the sill, known as the *apron*, is sometimes made thinner (Fig. 26), and the jambs may be splayed internally to admit the maximum amount of light. The filling of window openings with frames and sash bars for glazing provides fine opportunities for design. There are two general types of opening window—the sliding sash and the casement. The use of either will be determined by questions of utility and stylistic effect.

Proportion. The proportions of door and window openings are determined primarily by considerations of use.

Door openings must be wide enough and high enough for human beings; there may be single or double doors according to material requirements; the heights will normally be the same. Proportions determined for effect in monumental work usually give great height, historic examples ranging from two to two and a half times the width. But these openings will usually have a fanlight or other feature in the upper part, as in Fig. 19, or the large doors may be normally open, with a smaller door for constant use inside a lobby.

Window openings are also subject to material considerations—the respective widths possible with casements or sliding sashes, or the need for one or more lights or divisions. In small openings, the same proportions as those of doors are frequently used, though it is logical to make the heights relative to the heights of the different stories, the widths being approximately the same. The proportions of window openings may be adjusted by the introduction of a railing or balustrade, which may or may not be included in the apparent total height by the adjustment of details. In Fig. 24 it will be seen that the railings to the upper windows are too light to affect seriously the proportions of the entire openings, but in the lowest window the opening appears to end at the top of the more substantial stone balustrade.

Although the use of steel permits lintels to be used over wide spans, it is aesthetically logical that the arch should be employed for the wider openings in a composition; it is also logical that the height to the springing of arches should decrease as the span and consequent thrust increases, thereby increasing the stability. There are, however, notable exceptions in monumental work, in which the opening is about twice its width in height. The Arc de Triomphe in Paris is an excellent example, but here the opening is in scale with every other element in the composition, and its great width is not so apparent.

BALCONIES

The balcony is an accessory which may add great interest to a window opening. Balconies may be limited to one window or be common to several.

When constructed of iron, there is great scope in their design; but when in stone, their treatment is more limited.

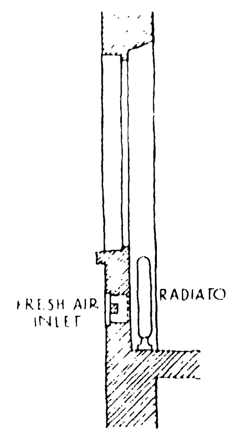

FIG. 26. THE "APRON"

The usual elements are round or square balusters with a capping, and a base or plinth. When the balustrade is too long for a single capping stone, it requires solid blocks or dies at intervals, and if continuous over several bays, should have further strength added by means of pedestals. The whole may be supported by a thickening of the wall, as in Fig. 12, or by consoles, Fig. 20. Ornaments, such as vases, may be placed on the pedestals, though these latter sometimes support columns, as in Fig. 12. The daylight between the dies should equal the width of the window opening—it may be a little wider, but must never be less. Balustrades must always be designed to the human scale; they should be about one metre high. Work of the Italian Renaissance contains many examples of other types of balcony, such as those with stone panels instead of balusters, while the study of the wrought-iron balconies in French work will be very profitable.

MASONRY

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LESSON VI

STRING COURSES AND CORNICES

String Courses are the horizontal bands of stonework projecting from the face of the wall. They are usually moulded, and placed to accentuate the horizontal divisions of the building; sometimes they are in the form of a plain face projecting only a few inches from the face of the wall. A drip should be formed by working certain points, where holes are cut through the cornice to the face of the wall below, and a lead pipe inserted, discharging into a *rain-water head*; or the channels are carried through to the back of the wall and run direct into a *rain-water pipe* running down the inside of the wall. The exposed upper surfaces of cornices should be covered with some impervious material. *Sheet lead* is the finest covering for stonework, but is now rather expensive.

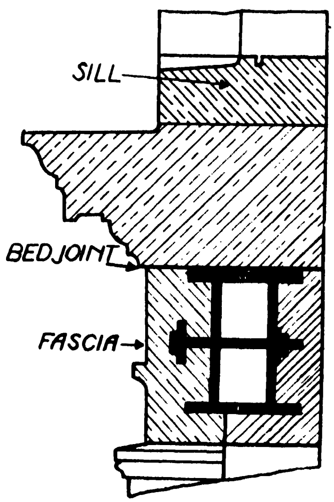

Fig. 36. Section of Cornice (in One Bed)
Showing stone fascia bolted to steelwork

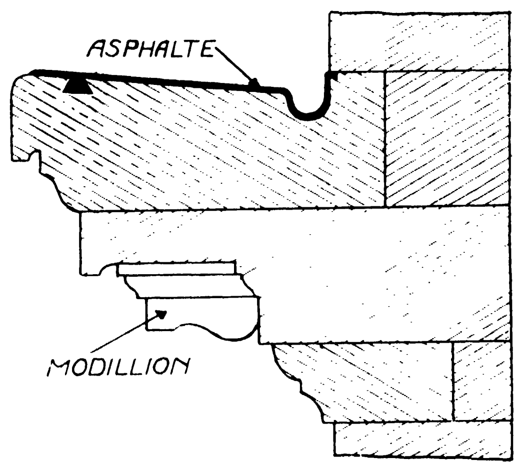

Fig. 37. Section through Cornice (in Three Beds) Covered with Asphalte

a throat underneath the projection, and the top surface of the projection should be weathered.

Fig. 14 is a sketch of a moulded stone suitable for a string course.

Cornice. The term *cornice* is usually applied to the moulded projecting course crowning the part of the building to which it is affixed. Fig. 36 shows a section through a stone cornice in one bed.

Fig. 37 shows a section through a stone cornice built up in three beds of stone. The weathering is shown inclined towards the wall face, with channel provided for carrying off the rain-water; the channel is inclined towards

Asphalte is very often used, as shown in Fig. 37. The asphalte is spread on the surface while hot, *trowelled* to the correct *falls*, and rounded off at the nosing of the cornice. A *dove-tailed groove* is worked in the stone a few inches from the nose line, to form a key for the asphalte. This is not a good finish for the covering, as the rain-water is allowed to run down the front members of the cornice, soon causing discoloration of the stone-work in the form of dark streaks. A drip should be formed by a strip of sheet lead worked over the nosing and turned into the dove-tailed groove, the asphalte being finished on top of the lead strip.

COPINGS AND GABLES

The term *coping* is used for the top course of masonry covering a wall. Copings are designed to keep the wall dry. They should have projections from the wall face on either side, and be provided with a drip formed by working a groove on the underside of the stone.

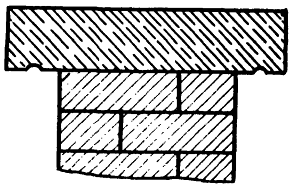

FIG. 38. FLAT COPING

Fig. 38 shows a section through a *flat*, or *parallel, coping* suitable for gables and inclined surfaces, but it is not recommended for horizontal wall coverings.

Fig. 39 is a section of a *feather-edge coping*, which is quite an economical covering for brick walls, etc. The top surface should slope towards the inside face of the wall.

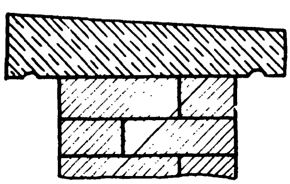

FIG. 39. FEATHER-EDGE COPING

Fig. 40 is a section of *segmental coping*, which is also suitable for horizontal wall coverings.

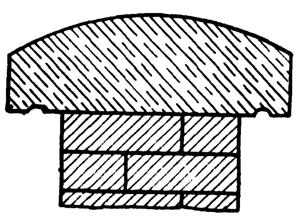

FIG. 40. SEGMENTAL COPING

Fig. 41 shows a section of *saddle-back coping* suitable for same purposes as above mentioned. The top surface is weathered both ways from the centre.

Fig. 42 is a section of one form of *Gothic coping*. There are various forms which are designed according to the particular period of architecture required.

Gables. Fig. 43 shows (*a*) elevation and (*b*) side elevation of a gable, or the vertical triangular piece of wall at the end of a roof, showing *springer, kneeler, apex*, or *saddle, stone*, and *coping*, the section of which is the same as shown in Fig. 38.

Plain ashlar *bands* are sometimes placed at various levels, usually at the level of the springer and kneeler. If the gable is large, two or more kneelers should be provided, to help resist the thrust of the *coping*, which should be cramped at each joint with a metal or slate *cramp*. The cramp should grip the two stones tightly, after which it is necessary to fill in with Portland cement, entirely covering the metal.

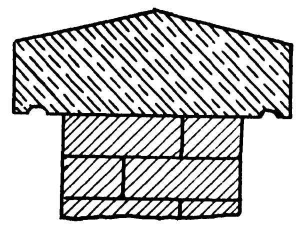

FIG. 41. SADDLE-BACK COPING

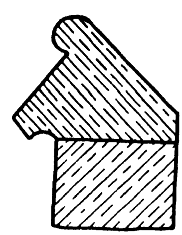

FIG. 42. GOTHIC COPING

RUBBLE WALLS

Rubble Walls are unlike those built with *wrought masonry*, because the resulting appearance and stability of the wall depends upon the skill and artistic taste of the mason or *waller*. The stones are placed in the wall in their rough state or roughly squared with the hammer, the interstices being filled with mortar. The bonding of the stones is a very important factor and entirely rests with the mason, who should select the stones to form as good a bond as possible; bonders or headers should be placed at intervals to provide a bond transversly through the wall. All uncoursed rubble walls are required by the London Building Act to be one-third thicker than walls built of wrought-stone or brick.

Coursed Rubble Wall. Fig. 44 shows a photograph of this type of walling. The stones are roughly squared to suit the height of the courses required.

A Random Rubble Wall Built to Courses is shown in Fig. 45. Small square stones called *snecks* are introduced to level up, to the height of the adjacent stones.

Polygonal Walling. Fig. 46 is a photograph showing this type of wall, the stones being built in the wall any shape, or pitched to fit the adjacent stones.

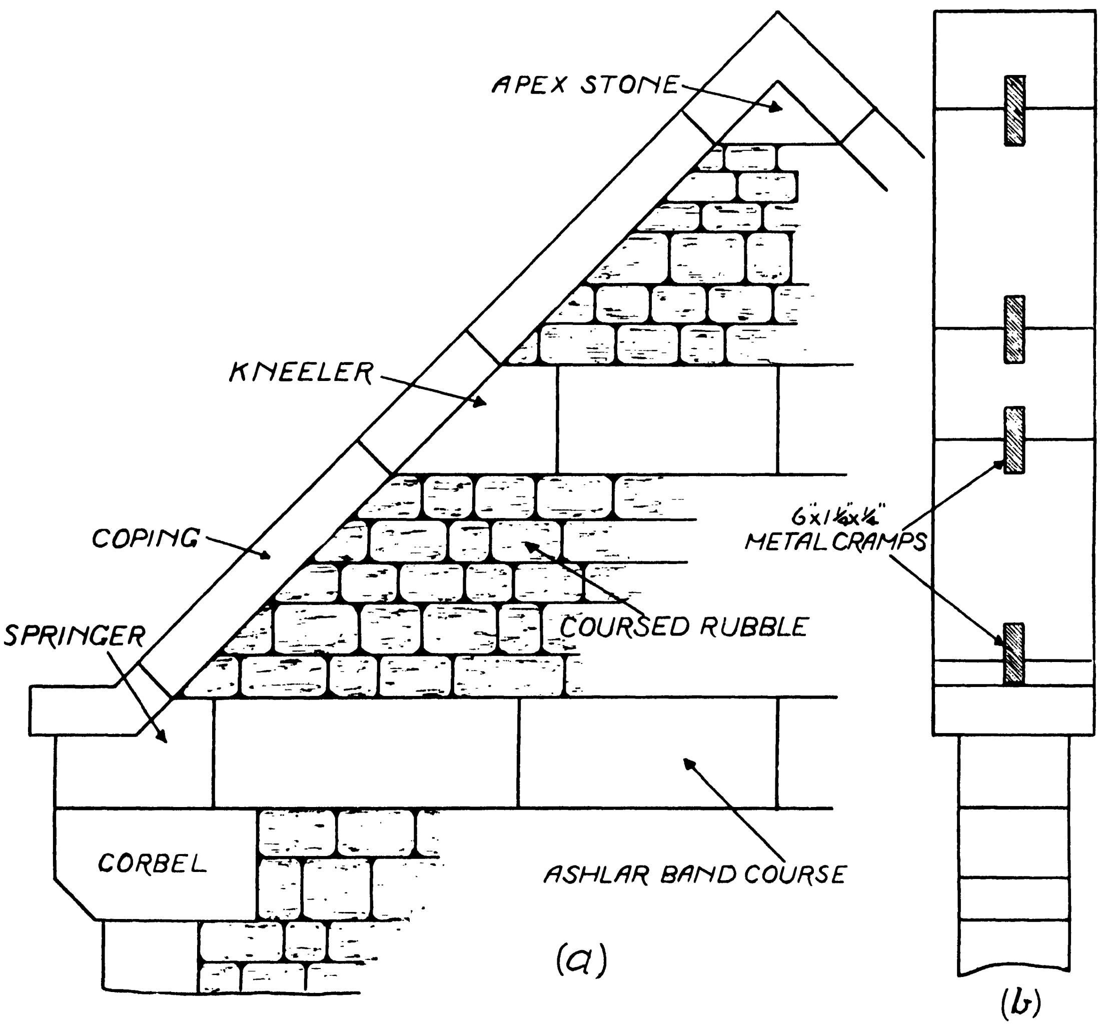

Fig. 43. Gable in Coursed Rubble Wall.

Flint Walling, Fig. 47, is a photograph of a piece of *polled flint walling*. The flints are split and the broken surface forms the face of the work. This class of work is generally arranged between wrought stone quoins and horizontal courses.

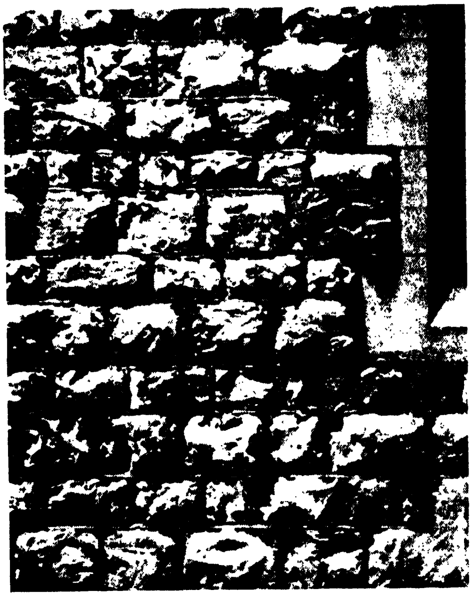

FIG. 44. COURSED RUBBLE WALL

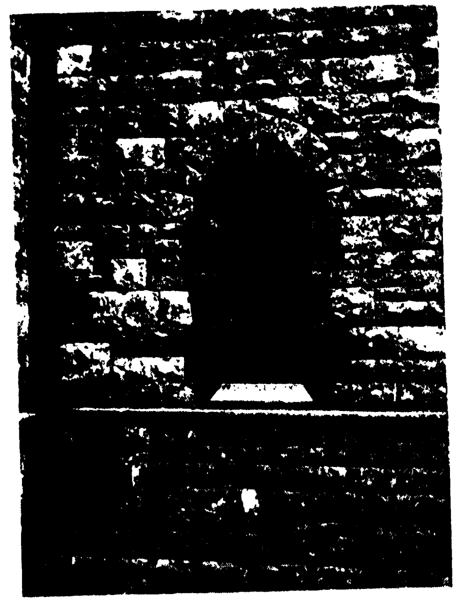

FIG. 45. RANDON RUBBLE WALL, BUILT TO COURSES, WITH SNECKS INTRODUCED

FIG. 46. POLYGONAL WALLING

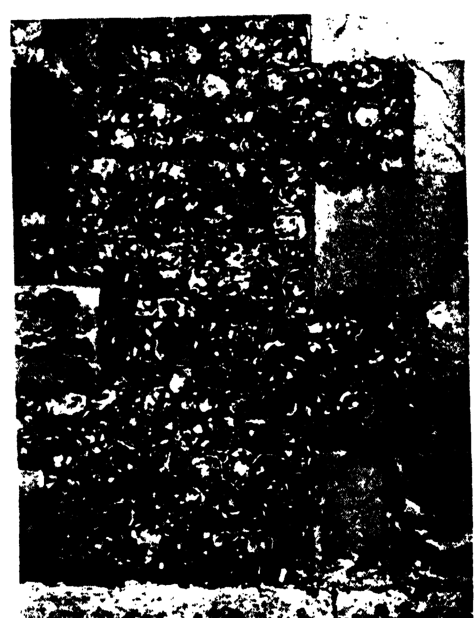

FIG. 47. FLINT WALLING, WITH WROUGHT-STONE QUOINS

STRUCTURAL ENGINEERING

By W. Arnold Green, M.A., B.Sc., A.M.Inst.C.E., M.I.Struct.E.

LESSON III

LOADS ON STRUCTURES—(*contd.*)

Crowds. With scientific packing of a crowd of picked men a load of 181 lb. (or 1·1 men) per sq. ft. was obtained by Professor Johnson at Harvard University, but such a design load is unnecessarily high.

Though the impact effect of a man suddenly rising from a sitting to a standing position may be more than 100 per cent, the chances of every one getting up suddenly at the same moment are remote, and in any case about 3 sq. ft. of floor space is required for a seated person.

It is obvious that the more densely packed a crowd is, the less will be the kinetic effect on the structure due to its movement Where the kinetic effect is likely to be greatest, as with rhythmic movement in a dance hall, the density of the crowd is, of necessity, small. A load of 140 lb. per sq. ft. should be an ample allowance for both crowd and maximum impact.

In a test on a bridge handrail[1] the maximum side pressure from a crowd of men, endeavouring to push it over, was found to be 168 lb. per ft. run. Generally, 100 lb per ft. run of rail should be an adequate horizontal design load.

Staircases. For a crowded staircase 100 lb. per sq. ft. should be a sufficiently large design load, but the staircase should be strong enough not to collapse under the load of the heaviest furniture (e.g. an office safe) which may come upon it.

Vibration. Serious vibration may be set up in a structure due to repeated impulses, if the time period of the impulses happens to coincide with the natural period of vibration of the structure; it is to avoid such risk that marching troops are ordered to break step when crossing a bridge.

It may sometimes happen that a floor carrying vibrating machinery may have a natural period of vibration responding to that of the machine, in which case undue vibration results. In the present state of our knowledge this contingency cannot be foreseen, but it may be cured by altering the speed or position of the machine, or even by adding extra weight to the floor.

[1] *Engineering News Record*, 20th January, 1925.

Wind Loads. Though knowledge of the effect of wind is considerably greater now than it was when the Tay Bridge was wrecked in 1879, there is still much that is not definitely known.

It is known that the wind load on a structure is influenced by its shape. Thus the side load on a square chimney is about twice that on a circular chimney having a diameter equal to the side of the square, the relative values for square, octagonal, hexagonal, and circular being approximately 1, $\frac{3}{4}$, $\frac{2}{3}$, and $\frac{1}{2}$ respectively.

It is also known that, other conditions being the same, the higher a structure is placed the greater may be the pressure upon it, and also that the smaller the exposed part and the greater is the average pressure, this last effect being probably due to local gusts of higher velocity than the average.

The effect of adjacent structures on the intensity of wind pressure is difficult to estimate. As one more often hears of windows being blown out than blown in, it is reasonable to assume that the suction effect of wind may be greater than its direct pressure.

Experiments at the National Physical Laboratory, on roof models, show that the outward normal pressure on the leeward side may be greater than the inward normal pressure on the windward side, when the windward side is open and there is no through passage for the wind on the leeward side. In sports stands this effect may be relieved by openings in the leeward wall.

The latest experiments at the National Physical Laboratory indicate that the pressure on an exposed plane surface in lb. per sq. ft. equals the square of the velocity, in miles per hour, of the wind blowing normal to the surface, multiplied by ·0032.

If Smeaton's wind velocity table (in which he gave 50 miles per hour as a storm, 60 as a violent storm, 80 as a hurricane, and 100 as a violent hurricane) is a safe guide, a pressure of 30 lb. per sq. ft. should be adequate for exposed structures in this country.

Near the ground this pressure may be considerably reduced. The Belgian Standard specification for structural steelwork gives the basis wind pressure as about 20 lb. per sq ft. For walls up to 50 ft. high the wind load is to be taken as

TABLE V RATIO OF NORMAL PRESSURE ON SLOPING SURFACE TO PRESSURE ON SURFACE NORMAL TO WIND

Inclination of Surface to Direction of Wind	5°	10°	15°	1 : 3	1 : 2½	1 : 2	30°	1 : 1½	40°	45°	50°	60°
By Hutton's Formula	·13	·24	·35	·42	·49	·59	·66	·73	·83	·90	·95	1·00
By Duchemin's Formula	·17	·34	·48	·57	·65	·74	·80	·85	·91	·94	·97	·99

10 lb.; from 50 ft. to 66 ft. as 15 lb.; from 66 ft. to 82 ft. as 20 lb.; and above that 25 lb. per sq. ft. For buildings in open country, 25 lb. per sq. ft. is to be taken for all heights.

Roof Loads. The wind pressure on a surface inclined to the direction of the wind is taken as normal to the surface. It is not, however, the normal component of the horizontal pressure; the normal pressure on a sloping surface 60°, with the horizontal being practically the same as on a vertical surface. The best known formulae for arriving at the normal pressure on a surface inclined at an angle i with the horizontal are (1) Hutton's, which gives the ratio of the normal pressure to that on a vertical surface (the direction of the wind being horizontal) as $\sin i^{(1\cdot84 \cos i - 1)}$; and (2) Duchemin's, which gives the ratio as $\frac{2 \sin i}{1 + \sin^2 i}$. Their values for various slopes are given in Table V.

If these values are plotted on radial lines on tracing cloth, as indicated in Fig. 3, on superimposing the tracing on a drawing of the sloping surface, so that O is above the intersection of the slope, with a horizontal line coinciding with the horizontal line on the tracing, the value for the ratio can be read at the intersection of the slope with the curve.

Snow loads (say 7 lb. to 13 lb. per sq. ft.) are rarely serious in this country, and can hardly occur on a sloping surface in conjunction with full wind load.

The possible load (other than snow load) on a flat roof depends on its accessibility; 30 lb. per sq. ft. is often an ample allowance. As the slope increases the chance of a crowd of people coming on the roof decreases. A load per sq. ft. of horizontal projection is often assumed for calculating the vertical roof load, say 50 lb. for a horizontal roof, diminishing 1 lb. for every degree of slope but not less than 15 lb. This load will include the vertical effect of wind and snow.

The horizontal load will be the horizontal component of the normal wind load.

Partitions. The position of partitions is often not settled till a building is complete, but an allowance for light partitions may usually be considered as included in the design load.

The L.C.C. regulations for reinforced concrete, however, specify that special provision must be made for partitions if the load as the base is greater than the floor load.

The weight per square foot of a hollow tile partition may be taken as 16 lb. per sq. ft., with an extra of 6 lb. for every 2 in. thickness greater than 4 in., and a further extra of 5 lb. for each side plastered.

Loads on Main Beams and Columns. If the floor and secondary beams are designed for the full load, it is sometimes permissible to assume

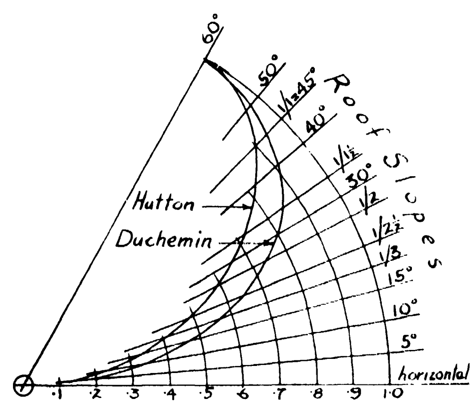

FIG. 3

that the area of floor carried by the main beams is not fully loaded. A 25 per cent reduction of the live load may sometimes be reasonable, but the deduction, if any, depends on circumstances.

The probability that all floors will be fully loaded at the same time is, except for warehouses, very remote, and it is usual to reduce the live load coming on the columns.

A common allowance is 10 per cent to be deducted from the live load on the floor next below the top, 20 per cent from the next, and so on, but not more than 50 per cent.

The live loads on roof and top story are usually taken in full, as the resulting columns will not usually be excessive for general stability.

It is permissible also to reduce the column loads due to wind, and often to ignore them altogether when stresses, due to wind, are not more than, say, 25 per cent of those due to dead and live load.

PRELIMINARY OPERATIONS

By R. Vincent Boughton

LESSON IV

SHORING—(*contd.*)

Scantlings for Raking Shores. Table I gives the sizes of members of raking shores under various conditions. The scantlings given are for new or sound second-hand timber; if the timber is old, and only in fair condition, then use scantlings shown for height of wall 5 ft. higher than the actual; i.e. if wall is 30 ft. high, then use scantlings for 35 ft.-high wall. Any special circumstances may necessitate an increase in sizes of members.

Table II shows the best *rectangular* sections to use compared with *square* sections.

Joints in Rakers. "Balk timbers" can be obtained in longer lengths than "planks," and where "balks" are used they should be in one length if possible, otherwise very strong fished

TABLE II

Square and Rectangular Scantlings for Rakers

Square	Solid Rectangular	"Built-up" Rectangular
Inches	Inches	Inches
4 × 4	4½ × 3½	
4½ × 4½	5 × 4	
5 × 5	6 × 4 or 7 × 4	
6 × 6	7 × 5	2/7 × 2½
7 × 7	8 × 6	2/8 × 3
7½ × 7½	9 × 6	2/9 × 3
8 × 8	9 × 7 or 11 × 6	9 × 3 and 9 × 4 or 2/11 × 3
8½ × 8½	9 × 8 or 11 × 7	2/9 × 4 or 11 × 3 and 11 × 4
9 × 9	11 × 8	2/11 × 4
10 × 10	11 × 9	3/11 × 3
11 × 11	13 × 9	
12 × 12	14 × 10	

DETAILS OF JOINTS IN RAKERS.

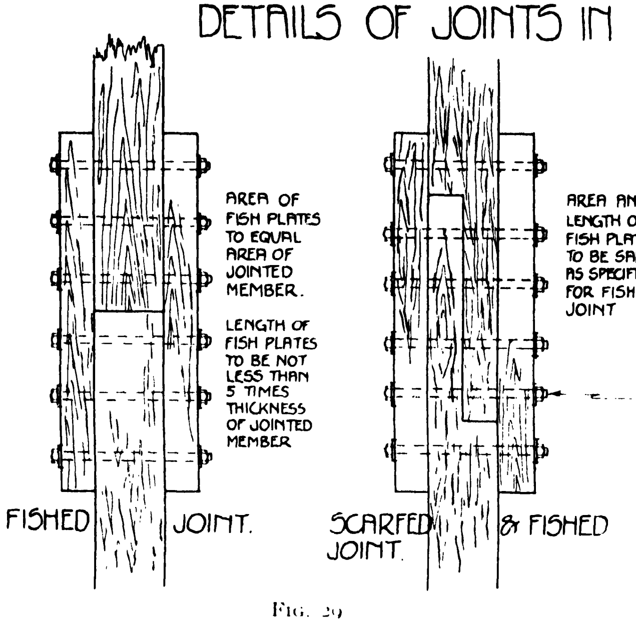

Fig. 29

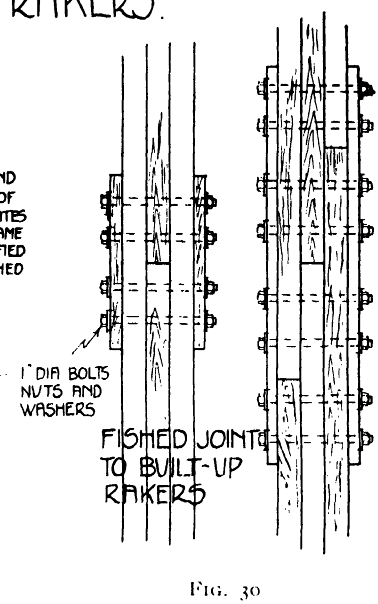

Fig. 30

or scarfed and fished joints must be used, as shown by Fig. 29. Rakers composed of "planks" lend themselves to economical jointing by well lapping the joints by the adjacent member and simply "fishing," as shown by Fig. 30.

Horizontal or Flying Shores are used to provide temporary support to two walls during the removal of an intervening structure, or the condition may be that one defective wall has to be supported by another wall that is in a good state. Also, in some cases, the internal walls and floors of one building may have to be removed without pulling down the external wall (which is bonded to the internal walls and carries the floors) which, unless laterally supported, would have a tendency to overturn. To maintain equilibrium, such a wall needs shoring from

TABLE I. SCANTLINGS FOR RAKING SHORES OF FIR TIMBER

Height of Wall in Feet	Number of Rakers	Distance Apart of Rakers in Feet Sectional Area of Rakers in Inches: 8 Feet	10 Feet	12 Feet	14 Feet	16 Feet	Angle of Outer Raker with Horizontal
		16	16	20	24	28	60 to 75
15	1	16	18	22	26	30	55
		17	20	24	29	33	50
		18	20	24	27	30	60 to 75
20	1 or 2	20	22	26	30	34	55
		22	24	29	33	37	50
		25	30	35	40	45	60 to 75
25	[illegible]	27	33	38	44	50	55
		30	36	42	48	54	50
		33	40	46	52	58	60 to 75
30	3	36	44	50	57	64	55
		40	48	55	62	69	50
		42	50	58	64	70	60 to 75
35	3	46	55	63	70	77	55
		50	60	70	77	84	50
		53	64	75	86	97	60 to 75
40	3 or 4	58	70	82	94	102	55
		63	77	90	102	114	50
		60	72	84	96	108	60 to 75
45	4	65	78	92	105	118	55
		72	86	100	115	130	50
		66	80	94	108	122	60 to 75
50	4 or 5	72	87	103	118	135	55
		79	96	113	130	147	50

Wall plates : 9 in. × 2 in. up to 30 ft. high, and 9 in. × 3 in. where over.
Struts : 9 in. × 1 in. or 1½ in.
Sole piece : 11 in. × 3 in. *Needles :* 4 in. × 3 in. or 4 in. × 4 in.

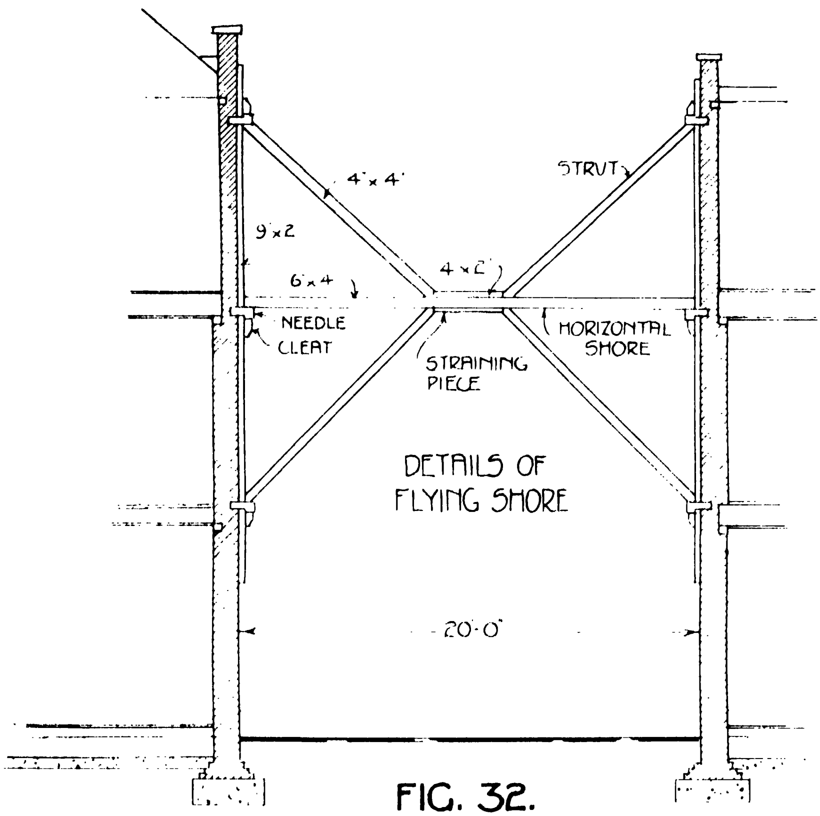

FIG. 32.

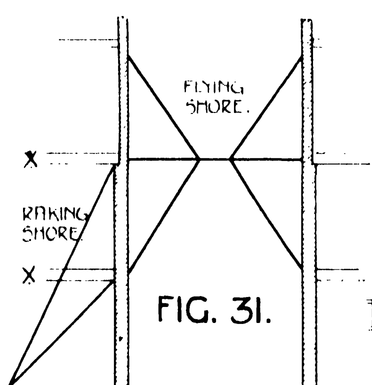

FIG. 31.

DIAGRAM SHOWING RAKING SHORE TO GIVE SUPPORT TO WALL WHERE FLOORS X ARE TO BE REMOVED

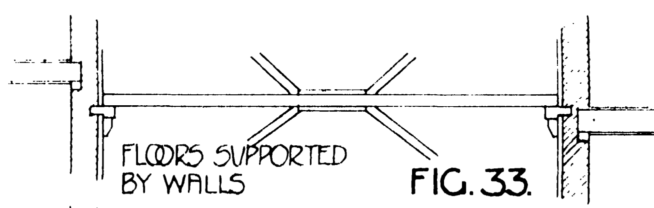

FIG. 33.

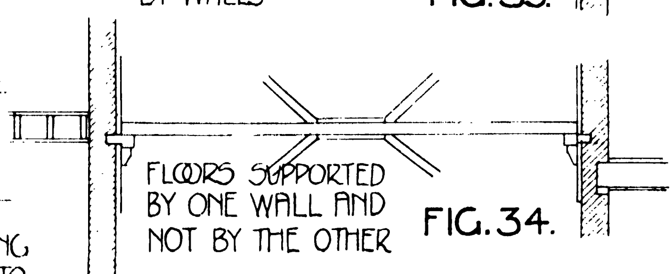

FIG. 34.

both sides, as it is manifest that any pressure exerted on one side would tend to overturn it to the other side. If there is a building near to the wall in question, separated by, say, an alley, the best way to shore the wall would be by a flying shore on one side and raking or flying shores on the inside. Such a condition is illustrated by Fig. 31.

Fig. 32 shows a simple flying shore. The wall plates, needles, cleats, and position of struts in relation to floors and roof should be in conformity with the rules for raking shores. Where the floors of both buildings are at the same level, there is no difficulty in placing the horizontal shore on the centre line of each floor; but where the floor levels vary 1 ft. or 2 ft., the best position to place this shore is a matter that requires a little consideration. Where the floor joists run parallel to *both* walls or where both walls support the joists, the horizontal shore should be placed between the two floor levels as shown by Fig. 33. If the difference in level is small, there is no harm in placing this shore a little out of horizontal if desired. The raking struts can be regulated to varying levels, as their angle of inclination is of no great import. In the case where the joists run parallel to one wall and into the other, as the latter condition provides a greater strength to the wall than the former, then if the floors are at different levels, the best course is to place the shore centrally with the floor which has its joists running parallel to the wall, and as near as possible to the other floor, as shown by Fig. 34.

The shores must be erected during or before demolition of a building commences, and removed when the new work is of a sufficient height to make shoring unnecessary.

The horizontal shore is placed between the two wall plates; and if there is a space between one end of shore and wall plate, a pair of folding wedges must be inserted and lightly driven up.

Straining pieces, 2 in. thick and of same width as struts, must be spiked to the shore to form an abutment for struts.

The struts should be fixed at about an angle of 45°, and cut tightly in between straining pieces and needles; they are further tightened by driving in folding wedges between struts and straining pieces on upper side, which will cause the horizontal shore to deflect slightly and so stiffen the lower struts and the whole framing. The horizontal shore is strengthened by the struts, which also support the walls.

A compound flying shore is depicted by Fig. 35 and is useful where high walls have to be supported. The details are very similar to a

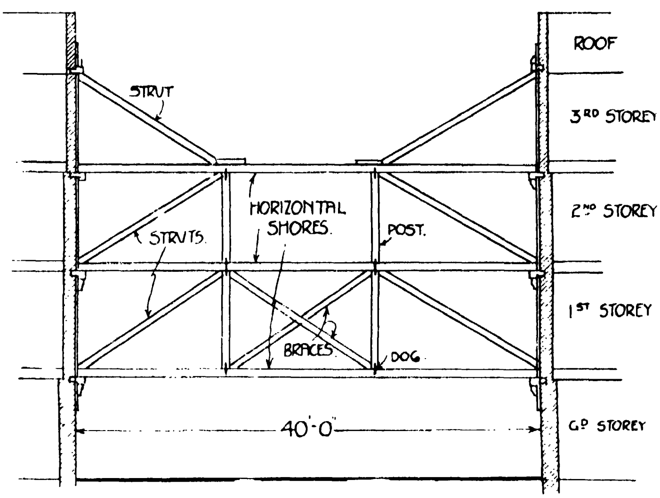

FIG. 35. COMPOUND FLYING SHORE

simple flying shore, the vertical struts being dogged to the horizontal shores.

A combination of simple and compound flying shores may be used where walls are very high.

Scantlings for Flying Shores. Table III gives sizes of the various members for different spans, but special conditions may require greater scantlings.

TABLE III

SCANTLINGS FOR FLYING SHORES

Span in Feet	Horizontal Shore	Struts	Straining Piece	Wall Plate
	Inches	Inches	Inches	Inches
Up to 20	6 × 4	4 × 4	4 × 2	9 × 2
,, 25	6 × 6	4 × 4	4 × 2	9 × 2
,, 30	9 × 6	6 × 4	4 × 2	11 × 3
,, 35	9 × 9	6 × 6	6 × 2	11 × 3

ELECTRICAL FITTING

By F. Charles Raphael, M.I.E.E.

LESSON I

GENERAL CONSIDERATIONS AND TECHNICAL TERMS

Introductory. Electrical fitting is specialists' work, both as regards specification and execution. For new buildings it may fall to the province of the architect and builder, but the practice is growing of employing a consulting electrical engineer to draw up the specification, let the contract, and see the work through. Similarly, the contract for the work may be let to the builder, who in turn may employ his own wireman or arrange a sub-contract with an electrical contractor. In any case, however, it is highly desirable that the architect and builder should have more than a superficial knowledge of the principles of electrical work and the manner in which it is carried out in practice.

Buildings may, of course, be in towns and urban districts in which electrical supply is available, or they may be at some considerable distance from electric lighting mains, involving the necessity of the erection of plant to generate the electric current required. The general principles and practice upon which the wiring of the building are based are the same in both cases, and although the supply pressure is, as a rule, considerably less when a building is supplied by its own plant, the quality of the material used for wiring must nevertheless be of the highest, and the methods of wiring are identical, except so far as the size of the wire in the cables is concerned. This may appear strange to the student at the outset, but it is easily explained. The wire and cable employed is insulated to prevent leakage of current, but, in practice, the thickness of insulation necessary to withstand the low electrical pressures employed in supply from private plants, will equally withstand the somewhat higher pressures of the public supply mains. The quality of the insulation of cables used for electric lighting purposes in house installations is, in point of fact, decided chiefly by the question of durability. Vulcanized india-rubber is the insulation almost invariably employed, and the lower grades have a much shorter life than the higher grades. For a cable which, in addition to enjoying a good life, has to withstand a certain amount of handling and bending about in erection, it is not possible to go below a certain thickness of insulation, and consequently the standard sizes are the same for all pressures up to the usual supply pressures of the electric lighting mains for electric light distribution.

It is true that when we get to accessories, such as switches, lamp holders, plugs, and fuses, a lower degree of protection would be adequate for the lower pressures than the higher ones; but, as the material required for lighting installations connected to public supply mains represents the bulk of that which is manufactured, and only a comparatively small proportion is used for installations supplied by low-pressure private plants, it is not worth while having a separate set of standards for the latter, and it is only in the case of a few particular pieces of apparatus and accessories that cheaper material can be used. These technical considerations will be gone into more fully in a later lesson. A few of the technical terms will, however, now be explained.

VOLTS, AMPERES, AND WATTS

Unit of Pressure. The first of these terms is electrical *pressure*, sometimes called *voltage*, or *difference of potential*. The volt is the unit of electrical pressure, and, if the installation is connected to the public lighting mains, there is a certain definite *declared pressure* for which all the apparatus must be suitable. The standard voltages for lighting from the public supply mains in this country vary in different districts, but the commonest ones are 200, 220, 240, and 250. On private electric lighting plants, however, pressures as low as 25 volts are used for very small installations, and, for larger ones, 50 volts or 100 volts. It is of the utmost importance to quote the voltage when ordering electric lamps or other apparatus. A lamp intended to burn at 220 volts pressure will give a very poor light at 200 volts pressure, while at 240 volts it would be considerably *overrun*, giving more light than it is intended to do and burning out after a short and merry life. Similarly, an electric fire employed at a lower pressure than that for which it is designed will give insufficient heat, while if it is supplied at a higher pressure the heating elements will burn out very quickly, as they will be run at a higher temperature than they should be.

Unit of Current. The unit of electric *current* is the *ampere*. If a number of volts is supplied to any piece of apparatus, a certain number of amperes will flow through it, and the maximum number of amperes required for the whole building is obtained by adding together the number of amperes required by every piece of apparatus.

Unit of Power. The foregoing two terms are comparatively simple, but now we get to a little more complication, namely, the conception of electric *power*. It is obvious that if a machine is driven by an electric motor, a certain amount of electric power must be required to drive it. Just in the same way, electric power is required to light a lamp or heat an electric fire, this amount depending on the amount of light or heat produced. Electric power is measured in *watts*, and this term represents the product of the volts and amperes; that is, if you know the pressure and know the number of amperes the apparatus or group of apparatus will take, you have only to multiply these two numbers together to get the number of watts of power taken. To put this in symbols, if V is the number of volts, A the number of amperes, and W the number of watts, then

$$W = V \times A$$

This may be put in another way, namely,

$$A = \frac{W}{V}$$

In other words, if you know the watts required and divide this by the pressure in volts, the result gives you the current required in amperes.

Electric lamps are nowadays rated according to their wattage. There are 30-watt lamps, 40-watt lamps, 60-watt lamps, 75-watt lamps, 100-watt lamps, and so on. The current taken by a 60-watt lamp at 200 volts pressure will, therefore, be 60 divided by 200, namely, ·3 ampere (three-tenths of an ampere). If there are a hundred 60-watt lamps in the building, the total current required when all the lamps are on will be 30 amperes, and the service cable supplying the building must, therefore, be strong enough to carry this current.

The Kilowatt. There is another unit of power, namely, the *kilowatt*, the usual abbreviation for which is kW. This is 1,000 watts. This unit comes in very usefully for larger pieces of apparatus. A very common size of ordinary domestic electric fire is 2 kW., that is to say, 2,000 watts. If the voltage is 200, every such electric fire will require 10 amperes. If the voltage is 240, you must divide 2,000 by 240 instead of by 200, and the current required by the fire will then be less, namely, $8\frac{1}{3}$ amperes. In the latter case, if three electric fires have to be provided for, the total current required will be 25 amperes.

Horse-power. The size of motors, on the other hand, is usually given in h.p., namely, the actual power which they will develop, which is somewhat less than the power that has to be put into them. The ratio between the power put in and the power given out is known as the *efficiency* of the motor. If, for instance, a motor has 90 per cent efficiency, this means that 10 per cent of the electric power put into it is used up in the heat developed by the windings, friction of the bearings, etc., and the balance of 90 per cent only is available for running the machine which the motor drives. To ascertain the watts required by a motor, one must multiply by the number 746, as 746 watts are equivalent to a h.p., and then one must make allowance for the efficiency of the machine. Suppose, for instance, a 5 h.p. motor is required for a mortar-mixing machine used in building operations, that, when working at full load, the efficiency of this motor is 85 per cent, and that the voltage supplied for the motor is 200. The actual watts to be put into the motor at full load will be

$$\frac{5 \times 746 \times 100}{85}$$

that is, about 4,400 or 4·4 kW. The division by 85, and multiplication by 100, makes allowance for the efficiency of the motor being only 85 per cent. To get the current consumed we divide the watts by the voltage, and 4,400 divided by 200 gives us 22, which is the number of amperes the motor will require.

ROOF COVERINGS

By John Millar, P.A.S.I., M.I.Struct.E.

LESSON III

SLATING—(*contd.*)

Preparatory Work for Slating. The groundwork to receive slates may be prepared in one of several ways, according to the nature of the work in hand and the framework of the roof.

Battens. Where the structure is of timber, battens alone may be employed. They are nailed horizontally across the roof at distances apart according to the gauge required (see Fig. 11). As only half of the width of the battens is used for nailing the slate to, the remaining half affords a support for the top of the preceding course. Battens used for ordinary slating are from 1½ in. to 3 in. in width, and ¾ in. or 1 in. in thickness, a usual size being 2 in. by ¾ in.

The spacing of the battens will be uniform throughout the roof where regular sized slates are used, with the exception of the first batten, when centre nailing is employed. The position of the first batten is measured from the front of the fascia to the bottom of the batten, and will be as given in Table IV.

TABLE IV

Positions of First Batten for Various Slates

Length of Slate	2½ in. Lap		3 in. Lap	
	1st Batten	Remaining Battens	1st Batten	Remaining Battens
24 in. .	10½ in.	10¾ in.	11 in.	10½ in.
22 ,, .	9½ ,,	9¾ ,,	10 ,,	9½ ,,
20 ,, .	8½ ,,	8¾ ,,	9 ,,	8½ ,,
18 ,, .	7½ ,,	7¾ ,,	8 ,,	7½ ,,
16 ,, .	6½ ,,	6¾ ,,	7 ,,	6½ ,,

To fix the battens correctly, a chalk line is struck across the rafters at intervals to suit the gauge of the slating, measuring from bottom to bottom of batten.

Another method employed for setting out and fixing battens on a roof is to cut a piece of batten to serve as a guide; this guide is made to fit in between each row of battens, its length being equal to the gauge minus the width of batten used. The use of battens is economical, and they are much used in general work where there is a ceiling below or where ventilation is required.

Tilting Fillet. At the eaves a special batten, called a *tilting fillet*, is fixed. It is ¾ in. or 1 in. thicker than the ordinary battens, in order to tilt up the under or double eaves course, so that a proper bed may be formed for the slates above, and at the same time prevent the lifting effect of the wind, by closing the space at the edge of the slates. In some cases the fascia board is utilized for the same purpose in place of the tilting fillet, by being placed higher than the boarding or battens by the amount required to tilt the slates. It is also necessary, for the same reason, to fix a thicker batten at the ridge, in order to give a proper bed to the under ridge slate, and so prevent it from "riding."

Boarding and Felt. A better method is to employ boarding, and to cover it with sheets of one-ply Willesden paper or inodourous sarking felt (see Fig. 12). As these felts are water-proof the risk of decay is negligible. This method gives a more equable temperature to the interior of the building.

A fairly satisfactory method sometimes used in cheap work is to employ two-ply Willesden paper, and place it directly on the open rafters.

Boarding, Felt, and Battens. This is similar to the above method, but with the addition of battens above the felted boarding (see Figs. 13 and 14). The battens provide an air space to the underside of slates, but there is probably a danger of decay through the lodgment behind the battens of any water that may be driven between the slates.

The best method to adopt is to place 2 in. by 1 in. *counter battens* directly over each rafter on the felted boarding, running from eaves to ridge, and to nail the slate battens to them. This allows any condensation on the underside of the slates, or water from any cause, freedom to make its way to the eaves. This method is generally adopted in good class work (see Figs. 13 and 15).

In modern work, roofs are often formed of steel and concrete or steel alone. If the roof is of concrete and slates are used for the covering, the battens may be fixed to plugs driven into

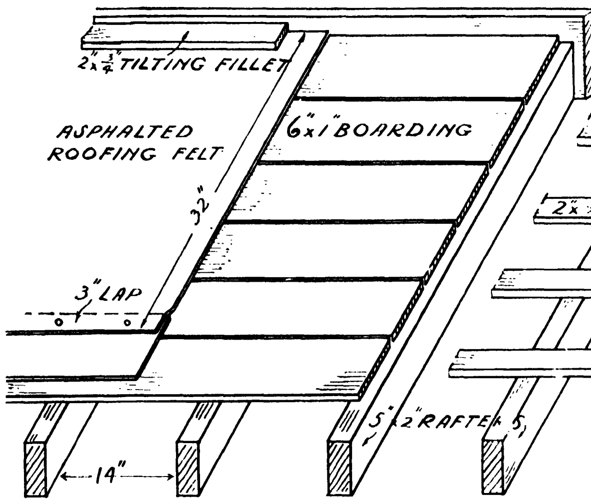

FIG. 12. BOARDING AND FELT

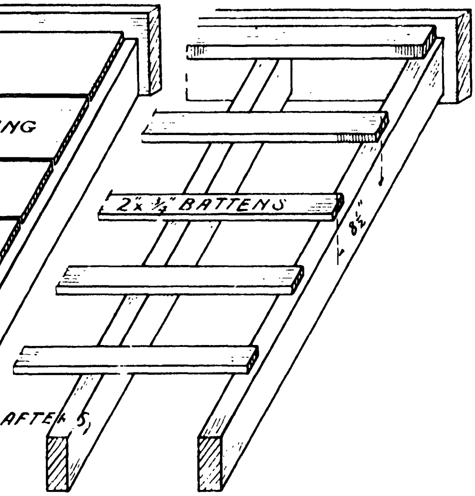

FIG. 11. BATTENS.

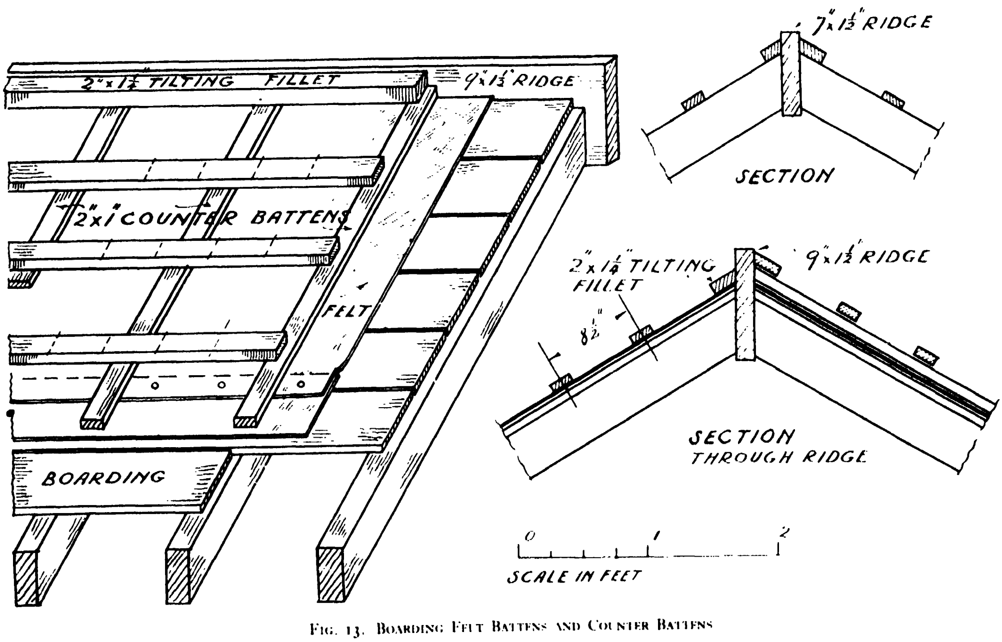

FIG. 13. BOARDING FELT BATTENS AND COUNTER BATTENS

the concrete, or the slates may be fixed to the concrete direct.

When a steel roof is employed to support the

Fig. 14. Battened and Felted Roof

covering, and where a more fire-resisting construction is desired, small steel angles take the place of the rafters and battens for securing the slates. For this purpose large slates are more

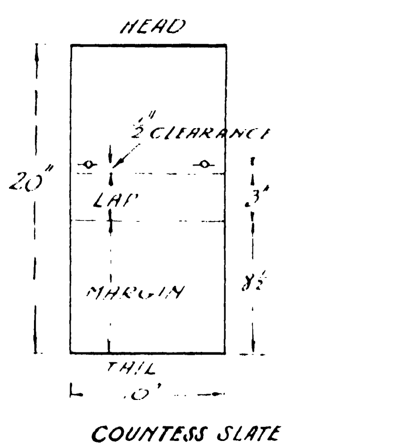

Fig. 16. Countess Slate, Dressed and Holed

suitable than small ones, for though they are a little more expensive, their extra cost is more than compensated for because wider spacing of the angles is possible. In this case the slates are fixed with copper wire or long lead nails.

Sorting. The slates are sorted out according to thickness, and piled on their edge for convenience of placing on the roof. The thicker

Fig. 15. Slate Battens and Counter Battens in Slated Roof

slates are placed at the lower part of the roof, and the thinner ones at the top. When Westmoreland or other slates are used for diminishing

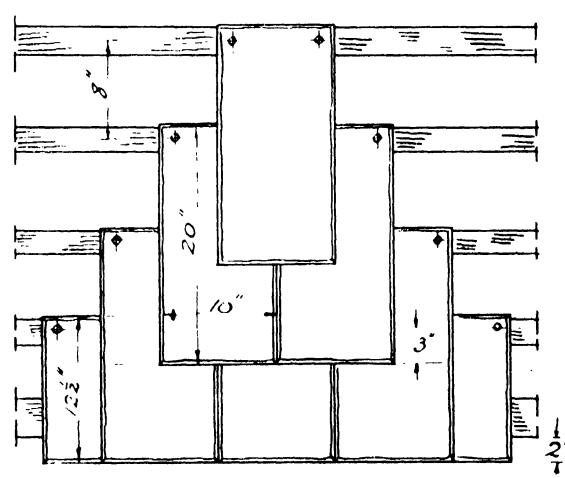

Fig. 17. Head Nailing

work, they are sorted out both in respect to thickness and size. The object of diminishing courses is to give to the roof an appearance of greater depth than it really possesses.

Nails. Slating nails are made in various patterns and of different materials—copper, composition, iron, and zinc. Copper nails, though practically imperishable, are soft and, owing to their cost, are not generally used. Composition nails, made from an alloy of copper and zinc, are the best. Zinc nails are much used in general construction, but they are soft. Nails of malleable iron, galvanized, are also satisfactory and are much in use.

Nails vary in length from $1\frac{1}{4}$ in. to 2 in., according to the size of the slate used. For Princesses, Duchesses, and Countesses slates, and also Westmoreland slates, the nails should be 2 in. long and weigh 90 to the pound; for Viscountesses and Ladies, $1\frac{1}{2}$ in. long at 180 to the pound. These nails are made with as thin a head as possible, so as not to project above the surface and interfere with the bedding, or cause

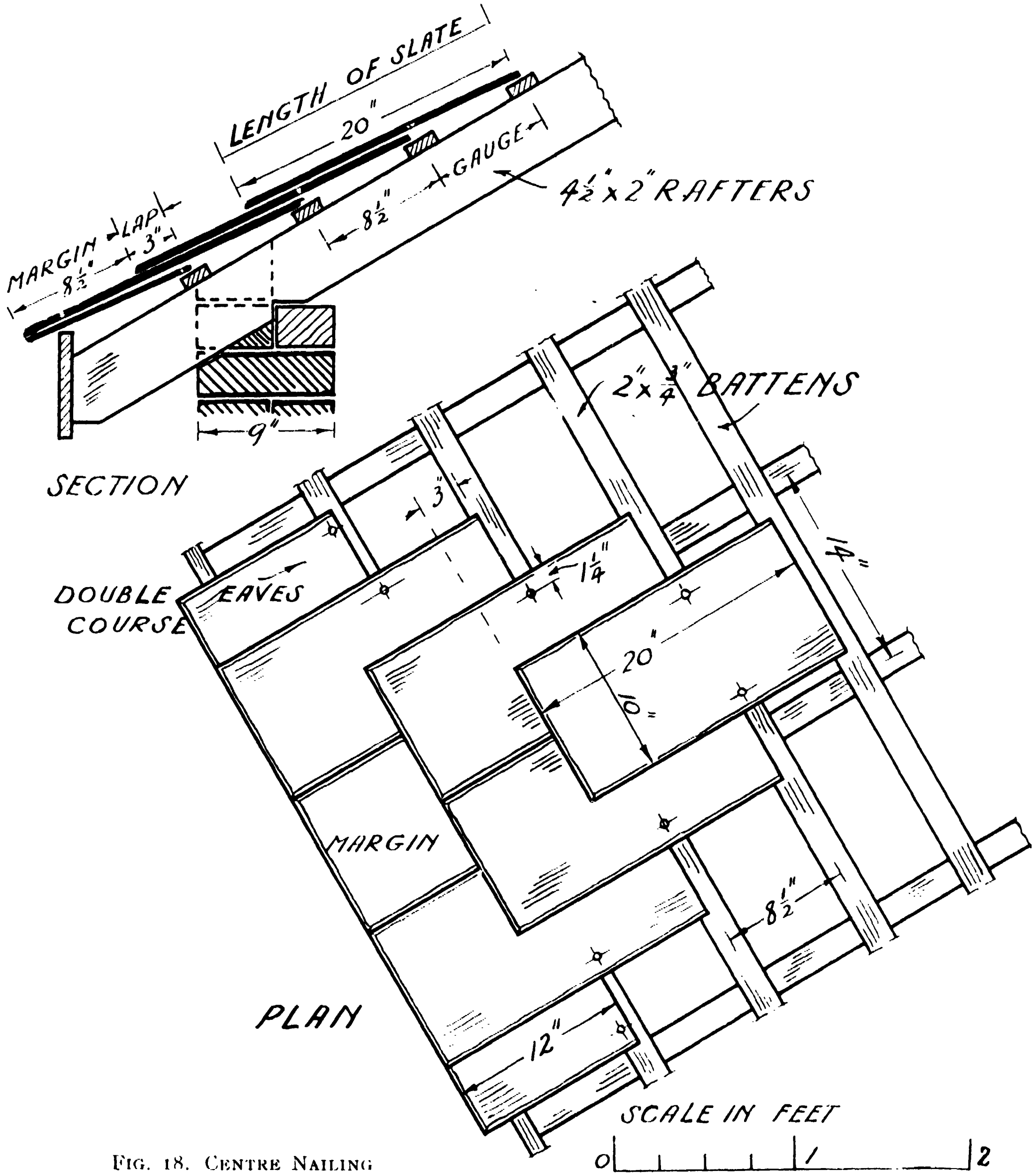

Fig. 18. Centre Nailing

any risk of breakage to the slate in the course above.

Fixing Slates. For fixing slates, two nail holes are drilled or punched in each. If the slate is to be *head-nailed*, the holes are made 1 in. from the head of the slate; when the slates have to be *centre-nailed*, the holes are made near the centre, at a distance from the tail of the slate equal to the gauge being used plus the lap, plus ½ in. for clearance. In either case, the nail holes are 1¼ in. from the long sides of the slates. A slate-and-a-half-slate may be fixed with three nails, and small slates with a single nail.

Fig. 16 shows a Countess slate dressed and holed ready for fixing on the roof. The punching or drilling is done from the bedside of the slate. By doing this a small amount of slate is splintered off, and forms a counter-sinking for the head of the nail.

Head-nailing. Each method has its advantages. In head-nailing, each slate is covered by two thicknesses of slate, so that if one is broken the nail is still protected, but the leverage offered to the wind is greater than if centre-nailed, and repairs to the roof are more difficult. The lap is measured from the nail hole, thus reducing the gauge by ½ in., and more slates are therefore required per square, making the roof slightly more expensive (see Fig. 17).

Centre-nailing. In centre-nailing, the nail hole is covered by one slate only, but it has a greater protection in that the leverage, as stated above, is much less than in the case of one nailed near the head. Centre-nailing is the method generally adopted (see Fig. 18).

The choice of a suitable slate for the roof will depend on the pitch and the position of the building, the practice being that the steeper the pitch the smaller the slate, and the flatter the pitch or the more exposed the roof the greater the lap.

The lap varies from 2 in. to 4 in., a good average being 3 in., which is the amount usually adopted.

Gauge. Having decided on the lap to be given, the gauge is next obtained by one of the following rules —

When the slate is centre-nailed: ***Deduct the lap from the length of the slate and divide by two***; the quotient is the gauge. This rule may be stated thus—

$$\text{Gauge} = \frac{\text{length of slate} - \text{lap}}{2}$$

When the slate is head-nailed: *From the length of the slate, deduct the lap plus the distance of the nail from the head of the slate (usually 1 in.) and divide by two*; the quotient is the gauge. This rule may be stated thus—

$$\text{Gauge} = \frac{\text{length of slate} - \text{lap} - 1\text{ in.}}{2}$$

As an illustration, consider a Duchess slate to be laid to a 3 in. lap, centre-nailed; then the gauge will be—

$$\frac{24\text{ in} - 3\text{ in.}}{2} = 10\tfrac{1}{2}\text{ in.}$$

If the slate is head-nailed, the gauge will be—

$$\frac{24\text{ in.} - 3\text{ in.} - 1\text{ in.}}{2} = 10\text{ in.}$$

Double Eaves Course. The length of the double eaves course will be the gauge, plus the lap, plus 1 in., the extra inch being to obtain the lap, as this course of slates is nailed at the head even if the other slates are centre-nailed. Adopting a Duchess slate as before, the length of the double eaves course will be, when the slating is centre-nailed, 10½ in. plus 3 in. plus 1 in.—that is, 14½ in.; and for head-nailed slates, 10 in. plus 3 in. plus 1 in.—that is, 14 in. Sometimes this course is formed by placing an ordinary slate lengthways along the eaves. This is unsatisfactory and should not be allowed.

In order that the nails of the first full course of slates will clear the top of the double eaves course, it is necessary for the nail holes in this course to be at a distance equal to the length of the eaves course, plus ½ in. for clearance, measured from the tail of the slate.

LAND SURVEYING AND LEVELLING

By Professor Henry Adams, M.Inst.C.E., F.R.I.B.A., F.S.I., etc.

LESSON IV

COMPLETE SURVEYS FIELD NOTES

Chain Lines Crossing Boundary—Ranging Line Over Hill—Small Complete Survey—Sketch of Chain Lines—Field Notes and Plotting—Trees and Hedges—Maps

Survey of Triangular Plot. Fig. 17 shows a survey that was made of a plot of grass land on the top of Primrose Hill, London. It is inserted to show that when circumstances permit, the chain line may cross and recross the boundary, which it could not do with a hedge or fence. It was also notable from the fact that on line 1 the ground rose in the middle, so that the station pole at one end could not be seen from that at the other end. By the surveyor and his assistant taking two poles *C* and *D*, Fig. 18, and standing between the extremities *A* and *B*, each can see the pole at the further end and direct the other into line step by step alternately, until they reach *EF*. The line can then be chained through from either end as may be needed. Fig. 19 gives the field notes for this survey.

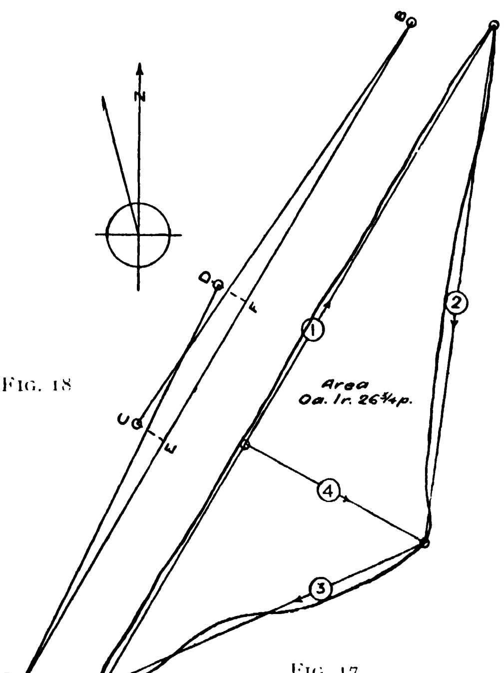

Fig. 18

Fig. 17

Fig. 17. Plot of Grass Land with Chain Line Crossing Boundaries

Fig. 18. Plan of Poling over Hilly Ground

Complete Survey. An example of a complete survey will now be given. Fig. 20 gives a sketch of the chain lines, Fig. 21 the field notes, and Fig. 22 the finished survey plan. It will be seen that the notes should commence with the name of the place and date, and the bearing of the first line, either true or magnetic. Sketches of the boundaries and junctions are made at each side beyond the offsets; then the first line should be measured and entered.

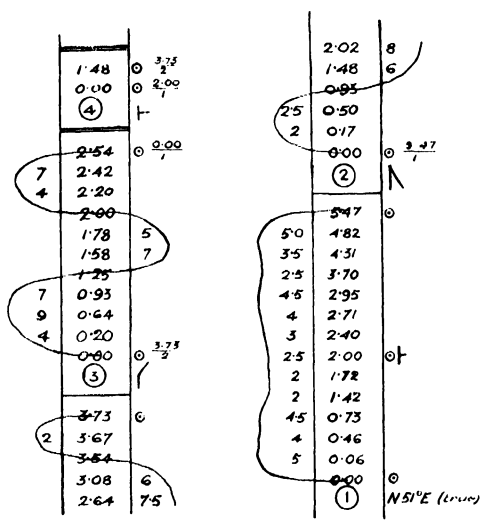

Fig. 19. Field Book for Fig. 17

In commencing a new line, a mark like a signal post is made to show by the upright part the old line from which the new one starts, and by the signal arm the approximate direction of the new line. This will be found of great assistance in the plotting, and is better than the old method of inserting a note "Go right," or "Turn to right," or to left, as the case may be. This only gave two possible directions, while the signal post can give eighteen, as will be seen from a close study of Fig. 23. Then against the first station on the new line a fraction is shown like $\frac{4{\cdot}90}{1}$, to indicate that the station was first reached at a distance of 4·90 on line 1. No difficulty should be found in plotting this survey. The note " line × " at 5·15 on (2) and elsewhere is inserted in the field book as a help in plotting the survey, showing where other lines cross.

It frequently happens that the exact crossing of the line cannot be determined until later, as it would require both the lines to be sighted through at the same time to a pole at the junction. In such a case the approximate position is first noted, and then when the other line is chained the exact crossing may be noted in the offset column of the new line as "back

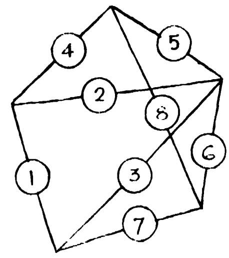

FIG. 20. SKETCH OF CHAIN LINES FOR SURVEY

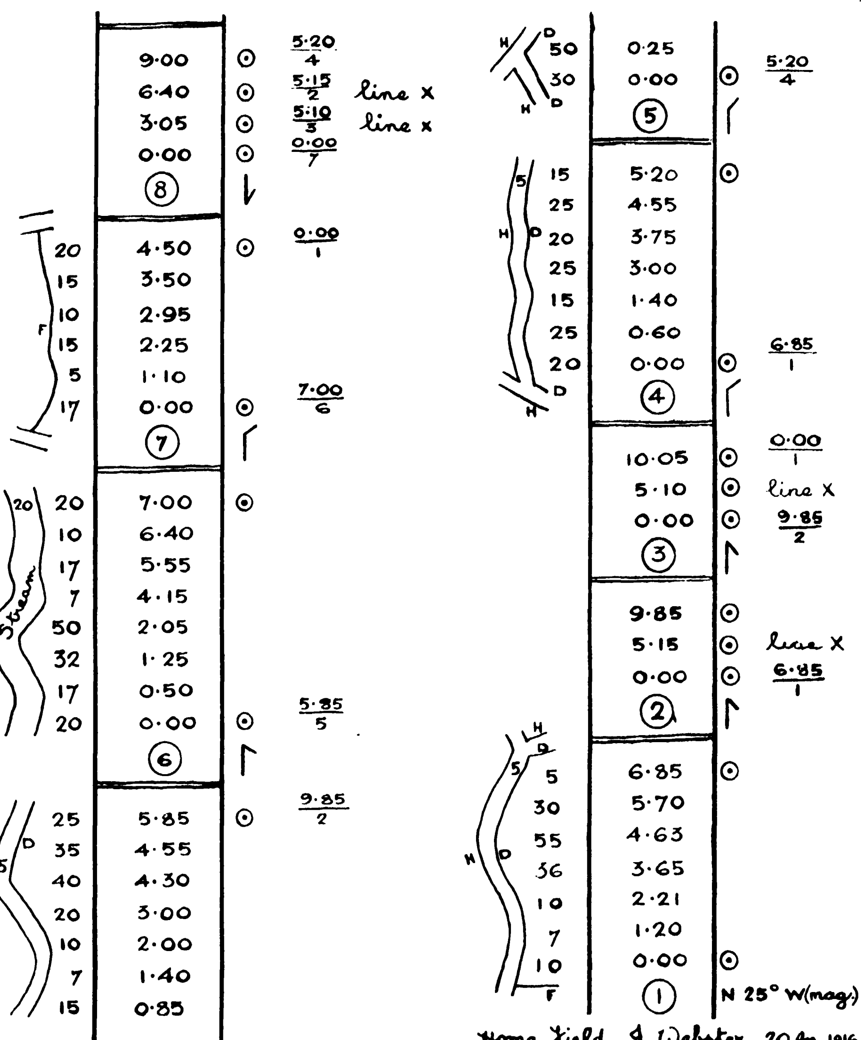

FIG. 21. FIELD NOTES FOR FIG. 22

3 from $\frac{5 \cdot 15}{2}$," or as the case may be. The lines may be set out in the order in which they are numbered, marking carefully the junction points on lines 2 and 3, and then seeing

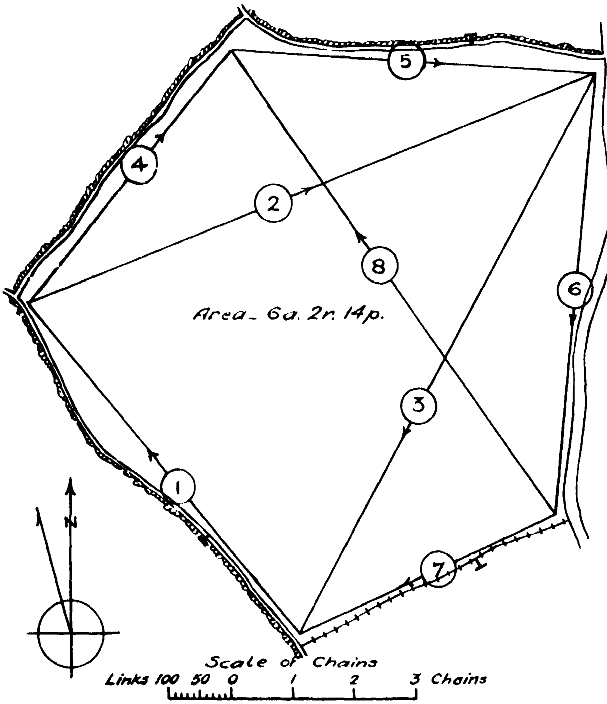

FIG. 22. SMALL COMPLETE SURVEY

that the check line 8 crosses with all the distances exact after having made any necessary corrections as suggested above.

True north should, whenever possible, be pointing vertically upwards on the paper, the survey plan being adjusted to suit this. The angle from the magnetic north may be noted in the field book, and reference made to *Whitaker's Almanack* to know the magnetic variation for the year, to enable the true north to be shown on the survey plan.

Hedges on Plans. Upon small scale plans the hedges are usually shown by plain lines, but on a larger scale freehand representations of the bushes forming the hedges are often shown, as in Fig. 24. Trees, where measured for position, are shown in plan as in Fig. 25, with a small cross for the actual spot.

The scale should at least be stated in words and preferably drawn also, upon

FIG. 23

FIG. 24

FIG. 25

FIG. 23. TYPICAL DIRECTION MARKS IN FIELD BOOK FOR LINES JOINING

FIG. 24. ENLARGED SKETCH OF HEDGE FOR SURVEY PLANS

FIG. 25. SKETCH OF TREE, THE CROSS MARKING POSITION

every survey plan. Sometimes it is useful to have "Feet equal" marked also. Thus a scale of chains may be drawn with the divisions marked above the line, and a scale of feet with the distances in 100 ft. lengths marked below the line. Tithe and parish maps are usually to a scale of $\frac{1}{2376}$ = 3 chains to 1 in., which gives nearly one acre to the square inch.

Land surveying cannot be learnt from books alone; every opportunity should be taken for actual practice in the field, as it is the only way to realize and surmount the difficulties that arise from time to time.

PLUMBING

By Percy Manser, R.P., A.R.S.I.
Honours Silver Medallist

LESSON IV

PIPES USED IN PLUMBERS' WORK

The pipes used by the plumber consist of lead, tin-lined lead, cast iron and wrought iron, brass, copper, and earthenware.

The manufacture of lead pipe has already been dealt with, whilst tin-lined pipe is similarly made, and consists of a pipe of tin contained in an outer pipe of lead. Tin-lined lead pipe is chiefly used where the water is of a soft nature; this will be dealt with more fully under "Water Supplies," etc.

Cast Iron is obtained by smelting the ore in blast furnaces and running the metal into moulds termed *pigs*. There are three kinds of cast iron—white, grey, and mottled.

Cast iron is crystalline in structure and is hard and brittle; it soon corrodes in moist air, ferric oxide (rust) being formed.

Cast-iron pipes are cast in three different ways: horizontal, inclined, and vertical. The last-named is the method now chiefly used, as it gives greater density to the casting, especially to the socket portion, which is at the lower part of the mould.

Wrought Iron is obtained from cast iron by a series of processes, chiefly by melting in a *puddling* furnace. The object of this is to remove the carbon and impurities which cause the cast iron to be brittle. The bars obtained from the puddling process are then passed between rollers of various shapes. Plates are obtained by passing the heated bars between straight rollers. Wrought-iron pipes are made by bending flat iron around a core and welding the seam, those used for gas having a butt-welded joint, and those for water a lap-welded joint.

Brass and **Copper** have already been dealt with under "Materials and Alloys." Tubes made of these materials are of two kinds: brazed-seam tubing and solid-drawn seamless tubing, the latter being much stronger and better for general use, especially where a lot of bending is required. The seamed tube is made by folding the flat metal round a core and then brazing the abutting edges. The solid-drawn tube is made by forcing the metal through a special machine, from whence it issues in the form of a tube. It is generally annealed before leaving the works, so that bends of a medium radius can be made by the aid of a bending machine without "loading" the pipe, that is, filling it with pitch, resin or lead to prevent buckling.

Earthenware Pipes are made from clay found in Dorsetshire and Devonshire, whilst fireclay comes chiefly from the Midlands.

The method of manufacture is by a machine consisting of a mould, hopper, and ram. The clay is placed in the hopper, at the bottom of

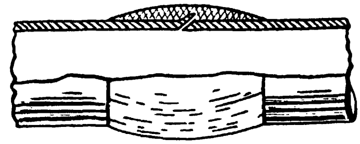

Fig. 28. Wiped Joint

which is the mould; the ram descends and completely fills the mould with clay, the socket or collar of the pipe being at the bottom and secured to the upper part of the mould by clips. The clips are then released and the pipe is forced out through the bottom, where it is cut off by a wire to the desired length. It is then trimmed, and the grooves on the socket and spigot are formed. The articles are next dried and then fired in a kiln, and whilst in the kiln are glazed by the volatilization of salt.

METHODS OF JOINTING PIPES

Lead Pipes. There are several methods of joining lead pipes by means of fine and coarse solder. Fig. 28 shows a *plumber's wiped joint*.

The method of preparation is to rasp the ends of the pipes square; one end is opened out by means of a turnpin, and the other end is slightly tapered with the rasp to fit well into the opened end. The pipes are then soiled for a distance of about 6 in., and when dry are marked with the joint gauge. The ends are shaved perfectly clean with a shavehook and rubbed over with tallow (or " touch "), after which the pipes are entered and firmly fixed with steel fixing points and tie-cords ready for wiping. In the case of an underhand joint, the solder is poured on to the pipe from a ladle, the wiping cloth being held beneath the pipe to catch the metal and work it

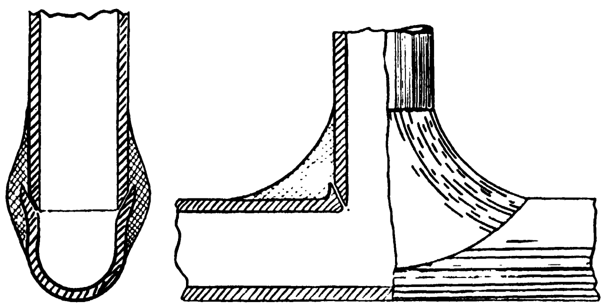

FIG. 29. BRANCH JOINT

round the whole of the joint until a proper wiping " heat " is obtained. By a few quick movements the joint is roughly moulded into shape, and finally wiped to a smooth surface with the cloth. It is necessary to clear the edges of the joint first, as the solder or metal cools much quicker at this point ; unless this is done an ugly thick edge is the result.

For an upright joint a lead collar is used. The solder is splashed on to the joint, and the collar—which is fixed just beneath—catches the solder ; this is continued until sufficient solder is splashed on. By means of the splash-stick the hot solder is picked up from the collar, and this, together with that on the joint, enables the plumber roughly to mould the joint and wipe it smooth, as with the underhand joint. The chief points to remember are : a good heat, clear the edges, and quickness in wiping ; these points apply to all wiped joints.

A **Branch Joint,** Fig. 29, is prepared by piercing a hole in the main pipe and opening out the pipe, by means of a bent bolt and hammer, to form a lip around the opening as shown.

The branch pipe should now be rasped square and tapered down slightly to form a good fit into the main pipe, but it must not project inside. The pipes are now soiled, the shape of the joint on main pipe being marked out by means of scribing gauge and compasses. The branch, or entry, pipe is marked with the joint gauge. The pipes are then shaved and smeared with " touch " and firmly fixed. The method of wiping is similar in all respects to an upright joint, except that a collar is only used if the branch joint is to be wiped in an upright position. For a horizontal branch a small platform can generally be fixed up to catch the

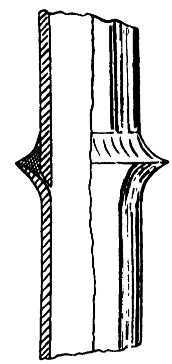

FIG. 30. TAFT, OR FLANGE, JOINT

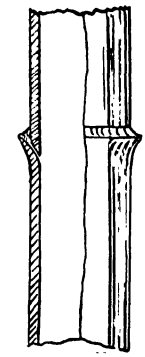

FIG. 31. COPPER-BIT JOINT

surplus solder ; of course, when wiping on the bench, this is unnecessary, as the bench itself acts as a platform.

The Flange Joint, Fig. 30, sometimes called a *blown joint* and a *taft joint,* is about the simplest type of joint. One end is opened out by means of a short thick turnpin and shaved clean inside. The entry pipe or male end is shaved clean ; a little tallow and resin are used as a flux, and fine solder is melted in by means of a blowpipe or lamp. Another method is to use only tallow and coarse (wiping) solder, and finish the joint by wiping round with a very narrow cloth, leaving what is termed a *finger-wipe.*

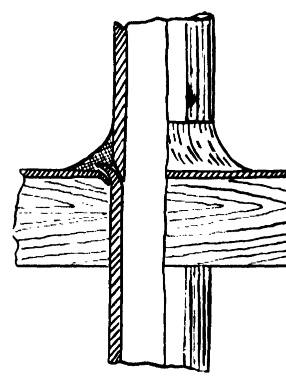

FIG. 32. BLOCK JOINT

The Copper-bit Joint, Fig. 31, is chiefly used by gas-fitters when jointing brass unions to lead pipe. The preparation is the same as for the flange joint, and the solder is melted in by means of a copper bit. Fine solder is used for this joint.

The Block Joint, Fig. 32, is another example of an upright joint ; it is used where pipes are fixed in a chase inside a building. Stout wood

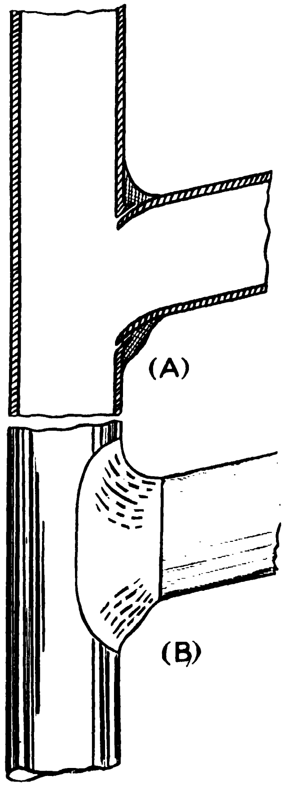

Fig. 33. Upright Joint connecting Branch Waste Pipe

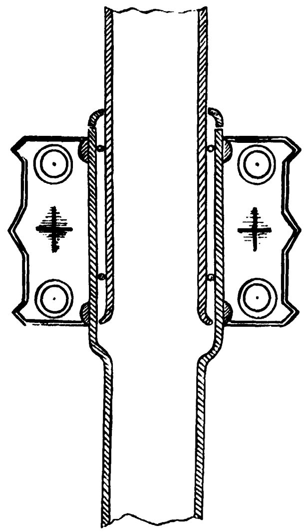

Fig. 34. Expansion Joint

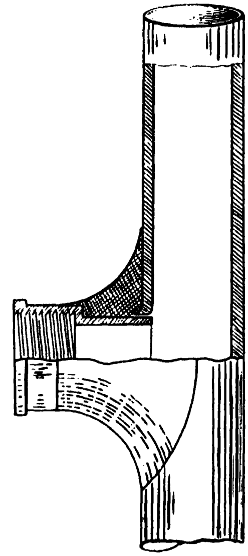

Fig. 37. Branch Joint for Tap Connection

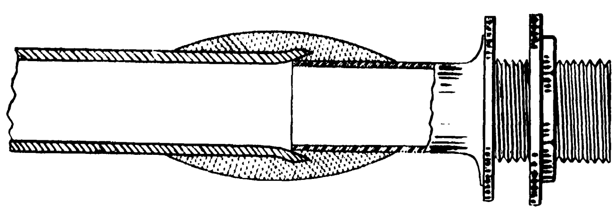

Fig. 35. Cistern Connection with Single-nut Boiler Screw

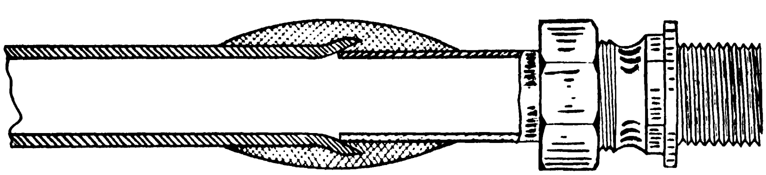

Fig. 36. Lead-to-iron Union Joint

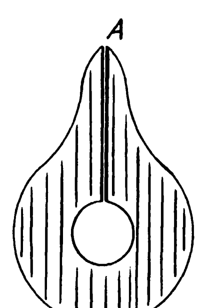

Fig. 38. Lead Collar

blocks, with holes the size of the pipe cut in them, are built in the wall on either side of the chase; the pipes are prepared, and then passed through the block far enough to form the joint. A lead collar is passed over the top end of the first length, which is then opened; the next length is then placed in position, and the whole wiped as shown in the drawing. It not only makes a most reliable joint, but a good fixing. Where lead pipes pass through lead flats a joint of this description is used, the leadwork of the flat forming the collar piece.

Fig 33 (A) shows the method of connecting a branch waste pipe to a vertical waste pipe, the end of the branch pipe being bent slightly to meet the direction of the flow. Fig. 33 (B) shows a view of the finished joint.

Expansion Joint. Where hot water is used, and the waste pipes are of lead, it is necessary to fix them with expansion joints, Fig. 34, more especially if the pipe is of any great length, owing to the expansion and contraction caused by the varying temperatures to which the pipe is subjected.

The joint is prepared by forming a socket on the end of a length of pipe by means of a reducing mandril; this operation expands the pipe, for a length of 6 in., large enough to receive the spigot end of the next length and two rubber or asbestos rings. A pair of astragals and cast-lead tacks are then soldered to the socket for fixing the pipe to the wall, the astragals giving the socket a finished appearance; the spigot end is slightly opened. A lead capping piece is placed on the top of the joint to prevent dirt, etc., from getting in.

Brass-to-lead Joints. Fig. 35 shows a single-nut boiler screw wiped to a lead pipe, and is the method of connecting a pipe to a cistern. Boiler screws can be obtained with either single or double nuts and with threads of different lengths suitable for iron or slate cisterns. The advantage of the double nut is that it can be tightened up from inside or outside the cistern, and will allow of a little adjustment.

Lead-to-iron Connection. This joint, Fig. 36, is formed by a brass union, consisting of a cap and lining and a nipple piece screwed for iron. The lining is wiped to the lead pipe, and the nipple is screwed into the socket of the iron pipe, and connected up by means of the cap and lining. This union is sometimes termed a *lead-to-iron union*, or a *nipple union*.

Tap Connection. Fig. 37 shows the joint required for fixing a tap to lead pipe, and consists of a brass screw boss wiped to the lead by a branch joint. The pipe is opened as described for a branch joint; the brass boss is "tinned" and fitted to the pipe, and joined by a wiped solder joint. The *stop end* is formed by rasping the end of the pipe tapering, then bossing over square, and finishing with a wiped convex end of solder, as shown at top of drawing. The interior of the boss is screw-threaded to receive the tap.

Brasswork. The preparation of brasswork ready for soldering to lead pipes needs care and attention. The brasswork to be wiped is first filed quite clean and then soiled to the length required. A flux of resin or fluxite is then placed on the filed portion, and with a copper bit and fine solder a coating or film of "tinning," i.e. solder, is formed on the brass, which is then securely fixed to the lead pipe ready for wiping; this "tinning" causes adhesion of the solder and thus makes a sound joint. Killed spirits of salts should never be used for tinning brasswork, as, being a chloride of zinc, it would not improve the solder owing to the presence of zinc.

Plumber's Soil, or Smudge. This is a mixture of lampblack and glue size mixed to a stiff paste. There are also other good forms on the market; one is a powder that simply needs mixing with water, and another is in the form of a block similar to blacklead, and only requires a wet brush to moisten it. The portion of pipe to be soiled is first cleaned by cardwire to remove the greasy surface, then well rubbed with chalk to assist in *killing* the grease. The soil is applied by means of a brush; a straight edge is quite an easy matter if the length of the "soiling" is marked by the scribing gauge. To dry the soil quickly slight heat may be used.

Fig. 38 shows a collar used for catching the solder when wiping upright joints. It is cut out of a piece of sheet-lead, well soiled to prevent the solder adhering by tinning, opened out at *A*, and placed round the pipe in the form of a shallow cup or basin. It is the usual procedure to have several collars of different sizes in the workshop

SPECIFICATIONS AND QUANTITIES

By WILFRID L. EVERSHED, F.S.I.
Chartered Quantity Surveyor

LESSON IV

SPECIFICATIONS— (*contd.*)

THE REMAINING TRADES

WE now continue with the typical paragraphs for a specification.

BELL-HANGER

Electric Bells. The conductors are to be not less than 1/·036 standard wire covered with a double layer of pure rubber, double cotton covered, and properly treated with paraffin wax.

Flexible wires to be not less than 10/·0048.

The wires are to be run in zinc or split conduit tubing concealed, of a size to avoid cramping wires, and having insulation as necessary to prevent abrasion.

Where staples are used they are to be insulated.

Provide all necessary blocks sunk in wall for fixing pushes.

The pushes are to be of an approved pattern having a screw top and properly insulated backs.

The batteries are to be of Leclanche type of sufficient size and number to properly work the system.

The indicator is to be of the pendulum type having glass front and enclosed in polished teak case with the names of rooms written in gold.

The whole system is to be left in proper working order with batteries charged.

[*Note*. It is better to give a schedule of bell points as—

Drawing-room.	Two pushes at side of fire.
Dining-room.	One ditto.
	One having loose plug and flexible wire in centre of room.
Bedroom No. 1.	One at side of fire and one pear push at bed.]

The pushes are to be of an average p.c. value of .... each to the selection of the architect, those to the outer doors to be of a water-tight description.

PLASTERER

Materials. All laths to be " lath and half " thickness, butted at joints and to break joint every three feet, and nailed with iron nails.

[*Note*. If any metal lathing is to be used, specify thus —

Lathing throughout (or to so and so) to be metal lathing (give the make), fixed in accordance with the instructions of the manufacturers.

If rent laths are required substitute the word " rent " or " riven " for sawn.]

The lime to be fresh well-burnt stone lime, free from cinders, and to be run into putty at least one month before being used.

Portland cement to be of approved manufacture equal to the British standard specification.

The sand to be clean and sharp and to be washed if required.

Hair to be sound, long, black ox hair, well beaten up when dry and thoroughly incorporated with the mortar.

Coarse Stuff. Is to be composed of one part of lime to three parts of sand and 1 lb. of hair to be added to every 3 cub. ft. of mortar.

Setting Stuff. Is to be composed of one part of lime to two parts of washed sand.

Ceilings. The ceilings of .... to be lathed, plastered, and set, all the remaining ceilings to be lathed, plastered, floated, and set.

Walls. All inner faces of walls and half-brick partitions to be rendered, floated, and set, and all quarter partitions lathed, plastered, floated, and set. Render in cement and sand and set in fine stuff to all breeze partitions. The plaster to be continued behind skirtings. Walls of .... to be finished with dinged surface.

Angles. External angles are to be run in Keene's cement and have the arris slightly rounded.

PLUMBER

Materials. The whole of the sheet lead to be the best new pig lead, properly milled and free from all defects, to be weighed whenever required at the contractor's expense, and equal to the specified weight. The contractor is to supply all necessary solder, copper nails, etc., required in laying leadwork. Solder is not to be used in fixing external leadwork, except where absolutely necessary. For securing edges turned into joints of brickwork, as in aprons and flashings, lead wedges are to be used, and joints are to be pointed in cement.

Lead in Flats and Gutters. Lay the flat over .... with 7 lb. lead laid to a fall of 1½ in. in 10 ft., having 2¼ in. rolls, not more than 2 ft. 8 in. from centre to centre, and cross rebated drips not more than 9 ft. apart, as shown on plan. The drips in all cases to be 2½ in. deep, and the ends of rolls to be properly bossed.

The gutters to main roof to be laid to a fall of 1½ in. in 10 ft. with 7 lb. lead, 9 in. wide in narrowest part, and turned up under slating equal to a vertical height of 6 in., and dressed over tilting fillet.

Flashings. Where lead flat abuts against brickwork the lead is to be turned up 6 in., and have cover flashings 6 in. wide of 4 lb. lead turned into joints of brickwork 1½ in.

Where the sloping edges of roof abut against vertical sides of dormer, put lead secret gutter 16 in. wide of 5 lb. lead covered with 5 lb. lead flashings 6 in. wide, with 4 in. laps. This flashing to be close copper nailed to boarded sides of dormer cheeks.

Where roof slopes abut against vertical faces of brickwork 4 lb. lead soakers are to be provided, one to each course of tiles (or slates), and having 4 lb. lead-stepped flashing 10 in. wide dressed down over tiles (or slates).

INTERNAL PLUMBER

Lead Pipes. The pipes to be of the following weights per yard run—

These are the Metropolitan Water Board requirements for London, but local regulations must be followed.

Wastes—

½ in.	3 lb.
¾ in.	5 lb.
1 in.	7 lb.
1¼ in.	12 lb.
1½ in.	14 lb.
2 in.	18 lb.

The services and supplies—

½ in.	6 lb.
¾ in.	8 lb.
1 in.	12 lb.
1½ in.	16 lb.

Pipe Fixing. All horizontal pipes are to be fixed on 1½ in. by 3 in. wrought and splayed fillets, plugged to wall, hollow groove on top side for pipe to lie in, and each to be laid with a fall towards the rising main, so that pipes may be emptied from draw-off tap at bottom of same.

Supply Pipes. Run supply pipes from cistern as follows—

[*Note.* Give a list of the supplies to be connected to cistern; when the pipes are lead they must be connected with a brass boiler screw and solder joint "full way" of the size of the respective pipes.]

Lavatory. Fit up the lavatory with Messrs. .... lavatory fittings as No. .... in their catalogue, including hot and cold supply taps, and plugs for waste p.c. £...........

The waste is to be 1¼ in. with drawn lead trap fitted with brass screw cap for cleaning. This waste is to be taken to discharge into slipper shown on plan [or into stack head or soil pipe].

GLAZIER

Sheet Glass. The windows number .... to .... on plans to be glazed with 26 oz. sheet glass of "seconds" quality.

The windows of scullery to be glazed with 21 oz. sheet glass of "thirds" quality.

The windows of larder and pantry to be glazed with 21 oz. sheet glass of "thirds" quality ground on one side.

PAPER-HANGER

Hanging of Papers. All walls which are to be papered are to be rubbed down, stopped, sized, and prepared for paper-hanger.

The walls of the following rooms are to be hung with lining paper before the wallpaper is hung—

Dining-room, drawing-room, etc.

All papers are to be butt jointed.

Papers. The wallpapers will be selected by the architect at the following p.c. prices, and the contractor is to add for preparing the walls, hanging, and profit—

Dining-room, 5s. per piece.

Drawing-room, 6s. per piece.

Bedroom (No. 1), 2s. 6d. per piece, etc.

PAINTER

Materials. In specifying the materials for the painter's trade it should be noted that the highest quality is not that described as "best."

There is a British standard specification for materials and ready mixed paints, and they may be required to comply with this.

The oil colours are to be prepared with genuine old white lead, pure raw linseed oil, and genuine American turps. The paint to be mixed on the premises, and all the materials to be tested, as the architect may direct, at the expense of the contractor. Each coat to be of different tint, and the finishing coats to be in approved tints.

It is very general to allow "ready mixed" paints to be used, and these when from one of the well-known firms are superior to any mixed on the job; this will be specified as—

The paint is to be Messrs. .... "Robolene" (or other name) delivered in the manufacturers' sealed cans and of proper under-coating and finishing qualities.

The exterior work is not to be proceeded with in wet, foggy, or frosty weather, or on surfaces which are not thoroughly dry.

All work is to be carefully prepared, and rubbed down between coats. Nail holes, crevices, cracks, etc., to be stopped with pure linseed oil putty after the priming coat is dry. All knots and sappy or resinous parts of the wood to be coated with two thin coats of best patent knotting, well brushed out.

All coats of paint, etc., are to be thoroughly dry before further coats are applied.

The wood is to be well rubbed down to a smooth face after each coat of colour; and no coat of paint is to be followed by another until it has been seen and approved by the architect.

The internal woodwork to be painted as follows—

The woodwork in drawing-room and dining-room to be painted in four coats of oil colour to approved tints in party colours.

Woodwork of morning-room and smoking-room to be painted in four coats of oil colour, grained imitation walnut, and varnished with pale oak varnish.

Woodwork of offices to be painted in four coats of oil colour of approved tints and varnished with hard oak varnish.

ALTERATIONS

In specifying work that has to be done to carry out alterations, it is a great mistake to attempt to divide the work strictly into the several trades as is ordinarily done in specifying for new work. It is far better to specify the whole work connected with any particular piece of alteration dealing with the work in all trades.

The description connected with each item should be split up into several paragraphs; this is done to enable same to be more easily read and understood. It is very easy to get confused when reading a long paragraph containing description of work by several trades.

As it frequently happens in carrying out alterations that part of the premises only can be given up to the builder at one time, it is important to express clearly to what extent and at what times the builder will be allowed to have access to the different parts of the premises. There will, therefore, generally have to be some special clause defining the method of operations.

JOINERY

By T. Corkhill, F.B.I.C.C., M.I.Struct.E., *Double Medallist*

LESSON VI

TIMBER

Growth. The trees from which we derive timber are called *exogens* or "outward growers." The growth takes place on the outside of the existing wood fibre and under the bark. Each year a new ring is added to the tree (except under very special circumstances); hence the term annual rings.

Fig. 97 illustrates the various parts of a tree trunk; *A* shows the sapwood, or *alburnum*,

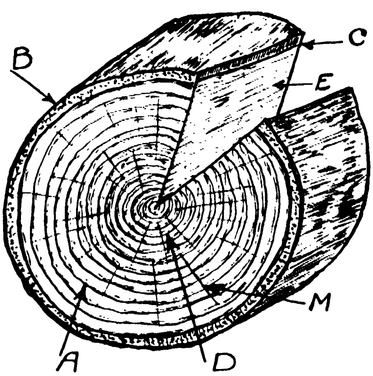

Fig. 97. Parts of Tree Trunk

portion of the annual rings, *B* the bark, and *C* the *cambium layer*. The heartwood, or *duramen*, portion of the annual rings is shown at *D*. The *medullary rays* are shown at *M* in the cross section, and at *E* in the longitudinal section. The centre round which the growth takes place is called the *heart*, *pith*, or *medulla*.

Each annual ring consists of two parts; the inner or softer part, and the outer or harder part. The difference is due to the change of the sap during the season. The formation of the new timber takes place in the cambium layer during the ascent and descent of the sap in spring and autumn respectively. The ascending, or spring, sap is immature and forms a soft spongy wood; but after the sun has perfected the sap during the summer, the woody cell formation during the autumn descent is thicker, darker, and more compact. This difference of structure is much more clear in some timbers than in others. It is very evident in northern pine and pitch pine; hence the difficulty in trimming up the end grain of these timbers.

The annual rings are divided into *heartwood* and *sapwood*. The heartwood is the inner portion of the tree and is more compact than the outer part of the tree which is the sapwood. The cell walls of the woody fibre continually thicken year by year, and this, together with the pressure from the outer rings, gradually builds up the heartwood. In most timbers the heartwood is more durable and better in every respect than the sapwood. If the tree is past maturity, however, there is a danger of the heartwood deteriorating by incipient decay. The sapwood should be avoided for good work, but it must be understood that much of the sapwood in the growing tree becomes good timber after conversion and seasoning. In soft woods the sapwood is usually of a bluey tint; in hard, dark coloured woods, it is of a whitish grey colour.

The *medullary rays* are vertical layers of cells, radiating to the centre of the tree, binding together the annual rings, and distributing the sap throughout the tree. In some trees the medullary rays are very evident, as in the oak, and the timber is cut purposely to expose the rays on the surface of the boards to give what is known as *silver grain*.

Timber trees are broadly divided into two classes, *conifers* and *broad leaf* trees. The conifers are cone bearing and have needle shaped leaves, and are evergreens; the timber is classified as softwood. The broad leaf trees are deciduous, that is, they shed all their leaves annually; the timber is classified as hardwood. There are several exceptions to both classifications.

PRESERVATION AND CONVERSION

Seasoning. To secure the utmost value from the tree, it is necessary to understand the best methods of seasoning and conversion. Unseasoned timber is a source of trouble, both from the constructive aspect and for durability. Seasoning implies the removal, or drying, of the fluid portion of the natural juices of the growing tree, which is called *sap*. The best period for felling the tree is when the sap is at rest, either in winter or in summer, preferably in winter. The strength and durability of many timbers are nearly doubled by good seasoning.

There are many methods of seasoning, but *natural* seasoning is the best, because the final strength, durability and colour of the timber are not impaired. The log should be cut to the smallest required dimensions and then stacked for seasoning. The timber should be well ventilated but protected both from the sun and rain. This method dries out the moisture and hardens the natural juices. The disadvantage of this method is the amount of time required, which varies from two to five years. Fig. 98 shows a method of stacking deals and planks. The balks *B* should be about four or five feet apart. The outer timbers *a* are closed in a little when the width of the stack is known. Fig. 99 shows the usual method of stacking boards after cutting up the log. The packing pieces, or *skids*, *S* must be placed one above the other, and from three to four feet apart. They must be of the same thickness between any two boards, otherwise they may be of any size. The ends of the boards are often painted or they have strips of hoop iron, called *cleats*, nailed across them, as shown at *a* in Fig. 99; this is to prevent the ends from splitting. Placing the skids level with the ends of the boards also tends to prevent splitting. The skids should be of spruce or pine, to prevent staining the boards as far as possible.

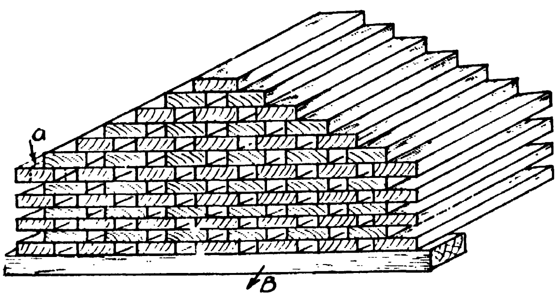

Fig. 98. Stack of Deals

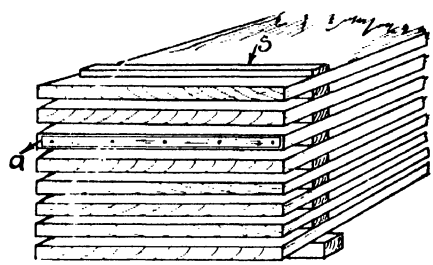

Fig. 99. Seasoning Boards

Wet Seasoning. The log is placed in running water, with the butt end facing the stream, for two or three weeks. This method washes out the sap and is not so good as natural seasoning, as it tends to destroy the elasticity and durability of the timber. The only advantage is the short time required.

Desiccation. The timber is placed in closed chambers having an internal temperature of about 200° F. The dry hot air is admitted at one end of the chamber, whilst the moist air is drawn off at the other end. This method also reduces the strength of the timber. It must be understood that seasoning does not mean drying; timber may be seasoned and still be wet with rain-water.

Second Seasoning. All framing, such as doors, panelling, etc., should be loosely knocked together and then placed in a warm dry room for some time before gluing up. Match boarding, floor boards, etc., should also be stacked as shown in Fig. 98. This is for the purpose of "second seasoning," before fixing the boards in position, otherwise shrinkage will cause open joints. Second seasoning is for the purpose of drying the stuff, rather than for removing or hardening the sap.

Preservation. Other methods of seasoning come more under the heading of preservation, because of the dual process. The methods vary in detail, but the general principle is the same. The timber is impregnated by some form of chemical or acid, which preserves the timber or gives it some special resisting properties; Boucherie's process (sulphate of copper), Burnett's process (zinc chloride), Kyanising (mercuric chloride), Blythe's process (carbolic and tar acids), Noden-Bretenneau (electric seasoning), are the most important methods.

Creosote oil is one of the best preservatives. Well seasoned timber is placed in tanks containing the creosote. The air is first extracted from the timber cells by reducing the atmospheric pressure in the tank, and then the oil is forced into the timber. The smell of creosote is objectionable, but the many variations of creosote oil such as *Carbolineum*, *Peterlineum*, *Solignum*, etc., are patent preparations in which the pungent odour is not so evident. Creosote brushed on to the timber is but much inferior to the pressure method.

Tar, either coal tar or Stockholm tar, is an excellent preservative, but it is unsightly, and again, the smell is objectionable.

Paint is a good preservative if applied properly; it has no objectionable features and is one of the best means of decorating.

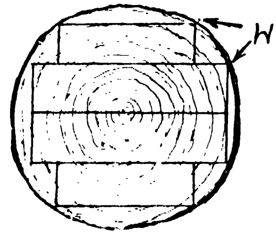

Fig. 100. Converting Softwood Log

Charring is one of the best preservatives, especially for timber about ground level, such as the foot of posts, etc. The coating of charcoal prevents decay.

Conversion. The conversion, or "breaking down," of the log into marketable forms of timber is usually performed in the lumber yard,

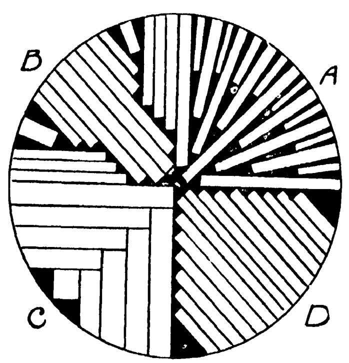

Fig. 101. Converting Oak Log

which is either near to the growing trees or at the nearest port of shipment. Different kinds and sizes require different methods. Fig. 100 shows the conversion of a log into deals and planks. Fig. 101 shows four methods of converting oak. The value of oak usually depends upon the presence of silver grain, hence for the better class timber the log is *quartered* and then cut radially as shown at *A*. This method produces wainscot oak, but is very wasteful. The other three methods *B*, *C*, and *D*, are more economical, but not so effective for figure.

Pitch pine depends upon the annual rings for the figure in the grain, hence the cuts are made tangential to the rings as shown in Fig. 102.

Shrinkage. The effect of shrinkage during seasoning must be considered when converting for special purposes. The shrinkage is due to the collapse or contraction of the cells after the

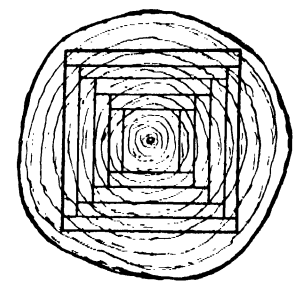

Fig. 102. Converting Pitch Pine

evaporation of the moisture. The medullary rays prevent the contraction taking place radially, so that it is all practically circumferential; hence the log is apt to split, as shown in Fig. 103. The effect on deals and battens is shown exaggerated in Fig. 104. The effect on a quartered log and on a rectangular section is shown in Figs. 105 and 106. Conversion for special

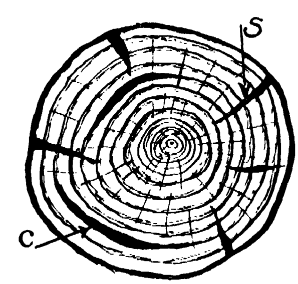

Fig. 103. Star and Cup Shakes

purposes is illustrated in Fig. 107, which shows the section for a beam; *A* will give a much stronger beam than *B*. Fig. 108 shows the correct and incorrect methods of cutting floor boards; *B* is bad because the hearts will shell out. If the board has been cut as at *B* the heart should be placed downwards.

DEFECTS AND DISEASE

Defects are distinct from diseases. The former usually means that some of the timber is wasted and also that there is a reduction in strength, but the latter implies decay and should be avoided.

Heartshake, Fig. 109, is due to shrinkage through age or lack of nutriment, or it may be due to the log lying for a considerable time without having the bark removed.

Starshake, Fig. 103, *s*, is often due to too rapid seasoning, but it may be caused by severe frost

tion of the log is useless. Very often it cannot be detected until after cleaning up (planing). Any form of shock will break the pieces apart at the upsett.

Wandering heart is found only in crooked trees. The converted timber is liable to twist badly, and is generally cross-grained. It is bad for structural work.

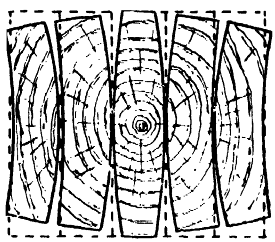

Fig. 104. Effect of Shrinkage

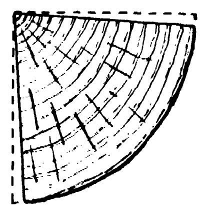

Fig. 105. Effect of Shrinkage

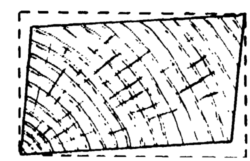

Fig. 106. Effect of Shrinkage

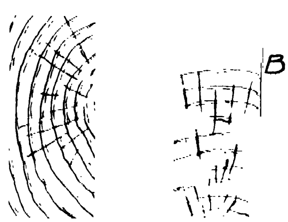

Fig. 107. Converting Joists

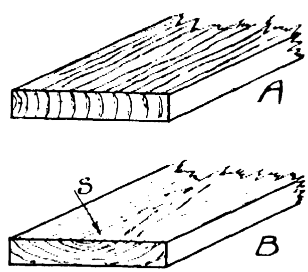

Fig. 108. Converting Floor Boards

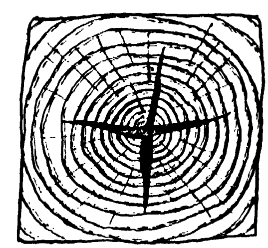

Fig. 109. Heart Shake

bursting the tissue. The sun may cause starshakes if the bark has been damaged. Exposing a felled trunk to the sun for any length of time will also cause them. The cleavage follows the line of the medullary rays.

Cupshakes, Fig. 103, *c*, are caused by unequal growth, probably due to a wet season following a very dry season, or to lack of nutriment during a season. Another cause is the twisting of the tree by the wind, in exposed positions.

Rindgalls are due to broken branches which are afterwards covered with timber which is not uniform with the tree. Any wound in the cambium layer prevents growth for a temporary period, then subsequent growth covers the weak place in the timber.

Upsetts, Fig. 110, are usually the result of bad felling, or *jamming* during the passage of the timber down the rivers. The defect is very prevalent in mahogany. The fibres are usually broken straight across the log, hence that por-

Twisted grain is due to exposure to wind and gives short grain. It i bad for structural work.

Waney edge is caused by too economical conversion, as shown in Fig. 100 *w*. It is accompanied by sapwood, hence it should be avoided for good work.

Diseases. Ordinary decay commences at the heart in the living tree and is due to old age, but with cut timber it starts with the sapwood.

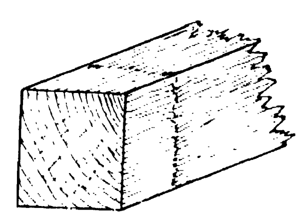

Fig. 110. Upsetts

Over maturity is really old age ; the tree has begun to decay, usually at the heart, before felling. The ages of trees vary, but maturity for pines is about 80 years, and for oak and most hardwoods about 150 years.

Druxiness is decomposition due to a broken branch holding water. The result is light coloured spots or streaks.

Foxiness is a reddish brown stain in hard woods.

Doatiness is incipient decay, causing a greyish stain with black speckles. It is easily attacked by dry rot.

Wet rot is caused by dampness, usually alternate wet and dry.

Dry rot. This is the most serious of diseases in timber. It is due to the fungus *Merulius Lachrymaus.* The timber is often infected soon after felling. The disease may be distinguished by the peculiar pungent odour, accompanied by red and brown stripes, when converting. The disease spreads rapidly when in a damp humid atmosphere, and forms a blanket-like covering over large areas. The best preventives are ventilation and well seasoned timber. The cure of dry rot is a difficult procedure. All the infected timber must be removed and destroyed. The brickwork should be subjected to great heat from a blow pipe; and the remaining timbers should be treated with creosote or sulphate of copper, or coated with hot lime. The cause, which is generally lack of ventilation, must be removed.

Good timber is an excellent conductor of sound. An experienced person can tell, by listening at one end of a log, whilst someone taps lightly at the other end, whether the log is sound or not. In fact, an expert can often tell the nature of the defects if any exist.

ARCHITECT'S OFFICE AND ROUTINE

By HERBERT J. AXTEN, A.R.I.B.A., A.I.STRUCT.E.
Chartered Architect

PART IV

PROFESSIONAL PRACTICE AND PROCEDURE

Work of an Architect. The present is becoming more and more the age of the specialist, and it is therefore not surprising that the practice of architecture comes also within this sphere. We find certain architects specializing in the design and construction of factory buildings, others in breweries, ecclesiastical work, and so forth; but the writer feels it will be more generally useful to concentrate attention here upon the activities of the office of the architect carrying on what might be termed a general practice. Within the scope of this section of the work, it would be quite impossible to deal with all the multitudinous activities which crowd themselves into the professional life of a busy architect, which vary more or less with every office selected for consideration, but a broad outline will be given of the general procedure in the chief matters with which practically every architect is sooner or later called upon to deal. Among other things, he will be required to advise as to the suitability of sites, and eventually to carry out the particular buildings thereon, for the following works—

- One or more private residences; residential hotels.
- Development of estate upon garden suburb lines.
- Shops—with or without dwelling accommodation.
- Shops—with or without business premises over.
- Blocks of flats, offices, garages.
- Business premises of all description.
- Places of entertainment.
- Public libraries, swimming baths, schools.
- Municipal offices.
- Factory buildings, workshops, warehouses.
- Conversion of existing premises, such as—
  - Houses into shops, flats, nursing institutions, schools.
  - Warehouse into billiard hall, etc.
- Extensions of existing buildings of all description.
- Carry out surveys and report regarding dilapidations, light and air cases, party wall awards, sanitary surveys.
- Prepare the valuation and report upon the various properties proposed to be purchased by clients, such as—
  - Private residences.
  - Shop property.
  - Factory or warehouse premises.
  - Office premises.
- Conduct arbitrations.
- Qualify for and give evidence in law cases arising out of building disputes or accidents.

Procedure. By selecting two of the foregoing items, and giving in detail the chief points for consideration, this will show not only the order of procedure, but the very considerable amount of work which has to be done, and the care and attention exercised in the preparation of a well-ordered and comprehensive report.

(*a*) **Erecting a Factory.** Assuming a client wishes to erect a factory in a provincial town, then, in order to prepare a satisfactory report upon a proposed site, the architect would obtain information upon the following items—

Centres of industries.
Price of land, local rates.
Level or evenness of site, nature of soil—
  High or low lying.
  Liability to floods.
Proximity of sewers.
Supply and price of electric power, electric light, gas power, gas light, water supply (high or low pressure, soft or hard water).
Proximity to coal-fields—if manufacturing business.
Proximity to steel works—if engineering business.
Source of supplies of raw materials—if manufacturing business.
Facilities for transport, import and export.
Railways: Main, branch, sidings—or possibility.
Canal or river or docks. Whether sheet piling wharfing required.
Roads: Main, secondary, private—upkeep. Whether steep hills in vicinity.
Possibility of outlet for effluent.
Possibility of extension of buildings.
Labour: Class of and supply, male and female.
Travelling facilities for employees.
Housings schemes, canteen, recreation ground.

(*b*) **Purchase of Small Estate.** Assuming a client wishes to purchase a small estate with existing private residence and garage, etc., just outside the limits of administration of an urban district council, the architect must obtain information upon the following, as data upon which to construct his report—

Situation: Surroundings, such as hills, houses, other buildings, sewage farms, gas works, asylums; shops, schools, churches, factories; sea, river, water; golf, rainfall, death rate, ordnance datum, soil.
Travelling facilities, trains, trams, buses.
Call upon local authorities or agents regarding rating in district, road charges, electric light, gas, water, and telephone services. Local matters affecting the property.
Check tenancies, fixtures, ancient lights—if any—rights of way, watercourse, fishing, shooting, boating.
Note plan, elevations, and dimensions for cubing, and regarding the following—

EXTERNALLY

Brick or stone facings, rough cast, half timber, weather boarding, windows—type, whether metal, wood, or both.
Roofs: tiled, slated, lead, zinc, copper, asphalt, vulcanite, ruberoid, asbestos tiling, corrugated iron, boarding, felt, battens; gutters: cast iron, zinc, asbestos; flashings: lead, zinc or cement.
Brickwork.
Chimney stacks, parapets, pointing, walls out of perpendicular, walls damp, signs of settlement.
Pavings.
Cement, blue brick, brick, tiling, tar-paving, crazy paving, forecourt, garage, and wash.
Gates, fencing, boundary walls, paths and drainage of same, gardens, garden buildings, pools and garden ornaments, trees, hedges, ditches, ponds.
Air bricks to w.c.'s and larders, ventilation under floors, damp-proof courses.
Paintwork: Wood, stone, stucco.
Drainage: Whether modern, septic tank, filter beds, cesspool.
Plan, description, size of main drain, branch drain; sewer—its position and depth, whether repairable by local authorities or private owner, outfall.
Manholes, ventilation pipes, intercepters, rendering, gullies; rain-water pipes: whether iron, zinc, asbestos; w.c. pans, traps, anti-syphonage pipes, sinks, slop sinks, lavatory basins, water-waste preventers, bath and wastes, shower-bath and overflow water supply, cisterns and covers, ball-valves, stop-cocks.

INTERNALLY

Ceilings: Condition, plaster, compo-board, panelled, enriched, cornices, beams.
Walls: Panelling, painting, papering, tapestry, distempered.
Paintwork: Paint, enamel, graining.
Floors: Level, dry-rot, solid, hardwood, soft wood, wood block, parquet, patent jointless, tiled, tesselated, terrazzo, mosaic, skirtings.
Doors, windows, cupboards, linen cupboards, locks and fastenings.
Re-lacquering, bells—electric or otherwise—glass, sweep.
Lighting: Gas, company or own plant; electric, company or own plant.
Electric heating or power.
Cooking: Range, gas cooker, electric cooker.
Heating: Water—boiler, radiators, coils, feed cistern, pipes generally.
Gas: Radiators, gas fires.
Electric: Fires, radiators.
Coal: Stoves, range.
Hot water: Domestic boiler, sizes of pipes, circulating cylinder, calorifier, geyser, tanks.
Sanitary fittings: Bath, w.c.'s, slop sinks, sinks, shower bath, lavatory basins, traps, taps, stop-cocks, cistern and cover, sizes of service and waste pipes, overflows.

GENERALLY

Suggestions as to improvements of plan, entrances.

PRICE

Freehold.
Leasehold: Term, ground rent.
Estimated rack rent.
Restrictions, tithes, land tax.
Road widening or charges.
Town planning scheme.
Portion of estate for building development.

FIRE-RESISTING CONSTRUCTION

By Walter R. Jaggard, F.R.I.B.A.

LESSON I

GENERAL PRINCIPLES

Introduction. It is doubtful whether any complete building can be regarded as absolutely fireproof At the best, they may be considered as slow burning, for apart from such comparatively small structures as bank and safe deposit vaults, every type of building can, or is liable, to be damaged by the combined efforts of fire and water. It is not so much the buildings themselves that burn so readily, as their contents. Our chief efforts are, and always must be, in fire-resisting construction, devoted to dealing with such inflammable contents, by providing preventive measures that have proved adequate for that purpose. It is trite to say that the most disastrous fires have small beginnings, and that the application of a bucket of water or a few handfuls of sand at the critical moment, would have saved enormous loss; but early warnings of fire, and the promptest action in the beginning, must be aimed at, and should be impressed upon every one, young and old.

Much greater attention has, of recent years, been given to the design of fire-resisting buildings, and this has been stimulated by research, experiment and experience. Various Government Building Acts, Regulations and By-laws, issued and promulgated by civic and local authorities, together with the results of experimental work, carried out at the instance of fire insurance companies and others interested in the prevention of loss by fire, control and influence the design and construction of fire-resisting buildings. It is not possible in this short section to fully enumerate these provisions, and the student must himself study the actual terms of the general acts and regulations relating to such buildings in his own district. Some general remarks may, however, be made. Buildings may be fired by the ignition of their contents, or by the burning of part of the structure, and this is called an *internal hazard*; they may also be fired by the burning of adjacent buildings or inflammable material, and this is known as an *external hazard*. Fire protection must be directed to combat the possibility of danger from these risks.

External Hazard. This may be met by solidly built and well bonded exterior walls, with relatively small openings; party walls should be carried from 15 in. to 3 ft. above the surface of adjoining roofs; parapet walls should be used instead of overhanging eaves and should be at least 9 in. thick, and, if the roof is adapted to be used as a means of escape, the parapet wall should be at least 3 ft. higher than the roof, which should be covered with a fire-resisting material to repel the possibility of firing by sparks or burning embers; dormer windows in a roof should be eliminated as far as possible, and access to the roof should be protected, so that it may be available for escape. Window openings should be fitted with metal frames, and, possibly, glazed with wired glass, while large openings and exposed doorways may be further protected by drenchers.

Internal Hazard. Internally, the hazard may be met by a limitation of its cubical extent, and many building by-laws have regulations to this effect. All parts of the building should be constructed with fire-resisting materials, including external and internal walls, partitions, and screens, with waterproofed fire-resisting floors. Fire stops, by means of solid 9 in. brick walls, limit the spread, and help to isolate an outbreak of fire. Stairs should be of fire-resisting material and isolated within a staircase, surrounded with fire-resisting walls or partitions, and direct light and ventilation, by means of windows opening upon the outer air, should be provided, to facilitate the escape of inflammable smoke. Various vertical shafts to accommodate passenger lifts, goods hoists, pipe ducts, ventilating shafts, dust and letter shoots, and small lighting wells are a source of great danger, since they frequently become flues for the rapid spread of fire from one part of a building to another, and their positions need very careful consideration.

Preventing Loss of Life. More important than the possibility of damage to property is the risk to human life through fire, and this must be constantly borne in mind throughout the whole design of the building. Adequate means must be provided to allow of the rapid escape of every one from a burning building. Panic of the occupants so frequently follows upon an alarm of fire, that it is very necessary to guard against accident from this cause. The staircase is the natural means of escape, and this should be so placed that it may be reached within a few seconds of the outbreak. The dog-legged form of stair, with a central dividing brick wall, is undoubtedly the best type to use; the flights of steps should be short—from 7 to 9 steps—and with an average width of about 4 ft. A recessed handrail should be provided throughout the whole height of the stairs, and the steps must be finished with a non-slippery surface to prevent stumbling.

All doors giving on to a staircase should open outwards, but in such a way that they do not block the passage of people descending from a higher level. Such doors are sometimes doubled and formed into a lobby, to guard against the smoke from the burning contents of one floor obtaining access to the staircase, and so making it unusable. The exit from the stair at the bottom should give upon the street or a large open yard, by doors opening outwards; similarly, the exit from the stair at the top, should give upon the roof, where further means of escape must be provided, either over the roofs of adjacent buildings or down an external iron fire escape stair.

It may be noted that three standards of fire-resistance have been agreed upon by the British Fire Prevention Committee. These standards are: (1) Temporary protection, denoting resistance to fire for at least three-quarters of an hour; (2) Partial protection, resistance to fire for at least one and a half hours; and (3) Full protection, maintaining resistance to fire for at least two and a half hours.

MATERIALS

Brick and Stone. It has already been suggested that most of the materials used for building are, in themselves, more or less, fire-resisting. Brick, stone, iron, slates, tiles, and plaster, as such, will not actually burn, but the combined effect of fire and water will affect them very materially, rendering some of them quite unsuitable for use in modern fire-resisting construction.

Brickwork built in cement mortar is probably the best known resistant of fire. Stone yields quickly; the best for the purpose is considered to be the sandstones. Granite, when subjected to great heat, crumbles, or cracks, and falls to pieces with a series of small explosions. Limestones are calcined and turned to quicklime, and all cohesion is lost when again exposed to air and water. Sandstones offer a better resistance, but they disintegrate after a short exposure to great heat, and even terra-cotta or tiles are not regarded as a perfect substitute for hard burnt brick. The well-known London stock bricks are excellent for fire-resistance, maintaining their shape and form under intense heat; this is attributed to the fact that they contain a very large proportion of sand or silica, and owing to their mode of manufacture, they are often of the nature of a firebrick. These latter, made from refractory clays, are, of course, eminently fire-resisting, since they are used for the formation or lining of furnaces, but their cost prohibits their use for ordinary brickwork. For internal fire-resisting partitions, terra-cotta blocks are frequently used. Two varieties are obtainable: in one case, the blocks are made from clays which, when baked, will give a hard and vitreous surface, scored or grooved for a finishing coat of plaster; while others are first mixed with a small percentage of straw, sawdust, or other combustible material, which is burnt out during their baking in the kiln, leaving them somewhat porous looking, and capable of taking and holding nails and screws for fixing purposes.

Concrete. Concrete shares with brickwork the advantage of being an excellent material for use in fire-resisting buildings, although, from its nature, its use is mainly restricted to the floors, roofs, and stairs of such buildings. As reinforced concrete, employing and thoroughly covering the steel in small sections, it may be considered as nearly fireproof as it is possible to obtain in modern building construction. For adequate fire-resistance, hard brick, gravel or shingle, and granite can be used, broken to pass a $\frac{3}{4}$ in. ring; while for upper floors and roofs where lightness of weight is desirable, coke breeze, pumice and porous brick or terra-cotta are often adapted. But the coke breeze, being a coal residue, burns out in a strong fire, and the porous nature of the concrete, when used in damp situations, probably insufficiently protects the steel reinforcements.

The sand used for concrete should be clean and not too fine. If the material passes a 50 × 50 sieve, it should be discarded as too fine, but it should be graded upwards to about $\frac{3}{16}$ in., the main object of the sand being to assist in filling the voids between the larger materials. For strong concrete, the sand must be clean; clay, vegetable matter and all impurities reduce the adhesion of the cement to the inert materials, although a small percentage, not exceeding $2\frac{1}{2}$ per cent of clay, will assist in the waterproofing of concrete, but will reduce its strength.

For good concrete, cement only should be used as a matrix; this should always comply with the current standard specification of the British Engineering Standards Association, and for ordinary work, a good manufacturer's guarantee of quality may be safely accepted.

A waterproof concrete is very desirable in fire-resisting buildings, in order that the water used to extinguish a fire may not unnecessarily damage merchandise or goods on the floors below. It is best obtained by using a rich concrete with a non-porous aggregate, with all voids perfectly filled, and placed in a rather wet and sloppy condition to ensure the greatest possible homogeneity of the mass. Various patent materials, either in the form of pastes or powders, for adding to the mixing water or to the dry cement, are available for the waterproofing of concrete. Of these *Truscon* is a paste, one part being added to 18 parts of water by volume. *Pudlo* is a white powder, of which about 2 per cent of the bulk of the cement and sand is first added to the dry cement. *Prufit* is another paste; and *Ironite* cement, a waterproof material which has been specially treated with iron compounds, will withstand a great pressure of water, besides being very durable for heavy traffic.

Iron and Steel. Iron, in its three forms, as cast iron, wrought iron, or steel, enters very largely into the construction of fire-resisting buildings, but its use is fraught with much danger. It conducts heat very readily, and expands and contracts under varying temperatures. Cast iron, with its granular structure, is liable to collapse, owing to its brittleness, and when too rapidly cooled, to snap or fly to pieces, because of its sudden and often unequal contraction. It is frequently used for stanchions supporting bressummers, and, when adopted for fire-resisting building, should be clothed with brick, terra-cotta or concrete casings, in such a way as to allow some expansion on occasions. Steel is in much greater use than either cast or wrought iron for general building purposes, and being more or less rigidly fixed with bolts and rivets, the unequal expansion of heated members results in strains, which, if continued, twist and contort beams and stanchions into most fantastic shapes; they thus become mutually destructive, and collapse of the building follows.

Heat is only slowly conducted by brick, terra-cotta, or concrete, and their expansion is therefore slower; but steel, if directly exposed, soon becomes hot, and for fire-resisting purposes must be protected with one of these slow heat-conducting materials, in order to prevent the temperature rising to a dangerous point within the period reasonably demanded for extinguishing the flames.

Timber. As far as possible, timber, especially that classed as soft-woods, should be eliminated from fire-resisting buildings, although certain hard-woods, of a recognized thickness, are accepted as fire-resisting. Ordinary floor boards should be dispensed with, wherever possible; but where this is not practicable, they should be so laid that there is no air space to supply a passage for flame or form a harbourage where vermin can carry various combustible materials liable to ignition. If a wood-surfaced floor is essential, solid wood blocks are preferable, although a batten floor can be directly secured to a pumice concrete floor. Terrazzo, granolithic, cement floating, tiles or composition flooring may more suitably be adopted for finishing fire-resisting floors. All small sectioned wood, in skirtings, windows and doors with their finishings, glazed wooden screens, shelves and fittings, should be replaced, wherever possible, by metal, which, though it will eventually suffer from the action of flame and water, will, to some extent, assist in the delay of the spread of fire, and thus give more opportunity for dealing with the initial stages of the outbreak. Timber coated with a solution of tungstate of soda or asbestos paint is stated to have resisted the action of fierce fire for as long as twenty minutes.

Timber, in bulk, is surprisingly fire-resisting, and it is reported that in some cases, where the stone was cracked and destroyed, red and blue bricks badly damaged, steel girders twisted and bent out of recognition, heavy wooden beams were merely charred, and ordinary stock bricks entirely uninjured. A type of fire-resisting floor and stair construction is based upon this fact, and will be subsequently discussed.

Roofings. Roofing stones, tiles and slates, are essentially fire-resisting materials, but their use as roof coverings involve their attachment to small sectioned wood battens, boarding and rafters, together with wooden or exposed steel or iron trusses, which when attacked by flames, speedily collapse, and bring down their fire-resisting coverings. Corrugated iron and asbestos tiles or sheets suffer from the same disabilities. Zinc sheeting will blaze freely, and melting lead from a lead-covered flat roof is a source of very great danger to firemen and salvage officers. A fire-resisting roof can best be formed upon the principles adopted for floors, and although roofs may be constructed with framed steelwork slopes, protected with terra-cotta blocks or concrete, or with reinforced concrete beams and slabs, and even covered externally with tiles or slates, for the sake of appearance, it will probably be more convenient for escape purposes to keep the roofs perfectly flat, finishing them in concrete and asphalt.

Plaster. Plaster is an excellent material for use in fire-resisting construction, and may be freely adopted. Metal lathing should always be used. In conjunction with small section steel framing and sheeting, plaster forms a light partition, which will often considerably delay the progress of a fire.

Glass. It is contended by some fire experts that skylights and windows should be of thin glass, so that they will easily break and permit the escape of smoke and gas; smoke is inflammable, and when it accumulates will often spread fire from floor to floor, but nothing so facilitates the spread of fire as a draught from a broken skylight or window. In many modern buildings, lanterns and skylights are glazed with the material known as *wire glass*, which consists of fine wire netting embedded in the thickness of the glass. It is stated to resist sudden or prolonged heat, even when accompanied by rapid cooling. The fusion of the glass occurs at a lower temperature than that of the wire, and glass being a poor conductor of heat, each protects the other, and tests are said to have shown that such glass will even melt before allowing the passage of flames. Although, in its present form, it is not particularly applicable for ordinary windows, it is conceivable that silvered wires, arranged in good patterns, might rather add to their attractiveness, than mar it.

BRICKWORK

By William Beaber
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LESSON VI

BRICKLAYING

The skill in any craft is not always apparent to the uninitiated onlooker, and particularly is this the case when the operations of a capable craftsman are being considered.

The apparent ease with which the work is executed is due to the skill of the mechanic, acquired after much practice and a great deal of careful study. Other important factors essential to success are the cultivation of clean, neat habits, and the development of the powers of observation and deduction. The acquisition of these will save the craftsman much manual effort, and will enable him to accomplish with ease that which would otherwise be strenuous.

The young beginner should cultivate the habit of thinking in advance; that is, to consider his efforts before making them. This lack of forethought in simple processes is responsible for much waste of time, energy, and material.

A few examples will more clearly explain these points. The mechanic who spreads his mortar with an eye to the thickness of the required bed, sets his brick into position with a slight pressure of the hand as he lays it. Another operative will have practically to hammer every brick into position with his trowel, frequently damaging the face of the brick in the operation. Again, when requiring a square, good-faced brick for a corner, one man will pick up a dozen at random, reject them and throw them down again, one after the other, before finally selecting the one that suits him. The thoughtful worker will look round the bricks as they are stacked on the scaffold, and generally this cursory examination enables him to pick out the right brick the first time, thus saving time and himself the physical effort of stooping several times, the repetition of which counts considerably at the end of the day's work. Apart from this, there is the risk of damage to the bricks—an expensive item when good facing bricks are being used.

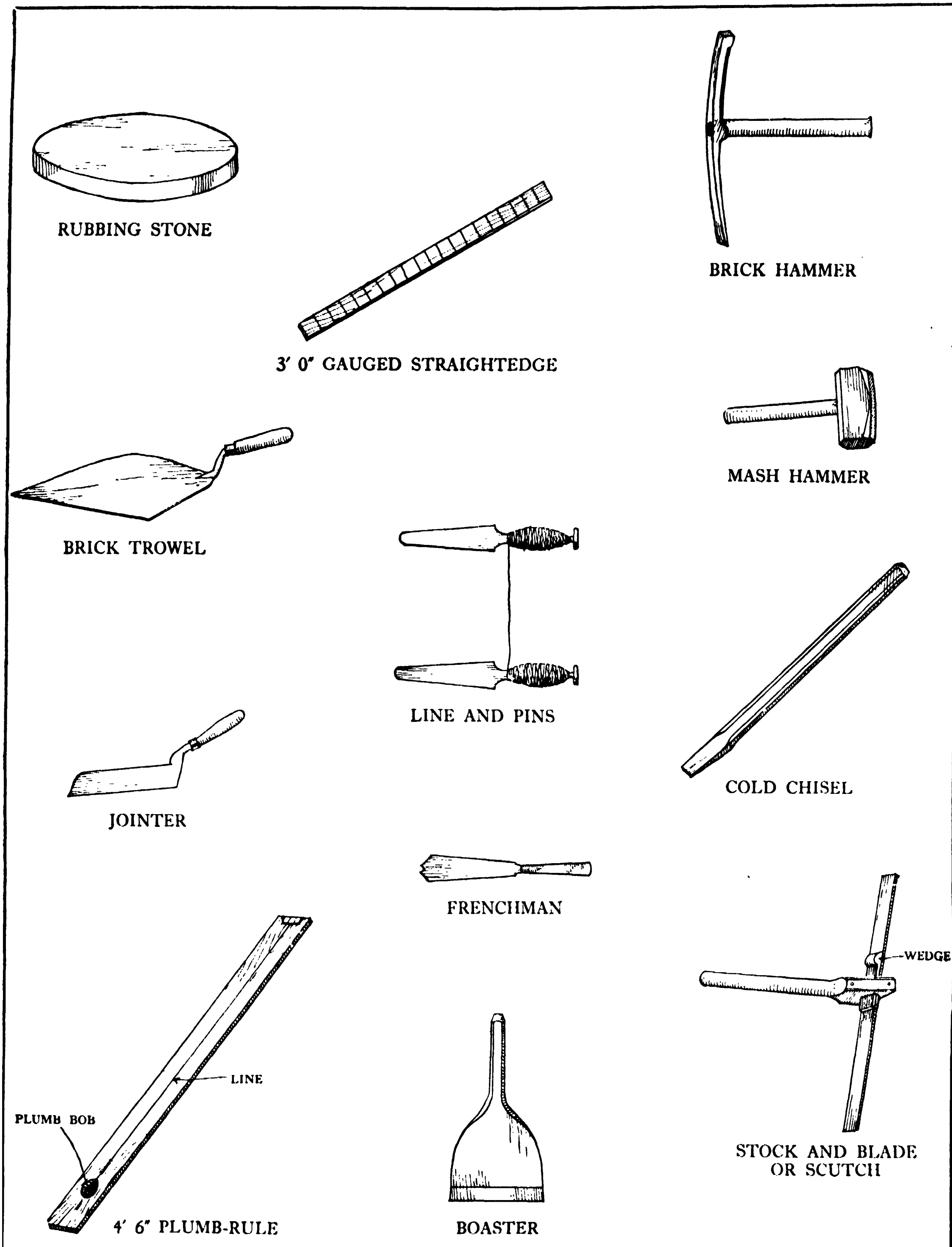

FIG. 33. BRICKLAYER'S TOOLS

One should always remember that the employer has to be considered, and that damage done due to thoughtlessness or carelessness is as culpable as wilful damage.

Clean habits are generally economical. Considerable wastage of mortar occurs in the ordinary course of any job; but note the quantity of mortar droppings at the base of the wall or pier that is being built by an indifferent craftsman, or track a flue that has been built by the same man and note the amount of material drawn from the flue when it is cored, and compare it with that of the clean, neat workman.

Tools. A list of the working tools of the bricklayer is shown in Fig. 33; their uses will be explained chiefly in connection with the work for which they are required.

The *brick trowel*, being the most important, is the one to consider first. It is used for picking up and spreading the mortar, and for rough cutting where approximate sizes and shapes only are required. One edge of the blade is curved slightly for this purpose, the other being straight. It is with the latter edge that the bricklayer picks up mortar from his board, and removes surplus mortar from the joints, as the bricks are laid. Skill in the manipulation of this tool makes all the difference between clean, neat, and easy workmanship, and a slovenly, laboured effort.

Where more accurate cutting is necessary, the bricklayer uses the *club*, or *mash*, *hammer* and *boaster*. The sharp edge of the latter is usually just over 3 in. in width, to enable the brick to be cleanly cut across the face at one cut. In using this tool, the best results obtain from a sharp direct blow, and not a series of taps, which are more likely to leave a ragged edge.

Before proceeding farther with tools and their uses, the student should have some idea of the processes and the general methods in use.

Operation of Bricklaying. In building permanent structures, the bricks are bedded in lime or cement mortar, the object of which is to even up the irregular bearing surfaces of the brick, and to enable the separate layers, or courses, to be brought to straight and level lines as the building rises. Other objects are to unite the separate units into a homogeneous mass so as to prevent the penetration of moisture and the direct passage of external air in volumes sufficient to interfere with the health and comfort of the occupants, and ensure uniformity of temperature within the building.

The operation of bricklaying in ordinary work is accomplished by spreading a bed of mortar, and setting the bricks into position by a sliding movement; drawing them along the bed with a downward pressure sufficient to bring them approximately to the line, when a slight tap with the trowel will set them into the desired position. The surplus mortar squeezed out of the joint in the process is removed by drawing the straight edge of the trowel along the face of the bricks, collecting the mortar on the blade and using it for buttering the end of the brick last laid, for the vertical joint of the next brick. This is repeated along both faces of the wall, the interior filling bricks being laid in a similar manner, and the open joints filled with mortar as each course is completed. This *flushing-up*, as it is termed, is frequently omitted for several courses on some jobs, and afterwards only done in an inefficient manner, but it is essential that every course should be flushed up if good work is required.

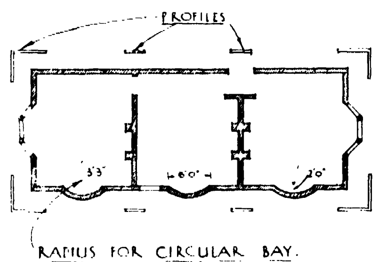

FIG. 34. SETTING OUT A SMALL BUILDING

Grouting. Where brickwork is set with a fine joint, it is usual to fill the interior joints with a thin liquid mortar. This process is called "grouting."

Larrying. In heavy engineering works or buildings where the walls are very thick, the facing bricks are laid in the usual manner. Mortar is then shovelled into the interior of the course, spread out with a larry, and water added at the same time to thin out the mortar. The filling bricks are then squeezed into position, the mortar rising and filling the vertical joints completely and forming an exceedingly strong and solid wall. This is known as "larrying."

SETTING OUT

Setting Out a Small Building. A knowledge of the general methods of setting out the foundations of a building is essential, and a simple description at this stage will enable the student more readily to understand the processes of bricklaying.

It is proposed to set out the small building shown in Fig. 34. The building line is generally fixed by the architect or surveyor. The position of the building on this line is set out by wooden stakes driven into the ground, and having nails driven into their heads to define more accurately their positions. Strain a stout ranging line to coincide with these pegs, but extending beyond the extremities of the building. Set out on a piece of stout board the thickness of the wall, projections of the footings, and the concrete on either side. Nail this to two stout pegs driven well into the ground, as shown in Fig. 35, with the face line of the wall, as indicated by the board, coincident with the ranging line. Repeat the operation at the opposite extremity of the line. These "profiles," as they are termed, fix the position of the front wall of the building, the projection of the footings, and the line of excavation for the concrete bed.

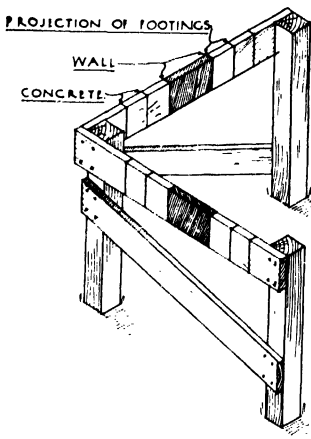

FIG. 35. DETAIL OF PROFILE OF QUOIN

In fixing profiles, care should be taken to ensure that they are placed clear of and not too near the excavations, or in any position where interference can take place before the foundations are completed.

Fix the position of walls making junction with the front wall by means of pegs and nails, and set up profiles as before from lines ranged at the correct angles, checked from the drawings. If the walls are at right angles, the ranging may be either performed with a *builder's square*, or by the construction of a right-angled triangle by the 3, 4, 5 *method*, as shown in Fig. 36. Mark off along the frontage line a distance of 4 ft. from the point fixing the position of the joining wall, and from the same point, along the line which is to be squared, mark off 3 ft. Now fix the position of this line so that the distance across the angle included by the two lines, and taken from the two measured positions, will be 5 ft. Other measurements may be used if desired, provided the ratios are constant, such as 6, 8, 10; 9, 12, 15; 12, 16, 20, and so on. Should the angle be other than square, a tie-line across it should be fixed on the drawing, the three measurements carefully checked to scale, and reproduced in the actual setting-out.

Walls parallel with the frontage may be now set out to the correct dimensions, and profiles fixed as before.

Setting Out Circular Bay. The circular bay may be set out by two methods:—

1. By taking a mould constructed of thin boards well braced together, and cut to the curve of the bay, set in position with the ranging line, and projections of footings and concrete set out from this.

2. By means of a trammel. The radius of the curve may be obtained either geometrically or by calculation. If of large radius, considerable space would be required for the graphical method, so calculation becomes necessary. A simple formula, also useful for setting out arches

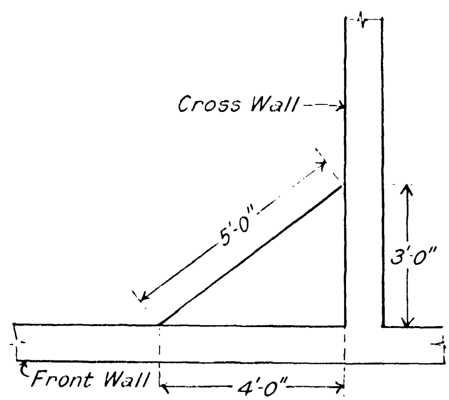

FIG. 36. SETTING OUT A RIGHT ANGLE

is here given. Terming the chord of the arc the "span," and the perpendicular distance from the centre of the span to the arc, the "rise" (as in arch construction); then $R = \frac{S^2 + V^2}{V \times 2}$, where R is required radius, $S = \frac{1}{2}$ span, and $V =$ the rise.

The "span" of the bay under consideration is 6 ft. and the rise 2 ft. From the formula,

$R = \frac{9+4}{4} = \frac{13}{4} = 3\frac{1}{4}$ ft. Applying this method to construction: bisect chord of the bay, and square a line away from this point. Measure 3 ft. 3 in. from one end of the chord to a point on the line, and drive a stout peg well into the ground. Bore a ½ in. hole in the head of the

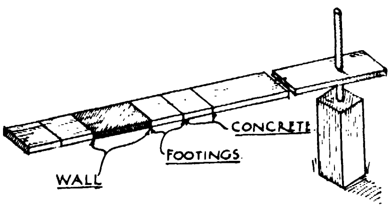

FIG. 37. TRAMMEL FOR CIRCULAR BAY

peg at the exact point, and fix therein a short length of ½ in. gas barrel or iron rod, braced in an upright position. Make a wooden trammel, Fig. 37, greater in length than the required radius, and bored at one end to slip over, and rotate on, the gas barrel. Mark on the other end the thickness of walls, footings, and concrete. In setting out, the trammel should always be kept approximately level and can be

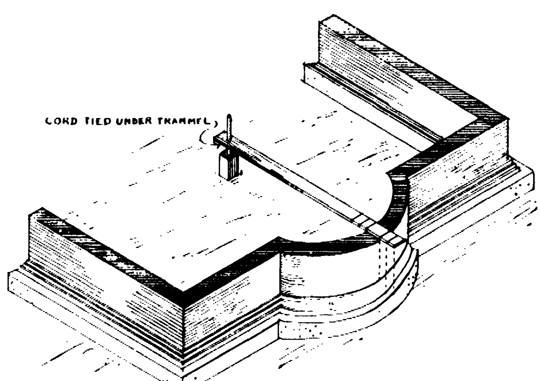

FIG. 38. BUILDING CIRCULAR BAY WITH TRAMMEL

raised with each course by tying a cord round the iron rod below the trammel as in Fig. 38.

If the work is to be carried to any height, a mould cut to the curve will have to be made for the use of the bricklayer.

Foundations. It is not for the bricklayer to concern himself with the designing of foundations, which is the business of the architect. At the same time, a knowledge of the principles governing the construction of the ordinary types is necessary.

The natural foundation is the earth directly supporting the structure. The term "foundation," in the accepted sense, usually applies to that part of the building in direct contact with the soil, and may consist of an extended base of brickwork to the walls, a bed of concrete, or both.

The object of foundations are—

(*a*) To distribute the weight of the superstructure over an area sufficiently large to prevent undue or irregular settlement likely to cause fractures in the building.

(*b*) To provide a level surface for the commencement of building operations.

If the natural foundation is rock or compact

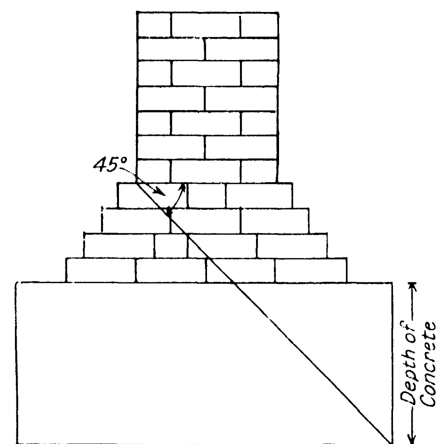

FIG. 39. METHOD OF OBTAINING DEPTH OF CONCRETE

gravel of great depth (which is practically incompressible), the wall may be built direct upon it after forming a level surface and ensuring the absence of faulty places such as soft patches and loose shale. If these should be present, they should be excavated and filled in with concrete.

In good dry soil, which is compressible but reasonably firm, an artificial foundation is necessary to increase the bearing surface. The standard type of foundation usual in these circumstances is obtained by extending the base of the wall to twice its thickness by projecting courses of brickwork called *footings.* Each course has offsets of 2¼ in. on each side, and below all is a bed of concrete of a depth calculated according to the nature of the soil, and exceeding the width of the bottom course of footing by 1 ft. 6 in. on each side.

A method of obtaining the depth of concrete for ordinary foundations is shown in Fig. 39. A line inclined at 45° is drawn from the junction of the wall and footings, and the point at which it cuts the perpendicular line of the concrete bed (which projects 6 in. beyond footings) determines the required depth.

Testing Resistance of Earth. The resistance of all soils should be tested. A good practical test can be made by the following procedure.

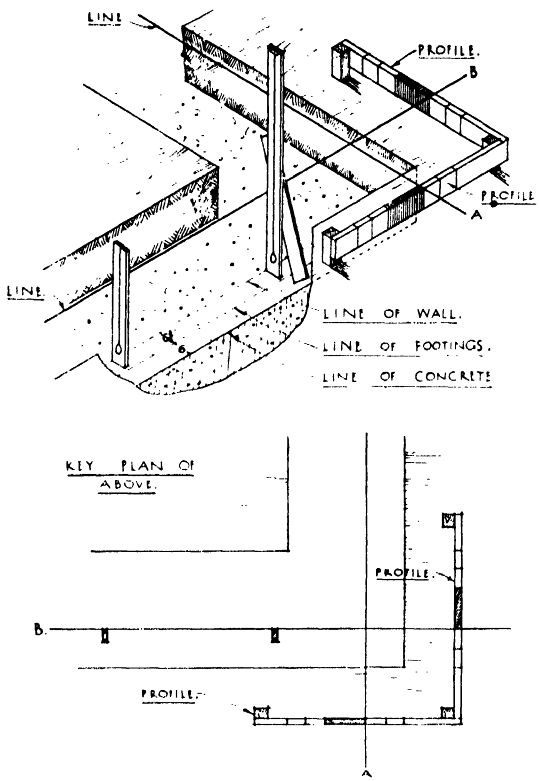

Fig. 40. Setting Out a Quoin of a Building

Construct a platform 3 ft. × 3 ft., and obtain four blocks 6 in. × 6 in. Place these on the ground to be tested, and under the four corners of the platform; on each side of, and level with its top, drive in stakes. Now evenly load the platform, and note the effect of calculated loading from time to time; any settlement can be measured by comparison with the stationary stakes. As the area of the four blocks is equal to 1 sq. ft., the total load registers the resistance of 1 sq. ft. of foundation bed. From this data the necessary foundation for the structure may be determined.

Soft or waterlogged soils require special treatment. This is the subject of another section of this work, which deals more fully with foundations of all descriptions. The foregoing description has been given here as being essential to a clear understanding of the operations of a bricklayer beginning work in the foundations.

Building the Quoins. It frequently happens that a young operative commencing work on a new job is called on to set up the quoins of the first wall. Without doubt, he will get considerable " kudos " from his foreman by knowing how to proceed without a lot of instruction.

Fig. 40 shows the external lines *A* and *B* of the wall in their respective positions on the profiles. The wall is a brick and a half thick; the bottom footing is twice this thickness, its projection on each side of the wall being three-quarters of a brick, or $6\frac{3}{4}$ in.

At a point near the corner on line *A*, mark the position of the line on the concrete bed by using the plumb-rule, as shown in the sketch. To steady the rule, hold at its back a straight-edge, in a raking position, and with one end resting on the concrete. In a similar manner mark another position farther away from the corner, and measure out $6\frac{3}{4}$ in. from these points. A line along these positions will be the line of the bottom course of footings. Repeat the operation on line *B*, and begin the first course of footings, three bricks thick, from the point of intersection of the two lines. No closers are used in footings, and bricks should be laid headerwise where possible.

In commencing the second course of footings, set back $2\frac{1}{4}$ in. from the edge of the first on both sides of the wall. This course will be two and a half bricks thick. Keep the headers on the outside faces, and lay the stretchers in the centre of the wall. Repeat the process with the next course, which will be two bricks thick. The next will be the first course of the wall proper, or, as it is termed, the " neat work." This course should be set by plumbing down from the setting out line to make sure it is exactly in line.

The opposite corner having been built in the same manner, the remainder of the wall can be built to a line strained from corner to corner for each course.

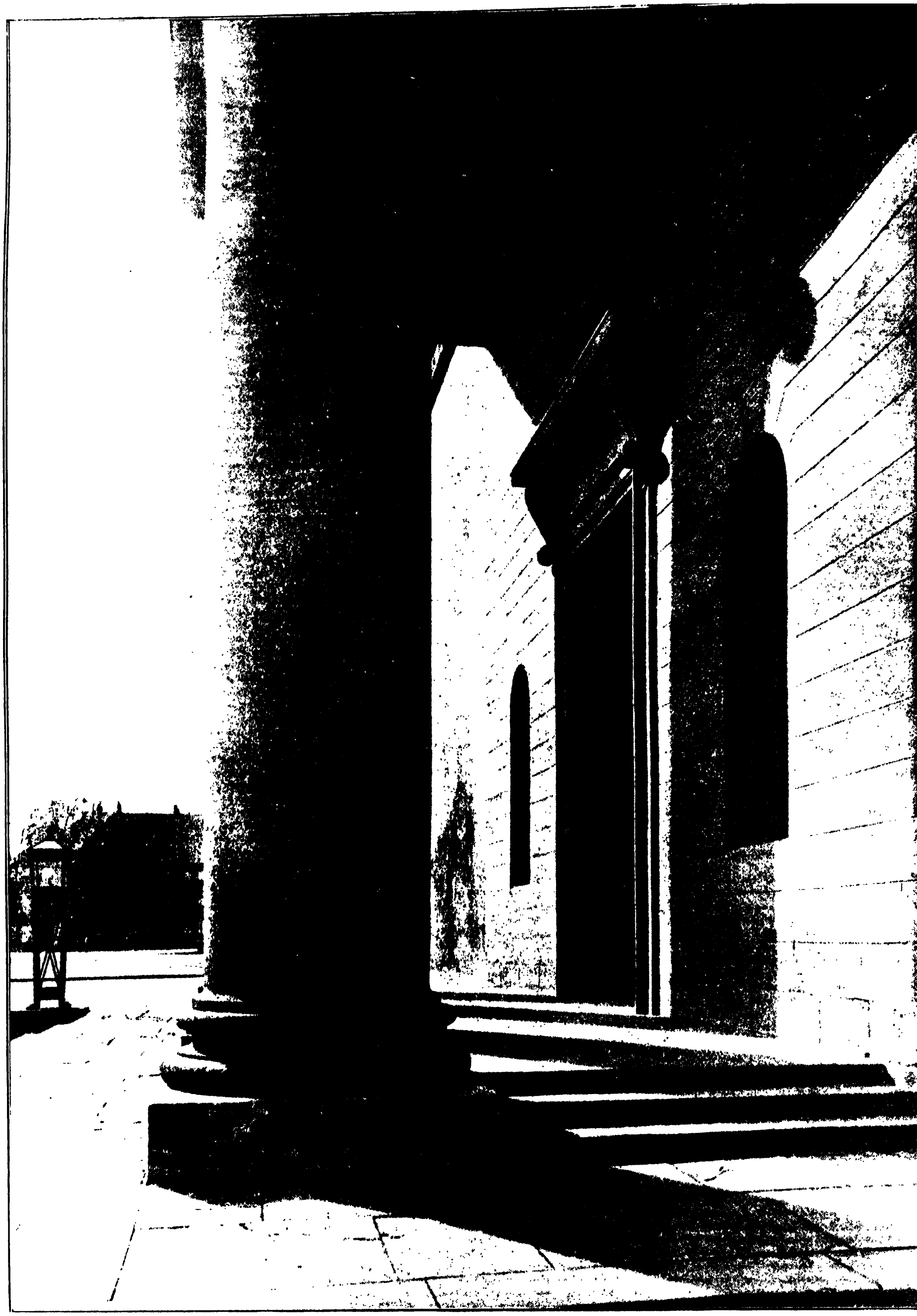

Photo by F. R. Yerbury

PORTICO, THE CASTLE CHURCH, COPENHAGEN

THE TOWN OF THE FUTURE

By Professor Abercrombie

In attempting to visualize the *Town of the Future*, it is necessary to distinguish between the *New Town* and the remodelled *Old Town*. The former has an opportunity of making use of all the most recent notions of town planning, the other must necessarily always be a compromise. There are two chief differences between the new idea of a town and the old town as it has come to us through the unconscious action of ages (and especially of the industrial age of last century). In the first place, the new town attempts a logical arrangement of its different parts and, where desirable, a separation of these parts; whereas in the old town, the factories, houses, and parks came wherever anyone chose to put them, and as often as not all jumbled together. In the second place, the new town sets up certain standards of density, or amount of space covered, particularly with regard to the residential parts.

Professor Patrick Abercrombie
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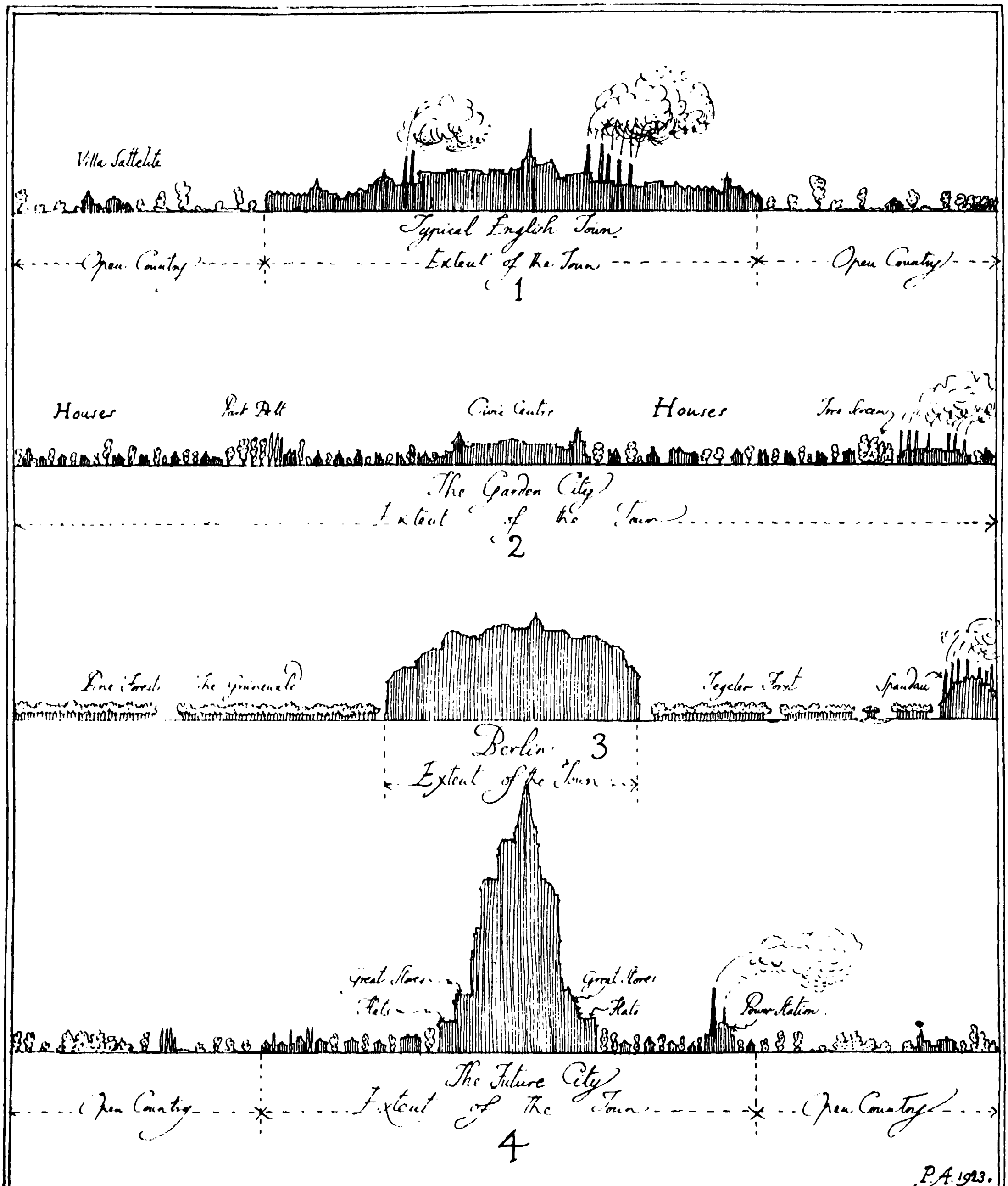
Professor of Civic Design, University of Liverpool

ZONING

The name given to the first idea is the rather unsatisfactory one of *zoning*. It is not difficult to see at once the advantage of a town having a definite zoning policy; for the industrial side of its existence, there are certain facilities which need to be encouraged towards the factory area—transport, such as road, rail, and canal; and other facilities, such as electric power and special water supply. It is manifestly wasteful for the town which has provided and encouraged these facilities to see the land, thus equipped for industry, used for housing purposes. Conversely, the residential areas must not be invaded by factories, a single one of which may sometimes damage a whole district. Again, it is not sufficiently exact to buy up an old house with a pleasant garden, when it comes in the market, and turn it into a park; we must find out what population there is in the neighbourhood, and then determine how many acres are required per thousand of the population for parks and playing fields. The National Playing Fields Association has adopted the standard of a minimum of five acres per thousand of the population, of which four acres should be for playing fields and small children's playgrounds, according to definite proportions. All this, therefore, implies a careful and scientific study of urban conditions and needs.

DENSITY

Density is perhaps a more difficult thing to understand. In town planning it is generally taken to refer to the number of buildings to the acre, rather than to the number of persons to the house; thus, if a town planner has spaced out his houses so as to obtain the right number per acre for health and general amenity, he can hardly be blamed because later on four or five times the number of people are allowed to live in each house. This is what has frequently happened in old towns, where fine Georgian houses on well-planned estates have become slums through overcrowding. Again, an originally



DIAGRAMS OF TYPICAL TOWNS

well-spaced town may be spoilt through later people cutting up the spaces at the rear, and building new houses or factories upon them. This is often seen in our old country towns, where the gardens at the back of the houses, facing the main wide roads, have all been turned into courts, approached only by narrow passages under the original frontages.

At the same time, the modern town must be a town and not an interminable straggling mass of houses. The present tendency, largely owing to the motor bus, is to spread the town in these riband-like strips on each side of the main roads. This is too loose, and such strips of houses can never become what we require a town to be.

THE CIVIC CENTRE

There must, indeed, be some focusing of interest, some climax, or civic centre. The old town, Greek, Roman, Mediaeval, and Renaissance, had its market-place, with its public buildings facing on to it, or adjacent. It was only during the rush of nineteenth century industrialism that a series of invertebrate monsters were spawned over the country. It is sometimes possible to create a centre in an existing town. Birmingham is about to do so, having bought up much of the property and expecting, by skilful planning, to recoup with interest this outlay.

The organized and co-operative effort in civic design, which is inevitable for the centre, should, in the town of the future, permeate its entire mass. Individualistic outrage in building must be suppressed as severely as a bad smell.

ROADS

The road plan of a town should also have some system about it. The ideal diagrammatic form usually adopted is that of the spider's web, with radial streets leading from the centre to the circumference, and circular or polygonal rings connecting them. If a town be very large, it may be necessary to have more than one centre, in order to avoid too much concentration of traffic at one place; but the chief idea of the diagram still remains. Another main object in the road system of a modern town is to avoid making all roads of equal importance. This is again a reaction against the standardization of road widths under the model by-laws of last century. The main streams of traffic are concentrated or canalized into a few avenues, over 100 ft. wide; this allows the purely local roads, especially for the approaches to houses, to be kept narrow and lightly paved, with forecourt gardens, so that the houses may be sufficiently far apart.

TYPES OF TOWNS

Some of these foregoing considerations, for the future city, may be aptly summarized in the accompanying diagram, which relates, in a general way, height and density with extent covered. The first sketch represents the *typical English town* of moderate extent and density, but of mixed contents, with villa satellites straggling into the country. The second shows the *garden city* ideal of a reduced general density, a larger area covered, a clearly marked civic centre, and a properly segregated industrial zone. With the same sized town as the first, the open country would be farther off, but it would not be deformed by uncontrolled riband development. This garden city scheme is, therefore, to be accompanied by a limitation of the size of town, or it would become too diffuse. The third may be said to illustrate the *continental idea*, shown typically by Berlin; here is great concentration of the town proper, most of the housing being in tenements, but the factories segregated. The open country marches up almost to the gates of the highly-built city. There are attractive features about this formula of city building, but the tenement house is too high a price to pay; Vienna, even to-day, is still using the tenements as the normal housing method, in the face of all expert opinion.

The fourth sketch, the *future city*, attempts to effect great concentration at the centre for business premises, central shops, and warehouses, etc., on the American model, including a few expensive flats; this intensive development at the centre, in which transport is chiefly vertical, should free more land for garden suburban development all round. The same extent of land is covered as in No. 1, but the contrast from centre to periphery is more marked.

Some such formula as this last must be devised, if we are to achieve a low density for town housing, and yet preserve rural England from continuous building.

MASONRY

By E. G. Warland
Instructor in Masonry at the L.C.C. School of Building, Brixton

LESSON VII

TOOLS AND APPLIANCES

The tools used by masons vary according to the particular rock or stone upon which they are to operate. Every mason, like other craftsmen, accumulates quite a host of various little devices to suit his own particular way of working, and to facilitate the execution of difficult intersections and undercut members of mouldings. Masons' tools have not undergone any fundamental change for a great number of years. A few devices have been added, but the principal tools remain the same. They should be made from the best *tool steel*. Some are, however, made from *mild steel*, but these are very inferior, and when sharpened lack that cutting edge which is necessary to the clean cutting of the stone.

The following are some of the tools in general use by masons—

Fig. 48. A mason's **Mallet** is usually made of beechwood, hickory, or a well-selected piece of applewood.

Fig. 49. The **Hammer** is made of cast steel, from 1 lb. to 5½ lb. in weight. The faces of the hammer should be inclined at an angle to receive the impact squarely.

Fig. 50. The **Dummy** is used by "soft stone" or "Bath stone" masons in conjunction with wood-handled chisels. It is made of zinc and lead, and varies from 2 to 4 lb. in weight.

Fig. 51. The **Pitching Tool** is used in conjunction with the hammer for reducing the stone to the working lines.

Fig. 52. The **Punch,** which is hammer-headed, is used in conjunction with the hammer for working off the superfluous stone.

Fig. 53. The **Mallet-headed Point** is used chiefly in furrowing the stone preparatory to chiselling the surface.

Fig. 54. **Hammer-headed Chisels,** with cutting edge varying from ½ in. to 1½ in. wide, are used for drafting or chiselling granite and hard sandstones.

Fig. 55. **Mallet-headed Drafting Chisels** are about ¾ in. wide for working the marginal drafts. Similar chisels of various widths from ¼ to ⅝ in. are employed for working mouldings. Sometimes the cutting edge is rounded to the curve of the moulding.

Fig. 56. The **Claw-chisel,** usually from 1½ in. to 2 in. wide, is used in conjunction with the mallet in making drafts over the stone surface, the teeth being formed to prevent the stone *plucking* or *lifting* in holes.

Fig. 56A. In the **Patent Claw-chisel** (Fauld's patent), the cutting edge is inserted and removed when blunt or broken. These tools are excellent on "Grit stones." The shells in Portland readily break the teeth. The use of these tools means a great saving in forging.

Fig. 57. The **Boaster** is a mallet-headed chisel about 2 in. wide, and is used after the *claw chisel* to straighten the surface in drafts.

Fig. 58. **Mallet-headed Gouges** are of sizes varying from ¼ in. to 1½ in. wide, and curved to suit curves of mouldings. The cutting edges are concave.

Fig. 59. The **Mallet-headed Waster** is a chisel similar to the claw-chisel, and from ½ in. to ¾ in. wide. It is used on Bath stone instead of the punch for removing the waste stone. The cutting edge is split, forming teeth similar to the claw chisel.

Fig. 60. The **Batting, or Broad, Tool,** usually from 4 in. to 4½ in. wide, is used for "batting" or "tooling" sandstones.

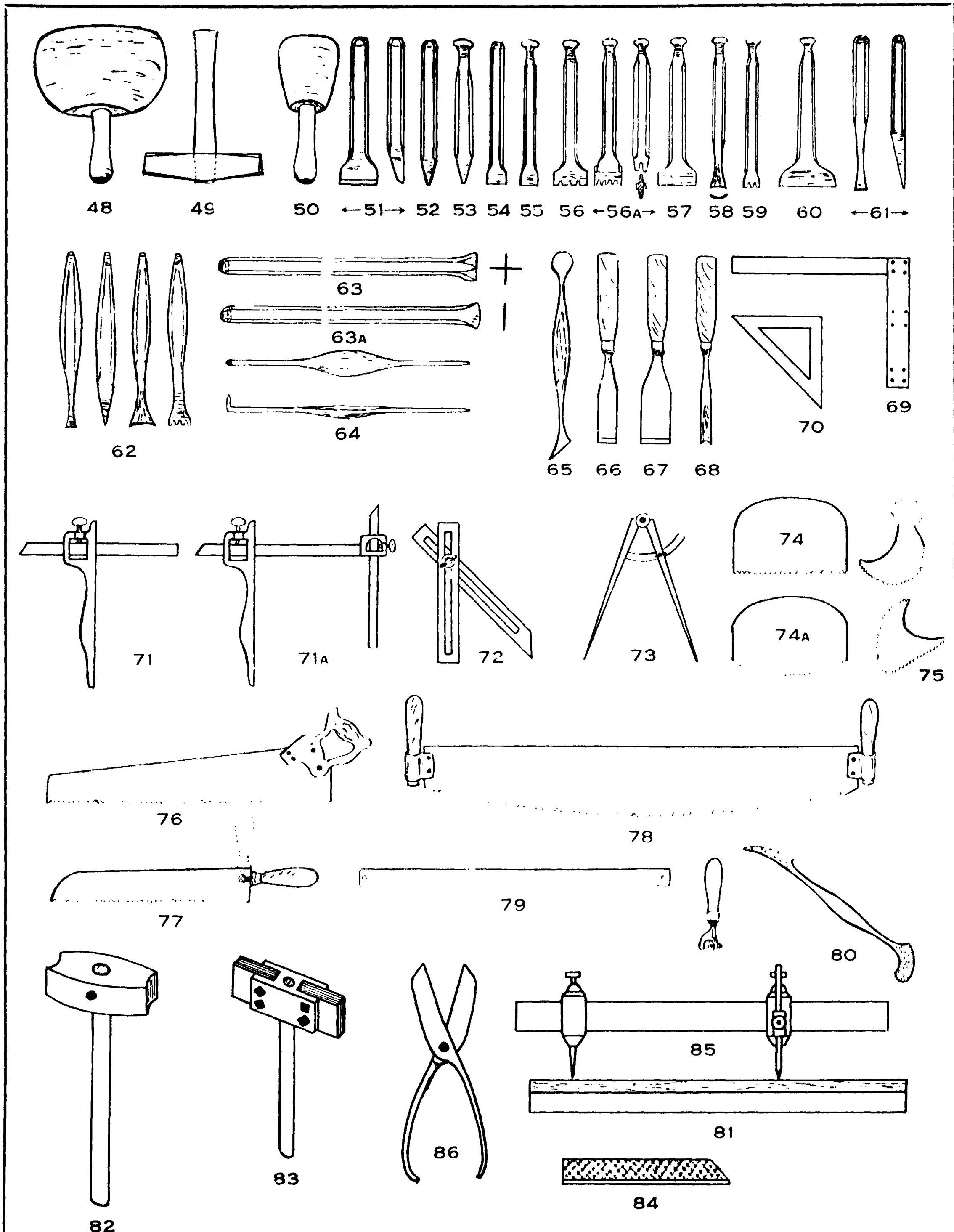
Fig. 61. **Lewising Chisels** are formed specially for cutting mortises for the insertion of the *lewises* for lifting stones. They are from ¾ in. to 1¼ in. wide.

The **Quirking Tool** is similar to the lewising chisel. It is from ⅜ in. to ¾ in. wide, and is used for cutting grooves in sills, also grooves for lead flashings, etc.

Fig. 62. **Cup-headed Tools** are used in conjunction with an iron hammer. They comprise chisels of various sizes, and are chiefly used for letter cutting.

Fig. 63. The **Diamond Jumper** is made from octagonal steel, with cutting edge in the form of a cross. They are used for boring holes and are made in various sizes and lengths.

Fig. 63A shows another form of **Jumper.** It is used for the same purposes as the diamond jumper.



FIGS. 48 TO 86. MASON'S TOOLS

These are used in quarries for drilling holes for blasting. When used for this purpose they are from 5 to 6 ft. in length; they are not struck with a hammer, but lifted and allowed to fall, being slightly turned whilst being lifted.

Fig. 64 shows a **Trammel and Scriber.** The ends are drawn out to a point, one end being bent at right angles. The centre of the tool is widened out to a concave surface to fit over a chisel handle. When being used, both are held tightly together and the head of the chisel is passed along the edge of the stone, the bent point of the trammel making a line parallel to the edge at the required distance apart. The *scriber* or *point* at the other end of the tool is used for marking lines and moulds on the stone.

Fig. 65. The **Mitre Tool,** having a cutting edge at each end, is made to various shapes and used for "truing-up" mitres and internal angles of mouldings.

Fig. 66. A wood-handled **Drafting Chisel** used in conjunction with the *dummy* for working drafts on Bath stone.

Fig. 67. The **Driver** is used for the same purposes as the boaster but on Bath and similar stones.

Fig. 68. **Wood-handled Gouges** of various sizes and curves are used for working mouldings, etc., on Bath and similar stones.

Fig. 69. **Double-stocked Squares** are used when squaring the stones to shape to test the accuracy of the surfaces that are intended to be at right angles to each other. The square should be tested from time to time and kept correct to the angle of 90°.

Fig. 70. **Set Squares** are made of steel plate. The one shown has both angles 45°. Another with angles 60° and 30° is also used.

Fig. 71. The **Sinking Square** is an adjustable square, and is used as a depth gauge; also for testing square sinkings of small dimensions.

Fig. 71A. The **Double-sinking Square** is used in cases where direct squaring or gauging is impossible. For instance, the raking moulding of a pediment springer as shown in Fig. 98.

Fig. 72. **Bevel, or Shiftstock,** is used for obtaining and testing angles and for working chamfers, etc.

Fig. 73. **Compasses** are for drawing circles and measuring distances, etc.

Fig. 74. **Drags** are used for finishing surfaces of Bath and similar soft stones; they are of various grades and are known as *course, second,* and *fine,* and are used in rotation to secure a fairly smooth surface.

Fig. 74A. **Circular Drags** are used in rotation as the former, but on concave surfaces.

Fig. 75. **Cocks' Combs** are used for combing mouldings. They are made in various shapes to suit all curves. The teeth are cut around the curved and straight edges. The combs are usually made in the form of French curves.

Fig. 76. The **Hand Saw** is used for sawing soft stones. It is usually called a *banker saw*. The teeth are cut at an angle of about 60°.

Fig. 77. The **Fillet Saw** is used for sawing down neat to the line for fillets, etc., the handle being adjustable in order to prevent damaging the corners of the stone.

Fig. 78. **Cross-cut Saws** are used for sawing the large blocks of Bath stone into slabs or to required sizes. Large **Single-handled Saws** called "Frig-bob" saws are used in the Bath stone mines for releasing the stones from the strata.

Fig. 79. **Whip Saws** are of various lengths and very pliable. They can be bent to suit whatever curve is required when working circular mouldings, etc. The handle is shown detached.

Fig. 80. **Riffler Rasps** are made to suit any curve, and are used for rasping and cleaning in difficult positions, such as at intersections, etc.

Fig. 81. A **Straight-edge** is a piece of wood or steel of any length, with both edges "shot" (planed) straight and parallel, usually with one bevelled edge. Used for testing the surfaces, etc.

Fig. 82. A **Small Hammer** is used for removing the superfluous stone when in large quantity. The faces are concave, forming two cutting edges.

Fig. 83. The **Patent Bush Hammer** is for finishing surfaces of granite. The plates, which are detachable, vary in thickness according to the work specified.

Fig. 84. **Mason's Fillet Rasps.** These are made to various shapes with one edge smooth, so that when rasping a fillet the edge of the rasp will not cut the surface at right angles, and thus make a groove.

Fig. 85 shows a pair of **Beam Compasses** for setting out or drawing large circles, etc.

Fig. 86 shows a pair of **Snips.** These are used for cutting zinc moulds.

HISTORY OF ARCHITECTURE

By Thomas E. Scott, A.R.I.B.A.

LESSON V

ROMAN ARCHITECTURE

The People and Their Buildings. The early history of the great Roman Empire is so wrapt up in legend, that it is difficult to distinguish between fiction and truth. It is generally accepted, however, that Rome was founded in 753 B.C. by a number of people, who established themselves on the Palatine Hill. There they built a walled city, and soon obtained supremacy over the surrounding tribes. The best known were the Etruscans, a people whose origin is obscure. Their works appear to have consisted chiefly of walls and tombs, although Vitruvius, a Roman writer of the first century A.D., whose writings are voluminous rather than reliable, states that they built temples similar to those of the Greeks, and also theatres and other public buildings. In general, these works were of the character previously referred to as "Cyclopean." There was, however, one feature which must be accepted as the seed of the great styles of architecture which were to spread over the whole of Europe: *that feature was the arch.* Although there is no definite information about the origin of the arch, it is probable that it was used in Asia Minor, as well as by the Etruscans, but its possibilities do not appear to have been fully appreciated.

There are no remains to suggest the existence of important buildings in the early days of Rome, but this is not surprising when it is remembered that the Romans were a stern, realistic nation, whose great object was to rule over all the nations with whom they came in contact in their efforts to discover the world. The history of the Roman Empire—too well known and too lengthy to discuss here—is a story of unremitting energy, of wonderful organization and discipline, and of united effort in the search for prosperity and power. No efforts were spared, and apparently no obstacle unsurmountable in the endeavour to develop the countries which came under Roman rule. In all the countries which once formed this great Empire, evidence is found of the roads, bridges, waterways, and other engineering works of stupendous nature, characteristic of the practical outlook of the great people.

How natural, then, that they should have no time for the arts of peace! The desire to create, rather than to perfect, is the temperamental quality of the Roman Empire which is reflected in its architecture, and in which it differs so from that of tne Greeks.

It was after Greece became a Roman province, in 146 B.C., that the desire to create beautiful buildings showed itself. Artistic treasures were pillaged and taken to Rome, and Greek architects and workmen were introduced to the capital. There the great constructional skill of the Romans and the artistic ability of the Greeks were associated in the production of buildings which were to equal in grandeur the

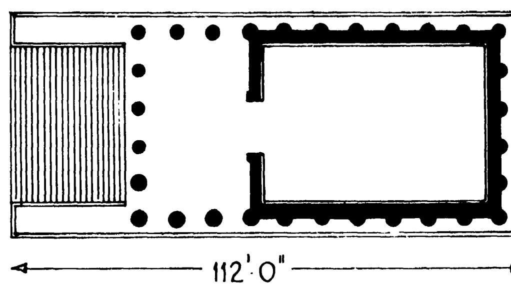
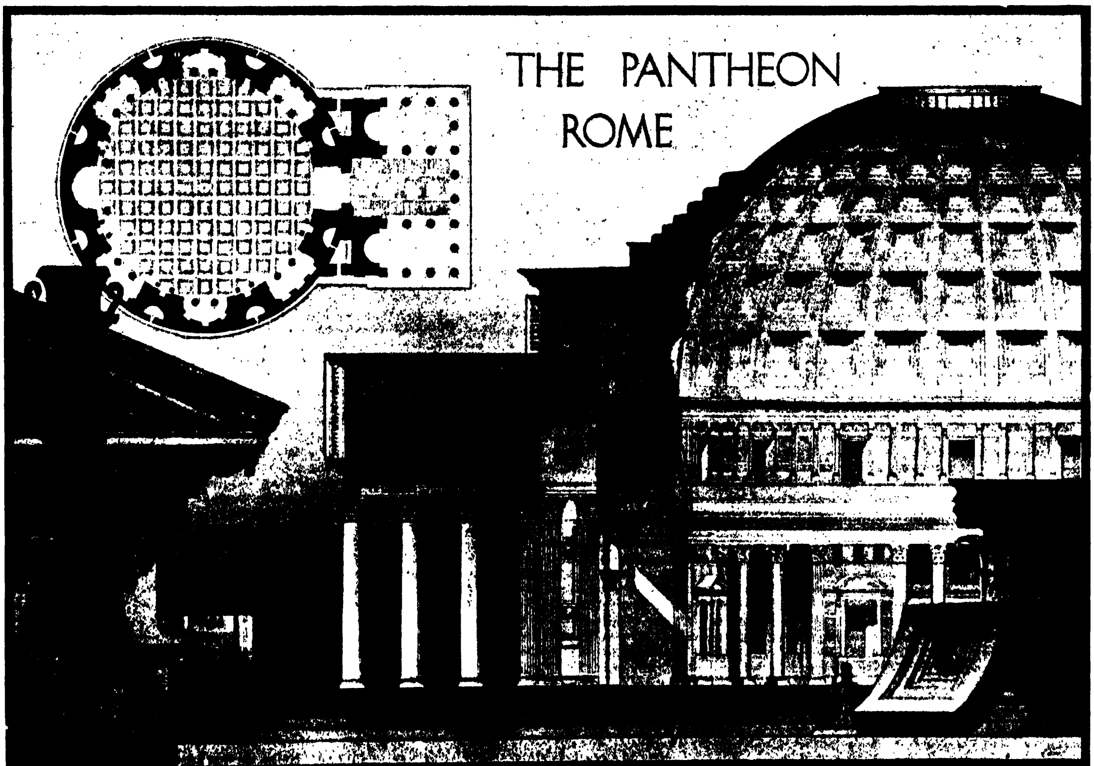


Fig. 28. Maison Carrée, Nimes
(A.D. 117-138)

Empire itself. The influence of Roman work naturally spread throughout the length and breadth of the dominion, and was the foundation of European architecture. There was little change in architectural character during the four or five hundred years when the Empire was flourishing, although there was an effort on the part of many of the emperors to outdo their predecessors in the magnificence and style of their buildings. The capital was removed to Byzantium (Constantinople) in A.D. 324, and soon afterwards the Empire was divided into two parts, East and West. Although the Western Empire did not come to an end until A.D. 475, the history of Roman architecture is considered to terminate about A.D. 330, for in the year A.D. 313, Constantine legalized Christianity, and the works which followed are usually known as Early Christian.

The Eastern Empire, after many vicissitudes, passed into the hands of the Turks in A.D. 1453. The architecture of Byzantium will be dealt with later.

The Use of Concrete. When considering the buildings which were such an important part of this great civilization, it is well to bear in mind a factor which greatly influenced the character of architecture—the use of concrete.



Student's Drawing: Northern Polytechnic School of Architecture.

FIG. 29. THE PANTHEON, ROME

Before the beginning of the Christian era, the Romans had mastered the use of concrete. With the almost unlimited and cheap slave labour, which their power and wealth enabled them to employ, they could build cheaply and speedily. Although the Romans were not, perhaps, artistic, they were an imaginative people, and their ingenuity in the use of concrete enabled them to solve the many great building problems which the desire for magnificence created.

Temples. The story of Greece is almost entirely told by the temples; this is not the case with the Roman Empire, although there existed a pagan religion with similar gods but with different names. Roman temples were part of the constitution, and appear to have served at times for certain official purposes. Part of the temple of Castor and Pollux, for example, was used as an office of weights and measures. The Romans were not consistently a devout people, and although many temples were built, few now remain. Many appear to have been pulled down to make way for bigger and grander building schemes, and others were doubtless demolished to provide space and material for the early Christian churches. The temples were based upon the Greek model, with a few important variations; the plan usually consisted of one cella, or chamber, with a deeply recessed portico at one end. In many cases, the cella was covered by a barrel vault of stone or concrete.

Externally, they closely resembled the usual Greek form, but were placed upon a podium wall, which projected to enclose a flight of steps.

The best preserved temple existing is the building now known as the Maison Carrée at Nîmes in France (Fig. 28). It is interesting to note that though columns were employed in the traditional manner to form a portico, their use on the sides and back of the temples was purely decorative or imitative. The magnitude of

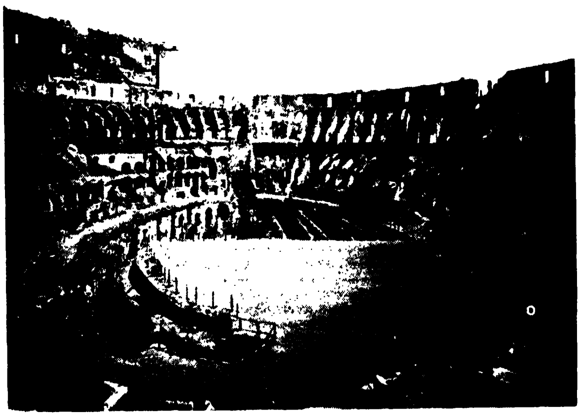


FIG. 30. THE INTERIOR OF THE COLOSSEUM, ROME, AS IT STANDS TO-DAY

some of the Roman work is illustrated in the great Temple at Baalbek in Syria. There the columns, of which six remain, were about 65 ft. high, supporting an entablature 13 ft. high. The substructure of the temple was built of gigantic stones, the three largest being each about 64 ft. long, and weighin about 500 tons.

Some circular temples existed, the best known being the Pantheon, one of the greatest of Roman works. The circular portion, known as the Rotunda, was erected by the Emperor Hadrian about A.D. 120–124. It is covered by a vast hemispherical dome 142 ft. in diameter, constructed of brickwork and concrete. Fig. 29 shows the plan, interior treatment, and some details.

Theatres and Amphitheatres. The Romans built a number of theatres which were based on those of the Greeks. In the central space, instead of a chorus, seats were provided for the more important State officials, while the stage was raised and increased in importance. They were not usually hollowed out of the hillside, but were built up on a system of concrete and stone vaults over corridors used as exits and retiring spaces (see Fig. 30).

The amphitheatres were the more characteristic Roman places of amusement, and were devoted to gladiatorial combats and similar displays, more suited to the Romans who preferred this sterner form of "amusement" to the drama of the stage. They were usually oval-shaped on plan, with tiers of seats all round an open arena. The best known example—the Colosseum, Rome (A.D. 70–82) was about 620 ft. long by about 513 ft. wide, surrounded by a wall of 157 ft. high, the architectural treatment of which will be referred to later. There were other similar places of amusement, such as circuses, which were used for horse and chariot races. Their magnitude will be appreciated when it is stated that one, the Circus Maximus at Rome, is believed to have accommodated about a quarter of a million spectators.

Basilicas. These served both as meeting-places for business men and as halls of justice. They were usually rectangular in plan, with rows of columns running all round internally, forming aisles, and one or more semicircular recesses or apses for the judges.

One of the finest was Trajan's Basilica at Rome (A.D. 98), a vast building about 385 ft.

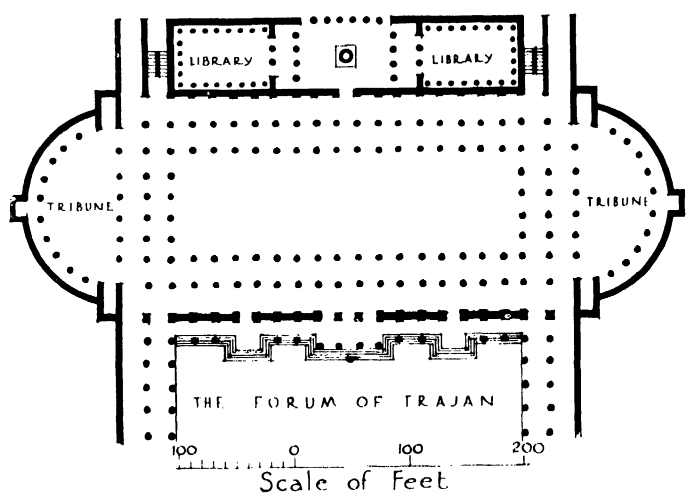


FIG. 31. TRAJAN'S BASILICA, ROME

long and 182 ft. wide (Fig. 31). Two rows of columns were ranged all round, leaving a central nave 87 ft. wide, which was covered by a timber-framed roof, with a coffered ceiling. The total height internally was about 120 ft.

The Basilica of Constantine (A.D. 312) was an interesting example, having a rectangular nave about 265 ft. long, 83 ft. wide, and 120 ft. high, with three bays on each side (Fig. 32). It was covered by a vast groined vault. The arrange-

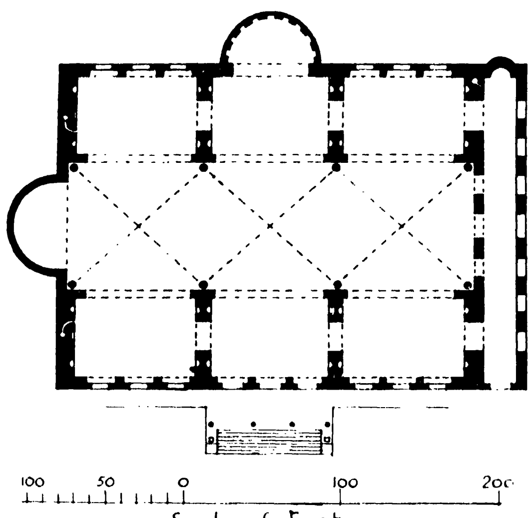


FIG. 32. THE BASILICA OF CONSTANTINE OR MAXENTIUS, ROME

ment of the plan is interesting, as it shows the special arrangement of piers to support the thrust and load of the vaults, which are concentrated at a few isolated points instead of being

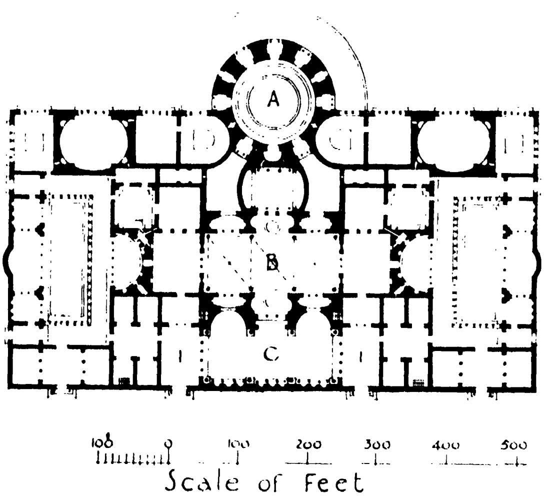


FIG. 33. BATHS OF CARACALLA, ROME
A Calidarium. B Tepidarium C Frigidarium

distributed evenly along a wall. This system is in many respects similar to that employed later in Gothic cathedrals.

The remains of basilicas found in many of the one-time outposts of the Roman Empire suggest a magnificence characteristic of the importance attached to commerce and the administration of justice.

Thermae. Although generally known as the "baths," these buildings were probably inspired by the Gymnasia of the Greeks, already referred to. They are all in a very ruined state; but from the few remains and from ancient writers, it is evident that they were magnificent buildings, not only used for bathing on a most luxurious scale, but as rendezvous for the people's pleasures and exercises. They entered very largely into the life of a pleasure-loving people,

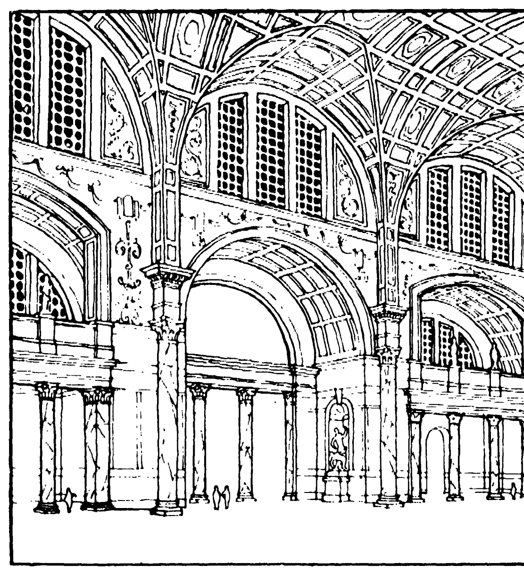


FIG. 34. A ROMAN INTERIOR

and were characteristic of the grandeur and magnificence of Rome in its prime. They consisted principally of a great central building, of which the Baths of Caracalla, Rome (A.D. 212-235), are typical (Fig. 33). The three principal apartments were the *calidarium*, or hot room; the *tepidarium*, or warm lounge; and the *frigidarium*, or cooling room, containing a huge swimming pool. These, with sundry other apartments for massage, etc., completed the arrangements devoted to bathing on a grand scale.

This central block was usually raised from the ground, the lower floor or basement containing the furnaces and other services connected with the building.

In this building some 1,600 bathers could be accommodated, while in a somewhat later establishment, erected by Diocletian (A.D. 302), over 3,000 persons were provided for.

The main building was surrounded by ornamental gardens, with a stadium for athletic sports, and by buildings which included small theatres and lecture rooms for orators, and accommodation for the slaves constituting the staff of the establishment.

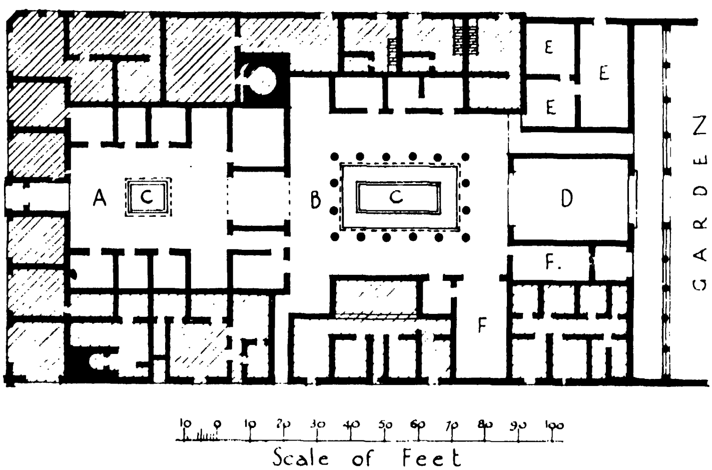


FIG. 35. THE HOUSE OF PANSA, POMPEII

A – *Atrium.* *B* – *Peristyle.* *C* – *Impluvium*, or water cistern. *D* – *Oecus*, or Reception-room. *E* – Kitchen, etc. *F* – *Triclinium*, or Dining room. The hatched portions of the plan indicate shops, etc.

Interior Decoration. Internally, these great buildings were lavishly decorated with marble and mural paintings, while the many art treasures, pillaged from Greece and other places, were set up there (Fig. 34). Externally, they appear to have been very simply treated with stucco, or the brick walls left plain.

Tombs. The tombs of the Romans were frequently impressive structures. A type of special interest was the Cenotaph, or monument, to the memory of a person buried elsewhere.

The Triumphal Arches and Columns, erected by the emperors to commemorate victories, are of great interest. One of the best known is the Arch of Constantine (Fig. 5).

Many of the buildings which have been described were grouped around an open space, known as the *forum.* This was a central public square or "place" used as a market or place of assembly.

Houses. Domestic buildings were of three kinds: the *villa*, or country house; the *domus*, or private house in the town; and the *insula*, or tenement building. The first frequently attained vast dimensions, including as it did many of the amenities of town life, such as thermae, theatres, and gymnasia.

The domus, of which the House of Pansa, Pompeii (Fig. 35), is a good example, consisted of two main parts. The outer, grouped around an *atrium*, or open court, contained reception and business rooms, while the more private apartments were arranged around an inner colonnaded court or *peristyle.*

In the example illustrated, the house was bounded by shops on three sides, with the garden on the fourth.

The third type was probably used by the workers, and the existence of a decree limiting the height of houses to 75 ft. suggests that such buildings were numerous.

As was to be expected, magnificent palaces were erected for the emperors, and though nothing remains but ruins, their vast extent and grandeur can be readily visualized, when the glory "that was Rome" is realized.

The construction of these buildings will be dealt with in the next lesson.

BUILDING SCIENCE

By Raymond R. Butler, M.Sc., A.I.C., F.C.S.

LESSON IV

BUILDING MATERIALS

The study of building materials naturally divides itself into the following subdivisions—

1. Natural building stones.
2. Cements and plasters.
3. Concrete in general.
4. Bricks.
5. Constructional metals.
6. Miscellaneous materials.

For the purpose of classification we shall adopt this scheme, and deal in this and following articles with the various sections.

Fig. 4. Granite (Mount Sorrel, Leicestershire)

NATURAL BUILDING STONES

These include the granites, sandstones, and limestones (including marble).

Granites. Granite is one of the *igneous* rocks, having been formed by the fusion of rocky matter deep within the earth's crust. Subsequent slow cooling has caused the fused mass to solidify in large crystals, consisting mainly, as has already been stated, of three minerals—quartz, mica, and felspar. A photomicrograph of granite from Mount Sorrel, Leicestershire (Fig. 4) indicates the manner in which these crystals are (as it were) welded together. In this respect they differ from the crystals of quartz, which form the main bulk of a sandstone. We shall see later that on the nature of the cementing material, which serves to unite the sandstone grains, depends the life and utility of the stone. In granite no such point arises. The stone is very hard, very compact, and has a porosity in the region of 0·8 per cent.

Granites are worked in the neighbourhood of Aberdeen and Peterhead in Scotland, in the West of England, Worcestershire and Leicestershire, and in the Channel Islands.

Aberdeen granite is usually of a compact,

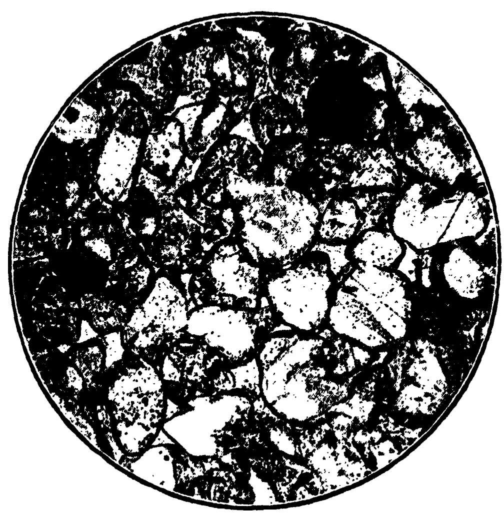


Fig. 5. Recrystallized Sandstone (Old Quarry, Penrith)

bluish-grey colour; it has been used in Trafalgar Square, London, and in London Bridge. Rubislaw granite is of a dark, greyish-blue (see Fig. 1), and has been employed for the balustrade of Waterloo Bridge.

Peterhead granite is usually a dark, flesh colour, and it is interesting to note that the colour of a granite is almost entirely due to iron and other compounds occurring in the felspar. The quartz portion is nearly always semi-transparent and smoky in colour; the mica occurs in flakes either black or white; the felspar may be white, but is frequently coloured and imparts this colour, in the mass, to the stone.

In the West of England the granite now worked is grey, and the Penryn Mass, in Cornwall, is responsible for the Embankment Wall, London, and was used in Vauxhall Bridge and in the New County Hall, Westminster.

Kirkcudbright granite is usually pale grey. The Mount Sorrel deposits in Leicestershire are practically unused as constructional material, but owing to their hardness are largely employed as "road metal."

Shap Fell, in Westmorland, consists of a mass of brownish-red rock, coarse in structure, of which the columns in St. Pancras Station, London, were constructed.

An average *mineral* analysis of granite shows the following figures

	Red Granite	Grey Granite
Felspar . .	50% to 70%	50% Average
Quartz . .	23% to 35·5%	37·5% ,,
Mica . .	47% to 11·3%	12·4% ,,

Corrosion of Granite. The disintegration of granite in town atmospheres is largely physical, there being little chemical action between the stone and atmospheric impurities. The effect of heat on granite is well illustrated by the condition of the plinth of the Nelson Column in Trafalgar Square. The surface has been destroyed in places by successive flaking under the action of heat, due to the celebration bonfires of Armistice Night, 1918. The coefficient of cubical expansion of quartz is 0·000036, and that of felspar is only 0·000017. Hence the effect of excessive heat is to cause internal stresses in the mass due to uneven expansion of the crystals, with the result that the free surface flakes. In granites suitable for use as building material, the constituents should be as nearly as possible equi-dimensional. The "weathering" of granite under natural conditions is a partial decomposition of the complex aluminium silicates called felspars, which are attacked by exposure, the soda or potash portion dissolving and leaving behind a complex hydrated silicate of alumina known as *china clay*. The mica and quartz remain practically unaltered.

Sandstones. These are what are called "sedimentary" rocks. They are the result of pressure and other influences on the products of denudation of other rock masses. For example, a microscopic examination of the deposits of sand now in process of formation at the Mersey mouth, has shown them to consist of the fragments of rock from Whernside, Penyghent, Ingleborough, and other parts of the Pennine Range.

As a result of the process of denudation, the separate sand grains ultimately settle elsewhere, and the obvious essential for conversion of the loose sandy deposit, into what we know as a sandstone, is a suitable cementing material between the grains.

Such cementing material may be—

(*a*) Chalky (calcareous).
(*b*) Clayey (argillaceous).
(*c*) Siliceous (of the nature of sand itself).

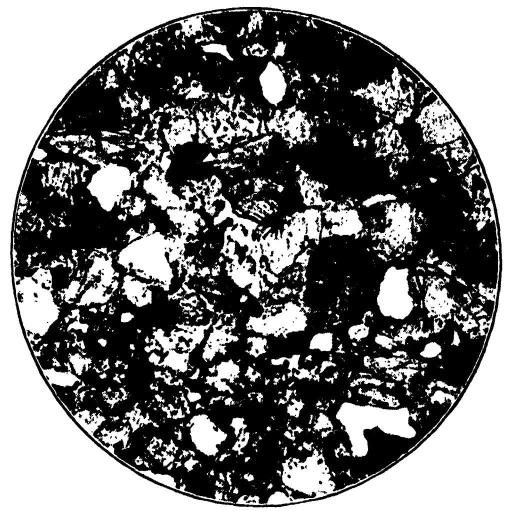


FIG. 6. PHOTOMICROGRAPH OF A CALCIFEROUS SANDSTONE (EDINBURGH)

Only the latter type is of permanent value as a building material.

Fig. 5 is a photomicrograph of a recrystallized sandstone from the old quarry, Penrith. It shows clearly the individual grains of silica (SiO_2), separate one from another, but united by the cementing material between the particles.

Fig. 6 is a specimen of sandstone, having a calciferous binding material between the grains, found at the Holyrood end of Salisbury Crags, Edinburgh. Such stones are not as durable as those in which the binding material contains no calcite, since in the presence of acid atmospheres, the calcium compounds are destroyed and the sand grains loosened.

Probably the most durable sandstone known is that formerly quarried at Craigleith, near Edinburgh. This is a stone in which, probably under the influence of intense pressure and partial fusion, the sand grains have become almost welded together, as in the structure of

FIG. 7. QUARTZITE (CRAIGLEITH, EDINBURGH)

granite. It is, however, a sandstone as regards its mineral constituents. The photomicrograph (Fig. 7) illustrates this condition, and may be compared with Fig. 5, in which the grains are separate.

The sandstones and millstone grits of Yorkshire belong to the carboniferous system (the coal measures), and are considerably younger geologically than the granites, though much older than the limestones. Fig. 8 shows the structure of Stancliffe stone from Darley Dale.

Corrosion of Sandstone. Given a satisfactory (i.e. siliceous) binding material, the main causes of corrosion in sandstones are physical; for example, the freezing of water in the pores of the stone results in a loosening of the surface grains, due to the expansive forces introduced when water freezes. In this connection it is interesting to note that a stone soaked in water has less power of resistance to a crushing stress than has a dry stone.

Limestones. Limestones, consisting largely of calcium carbonate ($CaCO_3$) are, by reason of their comparative softness, in great demand as building stones. Geologically they are the youngest of the natural building stones.

Under this heading are included the common limestones, frequently fossiliferous and often distinctly crystalline in structure; the hard crystalline limestones, such as are found in the Devonshire formations, very suitable for building stone; the oolitic limestones of the Portland and Bath beds, shown in Fig. 9; and the marbles (capable of high polish), which may contain magnesium carbonate in addition to the $CaCO_3$. An example of the latter is the Irish Connemara marble, shown in Fig. 10.

Portland Whitbed stone has been selected for Government buildings in the London area by the Office of Works. The arrangement of the beds at Portland is as follows -

Purbeck beds.
True roach—containing many fossil holes.
Whitbed—fine oolitic limestone.
Curf and flints.
Base bed roach.
Base bed—fine oolitic limestone.

It is peculiar that the Whitbed stone weathers better in London than does the Basebed.

Corrosion of Limestone. The presence of sulphuric acid in the atmosphere of cities is very deleterious to all limestones, since it rapidly

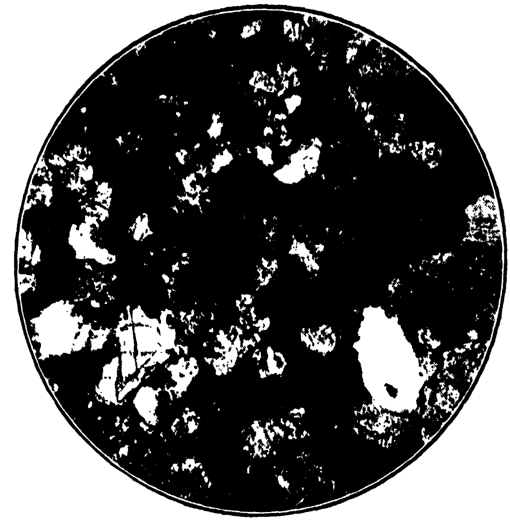


FIG. 8. STANCLIFFE STONE (DARLEY DALE)
A millstone grit (sandstone)

converts the calcium carbonate of the stone into calcium sulphate, thereby destroying the coherence of the stone as a constructional material.

Analysis of a specimen of Portland stone, from Hampton Court Palace, showed a large excess of calcium sulphate in the outer incrustation as compared with the centre of the stone;

and a sample of Bath stone, from the Hotel Metropole, London, showed 1·8 per cent calcium sulphate in the centre of the stone, and 38 per cent in the incrustations on the surface. Similarly,

FIG. 9, PORTLAND STONE
(An oolitic limestone)

Sir Arthur Church found 73·8 per cent hydrated calcium sulphate in the black deposit formed under the cornices in St. Paul's Cathedral, due to the action of the acid rain upon the limestone, of which the cathedral is constructed.

Chemically the reaction follows the equation

$$CaCO_3 + H_2SO_4 \longrightarrow CaSO_4 + H_2O + CO_2.$$

Dolomitic limestones are limestones which contain magnesium carbonate ($MgCO_3$) in addition to the $CaCO_3$. Such a stone was used in the construction of the Houses of Parliament, and does not seem capable of resisting the acids of the London atmosphere.

Two important methods of treating constructional stonework, to prevent corrosion, have been developed during recent years.

One method is to wash the surface with a solution of one part of sodium silicate to four parts of water, allow to dry for twenty-four hours, and repeat the process three or four times. For this purpose, a so-called " neutral " sodium silicate is now marketed, containing a greater proportion of silica than ordinary " waterglass." The solution penetrates the stone to a depth of about half an inch, and produces in the pores hard calcium silicate, thus rendering the material more resistant to corrosive influences and making it more impervious to water penetration.

A similar result is obtained by treating the stone with the substance known as " Silican

FIG. 10. MARBLE (CONNEMARA, IRELAND)

Ester," which, on drying in the pores of the material, deposits hard silica (SiO_2), which acts in a similar manner to the calcium silicate produced by treatment with waterglass.

JOINERY

By T. Corkhill, F.B.I.C.C., M.I.Struct.E., *Double Medallist*

LESSON VII

TIMBER—(*contd.*)

MARKET FORMS OF TIMBER

Log, the trunk felled and lopped.
Balk, a square log.
Plank, above 10 in. by 2 in.
Deal, less than 10 in. wide, but more than 2 in. thick.
Board, less than 2 in. thick.
Die Square Stuff, large stuff, square in section.
Quartering, small square stuff.
Flitch, balk, cut up centre.
Load (American), 50 cub. ft.
Float, 18 loads.
A Hundred Deals, 120
A Square, 100 superficial feet.
A Standard (St. Petersburg), 165 cub. ft. (London), 270 cub. ft.
Valuable hardwoods are sold by weight.

The terms log and plank are very often applied only to hardwoods; and the terms balks, deals, battens and boards to softwoods.

TIMBERS COMMON TO THE BUILDING TRADES

It is impossible to give in detail the characteristics of the many timbers used by the carpenter and joiner. Every kind of timber has many botanical variations, and each definite species varies greatly according to its source of origin. The following examples are selected, because every joiner should be familiar with them. The coloured plate (Part I) shows four of the coniferous or softwoods, and six of the broad leaved or hardwoods, to about one-third of the actual size. The exception to this classification is American Whitewood, which is a broad leaved tree, but is termed softwood. The specimens for the plate were provided by Messrs. James Latham Ltd., Curtain Road, E.C.2.

SOFTWOODS

Spruce, or White Deal. (See coloured plate.) There are many variations of this timber, some of them very inferior wood with very few good qualities. Other varieties, however, produce excellent timber; tough, elastic, clean, and easy to work. Hence we find that spruce is used for every kind of work from wood pulp to musical instruments. Good spruce is used for kitchen furniture because it is clean and white, with very little odour. There is little variation in colour between the spring and autumn wood. Other uses are: floor joists, floor boards, inferior joinery, and constructional work generally. The timber is subject to small hard knots, very often loose, and to resin pockets. It is not suitable for outside work because it weathers badly.

Red Deal, Scotch Fir, Northern Pine, or Yellow Deal. (See coloured plate.) These names are all applied to the same timber, which is the most used of any timber for constructional and outside work. It is heavier, stronger, and more resinous than spruce; and it is not so easily attacked by decay. The colour is reddish, or brownish yellow. The annual rings are very distinct, owing to the autumn wood being much harder and darker coloured than the spring wood. It is used to a great extent for roof and floor timbers, and all external joinery. It is easy to work, and the knots, though prevalent, are usually sound and firm. The table on page 315 gives further details.

Pitch Pine. (See coloured plate.) This is the strongest and heaviest of the pines, and also the hardest. It is very resinous, and the annual rings are very distinct. For heavy constructional work it has few superiors, because it can be obtained in large sizes and is usually sound inside, though subject to cup shapes. If it is cut tangentially the grain is very pronounced and ornamental, and the curly grain is valuable for panels, etc. Pitch pine is used largely for ornamental woik, especially for church work; it is usually finished by varnishing. It shrinks greatly and slowly, so that only well seasoned timber should be selected. The colour is a golden yellow, with strong reddish grain. Much of it is too resinous for painting, because the resinous parts soon show through the paint. Tools require liberal oiling for the resinous timber.

Douglas Fir, or Oregon Pine, is very similar to pitch pine, but not so resinous, and not so heavy or rigid. Very large sizes can be obtained without blemishes of any description. It has a coarse, open grain, and very pronounced figure. It stains and varnishes well, and is now being largely used for plywood. In America it is used for nearly every purpose. Formerly it was received very unfavourably by the joiner, but the exported timber is now much better in quality.

Yellow Pine, White Pine and Weymouth Pine (see coloured plate), are the names given to the softest and lightest of the pines. It is very easy to work and does not shrink or warp after seasoning. The timber can be obtained in large sizes, free from knots or other defects. For all inside joinery it is in great demand, also for pattern making, cabinet making, etc. It is expensive because of the demand, but the expense is compensated for by the easy working. The timber is straw coloured, with not much variation between autumn and spring wood. A characteristic is the very fine or hairlike resin ducts. It is not suitable for outside work, but excellent for taking glue and paint.

Sequoia, Californian, or Red Pine, is the largest of the pines. The timber is shortgrained and seems to have very little nature in it. It is easy to plane up, but very difficult for end grain working, because of its raggy texture. The colour is dull brown with reddish brown markings. It takes stain and varnish well, and is used for panels, shelving, etc., or for heavy structural work because of its great size.

Kauri Pine is a New Zealand timber, light brown in colour. It can be obtained in very large sizes without knots or defects. The grain is fine and straight, and the timber is lustrous, easy working, and polishes well. Owing to its tendency to warp it should only be used for fixed framing. It is one of the few timbers that shrink lengthwise.

American Whitewood. (See coloured plate.) The supplies under this heading comprise two different timbers, Basswood (Tilia Americana) and Canary wood (Liriodendron tulipifera). Even the timber merchants confuse the two, probably because it is an advantage to do so. It is impossible for the amateur to distinguish between them. Both timbers have the same characteristics: large sizes, easy working, staining and polishing well. They are both used as substitutes for more valuable hardwoods. The texture of the timber is very similar to that of the yellow pine, although it is a broad leaved tree. One piece of the timber will range through a great variety of colours, from greyish white to yellow and nearly every shade of green. The timber is light in weight, and is not suitable for outside work; it also warps freely.

The **larch** and the various **cedars** are also needle leaved, cone bearing trees; but the timbers can hardly be called softwoods. They are seldom used by the joiners in this country, except some of the cedars which are often substituted for baywood. Several species of cedar, however, are very soft and easy working, but they are used for cabinet work and pencil making.

HARDWOODS

Ash. Tough and flexible; used for wheelwright's work, tool handles, agricultural implements; ornamental varieties for cabinet making. Liable to insect attack, and weathers badly. Easy to bend. Greyish white in colour.

Beech. Hard, heavy, even and close texture; medullary rays show as wavy markings; reddish yellow or light brown in colour. Figured timber valuable for cabinet work. Used for planes (because it wears evenly), mallets, chisel handles, bleacher's beetles, furniture, etc. Weathers badly.

Birch. Fairly hard and tough, but straight grained. One of the cheapest hardwoods, hence it is used as a substitute for other hardwoods; it stains and polishes well. Works up to a smooth finish with sharp arrises. Light brown in colour; weathers badly.

Chestnut. Hard, elastic, durable, especially under the ground. Resembles oak, but coarser in grain, softer, and without silver grain. Often used as a substitute for oak. Used for cabinet making, coffins, and for timber foundations.

Ebony. Very hard, tough, and one of the heaviest of timbers. It sinks in water, weighing about 68 lbs. per cubic foot. The timber is black, but often there are streaks of green and brown. It works to a glossy finish, but with difficulty. Used for ornamental joinery and cabinet work.

Elm. Tough, flexible, rather coarse texture, with large knots; shrinks and warps badly. Very durable under water, hence used for piles; also used for wheelwright's work, turnery and inferior furniture.

Greenheart. Very hard, strong and durable. Difficult to work. The end grain appears very porous, like cane. Resists insects by reason of a bitter secretion. Dark yellowish green in colour. Used for heavy structural work, piers, jetties, etc., also for outside work or positions where great resistance and durability are required regardless of cost.

Jarrah. Hard, heavy, tough, and durable. Known as the Australian mahogany, but one of the many species of the Eucalyptus tree. It may be obtained in very large sizes. It is not much used in this country except for structural work, and paving blocks. Good qualities are used for furniture, and a little for joinery.

Karri. Similar to Jarrah; another species of Eucalyptus. Both Jarrah and Karri are gradually coming into favour in this country.

Lignum Vitae. Very similar to Ebony, but not so black or flexible. Used for similar purposes.

Mahogany (Cuban). (See coloured plate.) Very dense and heavy, but not difficult to work, except for the figured varieties, which in some cases produce one of the most beautiful of timbers. It is a rich red brown in colour, with a chalk-like substance in the pores. The timber polishes well and is in great demand for high-class joinery and cabinet work. It is used for pattern making because it does not warp and varies very little after seasoning. The specimen in coloured plate is highly figured and known as Cuban Curl, which is reserved for veneers.

Honduras Mahogany, or Baywood. (See coloured plate.) This is lighter in weight and inferior to Cuban in all respects, but used generally for the same purposes. Many specimens have a beautiful "rowey grain" with a golden red colour, which shows up well after polishing. It is easier to work than Cuban; but both varieties very often have grain which plucks up with the plane and which is difficult to finish for a polished surface.

There are several African and Asiatic timbers used as substitutes for mahogany, but they are all inferior to the above, in colour, texture and durability. Mahogany logs may be obtained 2 ft. 6 in. square.

Maple. Hard close grain, not liable to splinter. Resembles beech, but softer. Tangential cuts sometimes produce "bird's-eye" maple which is in great demand for veneers. Used for superior floor boards for hard wear, furniture and turnery,

Oak. (See coloured plate.) Tough, hard, and very durable, with a beautiful silver grain if cut radially. It is a widely distributed tree, there being about three hundred varieties. English oak is the best but the most difficult to work. To secure the silver grain the timber is cut as explained in "Conversion," which is very wasteful, hence it is expensive. It is a rich light brown in colour, polishes well, and looks well when fumed with ammonia fumes. The timber goes nearly black with age. *Austrian* oak is easier to work than English; and as only the best qualities are exported, it is in great demand, under the name of *wainscot oak,* which simply implies "radial cut" oak. *Dantzic* oak approaches nearest to English. *American* oak is inferior to all the above, but is the easiest to work; it is also lighter in weight and coarser and warps freely. Oak is the most valuable hardwood grown in the temperate zones, being useful for so many purposes. Its chief drawback is that it contains an acid which corrodes iron, leaving a dark stain on the wood.

Rose-wood. Hard, even texture, with beautiful grain; it is a rich dark red, polishes well, and only used for superior joinery and cabinet work.

Sycamore. Hard, tough, even grain, but brittle. Very similar to maple, but whiter and cleaner in appearance. Used for superior kitchen furniture, turnery, butcher's fittings. The timber polishes well, and sometimes the radial cuts produce a beautiful mottle which is in great demand for furniture.

Satin Walnut. Fine close grain, fairly easy to work. Polishes well and is used largely for bedroom furniture. It is a light yellowish brown in colour, with a lustrous finish when planed.

Teak. (See coloured plate.) Very heavy, strong and durable. The timber may be obtained in very large sizes without any defects. It is straight grained and easy to work when *green.* It contains an aromatic secretion which hardens with seasoning, and then the timber becomes one of the worst for working, as it is very difficult to keep an edge on the tools. The timber does not take polish, but looks very well when oiled. It offers the greatest resistance of any timber to insects and also to fire. When fresh cut the timber is a yellowish green, but on hardening becomes dark brown. It is not suitable for fine arrises, because it splinters easily; the splinters are liable to cause blood poisoning. The timber does not warp or shrink after seasoning. It is used for high class joinery, cabinet making, shipbuilding and for good constructional work.

Walnut. (See coloured plate.) Hard, close grain, beautiful figure. The timber, which is a rich dark brown in colour, is not difficult to work, and polishes well. It is used for high class joinery and cabinet making. There are several varieties; the Italian and Black Sea varieties are often artificially burred to produce a beautiful figured timber known as Circassian Walnut, used for veneers. The American black walnut is the most valuable straight grained walnut. It is used for better class work, and may be obtained in very large sizes. This timber is stronger and more durable than the European variety. American white walnut is a hard dense timber of a pinkish yellow colour. Like the darker varieties it works up well for polish.

STRENGTH AND CHARACTERISTICS OF TIMBER

Timber.	Where Found	Chief Characteristics.	Chief Uses.	Sp. G.	Approx. Wt. per cub. ft.	Elasticity (million lb.).	Ult. Crushing Strength (lb.).	Ult. Tensile Strength (lb.).
Ash. (Fraxinus excelsior)	N. Hemisphere Widely distribtd.	Whitish grey, yellow markings. Hard, elastic, tough. Weathers badly. Liable to insect attack. About 1′ 6″ diameter	Wheelwrights' work. Cabinet making. Agricultural implements	·8	50	1·65	9,000	15,000
Beech. (Fagus sylvatica)	N. Hemisphere Widely distribtd. N. Zealand	Light to dark brown. Hard, heavy, close texture, wears evenly. Few knots but large. Liable to insect attack. About 3′ 6″ diameter	Cabinet making. Tools. Musical instruments. Beetles for bleachworks	·8	50	1·35	9,000	14,000
Birch. (Betula alba) (Betula nigra)	N. Hemisphere Widely distribtd.	Pinkish brown. Fairly hard, tough when dry. Good finish for stain and polish. Sharp arrises	Cabinet making. Substitute for superior hardwoods. Kitchen furniture. Plywood	·7	45	1·5	7,000	14,000
Chestnut. (Castanea vesca) (Castanea vulgaris (Asculus hipp.)	Europe U.S.A.	Brown. Similar to oak except for med. rays. Hard, elastic, durable, especially underground. 4′ diameter	Cabinet making. Substitute for oak. Foundation work	·66	42	1·1	7,000	12,000
Elm. (Ulmus campestris)	Britain. Central Europe C. America W. Asia	Reddish brown. Tough, flexible, Shrinks and warps badly. Large knots. Durable under water Fairly even texture. Twisted grain. 4′ dia.	Piles and foundations Turnery. Wheelwright's work. Inferior furniture	·55	35	1·1	10,000	13,000
Greenheart. (Nectandra rodicei)	Guiana	Dark yellowish green. Very hard, strong, and durable. Resists insects. End of grain appears very porous	Structural work. Jetties. Outside work	1	62	1·7	13,000	9,000
Kauri. (Dammara Australis)	N. Zealand	Light yellowish brown. Close and even grain. Warps. Shrinks endways. Works easily. Very large sizes	Fixed joinery. Turnery	·55	34	2·0	6,000	7,000
Mahogany (C.) (Swietenia mahogani)	Cuba (W. Indian Islands)	Rich brown red. Chalky pores. Beautiful grain (feathers). Does not warp or shrink much. Hard, heavy, durable. Large sizes	High class joinery and cabinet making. Pattern making	·8	50	2·0	7,000	14,000
Mahogany. (Baywood)	Honduras (Mainland)	Golden red. Softer, lighter, and less durable than Cuban. Splits easily. Large sizes. Varies greatly for working	High class joinery and cabinet making	·6	38	1·5	6,000	15,000
Oak. (Quercus pedunculata) (Quercus robur) (Quercus sessiliflora)	Europe America Widely distribtd.	*English.* Rich light brown. Strong, durable. Silver grain. Hard to work. Fumes and polishes well. Knotty. Darkens with age. Many species. Large sizes. Corrodes iron.	Superior joinery and outside work. Structural work. Shipbuilding	·9	56	1·5	8,500	15,000
		Dantzic, not so good or durable as English, easier to work		·8	50	1·2	7,500	12,000
		Austrian, as Dantzic. Cut for wainscot		·8	50	1·8	7,000	10,000
		Canadian, inferior to European in every respect						
Pitch Pine. (Pinus Australis) (Pinus Regida)	U.S.A. (Southern States)	Golden yellow, deep red markings. Strong, stiff, durable. Resinous. Shrinks slowly and greatly. Some specimens very curly. Uneven grain. 2′ 6″ diameter	Structural work, outside and ornamental joinery	·8	50	2·0	7,000	9,000
Spruce. Picea excelsa) (Picea nigra) (Picea alba), (Picea rubra)	N. Europe (Baltic) N. America	White, yellow markings. Clean, silvery appearance. Even texture. Small, hard knots. Elastic. Not durable outside. 2′ diameter	Kitchen joinery. Inferior carpentry and joinery. Scaffold poles	·35 to ·66	22 to 40	1·2 to 1·8	To 7,000	To 10,000
Teak. (Tectona grandis)	India, Burmah, E. Indies	Light to dark greenish brown. Strong and very durable. Resists insects. Easy to work when green, difficult when seasoned. Gritty when dry. Polishes badly but oils well	Structural work. Ornamental and outside joinery. Shipbuilding	·7	46	2·3	12,000	12,000
Yellow Deal. (Pinus sylvestris)	N. Europe N. America	Yellow, reddish markings. Strong, stiff, durable. Resinous. Easy to work. Sound knots 2′ 6″ diameter	Constructional work. Outside joinery	·65	40	1·5	7,000	10,000
Yellow Pine. (Pinus strobus)	Canada, U.S.A., Japan and Manchuria	Pale yellow. Soft, light, even grain and texture. Easy to work. Very free from knots. Very fine resin ducts. 3′ diameter	Good joinery. Pattern making. Cabinet making. Cores for veneering	·45	28	1·8	4,500	6,000

The table on page 315 has been compiled from various sources, but authorities vary considerably. It must be remembered that timber is the most uncertain of structural materials, therefore a big factor of safety is necessary when used for structural work. The values apply to good, well seasoned timber.

PLYWOOD

Plywood consists of three or more layers of timber glued together with water-proofed glue. The layers are arranged so that the grains of the adjacent layers are at right angles to each other. This gives a stiff board not liable to split or shrink. The outer layers or veneers are usually $\frac{1}{16}$ in. thick, and may be of almost any timber.

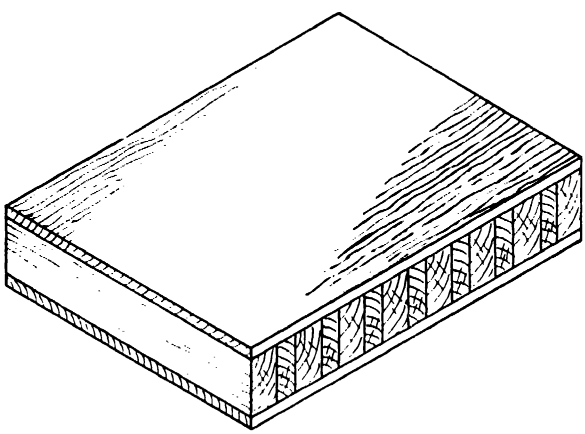


FIG. 111. MAHTAL LAMINATED PLYWOOD

They are prepared by circumferential cutting with knives against a revolving log, which produces unnatural grain. The inner layers are of varying thickness according to the thickness of the sheets.

The ordinary sheets are three-ply, and are about 5 ft. by 5 ft. by $\frac{1}{8}$ in. upwards, the timber usually being alder. Better qualities are of birch, and superior plywood may be faced with oak, mahogany, etc., with a different timber on each face.

The manufacture of plywood is in a state of development, and many new features are being introduced. Oregon pine is now being largely used, and the grain looks more natural, giving a bold appearance for varnishing. The latest development is *Mahtal* laminated plywood as shown in Fig. 111. It may be obtained in sheets 15 ft. by 5 ft. by $\frac{3}{16}$ in. to $1\frac{1}{2}$ in. thick. The glue is waterproofed, and shrinking or warping is nearly impossible. It is sufficiently stiff and strong to dispense with framing. The timber is Gaboon mahogany throughout.

Formerly plywood was only used for panels and drawer bottoms, etc., but the improvements in the quality are opening up new methods of construction, known as *hollow wood construction*. Doors and all kinds of framing are being made by this method. It is claimed for "Mahtal" that it is quite satisfactory to use it for doors, without any preparation; the panels to be formed by planting mouldings on the faces. It may also be used for counter tops, and as a substitute for any form of framing, the panel effect to be obtained as for doors.

TIMBERS FOR POLYCHROMATIC AND DECORATIVE WORK

The following timbers are used for coloured decorative work, because they are generally uniform in texture, polish well, and are suitable for turnery.

Brown. *Angico wood* (Brazil), yellow brown, black markings. *Calamander* (Ceylon), warm brown, black markings. *Prince-wood*, or *Cyp* (Jamaica), yellowish brown, veined. *Cocus wood* (Burma), yellowish brown, darker markings. *Snake-wood* (Guiana), warm hazel, black spots. *Amboyna* (Singapore), orange brown, small curls and burrs. *Bullet wood* (British Guiana), hazel brown. *Zebra wood* (Brazil), orange brown, darker markings.

Red. *Ruby wood* (India), the colour varies. *Brazilian rose-wood*, dark red, darkens with exposure. *Padouk* (India), rich red. *Tulip wood* (widely distributed), bright red, varies, darker markings, loses lustre on exposure. *Bar-wood* (Africa), dark red. *Beef-wood* (New South Wales), rich red. *Rata* (New Zealand), dark red.

Purple. *Amaranthus* (Brazil), from grey to deep purple with seasoning, test before use. *King-wood* (Brazil), varies, deep markings. *Rose-wood* (India), heartwood only.

Green. *Green sandal wood* (East Indies), olive green. *Green ebony* (West Indies), dull green. *Laburnum* (Europe), greenish brown.

Yellow. *Box-wood* (Europe). *Fustic* (West Indies), yellow to green. *Satin wood* (St. Domingo), lustrous yellow. *Degame* (West Indies), pale yellow. *Sandal wood* (East Indies), yellow to tawny brown.

The most satisfactory timbers for black and white are ebony and holly.

ESTIMATING

By Henry A. Mackmin, F.S.I., M.R.San.I., M.I.Struct.E.

LESSON IV

MASON

The pricing of a complete stone building is somewhat difficult to those accustomed to brick structures, but stone dressings are less difficult. Many firms sublet the work, and upon receipt of a bill of quantities the bill for the stonework is forwarded to a mason, who prices it. For convenience, stone walls can be described as either *rubble* or *ashlar* work. The former term indicates rough walls of untrimmed or roughly trimmed stone, whilst the latter term indicates walls built of stone worked to a finely dressed face. The erection of rubble walls is usually carried out by men accustomed to this class of work, and they are termed "wallers."

WALLER

It is practically impossible to give accurate data for this trade, as the conditions and prices in each district, and for each kind of stone, vary considerably. In accordance with the "Standard Method of Measurement," walls 18 in. and under in thickness are priced per yard super, but any walls above this thickness are priced per yard cube.

Detailed Example

Coursed Rubble Wall in Lime Mortar, 12 in. Thick

	£	s.	d.
1 yd. cube of local rubble, at 18s. per load of 1½ yd.		12	–
⅛ yd. cube of lime mortar (as before) at £1 18s. 10d. per yard cube . .		4	10¼
Waller and labourer, 4 hrs. at 3s. 2d. .		12	8
	1	9	6¼
Profit and Establishment, 12½% . .		3	8¼
	£1	13	2½

For uncoursed rubble walls, a waller and labourer will require about two hours each, and one-fifth of a yard cube of mortar should be allowed owing to the greater number of voids. In many districts rubble walls are built dry, with the exception of the coping course.

ASHLAR WORK

At the present time it is not usual for buildings to be erected entirely of stone; but frequently the structure consists of steel or of reinforced concrete, or perhaps may be constructed of brick, and is afterwards encased with stone. Ashlar work requires great care, and the mason fixing the stone usually receives 1d. more per hour than the ordinary rate. A very substantial scaffold is required, and this adds to the cost. The bill of quantities will describe the stone in detail and give the superficial area, stating the average depth of stone in the wall. The price for the work has to include all labours, but dressings and special stones are taken out in detail (see later). The measurement of all kinds of stone (except York stone) is similar; it is, therefore, proposed to take Portland stone and Bath stone as typical examples, as other building stones would be worked out in a similar manner.

Cost of Stone. At the time of writing, Bath stone is quoted at 3s. and Portland stone at 4s. 9d. per foot cube in trucks at London railway stations.

Cost of Finished Blocks. To the cost of the stone, it is necessary to add the cost of carting, unloading, stacking, converting into useful sizes, sawing to shape, and delivering to the job. The cost of the finished blocks will, therefore, depend upon the transport facilities and modern machinery possessed by the contracting firm. In these circumstances, it is impossible to give rules for finding the charges, as they can be found only by careful costing methods; but for the purpose of these articles we will assume an average price of 16s. 6d. per foot cube for Portland stone, and 12s. per foot cube for Bath stone, to include waste and all labours.

Several items in the detailed cost will require some explanation. The mortar used is composed of equal parts of lime and stone dust, and actual calculations should be made as described in an earlier lesson; but with lime at £2 15s. per ton, the cost of a yard cube of mason's mortar will work out at about £2 10s. per yard cube. One foot cube of stone will require about one-sixth of a foot cube of mortar, and a fair allowance for the scaffold will be 2½d. per foot super of stone. The hoisting of the stone into position is a speculative item, as the height may not be known and so much depends upon the plant available, but with ordinary work a fair allowance per foot cube would be one-third of an hour of a labourer's time. The bedding and fixing is worth half an hour of a mason and labourer's time per foot cube.

Detailed Example

Portland Stone in Ashlar Work, Average Depth in Wall 7 in., Bedded and Jointed in Special Lime and Stone Dust Mortar—

	s.	d.
Cost of stone and labours (as above), seven-twelfths of a foot cube at 16s. 6d.	9	7½
Use and waste of scaffold, per foot super		2½
Hoisting, labourer 10 minutes at 1s. 4½d. per hour		2½
Mortar, one-twelfth of a foot cube at £2 10s. per yard cube		1¾
Fixing, mason and labourer, ¼ hr. at 3s. 3d. per hour		9¾
	11	—
Profit and Establishment, 12½%	1	4½
Price per Foot Super	12	4½

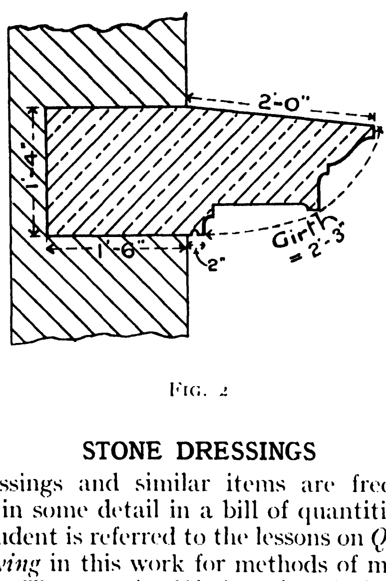


Fig. 2

STONE DRESSINGS

Dressings and similar items are frequently given in some detail in a bill of quantities, and the student is referred to the lessons on *Quantity Surveying* in this work for methods of measurement. The stone itself is first given in feet cube, and then all the labours thereon in feet super separately.

Waste. The sizes given are the sizes of the smallest blocks out of which the finished block can be cut; but the estimating surveyor finds it necessary to make a further allowance for waste, and an addition of 5 per cent is suggested.

Labours on Stone. As described elsewhere, the various labours are given separately; and, for accurate estimating, a series of costs, calculated over a considerable period, is necessary, so as to obtain average prices. From such data a list, as shown in Table I, can be prepared for different classes of stone.

TABLE I

Labours in Hours, per Foot Super

	Portland Stone	Bath Stone
Labour to Back	0·25	0·09
Beds and Joints	0·50	0·17
Sunk Ditto	0·75	0·25
Plain Face	1·50	0·50
Sunk Face	2·00	0·75
Moulded Work	4·00	1·50

The data given for Portland stone will serve for similar hard stones, and that given for Bath stone may be taken as indicating the less expensive stones. Derbyshire stone will probably cost 20 per cent more to work than Portland, and York stone about 15 per cent more than Portland. It often happens that certain labours, especially narrow widths, are given per foot run, and in such cases the prices can be found from the table, using proportionate methods. If the labour is prefixed by the word "circular," it is usual to double the allowance; and if described as "circular circular," then it will be necessary to treble the figure.

Moulded Work. In measuring moulded work, it must be remembered that the superficial dimension given is not the actual area, but is the result of multiplying the length by the *girth*. The "girth" is often difficult for some beginners to understand, but the typical example which follows should make the term clear. The "girth" is *not* the distance that would be covered by a tape folded into every member of the moulding, but it is the distance covered by a tape stretched from one end of the moulding to the other.

The sketch, Fig. 2, shows a section through a string course, and we will assume that the stone is 3 ft. in length. In a bill of quantities, the items shown on the opposite page would appear.

In this list, the beds and joints have been kept separate so that the student may check the quantities, but in actual practice the beds and joints would be given together. For convenience, the items have been numbered consecutively, and we can now deal with each one in detail.

Item 1. The stone roughly worked is taken at 10s. 6d. per foot cube; hoisting, one-third

Item No.	Quantity			Labour and Price		s.	d.
	ft.	*in.*				*s.*	*d.*
1	13	8	cube	Bath stone, hoisting and setting .	at	12	10¾
2	4	--	super	Labour to back .	,,		2¼
3	10	6	,,	Beds . . .	,,		3¾
4	4	7	,,	Joints . . .	,,		3¾
5	6	–	,,	Plain sunk face .	,,	1	4¾
6	6	--	,,	Moulded work .	,,	2	9¾
7	3	–	run	Plain 2 in. margin .	,,		2
8	3	--	,,	Labour to throat .	,,		½

of an hour for labourer at 1s. 4½d. is 5½d. ; mortar one-sixth foot cube at £2 10s. per yard cube is 3¾d. ; fixing, allowing half an hour for mason and labourer at 3s. 3d. is 1s. 7½d. ; making a total per foot cube of 12s. 10¾d.

Items 2–6 can be calculated from the data previously given, and will produce the following figures : item 2, 2¼d. ; item 3, 3¾d. ; item 4, 3¾d. ; item 5, 1s. 4¾d. ; item 6, 2s. 9¾d.

Item 7. This being per foot run, the cost can be found by taking one-sixth of the price per foot super for plain face work, two inches being one-sixth of one foot.

Item 8. It is usual to allow about ½d. per foot for this work.

YORK STONE

York stone is sold by the foot super and is used principally for sills, thresholds, copings, cover stones, templates, and similar items. In a bill of quantities, sills and copings are given per foot run, and templates are numbered. The labour preparing York stone sills and copings will be found to cost about 3s. 6d. per foot super, but naturally this price will vary in different districts.

Cost of York Stone. The cost of the stone at present is 2s. 6d. per foot super for 3 in. thicknesses, and 3s. 6d. per foot super for 4 in. stone delivered in trucks in London.

Cost of York Stone Items. Working on the prices given previously, the following items will work out as under –

			s.	*d.*
Stone Sills out of	12 in. by 4 in.	Per foot run	7	--
Stone Sills out of	9 in. by 3 in.	,,	4	6
Copings out of	15 in. by 4 in.	,,	8	9
Copings out of	13 in. by 3 in.	,,	6	6

Other items of worked York stone can be calculated by similar proportionate methods.

Cover Stones and Templates. For these items it will be sufficient to take the net cost of the stone and add 15 per cent.

Steps and Landings. It is necessary for the estimating surveyor to take out rough quantities for himself and price the labours—all as described in the previous typical example.

SLATER AND TILER

The measurements in these trades are similar, although in various parts of the country different methods exist, but in this article we will follow the "Standard Method of Measurement." By this method, the net area of the roof is taken and various extras for cuttings and waste are added per foot run. The builder frequently sublets the work in these trades, as the specialist contractors can usually obtain better terms by purchasing in bulk at the quarry. In these circumstances it is considered unnecessary to give many examples.

SLATER

It is necessary to bear in mind the difference between the terms *gauge* and *lap*. With slating work, it is usual to specify the "lap," and for the purpose of finding the spacing for the battens and the number of soakers (if required) it is necessary to find the "gauge." If the slates are nailed near the head, take the length of the slate, subtract the "lap" plus 1 in. (this is for the portion near the head), and divide by 2. If the slates are nailed near the middle, simply deduct the lap from the length of the slate and divide by 2.

Slates are sometimes sold by weight at the quarry, and per *mille* of 1,200 by the merchants. The number of the slates required per *square* of 100 ft. super, naturally varies in accordance with the size of the slate, the lap, and whether nailed at the head or the middle. As a lap of 3 in. is most usual, Table II gives the number of slates for this lap only, for it is a simple matter for the student to work out others for himself from the data given previously.

Detailed Example

Best Bangor Slating 20 in. by 10 in., Laid to 3 in. Lap and Nailed near Head with Two Composition Slate Nails—

	£	s.	d.
180 slates, at £27 per mille delivered .	4	1	–
Waste, add 5%		4	–½
Nails, 2¾ lb. at 4d.			11
Slater and labourer, 2 hrs. at 3s. 2d. .		6	4
	4	12	3½
Profit and Establishment, 12½% . .		11	6½
Cost per Square . . .	£5	3	10

TABLE II

NUMBERS OF SLATES PER SQUARE AND WEIGHTS PER MILLE

Sizes of Slates	Number Required per Square		Weight per Mille
	Nailed near Head	At Middle	Cwt.
18 in. by 10 in.	206	192	33
20 in. by 10 in.	180	170	36
22 in. by 12 in.	136	127	51
24 in. by 12 in.	120	115	56

Extras. The merchants will quote for special slate ridges and hips, but for cuttings it is usual to take the price per square as a basis and work on the following

Eaves	Length	by	12 in.
Verge	,,	,,	6 in.
Verge (slate and a half)	,,	,,	12 in.
Top Edge	,,	,,	6 in.
Square Abutments	,,	,,	6 in.
Valleys and Hips	,,	,,	6 in. (each side)

TILER

Tiles are sold per thousand, and the "gauge" is usually specified. The usual size of a tile is $10\frac{1}{2}$ in. by $6\frac{1}{2}$ in., and a square laid to a gauge of 4 in. will require 555 tiles; whilst a square laid to a gauge of $3\frac{1}{2}$ in. will require 634 tiles. An allowance must be made for waste, and usually 5 per cent should be sufficient; but if the tiles are very brittle this allowance must be increased. Very frequently the battens are included in the item, but these are more suitably included in the "carpenter" bill.

DETAILED EXAMPLE

Plain Broseley Tiling Laid to 4 in. Gauge Fixed every Fourth Course with Two Galvanized Pegs to each Tile

	£	s.	d.
555 tiles at £6 6s. per 1,000 delivered	3	9	11
Waste, allow 5%		3	6
8 lb. of tile pegs at 4d. per lb.		2	8
Tiler and labourer, 3 hrs. at 3s. 2d.		9	6
	4	5	7
Profit and Establishment, $12\frac{1}{2}$%		10	8
Cost per Square	£4	16	3

Extras. Special quotations can be obtained for special shaped valley tiles, and for hips and ridges, but for cuttings and waste allowances can be made as described for slater, viz.

Eaves	Length ×	by	8 in.
Verge	,, ×	,,	6 in.
Verge (tile and a half)	,, ×	,,	12 in.
Top Edge	,,	,,	6 in.
Square Abutments	,, ×	,,	6 in.
Valleys and Hips	,, ×	,,	6 in. (each side

Continental Interlocking Tiles. The measurement for these tiles is similar to the measurement of ordinary tiling. *Marseilles tiles* are usually laid to a gauge of $13\frac{1}{2}$ in., and *Courtrai tiles* to a gauge of $9\frac{3}{8}$ in. The former take 127 tiles and the latter 207 tiles to cover a square of 100 ft. super. The labour is about the same as with English tiles.

EXERCISE IV

1. Assume that the block of stone in Fig. 2 is of Portland stone, and work out in detail the net cost of the block. Assume rough trimmed stone at 10s. 6d. per foot cube.

ANSWER TO EXERCISE III

1. 2s. 7d. per foot super, without profit.

CIVIL ENGINEERING

By Professor F. C. Lea, D.Sc., M.Inst.C.E.

LESSON II

RETAINING WALLS AND DAMS

WALLS AND STRUCTURES EXPOSED TO FLUID OR EARTH PRESSURES

Forces Acting on Walls. Let it be supposed that a wall, abutment, or other structure is exposed to any lateral pressure which produces a resultant force P on any part of the structure above a section AB (Fig. 9). This may be due

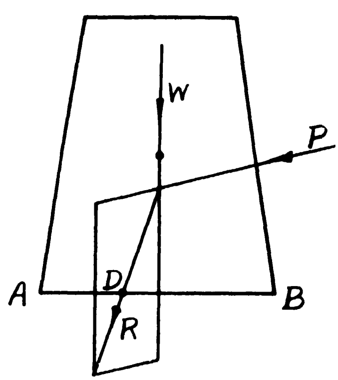


Fig. 9

to wind pressure, or water pressure as in the case of a dam, or to earth pressure as in the case of a retaining wall.

Let the resultant vertical load, apart from the lateral pressure P, above the given base be W. In the case of a wall subjected to wind pressure, this resultant may be due to the weight of the wall alone together with superimposed loads. In the case of a dam, W will generally be the weight of the dam only. In the case of retaining walls it will be seen later that W may include the weight of masonry and the weight of earth. However P and W are produced, the resultant R, acting on the given base AB, is the resultant of these two forces, and can at once be found by the triangle or parallelogram of forces.

Wall Exposed to Wind Pressure. A wall 2 ft. thick is 15 ft. high. The weight of brickwork is 130 lb. per cub. ft. A horizontal wind pressure of 20 lb. per sq. ft. acts on the wall. Find the resultant thrust on the base. The reader can draw a figure.

Taking one foot-length of the wall—

$$P = 15 \times 20 = 300 \text{ lb.}$$

$$W = 2 \times 15 \times 130 = 3{,}900 \text{ lb.}$$

The resultant R cuts the base at a distance x from the centre, such that—

$$W.x = P \times 7{\cdot}5 \text{ ft.}$$

$$\text{or } x = \frac{300 \times 7{\cdot}5}{3{,}900} = {\cdot}57 \text{ ft.}$$

The normal component on the base is W-lb. and the tangential component P-lb.

Effect of a Thrust R on Any Section of a Masonry Structure. The tensile strength of mortar is practically negligible, and also, when a masonry structure rests upon a foundation, tensile stresses clearly cannot exist between the structure and the foundation.

Let AB be a section of a masonry structure, as, for example, the section of a wall built in mortar, or it may be the joint between two stones of an arch ring, or it may be the plane of separation between a wall and its foundation. Let the resultant thrust R on the section be known in magnitude and direction.

Three cases are shown. Fig. 10 represents a portion of an arch ring, and on the joint AB there is a resultant thrust R. Fig. 11 shows the

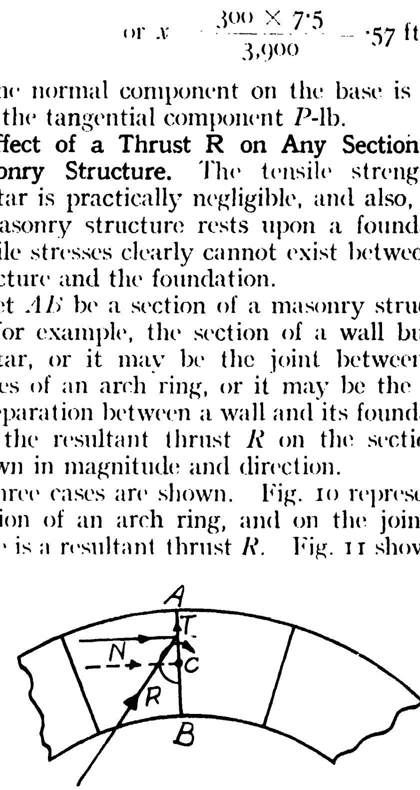


Fig. 10

section of a wall, which may either be a masonry dam or a retaining wall; AB may be any section of the wall, A_1B_1 the base of the wall, and A_2B_2 the base of the concrete foundation. Fig. 12 shows a circular column. In any one of these cases the resultant thrust R on the joint, or section AB, will depend upon the external forces. Let it be supposed that R is known. Resolve R into its two components, N and T, normal and tangential respectively to the section AB. Then

T is a shearing force on AB, and tends to cause sliding along AB. The frictional resistance to sliding along AB is μN, where μ is the coefficient of friction, and this must be greater than T.

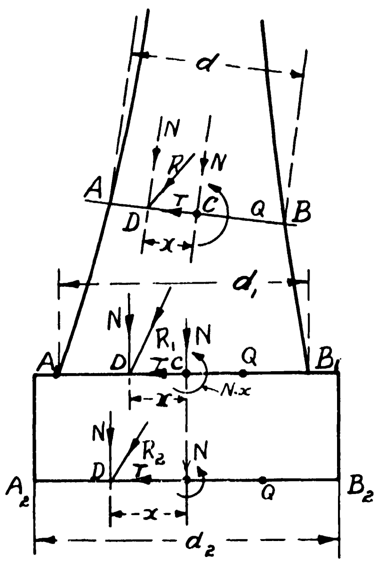


FIG. 11

The shearing force is not uniformly distributed along the section; this will be returned to later.

If R cuts the base outside AB, and there are no tensile stresses acting on AB, then there will be rotation about A. The wall (Fig. 11) will overturn and the arch (Fig. 10) will collapse.

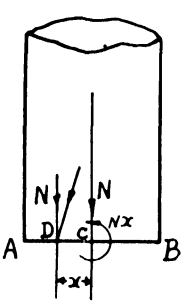


FIG. 12

Effect of a Normal Force N on the Section of a Masonry Structure. Let C be the centre of any of the sections AB (Figs. 10 and 11). It is a well-known principle of mechanics that any force N (Fig. 11), acting at D, can be supposed to be replaced by a force N acting at the point C, together with a couple Nx acting around an axis through C, perpendicular to the plane containing N and C, i.e. perpendicular to the plane of the paper. The value of N being known, there is then a normal force N acting at the centre of gravity C of AB, and a couple Nx which acts upon the section as a bending moment acts upon a beam. This really means that the body above AB is kept in equilibrium by the reactions below AB. There is a reaction at C equal and opposite to N and a couple balancing the couple Nx.

Stresses in the Section. The normal force N produces a uniformly distributed normal stress on AB. Let it be supposed that the section is a rectangle, the width of which through the paper is 1 ft., and let $AB = d$ feet. Then the stress per square foot on AB, due to N at C, is—

$$f = \frac{N}{d}$$

Let f_1 be the normal stress due to the bending moment M at any distance y from C. Then—

$$M = Nx = \frac{f_1 I}{y}$$

$$\text{or } f_1 = \frac{Nx \cdot y}{I}$$

I being the second moment of the section AB about an axis through C. The stress f_1 is a maximum when $y = \frac{d}{2}$.

For a rectangle $I = \frac{1}{12} bd^3$, or since b is 1 ft. $= \frac{1}{12} d^3$.

Then at A the resultant stress—

$$p = f + f_1$$

$$= \frac{N}{d}\left(1 + \frac{xd}{2\frac{1}{12}d^2}\right)$$

$$= \frac{N}{d}\left(1 + \frac{6x}{d}\right) \quad . \quad . \quad . \quad (1)$$

And at B the stress—

$$p_1 = \frac{N}{d}\left(1 - \frac{6x}{d}\right) \quad . \quad . \quad . \quad (2)$$

Stress Diagram on a Rectangle. The distribution of stress on AB due to N is then as in Fig. 13. At A the resultant p is $f + f_1$ and at B, p_1 is $f - f_1$.

Between A and B the stress is assumed to vary uniformly, as in the beam theory.

It will be seen from equation (2) that the stress at B will become zero when $6x = d$, and will become negative if $x > \frac{1}{6}d$; or, in other words, for the stress to be always positive (i.e. compressive) the force R (Fig. 11) must not cut the base at a greater distance from C than $\frac{1}{6}d$. Let AB be divided into three equal parts, then

R must cut the base within the " middle third," if x is always to be less than $\frac{1}{6}d$. When $x = \frac{d}{6}$ the stress at A is $p = \frac{2N}{d}$.

Case when the Resultant Thrust Acts Outside the Middle Third of the Section AB. When the resultant thrust R (Fig. 14) cuts a rectangular section outside the middle third, there must

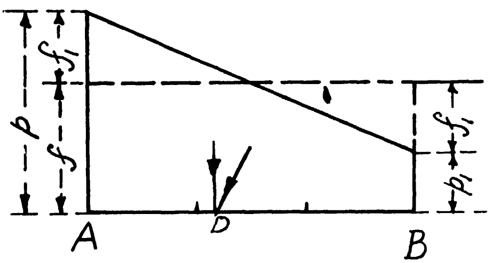


FIG. 13

either be tensile stresses in the section or else the joint must partially open. In a masonry structure it has been seen that tensile stresses cannot very well exist at a joint, and there is, therefore, a part of the joint AB (Fig. 14) on which there is no stress. Suppose EB to be liberated from stress and that at E there is just no stress. Let C_1 be the centre of AE and let $AE = d_0$.

Then if R acts on the edge of the middle third of AE, or at $\frac{1}{6}d_0$ from C_1, the stress at E will be zero, and the stress at A will be—

$$p_a = \frac{2N}{d_0}$$

When R acts outside the middle third of AB, the stress at A may, therefore, become larger than $\frac{2N}{d}$. Clearly R cannot act outside the base, as d_0 cannot be negative unless p_a is negative.

Stability of a Masonry Wall or Dam and the Effect of the Resultant Thrust being Outside the Middle Third when the Wall is Exposed to Fluid Pressures. It is often quite mistakenly stated that a wall is unstable when the thrust R cuts any section outside the middle third. As long as R is within the section, and the stresses are not too large for the material and foundation to resist, and there is no sliding, the wall is stable.

If the wall is resisting dry earth pressures, the thrust R can safely be outside the middle third, and walls are often designed, following the suggestion of Sir Benjamin Baker, so that R is within the middle half. If R cuts the section at the limit of the middle half, the stress at A is—

$$p_a = \frac{2N}{\frac{3}{4}d} = \frac{8N}{3d}.$$

When the wall is exposed to a fluid pressure on the side of B (Fig. 14), then it may not be permanently stable if R cuts AB outside the middle third. It will be seen that if the compressive stress is liberated between B and E, the fluid under pressure at B may get into even the smallest crack, and exert a normal or lifting force on the area BE. This will have the effect of diminishing the effective weight of the wall, and R will be moved outwards. A greater length will then be exposed to pressure, and R will be moved still farther until it may get outside the wall, and the wall will overturn. Or, what is perhaps even more likely, the resistance to

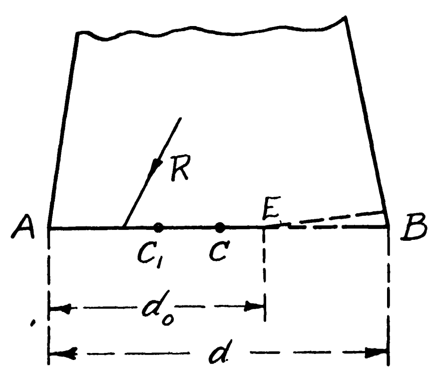


FIG. 14

sliding will be so much diminished that the wall will slide under the force T.

The famous case of the failure of the Bouzey Dam was no doubt due to this effect, and the writer has known several cases of walls in which the failure could no doubt be attributed to a gradual diminution of stability due to fluid pressure within the wall.

NOTE. Readers having little knowledge of mathematics and mechanics, may find it advisable to study the sections on *Building Science* (which includes elementary mechanics), *Building Calculations*, and *Structural Engineering* before tackling some of the lessons on *Civil Engineering*.

BRICKWORK

By William Blaber
Lecturer in Brickwork at the Northern Polytechnic, London

LESSON VII

SETTING OUT— (*contd.*)

When straining the line for each course of the wall, the line pins should be fixed in the joints at the return ends of the corners, Fig. 41, several courses below the one that is being laid, and brought over the corner of the quoin brick; otherwise, the line is apt to cut too deeply into the unset mortar, and the work set back slightly from its accurate position in consequence.

Where the distance between the two corners is great enough to cause the line to sag in its middle, a lo p of string, called "a tingle," is attached to the line about its centre. A brick is then bedded near the centre of the length of the wall, and the line fixed by the tingle, on the top of which a bat is bedded to hold it in position. Care should be taken to keep the tingle in the same position vertically for every course, and this place in the wall kept plumb. The horizontal line should be sighted through for each course before the bat is bedded, to ensure the work being kept straight and level.

Levelling. It may generally be assumed that the concrete bed is only approximately level, and in raising the corners the bricklayer should level from corner to corner when the work is three or four courses high, and establish a level bench mark from which he can gauge his work as it rises, so that by the time the wall is above ground, it will be level enough to receive the superior work that will be exposed to view. In important elevations, where good class facing bricks are used, nothing offends the eye so much as a series of thick joints at one end of a wall used to bring it to a level line.

Racking Back and Toothing. It frequently happens that some portion of a building has to be left down for some reason, and the remainder proceeded with. In this case, each successive course of brickwork on that side of the wall which is left down is stepped back, as shown in Fig. 41, or a toothing left. The latter is not good practice in main or external walls, as the joints cannot be satisfactorily filled when building into them, resulting later in unsightly cracks appearing, but in many instances it cannot be avoided. If toothing cannot be avoided, it is better to do it in short vertical lengths, racking back a course here and there so that the toothing itself is stepped (see Fig. 41).

Interior partition walls are often left down until the main walls are completed, sinkings, or *indents*, Fig. 42, being left in the alternate courses of the main walls, into which the partition walls are bonded when they are eventually built. These indents are termed *toothings*.

Toothings are generally left when it is desired to extend a building at some future date. To strengthen the junction when made, strips of galvanized hoop-iron are built in the wall that is toothed, at intervals of from three to six courses, and turned down out of the way for the time being (see Fig. 43).

In joining up new work to old, when the new and old wall are in the same straight line on an important frontage, toothings have to be cut in each *alternate* course of the old wall. If the join is in a position not exposed to view, or the new wall joins the old at an angle, it is better to make the connection with *block toothings*, as shown in Fig. 44.

Where one part of a building is carried to a much greater height than the remainder, as in the case of a tower or tall chimney, and in consequence the load on the foundations is much greater, a good method of preventing unsightly fractures due to unequal settlement, is to bond the heavier portion into a *chase*, Fig. 45, so that the heavy wall is free to take up its bearing independent of the other walls; the chase can be filled in and pointed up at completion.

Protection of Brickwork. Work built during frosty weather should be protected by covering it with straw, tarpaulins, empty sacks or boards, particularly during the night and early morning, as the water in the mortar freezes and expands. If frost is allowed to penetrate into the wall to any extent, this expansion will be sufficient to lift each course off its bed, thereby weakening the wall considerably.

Work built in Portland cement mortar is rarely affected unless the frost is very severe, as the mortar sets before freezing takes place. Lime mortar is more readily affected by frost;

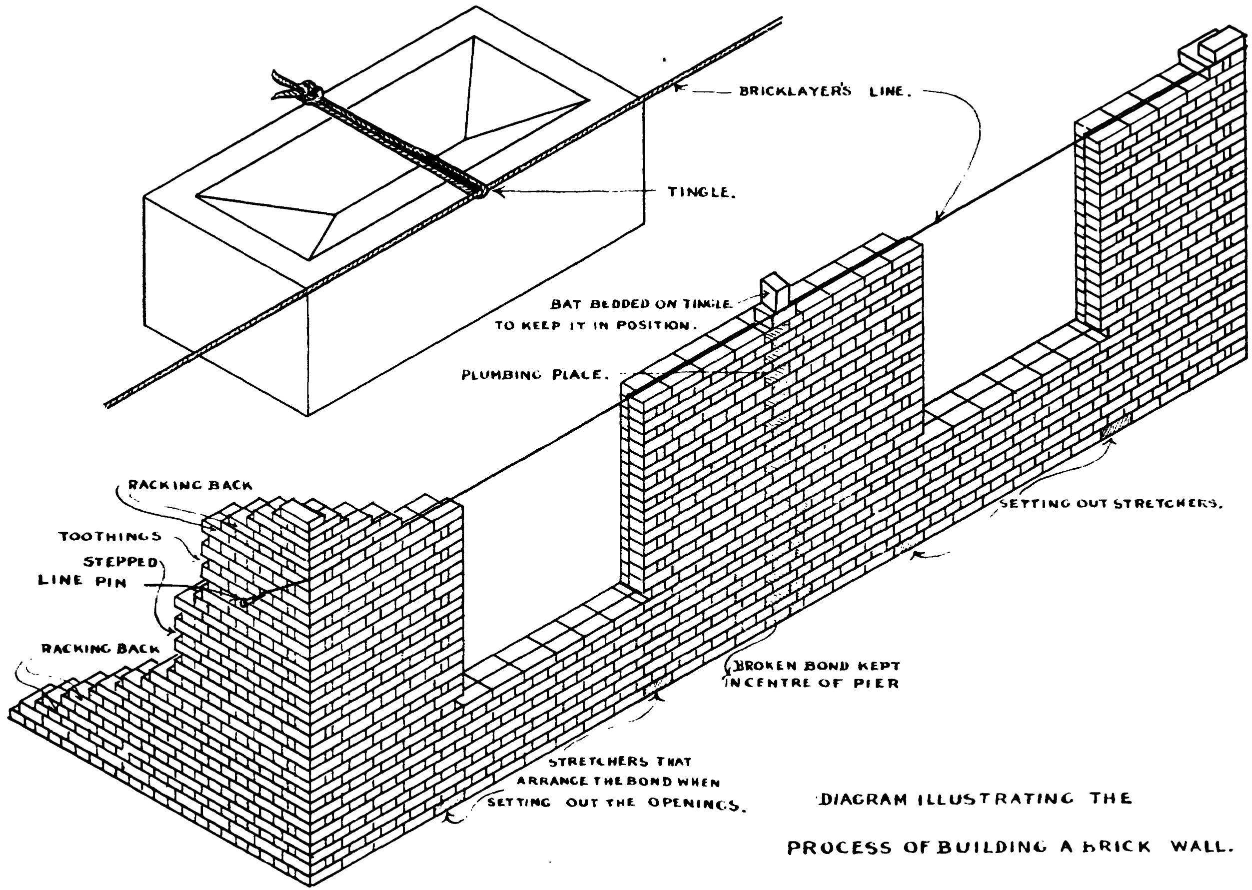


DIAGRAM ILLUSTRATING THE
PROCESS OF BUILDING A BRICK WALL.

FIG. 41

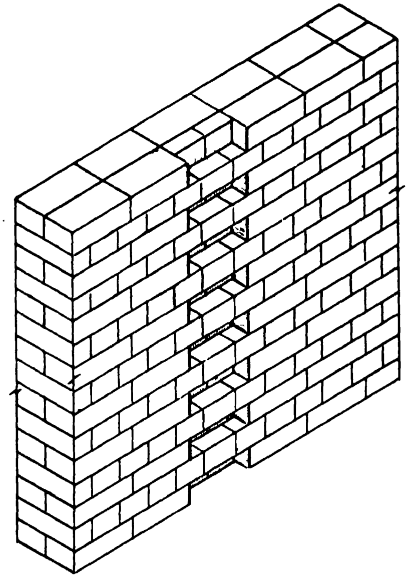


Fig. 42. Indent Toothing

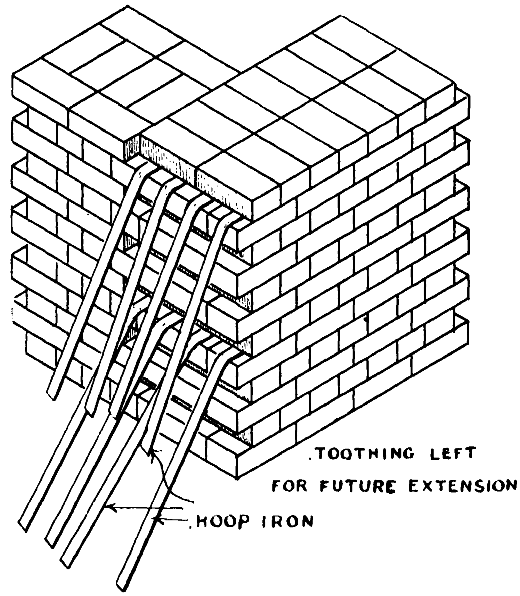


Fig. 43. Hoop-iron Bond

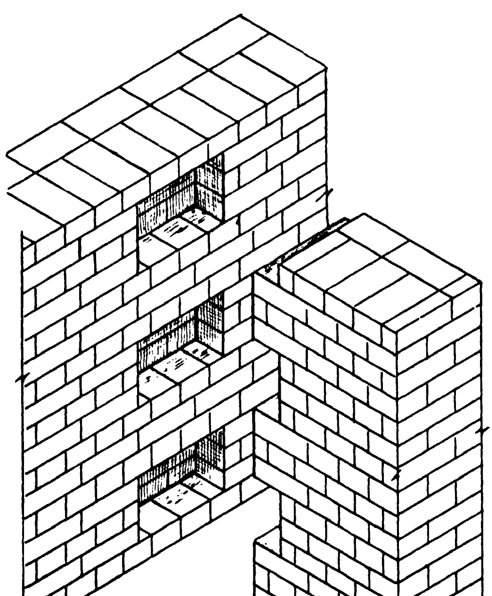


Fig. 44. Block Bonding

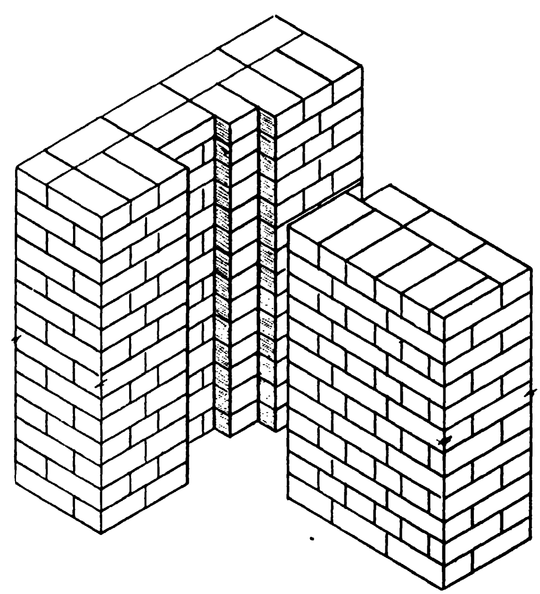


Fig. 45. Chase Bonding

but if reasonable precautions are taken, work may be continued even with the latter, if the pointing is left until more favourable weather. When the work has been well protected, only the surfaces of the joints will have been affected, and these will have to be raked out before the pointing is proceeded with. It may be generally assumed under these conditions, that by using only sufficient water to make the mortar workable, and keeping the bricks fairly dry, work can be proceeded with so long as the mortar does not freeze on the mortar boards.

Wetting Bricks. The principal reasons for this process are—

1. To ensure that sufficient water is retained in the mortar long enough for the process of setting to take place satisfactorily. This largely depends upon the combination of the water with the ingredients composing the mortar, particularly in the case of hydraulic limes and cements.

2. To remove any dust or loose particles from the bricks, so that the mortar will adhere more readily to their rough surfaces.

The wetting of bricks has, in the past, been laid down rather dogmatically in many textbooks on building, and is generally the subject of a clause under "Bricklayer" in most specifications, with no reference to weather conditions.

It is undoubtedly necessary during the hot summer months, when the bricks and mortar have both parted from their moisture by rapid evaporation.

During the winter months, particularly frosty periods, this process is liable to do more harm than good.

Dry bricks may absorb some of the water from the mortar, but it is retained in the bricks for a considerable time, long enough for the mortar to draw upon it for the setting process. Also, the atmosphere in winter time generally contains much moisture, which is absorbed by any porous type of brick.

Taking these facts into consideration, it is obvious that a little sound judgment should decide as to whether this process would be beneficial or otherwise in the production of satisfactory work.

BUILDER'S OFFICE AND ROUTINE

By R. F. Galbraith, B.Sc.

PART IV

BUYING

The buying department of a builder's business is one of the most important departments. A mistake in buying, even if due to a misunderstanding, may have very serious results. The following points must be considered in every purchase: Price, together with quality, delivery dates, terms of payments, and methods of delivery.

Every order should be made on a special order form (if the order is made by telephone it should be confirmed in writing). The order, Fig. 4, should set out the quantity, quality, price, how and when delivered, and terms of payment.

Certain materials, such as timber, cement, steel, sand, ballast, involve special consideration.

Timber. Softwoods are invariably sold "per standard" of 165 ft. cube for all sizes of deals, battens, and boards down to 1 in. × 4 in. Flooring, matching, and other prepared sections are sold "per square" of 100 ft. superficial; strips, i.e. sections 1 in. × 3 in. and less, are sold per 100 ft. run.

Hardwoods are sold "per foot superficial as 1 in. thick," or "per foot cube" when the thickness is 1 in. or over, and "per foot superficial" when less than 1 in. thick. For example, 2½ in. teak planks sold at "1s. 2d. per foot super as 1 in." cost 2s. 11d. per sq. ft., or 14s. per foot cube; whilst ½ in. teak planks at 9d. "per foot super" cost 18s. per foot cube. Logs are usually sold "per foot cube," caliper measure.

The Purchase of Timber may be divided into four classes—

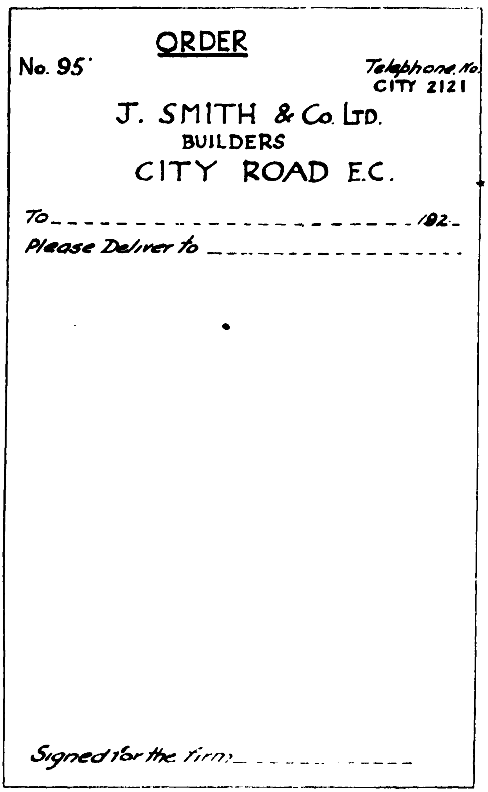
(*a*) Timber purchased before it is imported, i.e. a "bill of lading."

(*b*) Timber purchased for stock as and when a suitable parcel is available.

(*c*) Timber purchased for a particular purpose; for example, timber for housing work, joinery, or timber for a particular contract.

(*d*) Hardwoods.

(*a*) **Timber Bought Before Importation.** In this case, great care must be exercised in making the deal. The quantity to be purchased and the quality (i.e. first, second, third unsorted, and fourth) must be examined. The port of shipment and price asked must be compared with current quotations for "landed goods." It is usually cheaper to buy "goods to arrive," but a drop in the price of landed goods can easily


ORDER

No. 95 — Telephone No. CITY 2121

J. SMITH & Co. LTD.
BUILDERS
CITY ROAD E.C.

To .... 192..

Please Deliver to ....

Signed for the Firm ....

Fig. 4

occur between the signing of the contract, say in December, and the arrival of the shipment, perhaps in May. However, if the builder is buying for a special purpose, he knows what price he can afford to pay and so can eliminate any possibility of actual loss.

Having decided to make a forward purchase, a contract is signed between the builder and the importer or agent.

Definite lengths cannot be guaranteed, but they vary between 12 ft. and 25 ft. (Ends, i.e. 5 ft./11 ft. lengths, are usually imported separately.) The price quoted will be either "c.i.f.," "*ex ship*" or "delivered" to a specific place.

If the price is c.i.f. (which means cost, insurance, and freight), the buyer must take delivery from the ship and pay for the unloading and removal of the timber.

An *ex ship* price means the cost of unloading is paid for by the seller, but the buyer must provide a barge to receive and remove the timber.

The contract will detail the terms of payment, which may be as follows—

In a c.i.f. contract the cost of freightage is paid "net cash in 30 days," and the balance of purchase price either "cash in 30 days less $2\frac{1}{2}$ per cent," or by a bill of exchange at four months.

In an *ex ship* contract, the purchase price is paid for either "cash" or by a "bill of exchange."

(*b*) **Timber Purchased for Stock.** Although bargains can occasionally be obtained, it is frequently necessary to make a definite purchase of timber from landed goods for stock and other general purposes. The usual procedure is to consult two or three merchants, either by telephone or by reference to their monthly stock list, and obtain particulars of various parcels of timber that are *apparently* suitable. The parcels should then be inspected in the docks or at the wharf where they are stowed. This inspection is absolutely essential, because brands of timber that were recognized as standard before the war, are not absolutely dependable now, and one shipment from a particular port will vary from the rest. While inspecting the timber, a note should be made of the "number of hearts," or centres of logs, in the pile; whether the wood is strong, i.e. coarse grained with large knots; how the timber is piled; and whether in the open or under cover. A few boards on top of the pile should be turned over and examined.

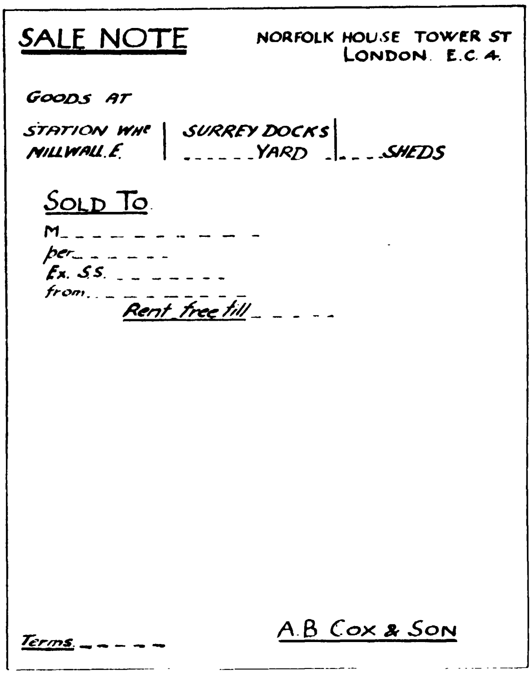
When a purchase of timber is made, the timber merchant sends the buyer a *sale note* (see Fig. 5).

The sale note is a contract and specifies the quantity of timber sold, quality, price, and how delivered. Any error in the sale note should be rectified immediately.

When the timber is sold "in docks," a *dock order* is issued to the buyer, showing the mark of the timber, number of pieces of each length, and place of storage.

Usually, the storage of timber is paid for by the seller for 14 days after the date of the sale note. After that date rent must be paid for by the buyer.

Timber purchased in this way is usually sold with 2½ per cent discount for cash at 30 days after date of sale note, or else for a four months' bill.


SALE NOTE

NORFOLK HOUSE TOWER ST
LONDON. E.C.4.

GOODS AT

STATION WHF MILLWALL E. | SURREY DOCKS ------YARD | ---SHEDS

SOLD TO
M----------
per------
Ex. SS.-------
from---------
Rent free till-----

Terms-----

A.B. COX & SON

FIG. 5

(*c*) **Timber for a Specific Purpose.** The chief point to be considered in this case is the question of "lengths." It is important that there shall be as little waste as possible, and to obtain every length required it is worth while to pay a little more or even split the order into two or three parts, and obtain some lengths from one merchant and the remainder from another; the extra cost of repiling is usually charged when timber is purchased in the docks, and the piles have been disturbed to obtain the length required.

(*d*) **Hardwood.** The purchase of hardwood is an extremely difficult task. Experience, together with a good knowledge of the characterization and uses of hardwood, are invaluable. The wastage in hardwood can be anything up to 50 per cent, so every effort should be made to obtain lengths and widths to suit the job in hand. If unsawn logs are purchased, great care should be taken in converting to planks. The heart should be cut into a thick plank 3 in. or 4 in. thick suitable for frames or sills. The widest parts of the log next to the heart should be cut into panels and the remainder into suitable thicknesses for door framing, counter tops, etc. (see Fig. 6). Unsawn logs must be well seasoned before use.

Steel. Steel bars, joists, etc., can either be purchased from "stock" or else procured direct from the rolling mills. Steel from stock is usually about 30s. per ton dearer than steel from the works, and the range of stock lengths is somewhat limited.

In dealing with a contract for steel from the mills, several points should be observed. The total quantity required, the rate of delivery, and the period over which delivery is to be made must be clearly stated. Any extra charges for lengths or small sizes should be clearly set out. The common term, "to approved specifications," should not be accepted without a definite written arrangement as to what constitutes "an approved specification." It is often better to clearly detail the exact requirements.

The testing of steel sometimes causes trouble unless the matter is settled before the signing of the contract. Most steel is supplied in accordance with the British standard specifications for steel. These specifications provide that test pieces shall be tested by an inspector appointed by the buyers. Many steelworkers like to insist that all tests shall be made at the works and some mills charge extra if Lloyd's (the surveyors to Lloyd's Registry) carry out the test.

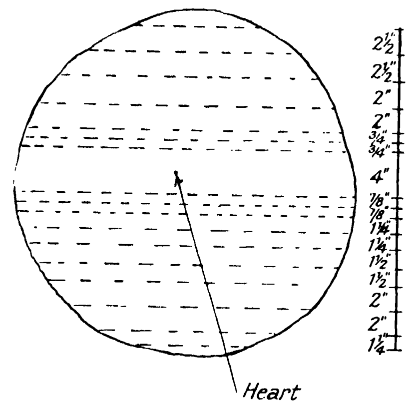


FIG. 6

The following notes on *basis sections* and *extras* may be of interest—

STEEL ROUNDS

		Extra per Ton s.	d.
Size.	⅝ in. diam. up to 2⅞ in. diam.	*Basis*	
	½ in. diam.	5	–
	7/16 in. diam. to ⅜ in. diam.	30	–
	5/16 in. diam. to ¼ in. diam.	50	–
Lengths.	5 ft. to 40 ft.	*Basis*	
	5 ft. to 2 ft.	5	–
	Over 40 ft.: 1s. *per ton per foot extra.*		

STEEL JOISTS

		Extra per Ton s.	d.
Sections.	3 in. deep and 4 in. × 1¾ in.	20	–
	4 in. × 3 in. and 4¾ in. × 1¾ in.	10	–
	5 in. × 3 in. to 14 in. × 6 in. (except 9 in. × 7 in. and 10 in. × 8 in.)	*Basis*	
	9 in. × 7 in.	5	–
	10 in. × 8 in.	10	–
	15 in. and 16 in. deep	5	–
	18 in. and 20 in. deep	10	–
	24 in. deep	20	–

Quality. The following conditions are worked to without extra charge, namely: (1) 28/32 tons tensile. (2) Ordinary tests and inspection, not involving chemical analysis. (3) British Standard Specification No. 15. With few exceptions all British joists are of open hearth steel, basic process. Conditions other than the above must be quoted for specially.

		Extra per Ton s.	d.
Length.	Lengths over 40 ft.—*Per extra foot or part*	1	–
Lengths.	Under 5 ft. to, say, 2 ft.	2s. 6d. to 5s.	
	Cutting "exact" within ⅛ in. plus/minus	5	–
	Oiling or painting, per coat	2	6
	Lots under 4 tons, in addition to extra carriage	5	–
	Rolling Margin: 2½ *per cent under and over.*		

STEEL ANGLES, TEES, CHANNELS, ETC.

(*a*) *Basis Sizes and Extras for Shape*—

	Extra per Ton over Angles s.	d.
Angles 6 to 12 united inches by ¼ in. thick and upwards	*Basis*	
Tees 6 to 10 united inches by 5/16 in. thick and upwards—		
Home Trade	10	–
Export Trade	7	6
Channels, 6 in. to 12 in. deep	5	–
Flats for Home Trade 5 in. × 5/16 in. and thicker	5	
Flats for Export Trade 5 in. × ⅜ in. and thicker	5	–
Bulb Angles 8 in. to 12 in. (united) by ½ in. thick and upwards	*Basis*	
Zeds 3 in. to 7 in. deep	5	–
Round Backed Angles (ordinary)	5	–

(*b*) *Section or Size Extras* (*Additional to* (*a*))—

	Extra per Ton s.	d.
Angles under 6 united inches, per inch or part	7	6
Angles under 6 united inches, per inch or part for export	5	–
Angles over 12 united inches, per inch or part	5	–
Tees under 6 united inches, per inch or part	5	–
Tees over 10 united inches, per inch or part	5	–
Channels 3 in. to 6 in. deep, per inch or part	5	–
Channels over 12 in. to 15 in. deep	5	–
Channels over 15 in. deep, at least	10	–
Flats under 5 in. wide, per inch or part	2	6
Bulb Angles over 12 united inches, per inch or part	5	–
Bulb Angles 4 in. × 2½ in.	15	–
Zeds over 7 in. deep, per inch or part	2	6

(*c*) *Thickness* (*Additional to* (*a*) *and* (*b*))—

	Extra per Ton s.	d.
Angles under ¼ in. thick—		
3/16 in.	10	–
Under 3/16 in.	20	–
Tees under 5/16 in. thick—		
¼ in.	5	–
3/16 in.	10	–
Under 3/16 in.	15	–
Flats under ⅜ in. thick—		
¼ in.	5	–
3/16 in.	10	–
Under 3/16 in.	15	–

(*d*) *Lengths over 40 ft.*—

	Extra per Ton s.	d.
Flats, per foot or part	1	6
Other sections	*Special*	

(*e*) *Lengths under 5 ft. to 2 ft.*—

	s.	d.
Angles, Bulb Angles, Flats, and Zeds	5	–
Tees, Channels, per foot or part	2	6

(*f*) *Cold Straightening*—

	s.	d.
Basis Sizes—		
Channels	2	6
Other sections	3	6

Smaller Sizes: *Either* 5s. *or* 10s. *per ton.*

GAS-FITTING

By R. J. Rogers
Chief Superintendent, Fittings Department, City of Birmingham Gas Department

LESSON IV

PIPING OF BUILDINGS

The improvement and development in the design and efficiency of gas appliances during recent years has led to their adoption in all classes of premises. It is, therefore, necessary that these appliances should be considered when the plans of the premises are being prepared, and provision made for their installation when the building is in a carcass state.

The pipes chiefly used on internal fitting work are *wrought iron* or *compo.* Copper or brass pipe is sometimes used for connecting up gas fires or other apparatus to the internal supply pipe.

Wrought-iron Pipes. Those used for internal supplies are usually of gas quality. For services underground best steam quality pipe should be used.

A very large amount of steel gas pipe is sold, and is often used under the impression that it is wrought iron. Steel tubing is cheaper than wrought iron but does not resist corrosion so well, and it is best to specify that only wrought-iron pipe, or, as it is sometimes termed, *wrought-iron barrel,* manufactured from *puddled iron strip,* be used.

Fittings. The commonest wrought-iron fittings are sockets, diminishers, elbows, tees, crosses, bends, plugs, caps, nipples (preferably space or barrel nipples), long screws, and back nuts or connectors.

Malleable cast-iron fittings are largely used. They are cheaper than wrought iron, and if of good quality are quite satisfactory.

Jointing of Iron Pipes. Iron pipes and fittings are threaded with a special Whitworth thread known as *gas thread.* The size of iron pipes is designated by the diameter of the bore. Pipes of less than ½ in. bore should not be used for the conveyance of gas in houses. Pipes are jointed together by sockets, the thread having first been smeared with a mixture of red or white lead and boiled oil of the consistency of thick paint. Graphite and several of the proprietary jointing materials on the market are quite satisfactory, but ordinary paint should not be used for jointing.

Tools for Iron Pipes. The following are the tools most commonly used—

Stocks and dies, or screwing machine, for threading pipe.

Three-wheeled cutters, or hacksaw.

Portable vice.

Tongs, footprints, or pliers.

Small tools, such as saw, chisel, gouge, augur, drills, etc.

Composition Pipe. Compo pipe is made of an alloy of lead and tin. The admixture of tin allows a thinner pipe wall to be used than would be the case with pure lead. It tends to make the pipe more rigid and less porous. Compo pipe can be very easily bent, and therefore

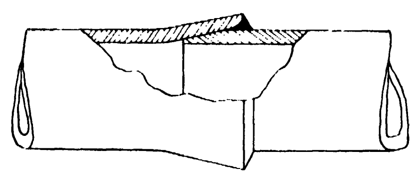


Fig. 6. Straight Compo Joint

obviates the use of various fittings. It is largely used for making the bend connections to meters of the smaller sizes. It presents a smooth surface to the flow of gas, and is not subject to corrosion.

The chief disadvantage of using compo pipe for gas supplies is its tendency to sag, and so allow the accumulation of moisture from condensation. Also, nails are apt to be driven into it, and mice and rats have a habit of nibbling through it. If it is used, copper or brass fittings must be soldered to it to enable pendants or brackets to be attached. Straight and tee joints are made by tan-pinning out, chamfering off the pipe (Fig. 6), and soldering with best tinmen's solder, composed of 60 per cent tin and 40 per cent lead.

Remember that the designated size of compo and lead pipe is the external diameter, not the bore, as is the case with iron gas supply pipes.

The Fitting of Iron Pipes. The following general rules should be observed when fitting up premises with iron gas supply pipes—

1. Pipes must be laid with a definite fall

towards a syphon in which condensed moisture may collect. This syphon should be left in an accessible position near the meter, a sett being

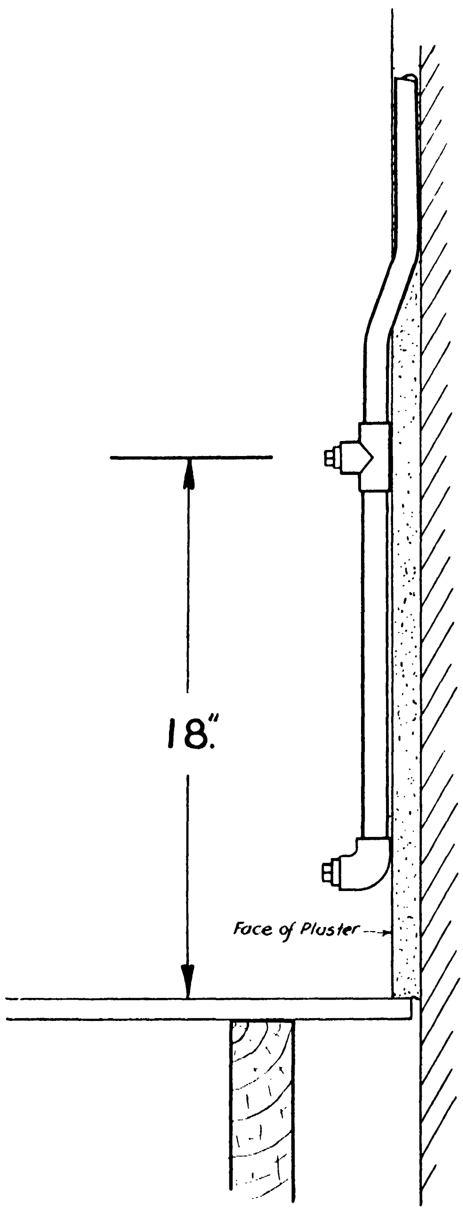


FIG. 7. RISING MAIN FROM METER POSITION

made on the rising main (Fig. 7), and a tee left about 18 in. from the floor for connection to meter. If it is impossible to lay all pipes with a fall to this main syphon, another must be left in an accessible position.

2. Keep pipes well away from all electric cables.

3. Do not notch joists more than 3 ft. away from supporting walls, and do not cut out any more of the joist than is necessary to accommodate the pipe.

4. Do not lay pipes in the plaster of ceilings.

5. Leave a plugged tee, not an elbow, on the bottom of all risers to brackets. Properly plug

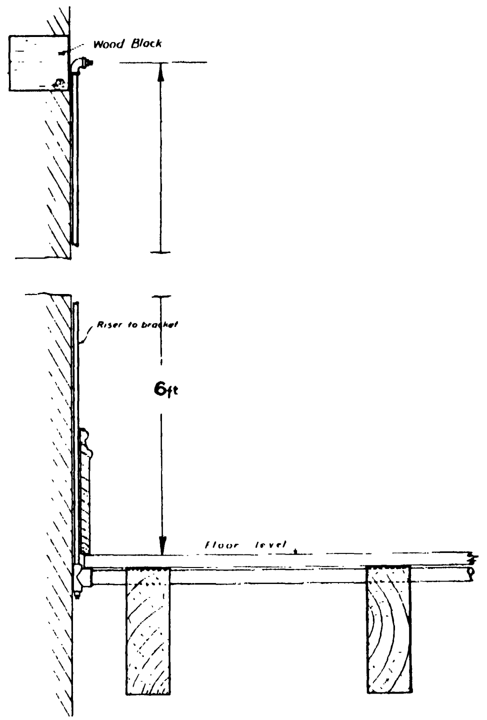


FIG. 8. BRACKET SUPPLY

the wall with a wood block on to which the pattress block is to be screwed (Fig. 8).

6. Pendant drops should project $1\frac{1}{2}$ in. below the under surface of the joist to allow for plastering. Where the pendant position comes between the joists, a wooden bridging piece must be provided to take the weight of the fitting, and keep the drop in a vertical position (Fig. 9).

7. Long screws and back nuts should be left in convenient positions for disconnecting purposes.

Sizes of Pipes. In deciding on the sizes of pipes, allowance should be made for possible extensions. The tendency is frequently to lay pipes too small for requirements.

The following general rules should be borne in mind—

1. A $\frac{1}{4}$ in. pipe is sufficient for one bracket light; to supply two brackets a $\frac{3}{8}$ in. pipe should be run.
2. Never lay a pipe of less than $\frac{1}{2}$ in. diameter under floor boards.
3. Not less than $\frac{1}{2}$ in. supply should be laid to every gas fire or wash boiler.
4. A $\frac{3}{4}$ in. pipe will supply a cooker or two gas fires.
5. No rising main from meter should be less than $\frac{3}{4}$ in.

Typical Plans. The application of the foregoing general rules will be seen in the fitting up of the residence, the ground floor and upper floor plans of which are shown in Figs. 10 and 11.

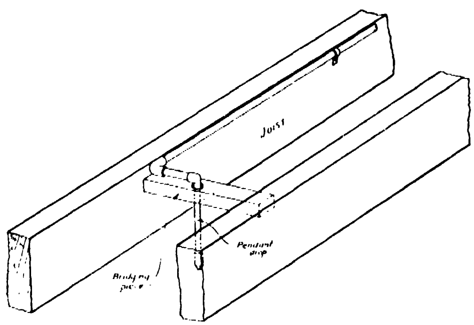
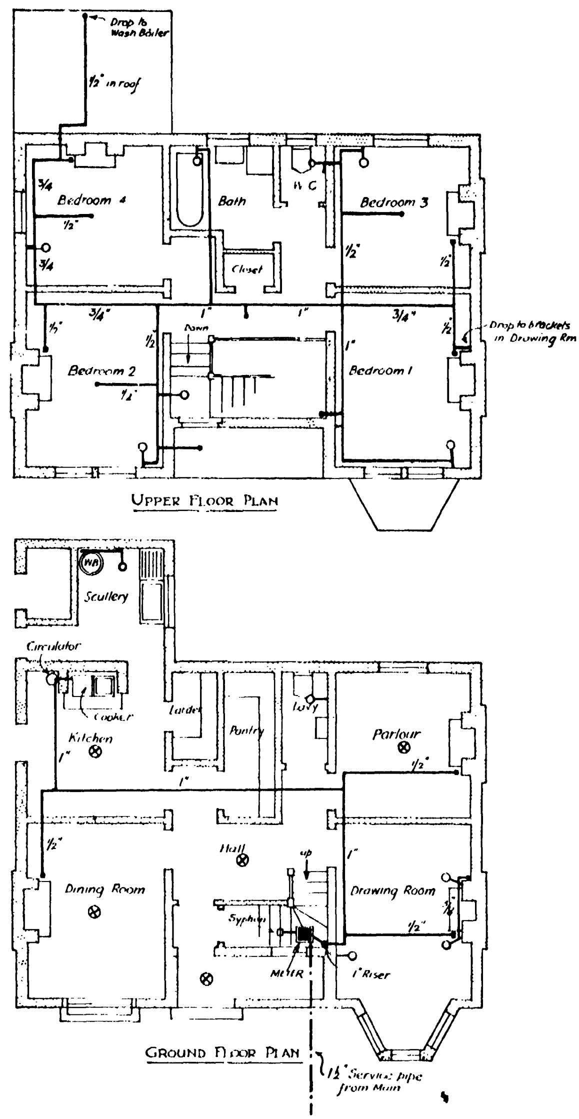


FIG. 9. BRIDGING PIECE FOR PENDANT

The position for the meter is usually arranged by the architect or builder with the gas undertaking concerned. The apparatus required and the positions for lights, etc., are matters for the architect or his client, and this information must be obtained by the gasfitter before starting on the work. The first things to decide on are the runs and sizes of pipes, bearing in mind the rules already given. In the example given, in addition to the usual lighting points, provision has to be made for gas fires in each of four bedrooms and three rooms downstairs, also a cooking stove, hot-water circulator, and a wash boiler.

In this case we should recommend that two main pipes be run from the meter, each of 1 in diameter, the first clipped to the underside of the joists carrying the ground floor, to supply the cooker and circulator in the kitchen and the gas fires on the ground floor; the second 1 in. main rising to the chamber floor level and running along and across the top of the joists, these being notched where necessary. This pipe will supply the lighting points and the gas fires in the bedrooms. It will be noted that the size of pipe is diminished as the various points are taken off, but that no horizontal pipe is less than $\frac{1}{2}$ in. diameter.

The wash boiler is more conveniently taken off



FIGS. 10 AND 11. LAYOUT OF PIPES IN VILLA

the chamber floor system of pipes, and the scullery bracket off the supply to the wash boiler. The pipes should be given a slight fall back to the main riser in every case, and a length of pipe (syphon) left under the hollow floor near the meter to collect any condensation from the pipes. Arrangements should be made for the carpenter to leave a section of board

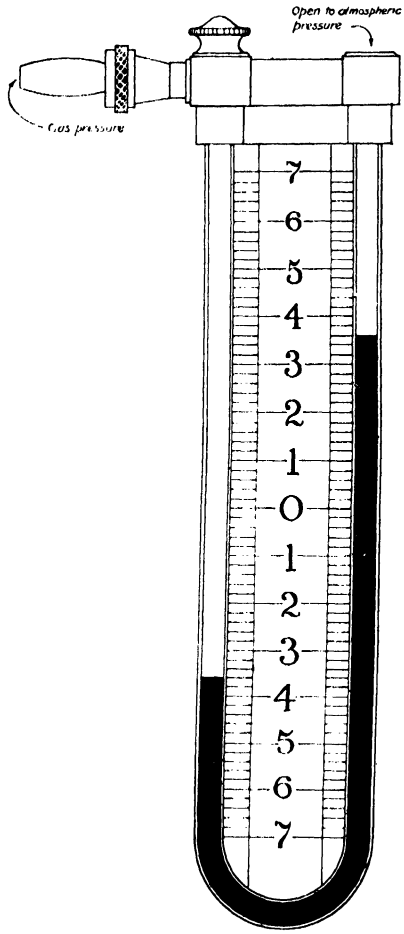


FIG. 12. PRESSURE GAUGE

screwed down over the syphon and also over the gas fire points, pendant drops, etc.

The whole of the pipes should be painted some days before being fitted, and touched up afterwards as required.

Testing of Installation. Where alterations or extensions have been made in a house already fitted for gas, the system where completed is tested by a gasfitter's **U**-shaped pressure gauge (Fig. 12).

When, however, gas is not available—as is often the case with new installations—the following method will be found satisfactory. An ordinary pressure gauge containing mercury instead of water is fixed in a convenient position (say, the bracket point in the scullery). The attachment shown in Fig. 13, which consists of

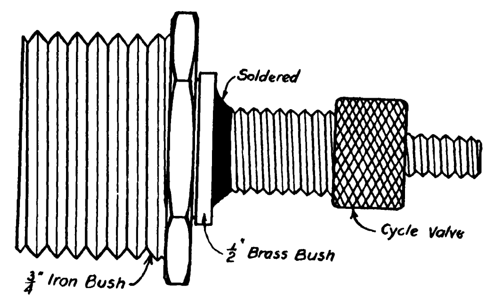


FIG. 13. FITTING FOR ATTACHMENT OF CYCLE PUMP

a bush piece with an ordinary cycle tube valve soldered in it, is then fixed at a point some distance away (say, on the tee left for the meter). These connections should be carefully made and care taken to see that the gauge is sound. All other positions are then properly plugged or capped.

By means of a cycle pump the pressure of air in the pipes is slowly raised until the difference of level of the mercury in the two arms of the gauge is about 4 in. The pressure in the pipes will then be roughly 2 lb. per sq. in. The gauge is now watched. If there is no alteration in the level of the mercury after five minutes, the installation may be passed as sound. If there is a leakage the pressure will fall.

BUILDING CALCULATIONS

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LESSON III

FACTORS

14. The numbers that will divide into another number, without leaving a remainder, are called **factors**; 1, 2, 4, and 8 are factors of 8.

A *common factor* is a number that is a factor of two numbers; 2 is a common factor of 4 and 6.

A *prime* is a number which has no factor except itself and 1, therefore a *prime factor* is a factor which is also a prime.

Example. Find the prime factors of 2,310.

Solution.

```
2|2310
 3|1155
  5|385
   7|77
     11
```

Hint. Commence dividing by the smallest factor first.

Hence the prime factors of 2,310 are 2, 3, 5, 7, and 11, because each of these numbers contains no factor, except itself and 1.

15. **Highest Common Factor (H.C.F.).** The *highest common factor*, or *greatest common measure*, of two or more numbers is the *greatest* number that will divide into them *without a remainder*; i.e. 2, 3, and 6 are *common factors* of 12 and 18, but 6 is the *highest* and is the H.C.F. of 12 and 18.

Example. Find the H.C.F. of 44, 66, and 176.

Solution.

$44 = 2 \times 2 \times 11$, which are the prime factors.
$66 = 2 \times 3 \times 11$
$176 = 2 \times 2 \times 2 \times 2 \times 11$

∴ The H.C.F. $= 2 \times 11 = 22$, because only *one* 2 and 11 are common to the three numbers.

When the numbers are difficult to factorize, the H.C.F. may be found by the "long" method. First remove any factor evidently common to the numbers. If there are more than two numbers, find the H.C.F. of any two, and then of this H.C.F. and another number. The method is illustrated in the following example—

Example. Find the H.C.F. of 1,311, 1,610, and 1,978.

Solution.

```
1311)1978(1
     1311
      667)1311(1
           667
           644)667(1
               644
                23)644(28
                   46
                   184
                   184
```

∴ The H.C.F. of 1,311 and 1,978 is 23.

Explanation. (1) Select any two of the given numbers and see how many times the smaller number will go into the larger number. Find the remainder as in ordinary division. (2) Repeat for the first remainder into the smaller number. (3) Repeat the process, until there is *no remainder*, then the *last divisor*, which is also the last remainder, is the H.C.F. (4) Now find the H.C.F. of the H.C.F. just found and the remaining number—

```
23)1610(70
   161
     0
```

In this case the first H.C.F. divides into the third number; hence 23 is the H.C.F. of 1,311, 1,610, and 1,978.

The following will probably make the method more clear. Let S = smaller number, L = larger number, and R = the various remainders, then—

```
S)L    (x
  S × x
  R₁ )S    (y
      R₁ × y
      R₂ )R₁   (z
          R₂ × z
           ...
```

Then R_2 is the H.C.F. of S and L

16. **Least Common Multiple (L.C.M.).** The L.C.M. of two or more numbers is the *smallest* number which is divisible by each of the numbers, *without a remainder*. Thus 24 is divisible by 4 and 6, but 12 is the smallest number divisible by 4 and 6, therefore 12 is the L.C.M.

To find the L.C.M. of several numbers, first find the prime factors.

EXAMPLE. Find the L.C.M. of 30, 36, and 48.

SOLUTION.

$$30 = 2 \times 3 \times 5$$
$$36 = 2 \times 2 \times 3 \times 3$$
$$48 = 2 \times 2 \times 2 \times 2 \times 3$$

$\therefore$ the L.C.M. $= 2 \times 2 \times 2 \times 2 \times 3 \times 3 \times 5 = 720.$

EXPLANATION. Take the greatest number of *twos* from any set of factors, then the greatest number of *threes*, and so on, and then find the continued product.

720 is the L.C.M. of 30, 36, and 48, because it is the smallest number exactly divisible by 30, 36, and 48.

When the factors are difficult to find, proceed as follows.

Find the L.C.M. of 56, 70, 84, and 728—

2	56, 70, 84, 728
2	28, 35, 42, 364
2	14, 35, 21, 182
7	7, 35, 21, 91
	1, 5, 3, 13

If at any stage a number is not divisible by the divisor, bring the number down without any change.

The L.C.M. is

$2 \times 2 \times 2 \times 7 \times 5 \times 3 \times 13 = 10{,}920$ *Ans.*

The L.C.M. of two numbers is equal to their product divided by their H.C.F.

$\therefore$ L.C.M. of 56 and 70 =

$$= \frac{56 \times 70}{\text{H.C.F}} = \frac{56 \times 70}{14} = 280.$$

17. To find the H.C.F. of fractions, we find the H.C.F. of the numerators for a new numerator, and the L.C.M. of the denominator for a new denominator.

Hence the H.C.F. of—

$$\frac{17}{9}, \frac{34}{3}, \frac{51}{8} \text{ and } \frac{17}{12}, \text{ is } \frac{17}{72},$$

because 17 is the H.C.F. of the numerators, and 72 is the L.C.M. of the denominators.

FRACTIONS

18. A fraction is a part of a whole. For instance—

1 in. is $\frac{1}{12}$th of a foot.
2s. 6d. is $\frac{1}{8}$th of a £.
6d. is $\frac{1}{2}$ of one shilling.

The *unit* of our calculation is divided into a number of equal parts, and the *fraction* tells us how many of those equal parts are being used.

The top figure is called the *numerator*, and the bottom figure the *denominator*; hence, if we divide one ton into 20 cwt. and take 7 cwt., the fraction will be—

$$\frac{7}{20} \begin{array}{l} = \text{numerator} \\ = \text{denominator,} \end{array}$$

which means $\frac{7}{20}$ of one ton.

When the denominator is 10, or 100, or 1,000, etc., it is omitted, and the numerator becomes a decimal fraction, i.e.—

$$\frac{145}{1000} = \cdot 145, \quad \frac{14}{100} = \cdot 14, \quad \frac{1}{10} = \cdot 1.$$

All other fractions are vulgar fractions, and building calculations generally involve this kind of fraction.

19. **Addition of Vulgar Fractions.** Add together $\frac{1}{2}, \frac{3}{4}, \frac{1}{8}$.

First find a denominator common to all the fractions, i.e. the L.C.M. of the denominators; in this case it is 8. Then the fractions are—

$$\frac{4}{8}, \frac{6}{8}, \frac{1}{8} = \frac{4+6+1}{8} = \frac{11}{8} = 1\tfrac{3}{8}$$

Note that the value of a fraction is not altered when we multiply top and bottom by the same number.

The three fractions are *proper* fractions, because the numerator is less than the denominator, but when they are added together the result is an *improper* fraction, because the numerator is greater than the denominator, i.e. $\frac{11}{8}$. The final answer, $1\frac{3}{8}$, is a mixed number, because it is a combination of a unit and a part of a unit.

20. **Subtraction.** From $\frac{7}{8}$ take $\frac{5}{32}$.

Find the common denominator, which is 32.

Then the fractions are $\frac{28}{32}$ and $\frac{5}{32}$; therefore the answer is—

$$\frac{28-5}{32} = \frac{23}{32}$$

EXAMPLE. Find the result of $\frac{5}{8} + \frac{3}{16} + \frac{7}{12} - \frac{1}{4} - \frac{5}{16}$.

SOLUTION.

$$\frac{30+9+28-12-15}{48} = \frac{40}{48} = \frac{5}{6} \textit{ Ans.}$$

EXPLANATION. (1) Find the common denominator. (2) See how many times the denominator of each fraction will divide into the common denominator, then multiply the numerator by this number; i.e. for the fraction $\frac{5}{8}$, 8 goes into 48 six times, $\therefore 6 \times 5 = 30$,

∴ 30 is the numerator for the first fraction. (3) Add together the numerators with a plus sign in front, and then those with a minus sign in front, and see which is the greater; the difference is the numerator of the answer. If the minus quantities were the greater, then the answer would be a minus quantity.

21. **Multiplication.** Multiply together the numerators for a new numerator.

Multiply together the denominators for a new denominator.

$$\frac{5}{8} \times \frac{3}{4} \times \frac{1}{2} = \frac{15}{64} \textit{ Ans.}$$

Division. Turn the divisor fraction upside down, and then proceed as in multiplication—

$$\frac{7}{8} \div \frac{3}{4} = \frac{\frac{7}{8}}{\frac{3}{4}} = \frac{7 \times 4}{8 \times 3} = \frac{7}{8} \times \frac{4}{3} = \frac{28}{24}$$

$$= \frac{7}{6}, = 1\tfrac{1}{6} \textit{ Ans.}$$

Therefore, we multiply the extremes for a new numerator, and the means, or insides, for a new denominator.

Note that when we divide by a fraction we increase the value, i.e.—

$$\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}, \text{ but } \frac{1}{2} \div \frac{1}{2} = \frac{1}{2} \times \frac{2}{1} = 1.$$

When the fractions are connected together by multiplication and division signs, we should *cancel* (or simplify) before finding the result; that is, we divide numerator and denominator by a common factor—

$$\frac{3}{4} \times \frac{4}{12} = \frac{\not{3} \times \not{4}}{\not{4} \times \not{12}} = \tfrac{1}{4} \textit{ Ans.}$$
$$4$$

because the fractions could be arranged as

$$\frac{3 \times 4}{12 \times 4} = \frac{1}{4} \times \frac{1}{1} = \frac{1}{4}.$$

22. **Conversion of Decimal Fractions to Vulgar Fractions.** Place the decimal quantity over a multiple of 10, so that the denominator has one more digit than the numerator, then simplify, or cancel, if possible—

$$\cdot125 = \frac{125}{1000} = \frac{1}{8} \cdot \quad \cdot75 = \frac{75}{100} = \frac{3}{4}.$$

Conversion of Vulgar Fractions to Decimal Fractions. Divide the numerator by the denominator.

The student should work out the decimal equivalents of the fractions common to building calculations, such as $\frac{1}{8}$, $\frac{5}{8}$, $\frac{3}{16}$, etc., and memorize the results; or memorize for $\frac{1}{8}$ and $\frac{1}{16}$, and multiply the decimal equivalent by the numerator of the vulgar fraction—

$$\tfrac{1}{8} = \cdot125, \therefore \tfrac{5}{8} = \cdot125 \times 5 = \cdot625$$

HINTS. (1) Always convert improper fractions to mixed numbers before working, and add together (or subtract) the whole numbers separately from the fractions. (2) Reduce all proper fractions to their lowest terms (cancel), before working (3) Keep the common denominator in factors until the last step.

EXAMPLE. Add together $2\frac{3}{4}$, $\frac{7}{6}$, $3\frac{1}{10}$, $4\frac{4}{15}$.

SOLUTION. Converting and cancelling, we have—

$$2\tfrac{3}{4},\ 1\tfrac{1}{6},\ 3\tfrac{1}{10},\ 4\tfrac{4}{15}$$
$$= 2 + 1 + 3 + 4 + \tfrac{3}{4} + \tfrac{1}{6} + \tfrac{1}{10} + \tfrac{4}{15}$$
$$= 10 + \frac{45 + 10 + 6 + 16}{2 \times 2 \times 3 \times 5}$$
$$= 10 + \tfrac{77}{60} = 11\tfrac{17}{60} \textit{ Ans.}$$

EXPLANATION. $\frac{3}{4} = \frac{3 \times 15}{2 \times 2 \times 3 \times 5}$. Take the factors of the common denominator that are not contained in the denominator of the fraction, in this case 3×5, then multiply the numerator of the fraction by these factors, i.e. $3 \times (3 \times 5) = 45$. Place the 45 in the numerator. Repeat for each fraction.

Recurring Decimals are those decimals which continue indefinitely. For example—

$\frac{1}{3} = \cdot333 \ldots$ and is denoted by $\cdot\dot{3}$

$\frac{2}{3} = \cdot666 \ldots$ and is denoted by $\cdot\dot{6}$

If the decimal recurs in groups, as ·407407407 . . ., we place a dot over the first and last figures of the recurring part; therefore—

$$\cdot407407 \ldots = \cdot\dot{4}0\dot{7}$$

When we require a recurring decimal as a vulgar fraction we place the recurring part over as many *nines* as there are figures in the numerator; therefore—

$$\cdot\dot{3} = \frac{3}{9},\ \cdot\dot{4}0\dot{7} = \frac{407}{999}.$$

EXERCISE III

1. What is the length of steel rod required, to cut the following lengths, which are in inches? Allow $\frac{1}{8}$ in. per cut. $2\frac{1}{15}$, $7\frac{1}{12}$, $10\frac{1}{2}$, $14\frac{2}{3}$.

2. The area of a circle is given by $\frac{22}{7} \times R \times R$. What is the weight of a circular slab of stone $1\frac{1}{2}$ ft. thick, when $R = 3\frac{1}{4}$ ft.? Weight of stone $= 1\frac{1}{4}$ cwt. per cubic foot.

3. Find the value of $2\frac{5}{16} + 3\frac{1}{7} + 1\frac{11}{14} + 2\frac{2}{3} - 3\frac{1}{21}$.

ANSWERS TO EXERCISE II

(1) $3\frac{7}{8}$ loads, approx.

(2) Opening casements = 14·15 sq. ft.

(3) 4,865.

SUPERINTENDENCE

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PART V

OFFICE EQUIPMENT AND METHODS

Duties of Clerk of Works. The general practice governing the circumstances, qualifications, and appointment of both types of building superintendent have been explained. There will now follow a description of the duties of a clerk of works on taking up an appointment.

A typical specification clause referring to his duties is the following –

The clerk of works shall be considered to act solely as an inspector and under the architect, and the contractor shall afford him every facility for examining the works and materials.

This, it will be seen, does not give him direct authority to demand that any particular operation shall be performed or not performed, or materials used or not used. Theoretically his duty is to see that the intentions of the drawings, specifications, and other documents forming part of the contract are observed, and if they are not to report to that effect to the architect, whose decision is final.

In actual practice, unless there is something radically wrong with the parties concerned, the position is otherwise. The clerk of works is treated as the architect's representative on the works, in that any reasonable demand on his part, respecting the interpretation of the contract, is regarded as being the demand of the architect. The contractor's representative can easily judge whether an appeal to the architect direct over the head of the clerk of works, when the latter states his attitude, would produce an alteration. If the demand is a fair one, it obviously would not, hence the custom of acknowledging the clerk of works' authority. There are many small points which the architect settles by direct instructions when visiting the job. Here the clerk of works conveys the instructions to the contractors, perhaps a written explanation, perhaps a drawing, and such instructions are accepted as being from the architects.

The clerk of works has no authority to incur extra expenditure, and should carefully refrain from doing this unless the circumstances are exceptional. When a failure takes place, such as a settlement, and immediate action is required, it is up to the clerk of works to undertake the responsibility for instructions. Perhaps a job has to be finished quickly ; an unexpected point arises involving expenditure, which, if referred to the architect, means loss of valuable time. This, again, is a case where the clerk of works must assume a position which lies outside his authority. Such occurrences, however, are exceptional ; on all ordinary occasions he should not incur extra expenditure without the implied or direct instructions of his superiors, which the latter afterwards confirm.

The Office. Another clause in a specification refers to the clerk of works' office, etc. It is usually on the following lines, although there does not appear to be any recognized standard—

The contractor shall erect and keep in repair a proper office for the use of the clerk of works. It is to be fitted up by the contractor, with a desk with large drawers for drawings, and small drawers for papers, etc., and with locks and keys ; also with a large table and chairs, drawing board, T-square, etc., and other necessary conveniences for keeping and preparing drawings and for writing. The contractor is to provide a stove and light, and necessary attendance.

Sometimes the size of the office is stated – such as 80 ft. super, and the contractor may be required to provide stationery. On the other hand, this clause may be a bare reference to a suitable office and attendance.

These two clauses, one defining his status, and one the equipment to which he is entitled, define the position of the clerk of works under the contract. Before paying his first visit to the job, he will probably be supplied with a set of $\frac{1}{8}$ in. scale drawings, any $\frac{1}{2}$ in. scale or full-size details that may be available at the time, and a copy of the specification. He may also receive an unpriced set of bills of quantities, weekly report forms, and be given instructions to purchase stationery, etc., as required. He usually has his own 5-ft. rule, a steel tape, and some drawing instruments, and it is desirable that he should have his own dumpy level. As little can be done beyond a general survey of the site, and a first inspection of the drawings, etc., without some stationery, it is advisable to obtain this without delay.

Stationery, etc. A diary will be required; a ruled foolscap book is better than an ordinary printed foolscap diary for this purpose. Entries vary in length, and increase as the building rises. A squared-paper notebook for sketches, costing about 4s. 6d., an ordinary notebook with stiff covers, opening lengthways, at 2s., a surveyor's dimension book at about 3s., some plain and ruled foolscap, detail paper for drawing (supplied by drawing office materials' firms at about 3d. per yard), thin typewriting paper for rough notes, drawing pins, rubber, pencils, and similar minor accessories will nearly complete his outfit. Receipted bills should be obtained with these purchases, as the clerk of works will be refunded for his outlay by the employer.

For letter writing, a duplicate book, quarto size, with numbered pages, and the name of the job across the top, and "Clerks of Works' Office" and address in the right-hand top corner, is as good a plan as any. Copies are kept together, and if indexed can be found without difficulty. A fountain pen with a hard nib will leave a clear impression on the duplicate sheet. Some memo paper, with a similar printed head line, is also useful for correspondence not requiring copies, such as acknowledgments.

Correspondence received is best kept in files; a double sheet of foolscap answers the purpose. On the outside the name of the sender is written—architect, contractor, surveyor, the names of sub-contractors, etc. Miscellaneous notes, calculations, etc., should be collected and made easily accessible in the same way. If the list of architect's drawings received is scheduled—number of drawing, subject, and scale—and the schedule is pinned to the wall, it is readily available for reference when a particular drawing is required. As far as possible, of course, these drawings should be kept in their right order; on them the date of receipt should be pencilled.

Diary. It has been mentioned that a convenient form of diary is a foolscap book. This should have a pencilled line drawn down the left-hand side, far enough from the edge to allow room for the date and a description of the paragraphs. The number of items to be recorded will depend on the size of the job and the requirements of the architects. The diary is a record of progress, and all events and particulars connected therewith should be inserted. In the event of an arbitration or controversy, it forms part of the evidence, and great care must be taken to explain clearly and in detail any matter that is likely to be of importance. It is constantly needed throughout the job for information as to past events, and forms the basis of the weekly reports. The following extract from a mythical diary illustrates the method—

June 21st .	Weather. Showery. 2 hours lost.
Men . .	30 labs., 19 bklyrs., 12 carp., 4 plbrs., 4 plbrs.' mates, 6 plas., 4 scaff., 2 Mortise, Tenon & Co., 4 Bibcock & Son.
Visitors .	Architect: Mr. Gaskin: Mr. Pinn (Mortise, Tenon & Co)
Drgs recd. .	Nos. 81, 82. From Bibcock & Son. Nos. 123/5, and 6.
Materials .	6 yd. sand; steel windows for basement; 3,000 red facings; 4 y.c. chalk lime; 2 tons P. cement.
Work . .	North Wing. Gd. Rendering ceiling, Room 2; setting walls, Corridors and Lobby; hanging sashes, Rooms 4-9.
	1st. Laying floors, Bed. R. 6; fixing grates and building m.p. Sitting R.
	External. Pointing W. wall.
	East Wing. 2nd. Raising bkwk.: S. and W. external walls; centering for 3rd floor over annexe.
	Drains. Excavating for connection to sewer.
Architect's instns.—	
Ironmongery	Locks to be separately suited for each wing. Front door key to pass West Gate. Basement on master only. Messrs. Box Staples' representative to visit site and obtain particulars.
Hearth tiles.	Hearth tiles to be rejected on account of colour. Makers to send further sample for approval.
Roof light .	Roof light opening in East Wing Annexe flat to be increased in size to 6 ft. 6 in. × 7 ft. 3 in. Contractors have been informed.
Panelling .	Mr. Pinn took dimensions of Entrance Hall panelling. He stated that his tender did not provide for painting back; architect instructed that this must be done. Delivery promised on 18th July.

Usually, it is not worth while to mention in detail the work of electricians, heating engineers, or plumbers, when pipe running is being done. A lot of ground can be covered in a day, and the description would have to include the names of all sorts of rooms, corridors, etc. It will be sufficient if occasional mention is made of these activities, such as the completion of a floor or section. On an ordinary contract it is not often necessary to give exact details of quantities of materials received. The only reason for mentioning the subject at all is that the record shows

BARLEY PARKS HYDRO

Clerk of Works Report for Week ending .... June 23rd, 19 - .... No. 29.

NO. OF MEN EMPLOYED	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	DRAWINGS RECEIVED
Labourers	27	30	29	30	30	30	Nos. 81, 82, 87
Scaffolders	4	4	4	4	4	3	
Bricklayers	20	20	19	19	19	19	
Masons	2	2	—		—	—	From Bibcock & Son—
Tilers							Nos. 123/5–6
Carpenters	12	12	12	12	14	14	
Joiners							
Plasterers	6	6	6	6	6	6	
Plumbers	4	4	4	4	4	4	
,, Mates	4	4	4	4	4	4	
Painters and Glaziers							
Watchman	1	1	1	1	1	1	
SUB-CONTRACTORS							**DRAWINGS REQUIRED**
Mortise, Tenon & Co.	-	-	2	2	2	-	Details of dormer to Lavy., E.Wg.
Bibcock & Son	4	4	4	4	4	2	
Black Asphalt Co	3	3	-	—	-	-	
				2 hours lost			
WEATHER	←	Fine	→	Showery ←	— Fine —	→	
VISITORS	Architect	Mr. T. Smith		Architect Mr. Gaskin		Sir E. Knight	

MATERIALS DELIVERED.

18 y.c. sand; 5,000 red facings; 6 tons P. cement; 18 y.c. ballast; 4 y.c. chalk lime; 2 y.c. grey lime; drain pipes; steel windows for Baset.; 2 baths; 6 squares 1 in. T. and G. flooring.

STATE OF WORKS.

MAIN BLOCK. **N. Wing.** BASET. Plastering ceilings completed.

GD. Plastering: completed in Rooms, 1, 3, 4, and Lavy.; part do. in Corridors and Lobby; Rooms 2 and 5 rendered; Kitchen floor screeded. Sashes hung on N. and E. sides.

1ST. Laying wood floors completed except in Store Room; sash hanging completed; wall tiling commenced in Lavy. and w.c.'s; m.p. fixed in Sitting R. and Library; balusters fixed, 1st to 2nd floors.

2ND. Fixing locks in progress.

EXTERNAL. Pointing completed except plinth; all R.W.P. fixed.

East Wing. GD. As Report 28.

1ST. Breeze partitions fixed in Bed R. 4–10; stair concrete, 1st to 2nd floor completed.

2ND. Bkwk. above floor level: N. external wall, 9 ft.; W. and S. do., 7 ft. 3 in.; E. do., 6 ft.; Annexe, to ceiling level; centering for Annexe 3rd floor fixed.

GARAGE. Excavation about half completed.

DRAINS. Excavation for connection from interceptor M.H. to sewer in progress.

Signature.............. J. VANCE, *C. of W.*..............

A TYPICAL REPORT SHEET

whether proper progress is being made. If the contract is not completed within the agreed period, the question of enforcing the penalty clause may arise. The record in the diary of materials received would show whether any delay arose on account of belated delivery on the part of the contractor or the sub-contractors.

The diary can be written up either on the evening of the day recorded or the next morning. The latter is usually the more convenient time, and the entries are made from rough notes. The foreman would supply information about men employed and materials received; the clerk of works would check these particulars occasionally.

Weekly Report. The weekly report sheets may be provided by the architect, or the clerk of works may be requested to obtain them himself. The items include men employed in each trade, and by sub-contractors, drawings received and required, names of principal visitors, weather, progress of works, and, perhaps, queries. The queries may be either entered on the report sheet or stated in a letter; a third way is to place them on the left-hand half of a sheet of foolscap, the replies being written on the right. The architect will state which method he prefers.

A typical report sheet is given on page 340.

Filling in a Report Sheet. Everything is tabulated except the progress of works. As the essential requirement is to arrange the description of this progress so that, while being as brief as possible, it is lucid, a definite method is necessary. The obvious grouping is in blocks or sections, floors, roofs, and external work. Walls will be located by the points of the compass, or the names of adjacent rooms, and the interior work by the names or numbers of rooms, etc., given on the plans. When the building is rising, it is convenient to speak of constructional floor work as being "over dining hall" or wherever it may be. Drains will be located by inspection chamber numbers—"from R.W. gulley to M.H. 6"; staircases by their position—"Main," "Left," "East," and so on. The name of the wing or block can be made prominent by printing it, and the description of the floor—whether ground, first, second, etc. —by underlining. Examples are "NORTH WARD BLOCK. Gd.," or "WEST BLOCK Front wing, 2nd."

Methods like these enable the architect to grasp readily the description of works in progress, and save a lot of irritation.

It is not necessary to give each week a full description of the condition of the job. The report sheets must be regarded as a series which have to be read as a whole. Each sheet will record progress during the current week; if nothing has been done on a floor or section, the entry will be "As Report No. . . . ." If the statement is made that the rafters are fixed on a roof, a parapet wall built, or chimney pots fixed, it is obvious that all walling lower down has been completed constructionally.

The most readily understood arrangement is to write on a small scale plan the conditions of different parts; a scale of $\frac{1}{16}$ in. to the foot is large enough. The use of coloured pencils is of assistance, all the walls at a particular level being coloured one tint, and those at other stages, other tints. Floors and roofs can be hatched in. Some kind of description would have to be provided; the advantage of the different colours is that the eye takes in the situation more easily.

Usually, the clerk of works has no time to prepare these plans, which need be line diagrams only, except at infrequent intervals. The written record has to be relied upon. Sometimes, however, on large jobs, prints are supplied by the architect which the clerk of works deals with in the manner that has been explained above; but, of course, many particulars relating to finishings cannot be conveyed except in writing.

Queries must be clearly stated; the best plan is to draft them first, and illustrate where necessary by intelligible sketches or drawings. When the inquiry relates to a piece of work in a particular position, a clause in the specification, or a matter which has already been the subject of correspondence, clear references should be given. In the first case, a sketch or drawing is nearly always required; drawing is the language of construction. If the architect frequently visits the job, queries can be collected on a sheet of foolscap, and probably be settled in the clerk of works' office. On country jobs his visits are fewer, and many things of comparatively minor importance have to be dealt with through the post.

BUILDER'S GEOMETRY

By Richard Greenhalgh, A.I.Struct.E
Honours Medallist in Geometry

LESSON VI

TANGENTIAL ARCS—ARCHES

An important rule to bear in mind when dealing with problems involving circles in contact, or curves made of tangential arcs, is as follows: *If two circles touch each other, then the line joining their centres passes through the point of contact.*

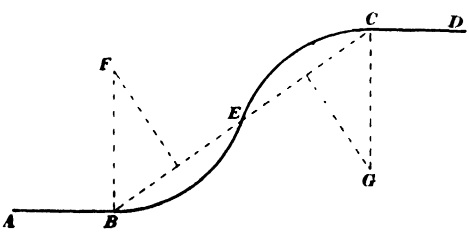

FIG. 57. TANGENTIAL PATHS

Suppose two straight paths, *AB* and *CD*, have to be joined tangentially by a curved path between the point *B* and *C*.

Join *B* to *C* and bisect *BC*, giving point *E*. Bisect *BE* by a line at right angles, and draw a line at right angles to *AB* from *B*. These two lines meet at *F*, which is the required centre for the arc *BE*. The centre *G* is similarly obtained. If the two centres *F* and *G* are joined, it will be seen that line *FG* passes through the junction of the two arcs.

Simple Approximate Ellipse. Set out the major and minor axes to the required dimensions, as shown in Fig. 58, and describe circles on each half of the major axis. Mark the radius of these circles from the top of the minor axis, and join the point *A* thus obtained to the centre *B* of one of the circles. The point *C*, where the bisector of *AB* cuts the centre line, gives the centre for the top part of the ellipse. Note that *CB* produced passes through the junction of the two arcs.

Elliptical Brick Arch. If a true elliptical curve were used for a brick arch, every brick (or pair of bricks) would be of different shape, and would require a separate pattern to cut or mould it. For small arches, the method given in the previous example would be fairly satisfactory, and only two patterns, or *templets*, would be necessary, because there are only two curvatures in the arch.

For larger or better work, a closer approximation to the true curve is desirable, and the method shown in Fig. 59 is often adopted. First, obtain two points on the true curve, as shown at the left-hand side of the illustration. To do this construct the rectangle *AEDF* on half the major axis. Divide *AF* and *AE* into three equal parts. Draw radial lines $1D$ and $2D$. Make *EC* equal to *DE*, and draw radial lines from *C* through points 1_1 and 2_1 to meet the first radial lines. Two points, 1^1 and 2^1, on the true curve are thus obtained.

The problem now is to draw a series of tangential arcs through $D2^1 1^1 A$. Bisect $2^1 D$ by a line; the intersection *H* of the bisector, with the centre line, gives the centre from which the portion $2^1 D$ of the curve is struck.

Join $2^1 H$. Bisect $1^1 2^1$. Then the intersection *I* of the bisector with $2^1 H$ is the second centre, from which arc $2^1 1^1$ is described.

A slight difficulty occurs with the third and last centre. Join $1^1 I$, and the point *J*, where

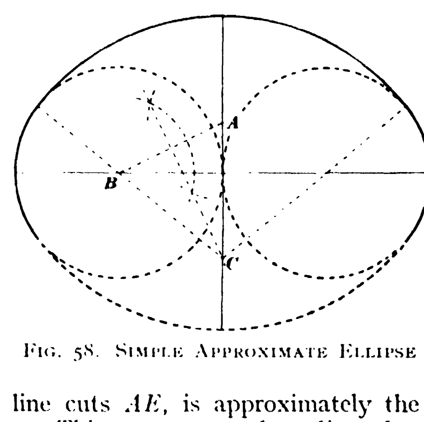

FIG. 58. SIMPLE APPROXIMATE ELLIPSE

this line cuts *AE*, is approximately the third centre. This centre may be adjusted a little from *J*, so that the curve joins the jamb and the arc $1^1 2^1$ with the best effect. If desired, this last centre may be geometrically obtained more accurately as follows. With *I* as centre and $I1^1$ as radius, describe the arc $1^1 K$, so that it cuts a horizontal line IK. Join KA and produce to cut the arc at L. The intersection M of LI with AF gives the centre required.

The right-hand half of the curve can be easily

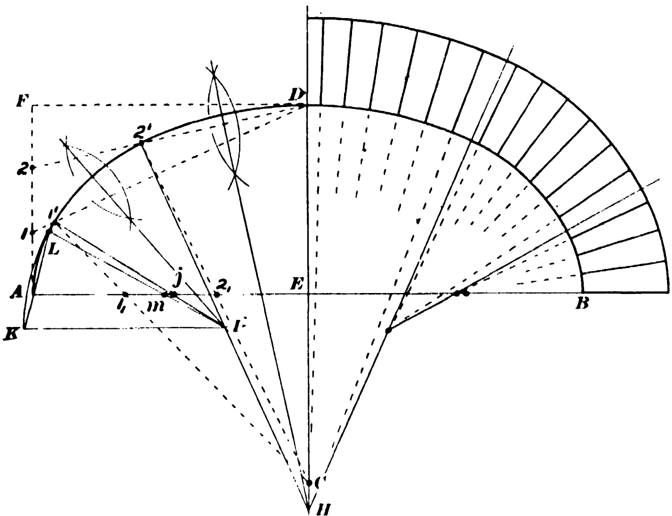

FIG. 59. APPROXIMATE ELLIPTICAL ARCH, USING THREE TEMPLETS

duplicated. The extrades curve is struck from the same centres as the soffit curve.

In order to make this five-centred arch from shaped bricks or stones three templets would be

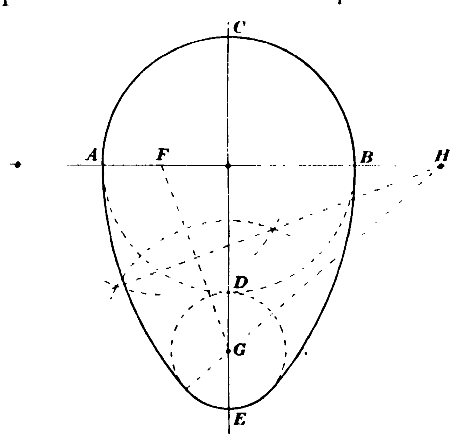

FIG. 60. CONSTRUCTING AN OVAL

required, as there are three different shapes of arch stones (voussoirs). If a more accurate arch were required, the same geometrical principles could be adapted to give an arch struck from seven or more centres.

Oval. The word *oval* is often used as being the same as ellipse ; thus, a carpenter speaks of oval wire nails, when the nails are really elliptical in section. Oval means egg shaped ; that is, an oval is narrower at one end than at the other, whereas an ellipse is symmetrical about its minor axis.

Fig. 60 shows the method of drawing an oval when the width and length are given. Describe a circle on the width AB. The vertical diameter of the circle is CD. Make CE equal to the large diameter given. Draw a semicircle on DE. We have thus got the curves of the top and bottom of the oval, and tangential connecting arcs are now required.

Mark off AF equal to the radius DG of the smaller circle. Bisect GF. The point H where the bisector cuts AB produced is the centre of the connecting arc. With H as centre and HA as radius describe the arc. This arc will join the smaller circle on HG produced.

Tudor Arch. The method of drawing a Tudor, or four-centred, arch when the span only is given is shown in Fig. 61. Divide the span into four equal parts ; draw two tangential circles with centres on the springing ; and construct

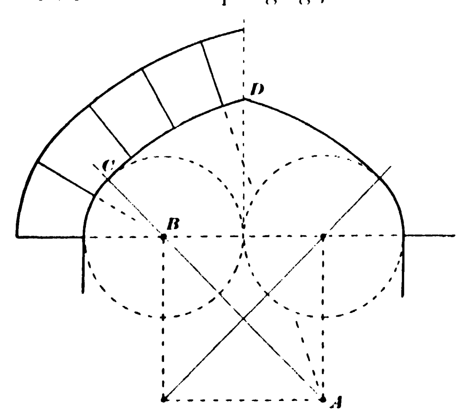

FIG. 61. DRAWING TUDOR ARCH

a square below the middle half of the span. Draw the diagonal AB, and produce to cut the small circle at C. With A as centre and AC as radius draw the arc CD. Finish the drawing as shown.

Gothic Arches. Three types of Gothic, or pointed, arches are given in Fig. 62. Assume that the span *AB* and rise *CD* are given (top diagram). Join *A* to *D*, and bisect *AD* by a line at right angles to it. This bisector cuts the springing line at *E*, from which centre the arch curves are struck. When this centre falls outside the span, the arch is said to be an *acute*, or *lancet, arch*.

If the arch curves are struck from the

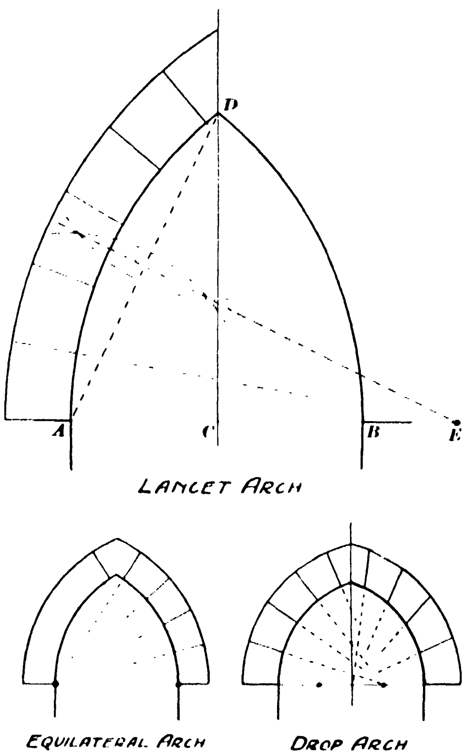

Fig. 62. Three Types of Gothic Arches

extremities of the span, an *equilateral arch* results, so called because the springing points and the apex form the corners of an equilateral triangle.

When the centres are within the span the arch is called a *drop arch*. Notice that in this type the joints between the voussoirs may, if preferred, converge to the centre of the span; both methods are shown in the drawing.

Ogee Arch. Let the span be *AB*, Fig. 63, and let the rise be *CD*. With *C* as centre, describe a semicircle on the span. Joint *AD*, cutting the semicircle in *E*. Draw from *C* through *E* to meet a horizontal line drawn through *D*, thus giving point *F*. With *F* as centre, and *FD* as radius, draw the arc *DE*.

Parabolic Arch. The method of drawing a parabola is shown at the left-hand side of Fig. 64,

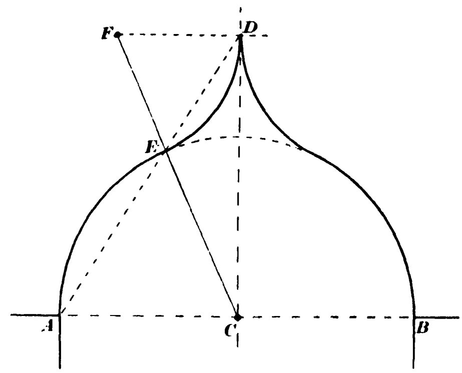

Fig. 63. Ogee Arch

the two half parabolas shown forming an arch. Let *AB* be the axis and assume that the curve has to pass through point *C*. Complete the rectangle *ABCD*. Divide *AD* into a number of equal parts, and draw lines parallel to the axis through the division points. Divide *CD* into the same number of equal parts, and draw radial lines to point *A*. Three intermediate points on the parabolic curve are thus obtained, and the curve is then drawn freehand.

Tangent and Normal to Parabola. Let it be required to draw a tangent and normal through the point *E*, Fig. 64. Let fall a perpendicular *EF* from *E* to the axis *GB*. Make *GH* equal

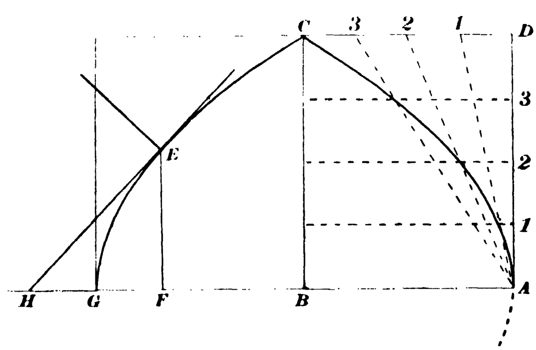

Fig. 64. Drawing Parabolic Arch

to *GF*. Then a line from *H* passing through *E* is tangential to the curve.

A line at right angles to the tangent from *E* gives the normal at that point. This construction could be repeated to determine the joint lines of a parabolic arch.

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ARCHITECTURAL DESIGN

By T. P. Bennett, F.R.I.B.A., and T. E. Scott, A.R.I.B.A.

LESSON V

THE ORDERS

Separate openings in walls have been dealt with; but they may occur in series, separated by simple supports, when they will form what is known as a *portico*.

In principle, porticos should be open; but in many cases they are closed in with doors or windows, and form part of a façade. They may consist of rectangular or arched openings. The consideration of the former will lead to "The Orders," while the latter are generally known as *arcades*, which will be dealt with later.

The intermediate pier is the first element to be considered. The simplest section is the square; its subsequent development to the polygonal is logical, and to the round inevitable, in the provision of easier passage between the piers. Thus the column is produced.

Upon a series of such piers are placed a number of lintels to carry the wall over the openings, and the basis of "The Orders" is established.

Space will not permit more than a general survey of the development of the Orders by the Greeks and Romans, and their subsequent application to later works.

It will be well, before considering the various subdivisions of the Orders, to consider the principles which underlie their conception, and consequently affect their use in design. The Order was perfected in Greek work, the study of which shows that at regular distances, determined by the maximum span of the lintel, columns were arranged; these were circular on plan. The column was not part of a cylinder, but tapered, being slightly larger at the bottom than at the top, and curved in outline. This shape was logical, for the lower part was more heavily loaded than the upper, and the curved line, or *entasis*, corrected an optical illusion.

The use of an intervening "cushion," or cap, between column and lintel may have been evolved from the supposed wood origin of the Doric Order, but its aesthetic value as a transition from the circle to the square abutment for the lintel is a strong reason for its retention in stone construction.

The lintel, known as the *architrave*, supported the wall proper, which, in the Classic Orders, consisted of two other elements—the *frieze* and *cornice*. These together constituted the *entablature*.

The *frieze*, the middle member, was found in most examples of the Order, and in early examples it probably served to cover the ends of beams carrying the ceiling or roof.

Above the frieze is the *cornice*, a horizontal projection which protected the lower part, and formed the crowning feature of the Order. The upper member of the cornice, the *cymatium*, belonged primarily to the roof; it was the gutter.

The great subdivisions of the Orders were the Doric, Ionic, and the Corinthian. These are dealt with in detail and illustrated in "History of Architecture."

The Doric Order. This Order belongs particularly to Greek architecture. The extent to which it owes its form to a wooden prototype is debatable; its development in stone shows little variety in detail, progress being always in the direction of the perfection of proportion of an accepted simple form. The frieze is the distinctive feature of the Order, and the spacing of its metopes and triglyphs is closely related to the spacing of columns. In Greek temples there is a triglyph at the end of the frieze, thus causing the end columns to be more closely spaced than the rest. This results in actual and apparent stability, and still leaves the wider passage in the centre where it is required.

In many early Roman examples of this Order, Greek detail was followed closely, but later it lost its character of refinement and majesty. It acquired a base, a moulded abacus, and other ornamental features. The column became more slender and the entablature less deep, but the triglyph was still an important controlling element in the design.

The Ionic Order. If the Doric Order may be called "masculine," then the Ionic is distinctly "feminine" in its grace and elegance. The characteristic feature was the voluted capital, which was usually rather plain. In Greek work, the volutes were parallel to the entablature, an arrangement which produced a fine capital, but presented serious difficulty at the angles of a

DIMENSIONS AND PROPORTIONS OF THE CLASSIC ORDERS

Based on Tables in the Work of J. Guadet

	Building	Actual Dimensions: Lower Diam. of Column.	Actual Dimensions: Between Centres	Actual Dimensions: Height of Column	Actual Dimensions: Height of Entab.	Actual Dimensions: Free Passage Between Columns	Proportional Values: Proportion to Diameter of Column: Between Centres	Proportional Values: Proportion to Diameter of Column: Height of Column	Proportional Values: Proportion to Diameter of Column: Height of Entab.	Proportional Values: Proportion to Diameter of Column: Height of Order	Proportional Values: Proportion of Entab. to Height of Column
THE DORIC ORDER	Paestum, Great Order (Exterior)	6′ 9″	14′ 8″	28′ 1″	12′ 8″	7′ 11″	2·168	4·290	1·871	6·161	0·436
	,, ,, ,, Interior	4′ 5″	11′ 6″	19′ 10″		7′ 1″	2·606	4·435			
	Parthenon	6′ 2″	14′ 1″	34′ 3″	10′ 9″	7′ 11″	2·294	5·568	1·749	7·317	0·314
	Propylaea (Large)	5′ 1″	11′ 11″	28′ 9″	9′ 11″	6′ 10″	2·351	5·698	1·967	7·665	0·345
	,, (Small)	3′ 6″	8′ 3″	19′ 3″	6′ 3″	4′ 9″	2·349	5·451	1·766	7·218	0·324
	Temple of Cori	2′ 4″	7′ 5″	20′ 4″	3′ 2″	5′ 1″	3·142	8·642	1·353	9·996	0·157
	Pompeii Triangular Forum	1′ 10″	7′ 3″	13′ 4″	3′ 3″	5′ 5″	3·991	7·326	1·768	9·094	0·241
THE IONIC ORDER	Temple of Nike Apteros	1′ 9″	4′ 8″	13′ 4″	3′ 10″	2′ 11″	2·701	7·797	2·222	10·019	0·287
	Propylaea	3′ 6″	12′ 0″	33′ 9″		8′ 6″	3·427	9·648			
	Erectheion	2′ 3″	6′ 9″	21′ 7″	4′ 11″	4′ 6″	3·037	9·747	2·207	11·955	0·226
	Temple of Minerva Polias	2′ 9″	10′ 2″	25′ 1″	5′ 6″	7′ 5″	3·078	9·091	2·003	11·085	0·220
	,, at Priene	4′ 1″	11′ 6″	38′ 4″	9′ 1″	7′ 5″	2·797	9·307	2·199	11·507	0·236
	Forum at Pompeii	2′ 1″	7′ 2″	20′ 8″	3′ 10″	5′ 1″	3·404	9·778	1·795	11·574	0·183
THE CORINTHIAN ORDER	Temple at Assisi	3′ 5″	9′ 7″	36′ 8″	5′ 9″	6′ 2″	2·839	10·844	1·692	12·537	0·156
	,, at Tivoli	2′ 6″	6′ 7″	23′ 5″	3′ 7″	4′ 1″	2·647	9·459	1·454	10·912	0·154
	,, of Vesta at Rome	3′ 1″	8′ 0″	33′ 9″		4′ 11″	2·588	10·952			
	,, of Mars the Avenger	5′ 10″	14′ 2″	57′ 10″		8′ 4″	2·410	9·868			
	,, of Antonius and Faustina	4′ 10″	12′ 1″	46′ 6″	10′ 10″	7′ 3″	2·491	9·574	2·229	11·797	0·232
	,, of Jupiter Stator	4′ 10″	12′ 5″	48′ 7″	11′ 7″	7′ 7″	2·551	10·004	2·380	12·384	0·238
	Pompeii, House of the Labyrinth	2′ 3″	12′ 2″	20′ 0″		9′ 11″	5·443	8·957			

building where a column is related to two elevations. Antae, or pilasters, were sometimes used at the angles to obviate this difficulty. Bases were generally moulded, and in some cases the base of the column was sculptured, as at

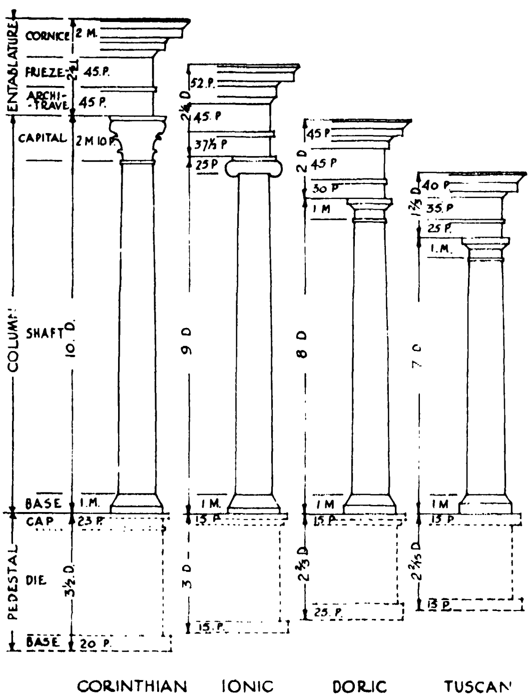


FIG. 27. THE PROPORTIONS OF THE ORDERS, ACCORDING TO VIGNOLA

Units of Measurement: *D = Diameter of Column; M = Module, or ½ D; P = Parts: 30 parts = 1 M*

the Temple of Diana at Ephesus. The Romans often used the horned or diagonal volute.

The entablature was composed of the three elements found in the Doric Order. The architrave was usually subdivided into three faces; the frieze was plain or enriched with sculpture in relief; the cornice was extremely simple, although in some cases a dentil course added a certain amount of interest and richness.

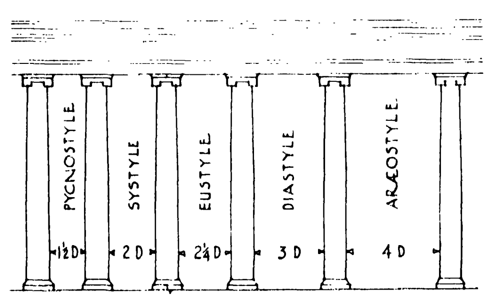
Many of the mouldings were enriched with the egg-and-tongue or other carved ornament, in some cases skilfully adjusted in detail to suit the light falling on it.

The Corinthian Order was essentially a Roman Order, for its rich decorative character appealed to the emperors, and was in accordance with the social ideals of the Roman epoch. There are few examples in Greek work, the best occurring in smaller buildings and monuments, such as the Tower of Winds and the Choragic Monument of Lysicrates. Although the original structural lines of the Doric Order were retained, the Corinthian Order was used chiefly as a decorative feature. The earliest Roman examples were robust, later becoming more slender. The shaft of the column was frequently of coloured marble, and in consequence flutes were logically omitted. Bases and capitals were highly decorated, the treatment of the latter being carried to excess in some later examples. The entablature reflected the richness of the capital; the architrave is usually simple, as is the frieze, although this is sometimes highly decorated as in the Temple of Vesta, at Tivoli. It was in the cornice that the Romans excelled. The voluted modillion and the enrichment of the mouldings with acanthus leaf motifs are the characteristic features amongst the extraordinary variety of detail used.

The Composite Order is a variety of the Corinthian, the only important variation being the use of a larger volute in the capital.

The Pedestal. The Roman Orders were frequently placed on a pedestal, which was from $2\frac{1}{2}$ to $3\frac{1}{2}$ times the diameter of the column in height. The pedestal, however, is more usually associated with the balustrade, and should, therefore, conform to the human scale, having a constant height of about 3 ft. or 3 ft. 3 in. By this means it will give the true scale to the column superimposed, instead of producing the appearance of a magnified "Order."

Proportion. Before considering the use of the Orders in buildings of more than one story, it



D = DIAMETER OF COLUMN

FIG. 28. THE SPACING OF COLUMNS

will be well to consider the proportions which resulted from their use on the monumental work of the Greeks and Romans. The relative sizes of columns and entablature are, perhaps, the most important distinctions between the various styles. There are several systems of standardization of the Orders, using the diameter or half-diameter of the column as the unit of measurement. These are useful for general guidance, but the ancients were not bound by any hard and fast rules of proportion, as the

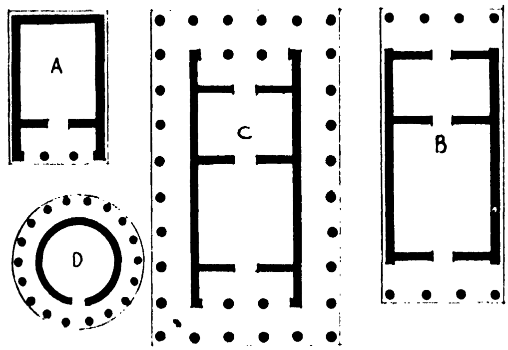


FIG. 29 SOME TYPICAL ARRANGEMENTS OF COLUMNS

A *Distyle in antis*, two columns between antae
B *Amphi prostyle tetrastyle*, four columns in front at each end
C *Peripteral hexastyle*, columns all round with six at each end
D *Circular Peripteral*

NOTE A range or portico of eight columns is known as *octastyle*, or with ten, *decastyle*

infinite variety of their work shows. The table, page 346, shows the general proportions and dimensions of a few of the best known Greek and Roman Orders. The proportions of the various parts of the Orders are given in Fig. 27.

In the spacing of columns other than in the Doric Order, there are no special requirements as to the exact arrangement, although where the cornice contains modillions, these should be spaced so that a modillion is on the axis of the columns. Fig. 28 shows a few of the spacings and the terms used to describe them.

The study of Greek and Roman temples will show the variety of ways in which the Orders may be used. Some typical arrangements and their nomenclature are given in Fig. 29.

Special attention should be paid to the use of the *anta*. When columns are placed in front of a wall, and the entablature returns to the wall, an *anta* should be introduced to support it; see Fig. 29 (*a*), (*b*), and (*c*).

An interesting break from the proportions usually associated with the Orders is to be seen in the "Colonial" style of America, which was adapted from English Georgian architecture. The buildings were generally constructed of timber, and as was natural, the material greatly influenced the proportions of the Orders used. Columns, formed from a single piece of timber, were very slender, being as much as eighteen or more diameters in height; the entablature was proportionate to the diameter rather than the height of the column, while the spacing was normal to the height of the column rather than the diameter.

Scale. After the first general proportion is settled, the question of scale must be considered. It is obvious that small and large Orders cannot have the same detail, while the position of the Order must always influence its scale and proportion.

Spacing. In the portico, the number of columns would appear to influence the spacing of the columns. One opening between two columns must be wide enough to give ample passage, while a number of openings between four, six, or eight columns gives an increasing choice of passage, and the spacing may therefore be decreased. Tradition seems to confirm what logic dictates.

Sometimes Orders of two sizes may be used in the same building, as in Fig. 30. Here, the safe span of the lintel permits equal distance between the centres of both series of columns, but the proportionate spacing is narrower in the case of the taller Order. It appears logical, therefore, to state that the taller the Order, the closer the relative spacing of the columns.

THE APPLICATION OF THE ORDERS

Superimposition of Orders. The requirements of Roman and later civilizations called into

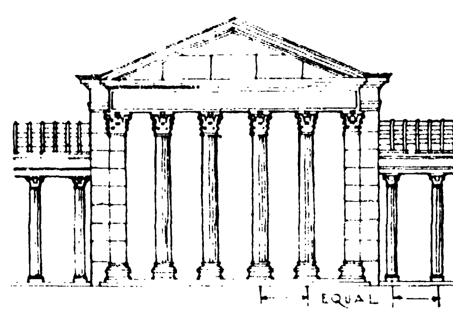


FIG. 30 PORTICO OF OCTAVIUS, ROME

existence buildings of more than one story, and it was inevitable that their decoration should involve the use of the Orders.

In Roman and Renaissance buildings in Italy, the most frequent arrangement is the use of an Order to each story, with arched openings between the columns, a treatment permitting great variety and interest.

The superimposition of Orders is not merely the placing of one Order upon another. The

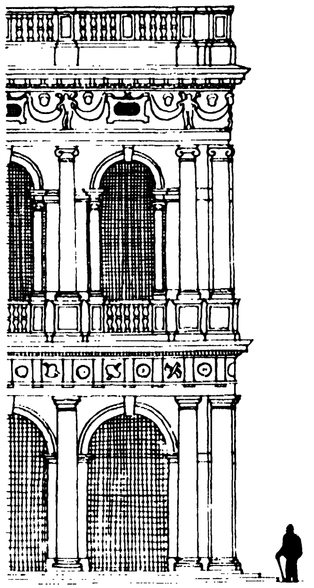


Fig. 31. Library of St. Mark's, Venice

stories must be welded together, and the composition unified by means of a cornice which is not only an element in the upper Order, but must dominate the whole façade. This may result

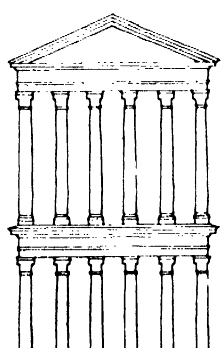


Fig. 32

from the sequence in which the Orders should be used, viz., starting from the ground, there will be Tuscan, Doric, Ionic, Corinthian, and Composite. This sequence must always be used, although it is not necessary to commence with any special Order. It will be seen that, not only will the topmost cornice be the richest, but that there will be a decrease in "weight," or sturdiness, towards the top, which is logical, both aesthetically and structurally (see Fig. 31, and also the Colosseum, Rome).

The balustrade and the fine deep frieze, in Fig. 31, are interesting methods of providing emphasis at the top of a building sufficiently important to unify the composition.

Frequently the entablature is broken around the columns, or pilasters, on either the lower story, or both, as in the Banqueting Hall, Whitehall. This treatment will give a vertical

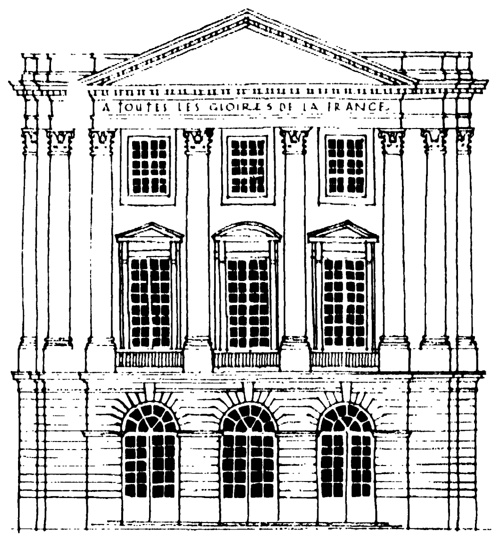


Fig. 33. Pavilion Gabriel, Versailles

emphasis which prevents lack of cohesion in a composition consisting of two equal parts.

The spacing of columns will require adjustment in superimposed Orders. In Fig. 32 each story seen separately is satisfactory, but together, the closeness of the columns is very depressing. It will be appreciated from this illustration that the eye is inclined to "read" the total height of the building against the distance apart of the columns, and that the spacing should, therefore, be wider than is customary in porticos.

There are many examples in which the Orders are used for upper stories, standing upon a wall or arcade (see Figs. 12 and 33). Here, again, the spacing must be adjusted to take account of the greater height of the building. It will be seen that in Fig. 33 the Orders are used to embrace two stories.

Bays with coupled columns will require wider spacing than those with single columns, not merely to find room for the extra column, but

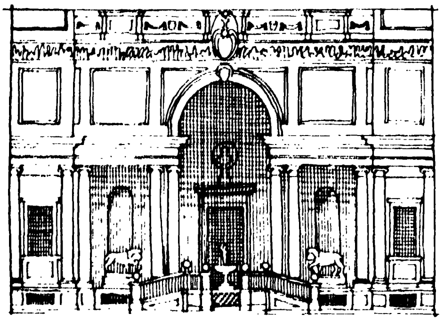


FIG. 34. THE OPEN LOGGIA, VILLA MEDICI, ROME

in order to clearly distinguish between the space between the pairs of columns and that between the coupled columns. In the latter case, spacing is regulated by the projection of the bases and capitals.

There is infinite variety in the handling of classic features in the work of the Italian Renaissance, one of the most interesting being the

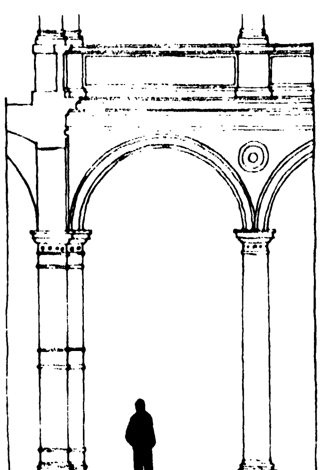


FIG. 35 THE LOWER ARCADE, PALAZZO CANCELLARIA, ROME

"Palladian" motive in Fig. 31, and developed more fully in Palladios Basilica, at Vivenza; another version of which may be seen in the open loggia of the Villa Medici (Fig. 34).

Arcades. The simplest form of arcade consists of a series of arches supported on rectangular piers. The piers themselves may be plain or panelled, with an impost mould and a moulded archivolt, or the whole may have channelled joints as in Figs. 12 and 33.

The use of the round column as the support between the arches provides the most graceful form of arcade, but its construction requires considerable care.

One of the finest examples is that illustrated in Fig. 35, a close examination of which shows that: (1) The caps and bases are of marble, and the shaft of the column monolithic and of

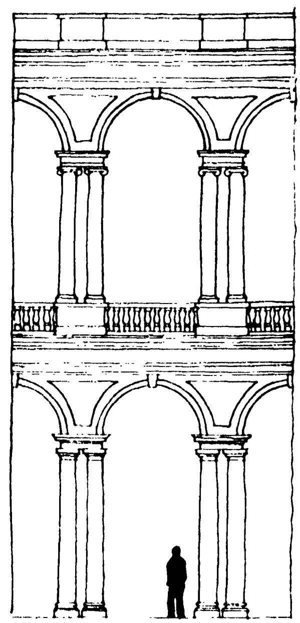


FIG. 36 THE COURTYARD, PALAZZO BORGHESE, ROME

granite. This has constructional significance, for not only is a hard, dense stone necessary to carry the load concentrated upon so small an area, but the liability of lateral displacement of small stones leads to the use of a monolith. (2) The vault between the arcade and the wall behind is tied back to the main wall with iron ties. The reason for this precaution is obvious.

The entablature is usually omitted from the columns supporting these arcades, for it would have no structural significance. There are, however, examples where a modified form of entablature has been used, particularly in Brunelleschi's work in Florence; the study of the interior of the Church of San Lorenzo will make his reasons clear.

Arcades may be decorated by means of circular panels, or openings, in the spandrels, or by means of carved enrichment which conforms generally to the shape of the spandrel. Study of the work of the Renaissance in Italy will reveal many examples.

The delicate nature of the single-column arcade tends to limit its height, and the need for better support leads to the use of coupled columns, when an entablature becomes necessary to "reconstruct" the wall and tie the columns together; see Fig. 36.

The ground story in Fig. 37 shows an "Order" used to provide extra strength to the support. The upper part is very interesting; the slender intermediate column which is introduced to support the upper entablature is, perhaps, a breach of structural laws, but its value in reducing the scale of the opening and giving two well proportioned shapes cannot be exaggerated.

It has been pointed out that the arch, in itself, is not in equilibrium, and that the end bay in an arcade will require a buttress to resist the oblique thrust from the arch. When the end pier was the same as the intermediate piers, a tie-rod was essential to the stability of the structure. Although many authorities have accepted this method, its adoption at once suggests possibility of failure, and therefore destroys the feeling of repose. It is therefore preferable to provide a buttress, or substantial angle, which has a definite place in the composition; see Figs. 12 and 31. This not only has apparent and real structural value, but it punctuates the façade in an excellent manner, creating a feeling of completeness.

Where an entablature is introduced above an arcade, the architrave should usually be omitted unless there are columns, pilasters, or keystones to support it; compare Figs. 35, 36, and 37.

When the Orders and arches are used in combination, it is advisable to give emphasis to one or the other: to the arches, by means of as great a depth of reveal as the scheme permits; or to the Order, by advancing it from the face of the wall, and exposing a bold soffit to the entablature, which should contrast with a shallow arch.

The proportions of arches used in arcades are usually based on those found in traditional

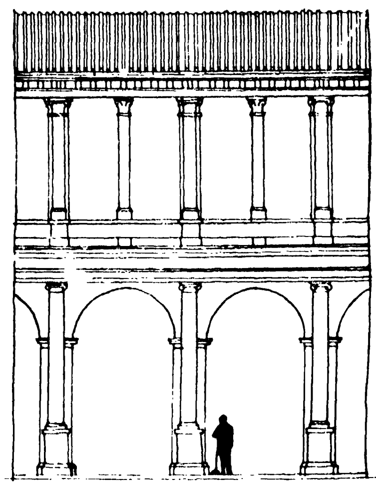


FIG. 37. THE CLOISTERS, S. MARIA DELLA PACE, ROME

architecture, a height of twice the diameter being productive of the best results. In some cases, however, the required width of opening may be too great to permit such proportions, and similar results to those referred to in Lesson IV may be obtained. There is an excellent example of such an arcade in the river front entrance to the Louvre, Paris.

It is not possible here to consider arcades in mediaeval architecture, which, although they conform to similar laws, are subject to very different spiritual and material considerations in their composition.

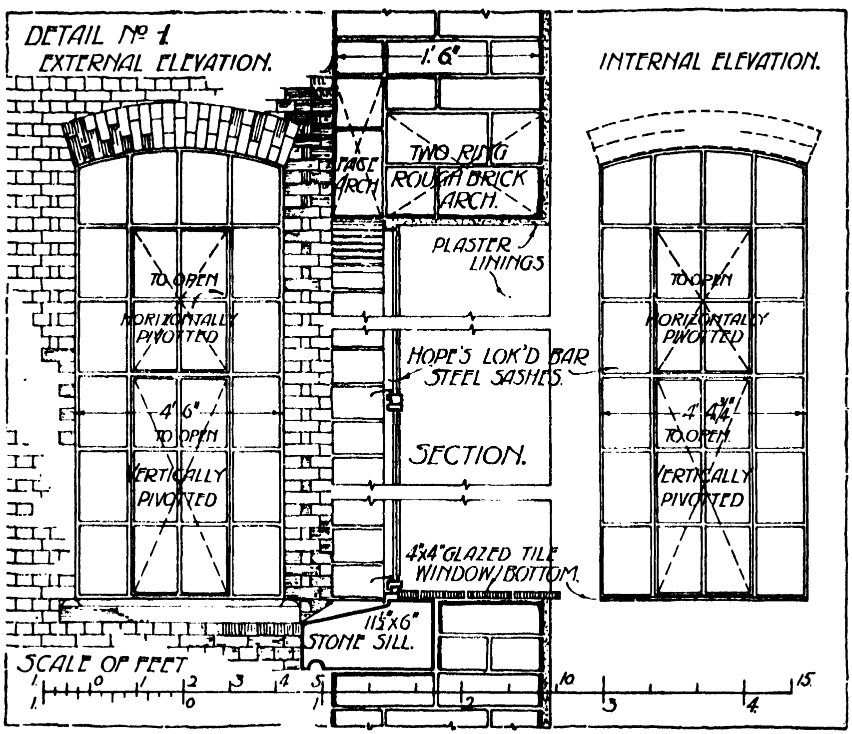
FIRE-RESISTING CONSTRUCTION

By Walter R. Jaggard, F.R.I.B.A.

LESSON II

CONSTRUCTIONAL DETAILS

The details of construction of fire-resisting buildings may be considered under the following subdivisions—



(*a*) Walling, including vertical and horizontal supports in iron, steel, concrete and timber.
(*b*) Floors.
(*c*) Stairs in wood, stone, concrete and metal.
(*d*) Partitions.
(*e*) Roofs.
(*f*) Door, window, and other fittings.
(*g*) Preventive measures and apparatus.

WALLING

Brick and Stone Walls. There is little doubt that brickwork is the best material to use for fire-resisting building. Well-burnt hand-made bricks, similar in composition to those known as "London stocks," are probably the most suitable; some comparatively hard, machine-made bricks are apt to be deformed by flaking under the combined effect of heat and water; and though walls built of them may not actually collapse, their appearance is so badly destroyed they that must be taken down and rebuilt. In a serious fire, this will also possibly occur with the best stock brickwork, the damage by falling debris, collapse of lintels or beams, so affecting the stability of the walls that it becomes essential to rebuild them. In some cases, however, even when the interior has been practically burnt out, it has been possible to retain the outer brick walls, merely cleaning the face and repointing the joints.

The brickwork should always be soundly built in cement mortar, used fresh, an average proportion of three parts of clean sand to one part of Portland cement being most common; the mortar should be fairly wet, and every brick course should be well flushed up and grouted in, all bricks being well wetted before being laid. Full attention should be given to correct bonding, whole bricks being used wherever possible, and any attempt to pack the interior of walls, either in length or at angles or junctions, with broken pieces of brick, should be resisted. English bond, with a weather struck external joint, and flush or raked internal joints, is the strongest and best for all purposes. The walls should not be less than 13½ in. thick at any point, even when used as panel or curtain walls in connection with a steel framed building.

Solid stone walls are of infrequent use for large buildings, but a stone face is often backed with brickwork. A fierce fire will quickly destroy the stone, and in its disintegration and collapse the stone will bring the brickwork with it. A stone face is sometimes essential for architectural reasons, but, wherever possible, it should be avoided in fire-resisting buildings.

Window, door, and other external openings should be spanned by axed brick or rough ring arches, instead of stone; the jambs built of brick, instead of stone quoins; and a stone sill, possibly the least objectionable member in stone, can also be quite easily replaced by moulded bricks or tiles.

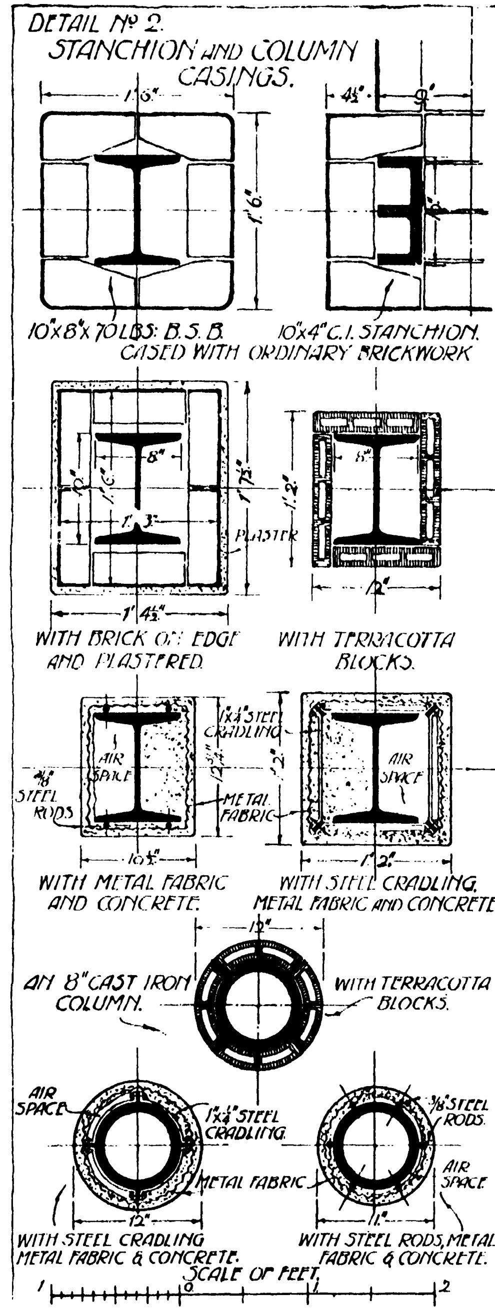
Terra-cotta, as an external wall facing in conjunction with a brick backing, is better than stone for fire-resisting qualities, but the glazed and semi-glazed faces will often be so badly affected by flame, smoke and water, that they will have to be renewed.

Internal wood lintels over door and window openings, should be replaced by concrete, which may be lightly reinforced with three or four ⅜ in. or ½ in. steel rods, and may be cast in situ, or precast in boxes and built into position.

A typical window opening is shown in elevations and section in Detail No. 1.

Internal Walls and Pillars. The main internal walls should always be constructed in brickwork, the openings being spanned with concrete lintels. Particular attention should be given to the arrangement and construction of fire-places and chimney breasts, to ensure their perfect isolation from any combustible material.

Isolated supports may, of course, be built as piers, in brickwork, but these occupy considerable space, and can usually only be permitted in unimportant basements and storage rooms.



It has already been stated that all ironwork used for constructional purposes in a fire-resisting building, must be protected from direct contact with flame. The London County Council regulations stipulate that a thickness of, at least, 4 in. shall cover all such external metal work, with, at least, a 2 in. thickness for internal work. This covering must be of incombustible material, and must entirely encase the metal, but it is not advisable to permit a too close adhesion thereto. The coefficients of expansion, under heat, of the materials named above, are by no means equal, although the variation, with the exception of the metal, is not great. Iron, when heated, expands rapidly ; a bar 10 ft. long has shown an increase of 1¼ in. in its length, while an increased length of 4 in. or 5 in. in a 50 ft. long girder is not uncommon. Stanchions and girders are seldom longer in ordinary buildings than 25 ft., but if bolted together, it is conceivable that the former may easily be from 80 ft. to 100 ft. long, while girders and beams may be much longer. Conductivity of heat in most metals is very rapid, and an exposed part of beam or stanchion will quickly conduct heat throughout its length, while the covering material may be scarcely affected. It would, therefore, seem most desirable, that any such coverings should fit somewhat loosely around the metal work, so that a layer of air—a bad conductor of heat—may intervene between them. The thickness of such coverings must not be less than 2 in., and concrete, brick, terra-cotta, firebrick, asbestos packing and plaster, are suitable materials for the purpose.

Detail No. 2 shows some examples of such coverings to steel stanchions, cast-iron columns, and flat-backed stanchions ; suitable casings for beams will be found illustrated in the section dealing with floors. No wood cradling or laggings should be permitted around stanchions or beams, but small section steel bracketing and rods may be used in order to secure metal lathing, and enable the concrete or plaster to obtain an efficient key.

It is probably true that many failures of steel and ironwork during fires may be attributed to the fact that the metal has rusted to the point of danger. Under ordinary conditions it would safely take any usual strain ; but in the case of a fire, with, perhaps, partial failures of minor parts, the metal stanchions and columns are suddenly called upon to bear an excessive strain, and should these be weakened by rust, a serious collapse may ensue, endangering the stability of the whole building. Removable coverings for stanchions and beams would enable periodic inspections for signs of rust, but these are not very practicable, and it is hoped that the extended use of cromium and the cheaper production of rustless steel will remove much anxiety in this direction.

Entire walls, composed of reinforced concrete piers and slabs, are undoubtedly very efficient from a fire-resistance point of view, and many modern buildings of large size have been so constructed ; but such a type of construction is the work of specialists, and cannot be adequately dealt with in this section.

Timber posts and beams, unless of balk sections, cannot be regarded as fire-resisting and should not be used. Large section timber should always be adequately protected with casings composed of good quality plaster on metal lathing.

Cast-iron or steel stanchions and columns are most generally adopted for the purpose of support ; and, in many cases, the whole structure may consist of steel framing, in the shape of vertical stanchions, and horizontal main, secondary and intermediate beams or bressummers, these latter being used to carry the panel brick walls between floor levels.

PRELIMINARY OPERATIONS

By R. Vincent Boughton

LESSON V

SHORING—(*contd.*)

Dead or Vertical Shoring is used temporarily to support walls, floors, roofs, etc., superimposed on work that has to be removed for such reasons as forming openings in walls, taking down defective lower parts of walls and rebuilding them, removing walls that are not required and permanently supporting the work over, removing ground story walls to permit the insertion of shop fronts, and for various other reasons. This type of shoring is generally a combination of beams and struts that have to support loads that are easily calculated, and such members must be of sizes that may be computed by the usual formula, as explained later in this lesson.

To explain fully the correct methods of shoring,

TABLE IV

Loads on Structures for Purposes of Calculating Dead Shoring

Part of Structure	Load in Cwt. per Super Ft. — Dead Load	Superimposed Load	Combined Dead and Superimposed Loads
Roofs, pitched, including rafters, etc., boarding, battens, slating or tiling, and *wind*, measured on slope of roof	0·25	0·25	0·50
Ceilings to last described roofs, including joists, plastering, etc.	0·10		0·10
Roofs, flat with timber joists, furrings, boarding, and asphalt or lead, with plaster ceiling under, including snow, wind, etc.	0·25	0·50	0·75
Roofs, flat, with 6 in. concrete, steelwork, etc., asphalt, plastered ceiling, including wind and snow	0·83	0·50	1·33
Floors, domestic, constructed with ⊙ fir joists, boarding ceiling, etc.	0·16	0·66	0·82
If constructed with ⋕ 6 in. concrete, steelwork, flooring, and plastered ceiling	0·75	0·66	1·41
Floors of lodging-house, hotel bedrooms, hospital wards, constructed as ⊙	0·20	0·75	0·95
If constructed as ⋕	0·75	0·75	1·50
Floors of offices, etc., constructed as ⊙	0·20	0·90	1·10
If constructed as ⋕	0·75	0·90	1·65
Floors of public place of assembly, schools, churches, lecture and meeting rooms, concert rooms, shops, etc., constructed as ⊙	0·25	1·00	1·25
If constructed as ⋕	0·75	1·00	1·75
Floors of ball or drill rooms, constructed as ⊙	0·33	1·33	1·66
If constructed as ⋕	0·75	1·33	2·08
Floors of warehouses, factories, etc., constructed as ⊙	0·33	2·00	2·33
If constructed as ⋕	1·00	2·00	3·00
Walls, measured overall of ordinary openings, which will approximately allow for plaster, etc.:			
9 in. thick	0·75		0·75
13½ „ „	1·12		1·12
18 „ „	1·50		1·50
	Cub. ft.		
Concrete, plain	1·00 cwt.		
Concrete, reinforced	1·33 „		

N.B. Where floors are not used for the purpose that they were constructed, during shoring operations, then the *superimposed* loads specified above may be reduced to one-half, the balance being generally sufficient to allow for builders' material, plant, men, etc., that may be superimposed on the floors.

the writer will carry the student through simple instances, and, finally, a rather complicated case of shoring will be considered.

In all types of dead shoring the first essential is to calculate the loads to be supported, and to compute them in a practical manner, allowing a reasonable margin for safety, and giving proper consideration to the fact that the building may or may not be inhabited or used for storage, etc., during the execution of the structural work.

Table IV shows the practical dead and superimposed loads of and on various parts of buildings that should be allowed in calculating dead shoring. The loads shown must not be considered as suitable for use in the actual design of floors, roofs, etc., as more detailed loads are then necessary.

Loads of Brickwork on Beams. For purposes of calculating shoring, it is advisable to allow that the whole of the brickwork over an opening has to be supported, and not to consider the "triangular area," explained below, except perhaps for openings not more than 10 ft. wide where the work is in good condition.

In calculating a beam to *permanently* support a *brick* wall, it is not usual to allow that the whole weight of brickwork over the beam will have to be supported by it, as, subject to certain conditions, a proportion of the load is transmitted, owing to the bond of the brickwork, to the walls or abutments at the side of the beam. In a case as shown by Fig. 36 it is manifest that practically the whole of the brickwork must be carried by the beam, but if there were abutments, as shown by Fig. 37, the load to be supported by the beam may be taken as equal to the area enclosed by the triangle marked *B*. If there are perforations in the wall, such as windows, as shown by Fig. 38, the load area would be as marked *C*.

The conditions under which such reduced areas of brick walls may be calculated are important and are—

1. That the breadth of each abutment is not less than half span of opening;
2. That the brickwork is thoroughly bonded together;
3. That great rigidity is not essential.

Calculation of Beams. After the loads have been calculated—examples will be given later—and the design of the shoring settled, the student must then be able to compute the sizes of beams and shores or struts. Calculations for determining the strengths of all types of structures are given fully in the section on "Structural Engineering," to which the reader is referred, but to make this lesson complete in itself, simple and suitable calculations for shoring are here given. For the purpose of shoring, the simplest formula for beams may be used; this is—

$$W = \frac{kbd^2}{Lf}, \text{ for } \textit{concentrated} \text{ load at } \textit{centre} \text{ of beam, and}$$

$$W = \frac{2kbd^2}{Lf}, \text{ for beams uniformly loaded}$$

where W = safe load in cwts.

k = constant of breaking weight on wood beams 12 in. long, 1 in. broad, and 1 in. deep, loaded in centre and supported at ends, and equals for—

Spruce fir	= 3·5 cwt.
Northern pine	= 4·0 ,,
English oak	= 4·5 ,,
Canadian oak	= 5·0 ,,
Pitch pine	= 5·0 ,,

b = breadth of beam in inches.

d = depth of beam in inches.

L = length in feet.

f = factor of safety = 4 for temporary shoring work with new or sound timber, and 5 or 6 if old timber is used.

EXAMPLE 1. Find scantling of needle of new northern pine, 10 ft. long, to support 100 cwt. concentrated in centre.

$$W = \frac{kbd^2}{Lf}; \therefore 100 = \frac{4bd^2}{10 \times 4}$$

$$\text{Or, } bd^2 = \frac{100 \times 10 \times 4}{4} = 1{,}000.$$

Try beam 9 in. wide × 11 in. deep; ∴ $9 \times 11^2 = 1{,}089$, which indicates that such beam is amply strong enough.

EXAMPLE 2. What distributed load will 9 in. × 9 in. northern pine beam carry over a span of 8 ft.?

$$W = \frac{2kbd^2}{Lf}$$

$$\therefore W = \frac{2 \times 4 \times 9 \times 9^2}{8 \times 4} = 182 \text{ cwt.}$$

Calculation of Dead Shores. These are calculated as "struts," with ends considered as free to rotate. Table V is practical and simple to use.

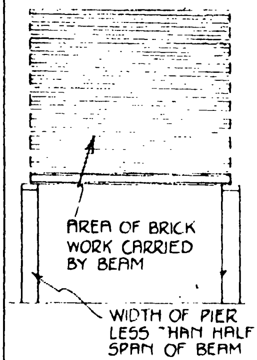


FIG. 36.

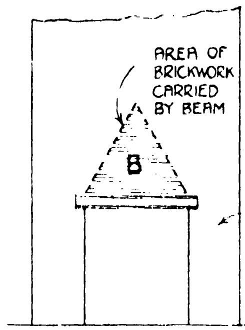


FIG. 37.

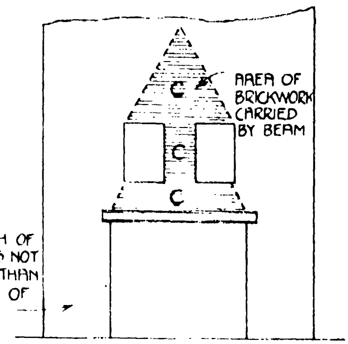


FIG. 38.

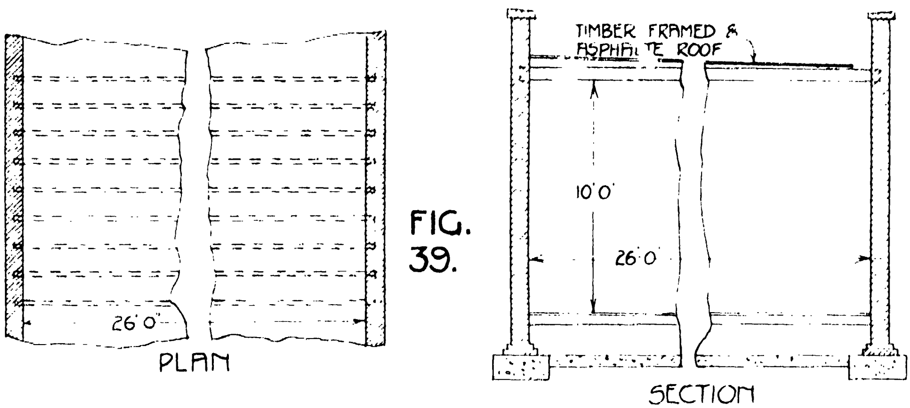
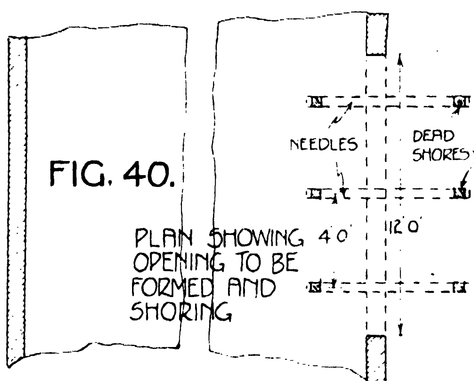


FIG. 39.



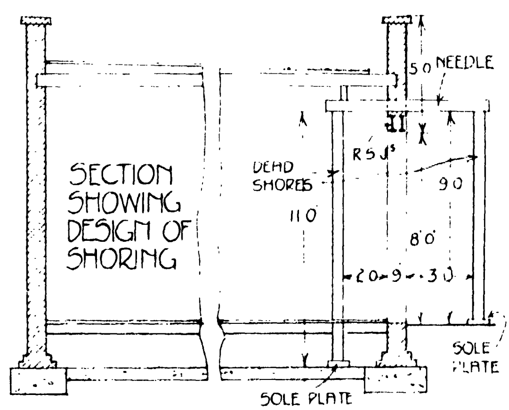


FIG. 41.

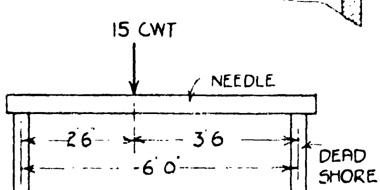


FIG. 42.

TABLE V

STRENGTH OF DEAD SHORES

Wood of Good Quality Fir or Northern Pine

R = ratio of length ÷ least dimension of cross-section. RC = *safe* stress per square inch in *cwt.* Ends considered as *rounded* or free to rotate.

R	RC	R	RC	R	RC	R	RC
5	9·55	19	3·85	33	1·56	54	0·58
6	9·25	20	3·60	34	1·43	56	0·55
7	8·85	21	3·38	35	1·35	58	0·52
8	8·30	22	3·18	36	1·28	60	0·49
9	7·75	23	2·92	37	1·22	62	0·46
10	7·20	24	2·75	38	1·16	64	0·43
11	6·70	25	2·60	39	1·11	66	0·41
12	6·25	26	2·41	40	1·06	68	0·39
13	5·80	27	2·25	42	0·96	70	0·37
14	5·40	28	2·11	44	0·87	72	0·35
15	5·05	29	1·96	46	0·79	74	0·33
16	4·75	30	1·82	48	0·72	76	0·31
17	4·45	31	1·71	50	0·66	78	0·29
18	4·15	32	1·60	52	0·62	80	0·27

If oak is used the safe stress may be taken as $1\frac{1}{3}$ times the figures given in table.

Example of Simple Dead Shoring. Fig. 39 represents part plan and section of a one-story building, in which it is required to form an opening 12 ft. wide, as shown by Fig. 40. The design of shoring should be as Fig. 41. Each needle will have to support practically only the wall; the small amount of roof load may be neglected, as it cantilevers over the bearer supporting it. The load will be the length from centre of one "bay" to centre of next, which is equal to distance apart of needles × by height of wall × by weight of wall = 4 × 5 × 0·75 cwt. = 15 cwt. The span of needles from centre to centre of dead shores = say, 6 ft. For practical purposes, the load should be considered as concentrated in centre of each needle—it is actually a little away from centre—and the calculation is as follows for northern pine:—

$$W = \frac{kbd^2}{lf} = 15 = \frac{4bd^2}{6 \times 4}$$

$$\text{Or, } bd^2 = \frac{15 \times 6 \times 4}{4} = 80.$$

Try 4 in. × $4\frac{1}{2}$ in. needle; $4 \times 4{\cdot}5^2 = 81$; which needle is therefore suitable.

The next process is to calculate the load on dead shores. As the wall is not supported in the centre of needles, it is obvious that the outer and inner shores do not have the same load to carry, the inner having more than the outer owing to the wall being nearer to the former; also, the inner shore has to support the roof in addition. The loading of wall on needle is shown by Fig. 42, and by simple mathematics the load at B will be 15 cwt. $\times \frac{2{\cdot}5}{6{\cdot}0} = 6\frac{1}{4}$ cwt. That at A will be $15 - 6\frac{1}{4} = 8\frac{3}{4}$ cwt. The flat roof will give a load on inner shore equal to half width of building × distance apart of shores × weight, as Table IV, = 13 × 4 × 0·75 cwt. = 39 cwt. Therefore the outer shore will have to support only $6\frac{1}{4}$ cwt. (as above) and the inner $8\frac{3}{4} + 39 = 47\frac{3}{4}$ cwt. The length of the inner and outer shores are respectively 11 ft. and 9 ft. long, and the timber to be used is northern pine.

First calculate outer shore by Table V. Try 3 in. × 3 in. Ratio of length ÷ least dimension of cross section

$$= \frac{9 \text{ ft.} \times 12}{3} = 36.$$

Safe stress per square inch = 1·28 cwt.; therefore 3 in. × 3 in. × 1·28 cwt. = 11·52 cwt., which indicates that the size computed is of ample size. Nothing smaller should be used.

The calculation of the inner shore, which has to support $47\frac{3}{4}$ cwt., is similarly made. Try 6 in. × 6 in.

$$R = \frac{11 \text{ ft.} \times 12}{6} = 22;$$

$$RC = 3{\cdot}18 \text{ cwt.}$$

Total safe load = 6 × 6 × 3·18 = 114·48 cwt., which shows that the proposed size is too heavy.

Next try 5 in. × 5 in.

$$R = \frac{11 \times 12}{5} = 26;$$

$$RC = 2{\cdot}41 \text{ cwt.}$$

Total load = 5 × 5 × 2·41 = say, 60 cwt., which shows that 5 in. × 5 in. shore is a little too heavy, but as it is the nearest convenient section, it should be used.

The beam supporting the roof should be calculated as before explained.

After the shoring is in position the wall may be removed, the jambs quoined up, the girders inserted, brickwork pinned in between top of girder and underside of existing wall, and then, after a lapse of two or three days to allow the new work to set, the shoring may be removed and floor and ceiling made good.

STRUCTURAL ENGINEERING

By W. Arnold Green, M.A., B.Sc., A.M.Inst.C.E., M.I.Struct.E.

LESSON IV

DEFINITIONS

Ideas are conveyed by terms which are often used loosely with varying shades of meaning, and it is difficult to give exact scientific definitions and consistently to keep to them, nor is it easy to know what terms are sufficiently technical to need definition.

Stress. When force is transmitted through a material, the latter is said to be *stressed*. Provided the material is homogeneous, that is, of uniform consistency, the stress is independent of the material used.

Thus, if a load of 100 lb. is lifted by a round bar 1 sq. in. in sectional area, the stress in the bar will be 100 lb. per sq. in., whether the bar is steel, glass or copper.

It would have been more scientific to have said, "The *intensity of stress* in the bar, etc.," instead of "the *stress* in the bar, etc."; but common usage permits the omission of "intensity of," and stress will hereafter be used to express a force or load per unit area, equalling total force divided by total stressed area if the stress is uniformly distributed.

If the 100 lb. weight had been lifted by a hook at the end of the bar, the stress would have varied across the section in a way that will be discussed later, in which case 100 lb. per sq. in. would be the average stress.

A force acting on a section at any point may be *normal* to the section (i.e. at right angles to it), *tangential* (i.e. parallel to the section), or inclined at an angle; in the latter case the force will have both normal and tangential components. Thus, if the direction of a force F is inclined at an angle θ with the normal to a surface, as indicated in Fig. 4, its effect is equivalent to a force $F \cos \theta$ acting normally to the surface, together with a force $F \sin \theta$ acting parallel to the surface, the components of F being the sides of the triangle of force (in this case right angled) of which the longest side, or hypotenuse, is drawn to scale to represent the force F in magnitude and direction. If the area of the plane surface on which the force is acting is A, then the average normal stress is $F \cos \theta / A$ and the average tangential stress is $F \sin \theta / A$.

A normal force may be a pull, in which case the stress set up is one of *tension*; or a push (as indicated in Fig. 4) in which case the stress is one of *compression*. A tangential force sets up a *shear* stress.

It often happens that a shear stress is combined with a direct stress in one direction, or with two direct stresses in directions at right angles to one another.

The resulting stress on any plane section of the materials, made in any direction, can be

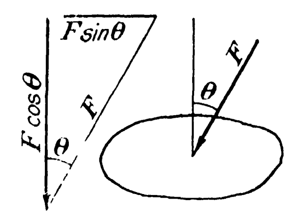


Fig. 4

found by resolving the forces (the product of the stresses by the areas on which they act) normally and tangentially to the plane in question, and it is found that there are two planes at right angles to one another along which there is no tangential stress. The stresses normal to these planes are known as *principal stresses*, and though a discussion of them is rather beyond the scope of this section, the student is advised to study the matter in a textbook on the theory of structures, such as that by Professor A. Morley, or Mr. E. S. Andrews, where he will also find a discussion on the *ellipse of stress*.

Strain. The change of dimensions in a material due to a stress is termed a *strain*. The same stress will produce different strains in different materials. A tensile stress will produce lengthening in the line of action of the stress; a compressive stress will produce a shortening; and a shear stress a distortion (see Fig. 5).

In a *plastic* material, such as lead, for all but very low stresses the strains are permanent; but in an *elastic* material the deformations are temporary, and the material returns to its original shape when the load is removed.

Elastic Modulus. If a steel bar of length l is submitted to a tensile stress t, its length will be increased. If this increase in length is plotted as a horizontal ordinate with the corresponding stress as a vertical ordinate, the resulting graph is a straight line.

A sensitive extensometer shows a slight divergence from the straight line, the curve as the load increases lying above the curve for a decreasing load, forming what is known as a

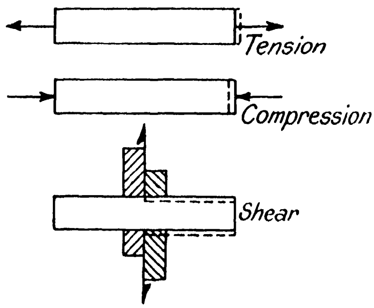


Fig. 5

hysteresis loop. For all practical purposes, however, Hooke's law, *ut tensio sic vis*, usually rendered "strain is proportional to stress," holds good for steel for the stresses used in design.

If the stress, instead of being tensile, is compressive, the length of the bar is decreased; and if this decrease is plotted against the compressive stress c, the resulting graph will be found to be in the same straight line as that for tensile stresses, as indicated by the full line in Fig. 6.

The actual length difference (δl) will also be proportional to the original length (l), and therefore may be written

$$\delta l = l{\cdot}c/E \text{ or } \delta l = l{\cdot}t/E \qquad (4)$$

where the value of E can be found from experiment.

This constant E is known as *Young's modulus of elasticity*. Its value for steel is about 30,000,000 lb. per sq. in., or about 13,000 tons per sq. in.

From the last equation, we get

$$E = t \text{ (or } c) \div \delta l/l \qquad (5)$$

where $\delta l/l$ represents the alteration in length of every unit of length and may be termed the *unital strain*. Hence E = stress ÷ unital strain.

If similar graphs are drawn for cast iron, wood, or concrete, it is found that instead of being approximately straight, as for steel and wrought iron, they are curved as indicated by the dotted line in Fig. 6. The value of E (which is proportional to the tangent to the inclination of the curve) is thus a maximum for the lowest stresses, and decreases as the stress increases.

For example, the test of a particular bar of cast iron showed $E = 6{,}073$ tons per sq. in. for a stress of 1 ton per sq. in., 5,528 for 3 tons per sq. in., and 4,400 for 6 tons per sq. in.

In using E in calculations, it should be recognized that the value assigned may be true for only one particular stress, and that for calculating the total extension of a bar at the stress on the assumption of a constant value for E, the value to use must be intermediate between the value at that stress and the initial value.

It will therefore be clear that the results of such calculations must not be interpreted too rigidly.

Poisson's Ratio. If a bar is stretched or compressed elastically, its dimensions at right angles to the direction of the stress are decreased or increased. The ratio of the lateral unital strain to the longitudinal is known as *Poisson's ratio*, and may be written $1/n$ where the value of n for steel is about 4.

Thus, if a 1 in. diameter steel bar is loaded to produce a stress of 30,000 lb. per sq. in., the increase (or decrease) in length for every inch

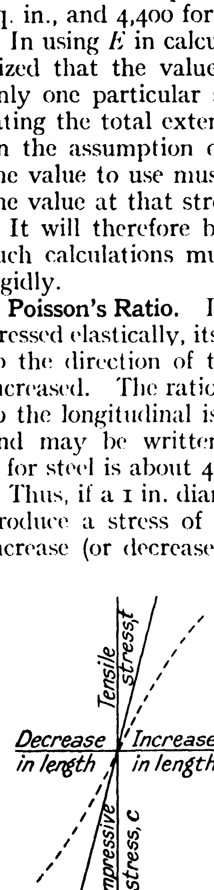


Fig. 6

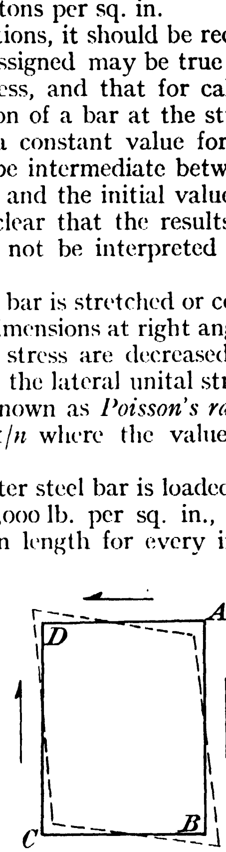


Fig. 7

will be, from equation (5), $t \div E = 30{,}000 \div 30{,}000{,}000 = {\cdot}001$; and the decrease (or increase) in the diameter of the bar will be $\frac{1}{n} \times {\cdot}001 = {\cdot}00025$, if $n = 4$.

Similarly, a compressive axial stress in a concrete column produces an increase in the diameter of the column. If the column is cast with horizontal binding to prevent the natural increase in the diameter, the column is capable of carrying a greater axial load.

Rigidity Modulus. If $ABCD$ in Fig. 7 is a section of a small rectangular prism of material of unit thickness and is subjected to a sheer stress s on the two faces AB and CD, the load on AB will be $s{\cdot}AB$ and on CD, $s{\cdot}CD$. These forces tend to produce clockwise rotation of the prism, the value of the rotating moment being $s{\cdot}AB{\cdot}BC = s{\cdot}CD{\cdot}DA$.

If the prism is in equilibrium, there must be reactions along AD and CB from the adjacent material tending to produce the same rotating moment in the opposite direction. As AB is the lever arm for this moment, the reactions must be $s{\cdot}AD = s{\cdot}CB$, that is, the stress along AD and CB must be s, the shear stress acting along AB and CD.

It will be noted that $s{\cdot}AD$ and $s{\cdot}AB$ combine to give a compressive force $s{\cdot}AC$ acting along AC, and balanced by the compressive stress $s{\cdot}CA$, resulting from the combination of $s{\cdot}CB$ and $s{\cdot}CD$.

Similarly, $s{\cdot}AD$ and $s{\cdot}CD$ combine to give a tensile force $s{\cdot}BD$ acting along the other diagonal BD, and balanced by the tensile force due to $s{\cdot}CB$ and $s{\cdot}AB$. The diagonal AC will thus be shortened and the diagonal BD lengthened, as the rectangle will be distorted as indicated in Fig. 7.

This distortion is measured by the tangent of the angular difference (ϕ) between the angles at the corners of the distorted figure and the original right angles. As the angle is very small, tan ϕ equals the value of ϕ measured in radians, that is, the length of the arc of a circle of unit radius subtended by the angle ϕ at the centre.

This angle ϕ, termed the shear strain, equals the shear stress s divided by the *rigidity modulus* G, that is, $\phi = s/G$ . . . . . (6)

For steel the value of G is about $\cdot 4 \times E$. If, in the figure $AB = BC$, the diagonals will cut one another at right angles, and there will be no shear stress along them.

The compression $s{\cdot}AC$ acts on an area BD, which equals AC, so that the diagonal compressive stress equals s. Similarly, the tensile stress along the other diagonal direction equals s. It is thus seen that a pure shear is equivalent to pure compression and tension in directions at 45° with the direction of the shear stress, and these are principal stresses.

Relation Between Elastic Constants. In the elementary analyses necessary for building construction design, it will rarely be necessary to refer to any elastic constant other than E. A clearer understanding, however, of what is required in design will be gained if an attempt is made to visualize what happens when a structural material undergoes strain.

It is thus of interest to examine the relationship between the foregoing constants, though many excellent buildings have been designed and erected by engineers who have rarely given a thought to any of them.

If a pure shear stress s acts on four faces of the cube of which $ABCD$ in Fig. 8 is a cross-section, the result has been shown equivalent to a compressive stress s in the direction AC and a tensile stress s in the direction BD. The

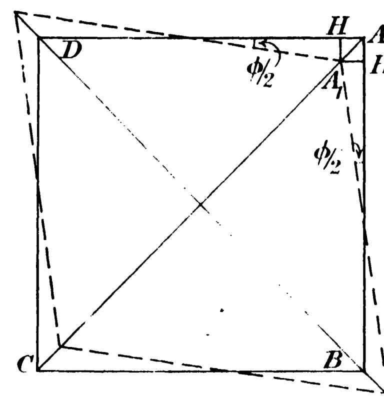


FIG. 8

original length of the diagonals AC and BD is $\sqrt{2} \cdot l$, where $l = AB = BC$; the tensile stress increases the length to $\sqrt{2} \cdot l \cdot (1 + s/E)$; and the compressive stress decreases the length to $\sqrt{2} \cdot l \cdot (1 - s/E)$.

The compressive stress along AC increases further the length of BD from $\sqrt{2} \cdot l \cdot \left(1 + \frac{s}{E}\right)$ to $\sqrt{2} \cdot l \cdot \left(1 + \frac{s}{E}\right)\left(1 + \frac{s}{E \cdot n}\right)$, and the tensile stress decreases the shorter diagonal to $\sqrt{2} \cdot l \cdot \left(1 - \frac{s}{E}\right)\left(1 - \frac{s}{E \cdot n}\right)$.

The change of length of each diagonal is thus the same, viz., $\sqrt{2} \cdot l \cdot \frac{s}{E} \cdot \left(1 + \frac{1}{n}\right)$, the last term resulting from the multiplication of the expressions in the brackets being $s^2 \div E^2 \cdot n$, and therefore negligible.

From Fig. 8 half of this change equals AA_1, which is the hypotenuse of a triangle of which

A_1H is the base and $AA_1 = \sqrt{2} \cdot A_1H$. But $A_1H = \frac{l}{2} \cdot \frac{\phi}{2}$, as ϕ is very small.

$$\therefore \frac{\sqrt{2} \cdot l}{2} \cdot \frac{s}{E} \cdot \left(1 + \frac{1}{n}\right) = \sqrt{2} \cdot \frac{l}{2} \cdot \frac{\phi}{2}$$

$$= \frac{\sqrt{2} \cdot l}{2} \cdot \frac{1}{2} \cdot \frac{s}{G} \text{ as } \phi = \frac{s}{G} \text{ (from equation 6).}$$

$$\therefore \left(1 + \frac{1}{n}\right) \div E = \frac{1}{2G} \quad . \quad . \quad (7)$$

If $n = 4$, $G = \cdot 4E$.

Properties of Sections. Before it is possible to investigate the stresses in a structural member

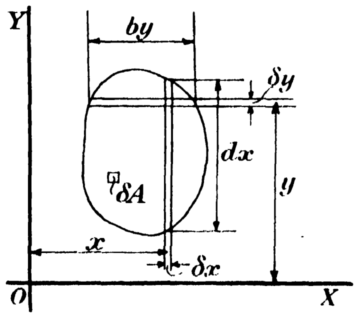


FIG. 9

it is necessary to know the properties depending on its shape.

If two axes OX and OY are drawn outside the section, which is divided up into narrow strips parallel to the axes, the total area is the sum of such strips, and may be written

$$A = \Sigma by \,.\, \delta y = \Sigma dx \cdot \delta x$$

where by and dx are the breadth and depth respectively of the strips a distance y and x from the axes, as shown in Fig. 9.

If a small element of area is called δA the total area may also be written as $\Sigma \delta A$. The symbol Σ (sigma) is the Greek letter S, and is commonly used to signify summation.

If the area of each horizontal strip is multiplied by its distance from OX, the sum may be written $\Sigma by \cdot \delta y \cdot y$, and is called the *first moment* of the area about the axis OX. If this area moment is divided by the area, the quotient is a length which may be called y_0.

Thus,

$$y_0 \times \Sigma by \cdot \delta y = \Sigma by \cdot \delta y \cdot y \quad . \quad . \quad (8)$$

Similarly,

$$x_0 \times \Sigma dx \cdot \delta x = \Sigma \delta x \cdot \delta x \cdot x \quad . \quad . \quad (9)$$

The two co-ordinates x_0 and y_0 determine the *centroid* of the area, or the point where the whole area may be considered to act, in determining the first moment of the area about any axis. The second moment of the area, or the *moment of inertia*, (I) about OX, may be written $Ix = \Sigma by \cdot \delta y \cdot y^2$.

If this is divided by the area, the quotient is an area which may be written g_x^2.

Thus,

$$Ix = \Sigma by \cdot \delta y \cdot y^2$$
$$= (\Sigma by \cdot \delta y) \cdot g_x^2 = A \cdot g_x^2 \quad . \quad (10)$$

Similarly,

$$Iy = \Sigma dx \cdot \delta x \cdot x^2$$
$$= (\Sigma dx \cdot \delta x) \cdot g_y^2 = A \cdot g_y^2 \quad . \quad (11)$$

The distances g_x and g_y are termed the ***radii of gyration*** of the section about the axes OX and OY respectively.

If axes O_1X_1 and O_1Y_1 are drawn through the centroid parallel to OX and OY, as shown in Fig. 10, the co-ordinates of any point P are x_1 and y_1 with reference to the new axes, and x and y with reference to the old. Then, $y = y_0 + y_1$, and $x = x_0 + x_1$; also $\Sigma by \cdot y \cdot \delta y = y_0 \Sigma by \cdot \delta y + \Sigma by \cdot y_1 \cdot \delta y$.

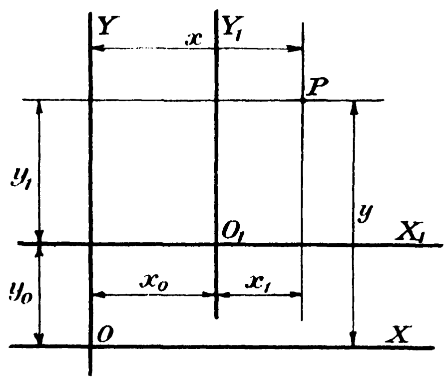


FIG. 10

From (8) $\Sigma by \cdot y \cdot \delta y = y_0 \Sigma by \cdot \delta y$.

$$\therefore \Sigma by \cdot y_1 \cdot \delta y = 0 \quad . \quad . \quad . \quad (12)$$

Similarly,

$$\Sigma dx \cdot x_1 \cdot \delta x = 0 \quad . \quad . \quad . \quad (13)$$

$$\Sigma by \cdot \delta y \cdot y^2 = y_0^2 \Sigma by \cdot \delta y + \Sigma by \cdot \delta y \cdot y_1^2 + 2y_0 \Sigma by \cdot \delta y \cdot y_1.$$

From (12) the last term $= 0$; therefore

$$\Sigma by \cdot \delta y \cdot y^2 = y_0 \Sigma by \cdot \delta y + \Sigma by \cdot \delta y \cdot y_1^2,$$

which may be written

$$Ix = A \cdot y_0^2 + Ix_1 \quad . \quad . \quad . \quad (14)$$

Similarly,

$$Iy = A \cdot x_0^2 + Iy_1 \quad . \quad . \quad . \quad (15)$$

These last equations enable the moment of inertia about an axis through the centroid to be readily obtained when the area of the section, the position of the centroid, and the moment of inertia about any parallel axis are known.

The moment of inertia of a rectangle of area $b \cdot d$ about the axis shown in Fig. 11, is

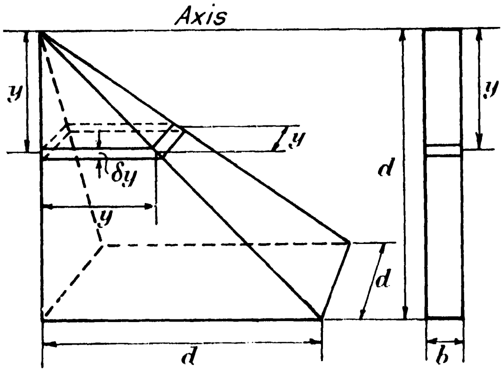


FIG. 11

$\Sigma b \cdot \delta y \cdot y^2 = b\Sigma\delta y \cdot y^2$. If a pyramid is drawn with a square base of area d^2 and height d, $\delta y \cdot y^2$ is clearly the volume of a thin horizontal strip, and $\Sigma dy \cdot y^2 =$ total volume $= d^3/3$.

I about end $= bd^3/3 = Ad^2/3 = A\left(\frac{d}{2}\right)^2 +$ I about centre, from (15).

$$I \text{ about centre} = A \cdot d^2/3 - A \cdot d^2/4$$
$$= A \cdot d^2/12 = b \cdot d^3/12 \quad . \quad (16)$$

By those familiar with the integral calculus this may be obtained directly for

$$I = \int_{-d/2}^{d/2} b \cdot y^2 \cdot dy = b \cdot d^3/12$$

For the circle and triangle shown in Fig. 12, the corresponding values of Ix are

$$A \cdot d^2/16 \text{ and } A \cdot d^2/18 \text{ respectively} \quad . \quad (17)$$

The moment of inertia about an axis through the centroid perpendicular to the section is

$$\Sigma\delta A \cdot (x^2 + y^2) = Iy + Ix \quad . \quad . \quad (18)$$

The moment of inertia of any area about an axis through the centroid will vary with the direction of the axis. It can be shown that the moment of inertia is a maximum, or a minimum, when $\Sigma\delta A \cdot x \cdot y = 0$, but for a proof of this the student is referred to a textbook on the theory of structures in which are also discussed the *ellipse of inertia*, and methods of calculating the moments of inertia of any section. It will be obvious that the moment of inertia about an axis of symmetry will be either a maximum, or minimum, . . for every value of x (or y) determining the position of an element of area δA, there will be two values of y (or x) equal in value

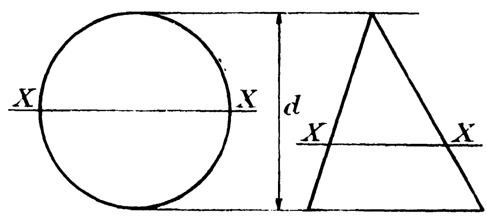


FIG. 12

but, being on opposite sides of an axis of symmetry, opposite in sign, so that $\Sigma\delta A \cdot x \cdot y$ must equal zero.

EXAMPLE. Two 15 in. × 6 in. rolled steel joists (R.S.J.) at 8 in. centres ($A = 17·3$ inch², $Ix = 726$ inch⁴, $Iy = 27·1$ inch⁴) are connected by a steel plate 18 in. × 1 in., riveted to top flange.

Find Ix and Iy of gross section, neglecting rivet holes.

SOLUTION. If A is area of constituent, y its distance from a chosen axis, Ic its moment of inertia about axis through its centroid, the calculation may be tabulated as below, the axes chosen being the bottom of the unplated flanges and the axis of symmetry parallel to the webs—

Member	A	y	$A \cdot y$	$A \cdot y^2$	Ic	
2/15 in. × 6 in. R.S.J.	34·6	$7\frac{1}{2}$	259·5	1946·0	+ 1452·0	= 3398
18 in. × 1 in. plate	18·0	$15\frac{1}{2}$	279·0	4324·5	+ 1·5	= 4326
Total A =	52·6	× 10·25	= 538·5	Ix about bottom		= 7724
	52·6	× 10·25²	= 538·5	× 10·25		= 5520
Centroid is 10·25 from bottom and Ix about centroid						= 2204

Member	A	y	$A \cdot y$	$A \cdot y^2$	Ic	
15 in. × 6 in.	17·3	+ 4	+ 69·2	276·8	+ 27·1	= 303·9
15 in. × 6 in.	17·3	− 4	69·2	276·8	+ 27·1	= 303·9
18 in. × 1 in. plate	18·0	0	0	0	+ 486·0	486·0
	52·6			Iy about centroid		1094

The radii of gyration are: $g_x = 6·48$ and $g_y = 4·56$.

SPECIFICATIONS AND QUANTITIES

By Wilfrid L. Evershed, F.S.I.
Chartered Quantity Surveyor

LESSON V

QUANTITY SURVEYING

In describing methods of procedure in the following lessons on "Quantity Surveying," it can be assumed that they apply equally to measuring on a building or from plans.

Upon receipt of instructions for the preparation of quantities, it is advisable that the surveyor should thoroughly understand the plans and specification, or notes, and for this purpose he should spend some time looking them over to obtain a mental picture of what they represent.

In this preliminary survey, notes should be made of questions which arise in his mind; the same idea of keeping notes should be followed during the period of *taking off*, a list being prepared for discussion with the architect before the bills are finally completed.

Whenever possible, a visit should be made to the site and any special feature noted, as also the description of the soil.

Systems. The general method of preparing a bill of quantities is that known as the *London system*.

The *Northern system* consists largely of the use of different units as the standard of measurement, the use of slightly different terms, and a general custom of each trade being tendered for separately, in many cases by different firms.

The *Scottish methods* are different again; the taking off is not the same, and there is no abstracting but a proper explanation requires more space than is available here.

The London System. In the preparation of bills on the London system, the order of work consists of (1) "taking off," and (2) "working up." The various kinds of paper used are illustrated in the examples given, and will be understood if carefully followed.

When writing the dimensions, do not crowd them together; also use sub-headings to indicate sections, such as windows, doors, etc. Always use figured dimensions, but if there are none, figure the plans up in pencil.

Always take the largest possible dimensions, and make a deduction for wants or voids.

Any quantity of work which is uncertain, or is likely to be varied, should be made a "Provisional" item.

Measure in full detail; do not let the description cover a lot of items which can, and should, be measured.

The description should be full, leaving nothing to the imagination.

Make a practice of starting at a given point and working in a particular direction from the same. Do not jump about.

Book all the dimensions in the order measured, whether they are "adds" or "deducts."

Dimensions, except sizes of timber scantlings, are booked in full figures; fractions are not used.

When booking "half-brick" walls, book as "H.B.," but when booking an additional half-brick thickness to a wall, enter as "½ B."

If a wrong dimension has been booked, do not cross it out, but write "nil" against it in the third column, and when abstracting use a "wavey" line in cutting out the item.

Fractions are always booked as ½, ¾, etc., and not 1/2, 3/4, etc., which can be mistaken for shillings and pence.

Abbreviations. In taking off, it is customary to use abbreviations instead of writing the full description, and the following list gives some of the more general used—

a.b.	As before.
a.d.	Average depth.
B.	Brick.
B. & P.	Bed and point.
b/s.	Both sides.
B.P.P.	British polished plate
B.N. & W.	Bolt, nut, and washer.
C.C.N.	Close copper nailing.
Chy.	Chimney.
Cir.	Circular.
Ct. or C.	Cement.
Ddt.	Deduct.
Dia.	Diameter.
D.P.C.	Damp-proof course.
E.O.	Extra only.
Exc.	Excavate.
F.F.	Fair face.
Frd.	Framed.
Foots	Footings.
F.E.	Feather edge.
Gal'd.	Galvanized.
H.B.S.	Herring-bone strutting.
H.B.	Half brick.
½B.	Half-brick, but additional thickness only.
Lab.	Labour.
L.P.F. & S.	Lath, plaster, float, and set.
L.W.	Lime white.
M.G.	Making good.
m/s.	Measured separately.
N.W.	Narrow widths.
n/e.	Not exceeding.
No.	Number.
o/s.	One side.
O.G.	Ogee.
P. & C.	Parge and core.
P.C.	Prime cost, or Portland cement.
P.C.C.	Portland cement concrete.
P.F.	Plain face.
P. & S.	Planking and strutting.
R. & S.	Render and set.
R.F. & R.	Return, fill, and ram.
R.W.P.	Rain-water pipe.
R.W. & P.	Rake, wedge, and point.
R.A.	Relieving arch.
Sup.	Superficial.
T.	Tee.
W.I.	Wrought iron.
W.o s.	Wrought one side.
W.b s.	Wrought both sides.
Xg.	Cross grain.
Xtg.	Cross tongued.
2ce.	Twice, etc.

Always take off and measure in a definite order and by a definite system.

Systems. There are two chief systems of taking off. One is taking off by " trades " ; in this method the work is measured off the plans more or less in the order of the specifications, each trade being completed before the next is attempted. But this system is not recommended even for the beginner.

The best system is the one in which the work is divided into three main divisions, comprising, (*a*) the carcase, (*b*) the joinery and finishings : and (*c*) the drains, sanitary work, fencing, etc. ; and this is the system which will be followed. It has, of course, some disadvantages, among them being the necessity of completing the " taking off " before the work can be billed.

The general order for taking off is that followed in describing the method of measuring, and from this the student can compile a list of the order.

Where Drawings and Specification Only are Supplied. The subject of quantities is of interest to the student in a builder's office, because many estimates are required for which the ordinary bills of quantities are not supplied ; in such cases, the architect asks for a tender by loaning to the builder a set of drawings and a specification. However, in certain districts the builders refuse to tender for work over a certain value unless quantities are supplied, the amount varying from £500 to £1,000.

The preparation of the quantities in the builder's office is not always done in as much detail as when quantities are prepared by the surveyor ; but it will be realized that if the person taking off has a sound knowledge of the surveyor's method of measurement, he can always adapt his work to suit the requirements of the particular job in hand ; and it is possible to prepare sufficient information in the form of rough quantities from which to make up an estimate, without going into all the detail and the process of abstracting and billing as carried out by a surveyor.

ELECTRICAL FITTING

By F. Charles Raphael, M.I.E.E.

LESSON II

THE LIGHTING LAY-OUT

POSITIONS OF LIGHTS

We now turn to the most important matter of all in the electric lighting of a building, namely, the position of the lamps and switches. It is a remarkable fact that one of the most difficult things with which an electrical engineer has to contend is to obtain precise instructions as to where the lamps are to go. A great deal will depend on the position of the furniture in the rooms ; most clients cannot bring themselves to come to a decision as to this on the plans, and start with the idea that the position of the lights can be determined at the same time as the position of the furniture. This is the difficulty, for in new buildings electric light wiring should be buried in the walls or between the floors and ceilings, for the sake of appearance. Some cutting away for them can usually be saved if the tubes for the wires are put in before the walls, partition, and floors are completed. In any case, the tubes must be in place before plastering.

Thus, the position of the lights and switches should be marked out on the plan at as early a stage as possible, and the man primarily responsible for the installation, be he a consulting electrical engineer, the architect, builder, or electrical contractor, should do this. It is his affair to see that the lighting is good, and he must therefore be capable of setting out the correct positions of the lamps, and indicating the sizes of these and the character of the most suitable fittings. Needless to say, the client will have a say in the matter, but the selection of the positions and fittings should not be left entirely to him, as is only too frequently done.

Lights in a House. The light in the **hall** should be placed in front of and not over the centre of the staircase, and the illumination of the hall and stairs should be less than that of the rooms, or the latter will appear dull in contrast.

The **dining-room** should have a light over the centre of the table, and if this light is sufficiently high, there is no need to employ the old-fashioned **dining-table** fitting with a flounce round it, which darkens the rest of the room. In a large dining-room, a bracket or a pair of brackets may be required in addition over the sideboard or carving table. If a dining-room is to be used as the regular "living room," wall sockets should be provided on the skirting board, to enable floor standards to be plugged in near the armchairs for reading.

In **drawing-rooms,** good central lighting from fittings hung from the ceilings is usually the best, but no hard and fast rule can be given, as so much depends on the position of the furniture. Brackets are decorative, but there are few rooms in which good illumination can be afforded by brackets alone, and they should be used sparingly, and chiefly reserved for cases where lights are necessary on the half-landings of staircases, or in other places where there is no ceiling for fixing. The place for the maximum light in a room is not close to the walls.

The proper place for the light in a **bedroom** is over the dressing table, half-way between the mirror and the person using it. If a second light is required, it should be over the head of the bed, or just in front of the mirror in the wardrobe door. If you put a centre light in a bedroom of average size, it usually comes just above the foot of the bed—the most useless place for it.

Writing tables are best lighted by pendant lights, a foot or two to the left of the centre of the table.

In **bathrooms,** well-glass fittings should be used, fixed on the ceiling.

The main light in the **kitchen** should be as close to the front of the cooking range as possible, not in the centre of the room behind the cook. As a rule, a pendant lamp in front of the range gives sufficient light on the centre table, and supplementary brackets can be provided if additional light is required in other parts of the room. A bracket or tube pendant, ending in a well-glass fitting, may be provided over the sink in the scullery.

SIZE OF LAMPS

The size to give to the lamps is a matter of experience, and depends very much on whether the decoration and furniture of a room is light or dark. From the light-reflecting point of view, purple, red, and brown wallpapers can always be considered dark, as must also green and blue, unless they are pale. White, cream, yellow, and the lighter greys give the best reflection. As a rough guide, an allowance of half a watt per square foot of floor area gives a good light in a brightly decorated room, with lamps hung at an average of 7 ft. from the floor, and having shades or bowls of satin-finished glass. If the colours in the room are dark, or the light from the lamps obscured with coloured silk shades or thick opal or alabaster bowls, two or three times this allowance may be necessary. Another thing to remember is that the lighter the decoration of room, the fewer is the number of lighting points that are required irrespective of the total wattage. Light colours are a cheerful form of economy.

POSITION OF SWITCHES

The position of the switch for one light in a room must always be just inside the door, and it is advisable to be quite sure which way the door is to be hung before marking out the position—which should, of course, be on the side away from the hinge. "Two-way" switches, that is control of the light from two switches in different positions, should be used for the hall light, staircase lamps, long corridors, and in bedrooms where there is no light over the bed with its own local switch. For the hall light, the second switch should be on the first floor landing. For other stair and landing lights, the usual position for the two switches are one on the same floor as the light and the other on the floor above, but in some buildings this may have to be varied, and the second switch placed on the floor below the lamp.

A useful height for switches is 4 ft. from the ground, but, whatever the height selected, it should be kept as a standard throughout the building, except when special circumstances demand a greater height for individual switches. In nurseries, for instance, the switches are often placed 6 ft. above floor level, so as to be out of reach of children.

WORKSHOPS, ETC.

In the above remarks, the position and size of lights have been dealt with in relation to ordinary private houses. In other buildings, the same general principles apply. In retail shops, put the lights where they will best light the goods displayed, and in workshops it is the work, and not the floor, that must have the best light without shadows, although a gangway between running machines must be perfectly lighted. A symmetrical arrangement of the lights is wrong if it is against this general principle.

JOINERY

By T. Corkhill, F.B.I.C.C., M.I.Struct.E., *Double Medallist*

LESSON VIII

WORKSHOP EQUIPMENT

The equipment required for a joiner's shop, outside the tools and machines, is neither elaborate nor expensive. There are several things which are necessary, and many things which are optional, but of great advantage when they are required. The latter are generally added to the stock as the occasion requires them; hence the equipment is a gradually increasing one. The former include benches, cramps and cleats, shooting boards, mitre boxes, sawing stools, grindstones, glue kettles, and saw sharpening equipment.

Benches. These may be either single or double. The joiner prefers the single bench because he is independent of his neighbour, and there is no confusion with the tools, or with the work when the men are on different jobs. Where the floor space is inadequate, the double bench is an advantage. For large framing they are nearly essential, hence it is usual to have both kinds in the workshop.

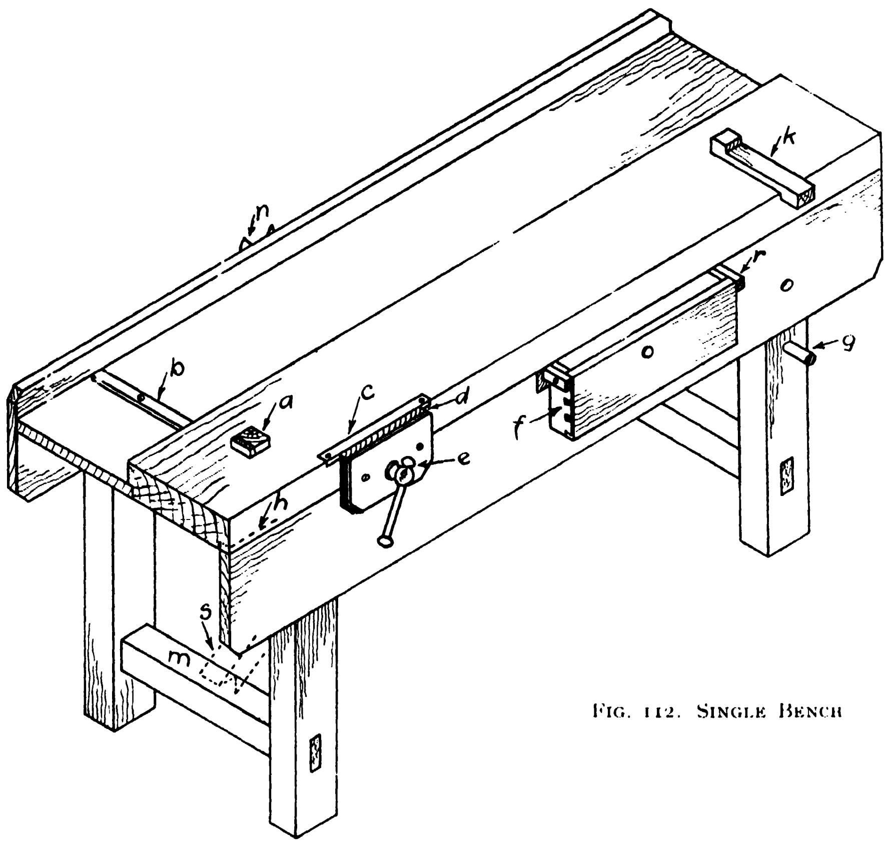


Fig. 112. Single Bench

A single bench is illustrated in Fig. 112. The usual sizes are about 10 ft. long by 2 ft. 9 in. high and 1 ft. 10 in. wide. The top should be about 11 in. by 3 in., and the legs from 4½ in. to 6 in. by 3 in. framed up with 3 in. by 3 in. rails *m*; all the rest of the stuff is 11 in. by 1 in. Very often the bench is made more rigid by using 3 in. by 3 in. braces *s*, with a rail under the middle of the top, to prevent sagging. The top is often rebated on both edges as shown at *h*. A

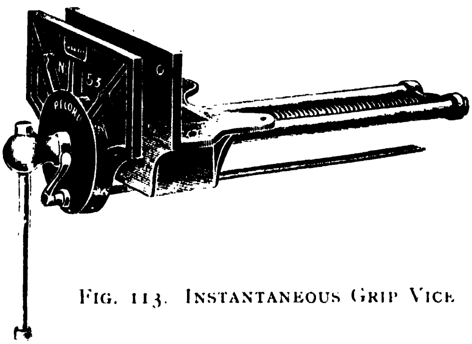


FIG. 113. INSTANTANEOUS GRIP VICE

drawer *f* is provided for the joiner's tools, and a rack *n* for the saws. To keep the plane irons off the bench, a strip *b* is screwed to the *well*. It

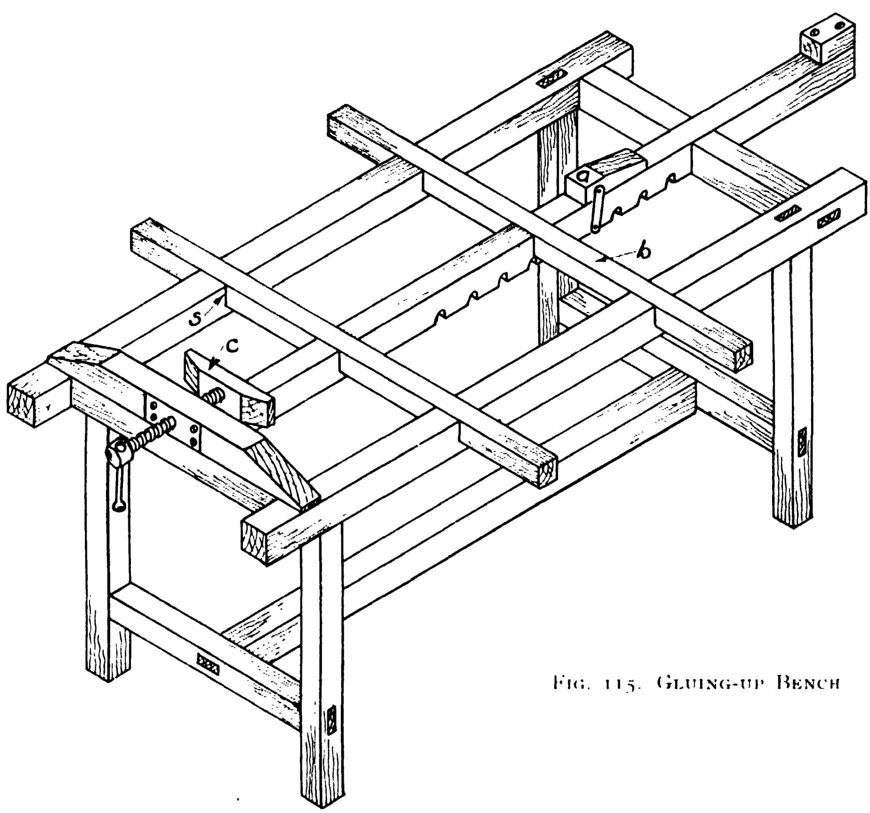


FIG. 115. GLUING-UP BENCH

is fixed with one screw only, so that it may be swivelled round for brushing down the *well*.

The two most important features are the stop *a* and the vice *c*. In both cases there are many variations, but an *instantaneous grip vice*, as shown in Fig. 113, is the most useful vice. The *bench stop* may be of metal, Fig. 114, or of hardwood as shown in Fig. 112 *a*. The metal stop can be adjusted by the screw *s*, but it is not

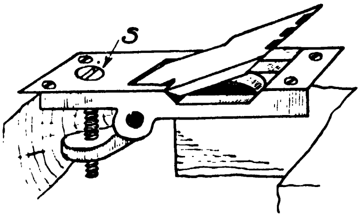


FIG. 114. METAL STOP

favoured by the joiner owing to the danger of damaging the tools. In fact all metal should be avoided on the bench top. The usual form of stop is a pair of hardwood folding wedges. Two *sprigs* are driven in the front and filed to a chisel point, to grip the stuff. This form of stop is easily adjusted with the hammer. The vice jaws should be kept below the bench top, and faced with hardwood *c* and *d*, to protect the tools and timber. When long stuff is in the vice, the other end rests on the drawer, or on *pegs g* which fit into holes bored in the bench front and leg. The drawer *f* is suspended from the bench top by hardwood runners *r* which slide in rebated pieces screwed to the bench top.

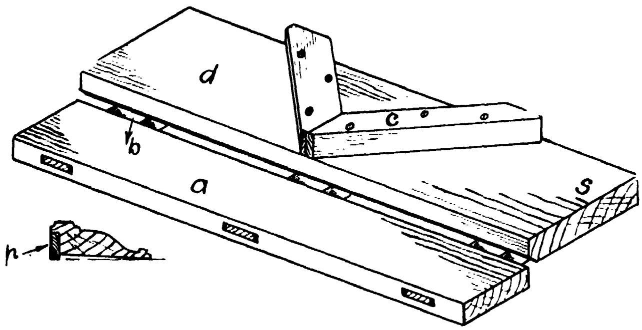


Fig. 116. Shooting Board

The *bench hook* shown on the bench is used for shouldering and sawing short lengths on the bench. It may be from 2 in. to 6 in. wide, and may be cut from the solid. The projecting pieces may be glued and nailed on for the wider hooks.

Gluing-up Benches. In large shops a skeleton bench, as shown in Fig. 115, is often

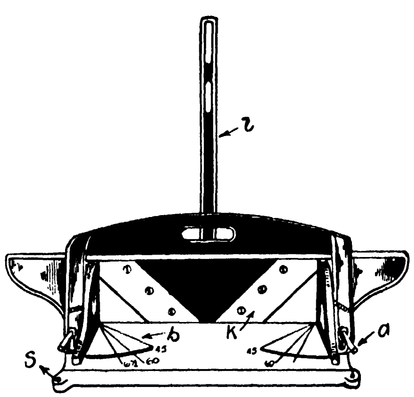


Fig. 117. Trimmer

used for cramping up framing. The stop, or shoe, *a*, is adjusted to the required distance, and then the screw *c* cramps up the framing. The rails *b* are loose and may be replaced by longer ones if required.

The *door cramping machine* is a metal bench which cramps up a door with one action of a foot lever. Two joiners can glue and cramp up 25 to 30 doors per hour with this machine.

Shooting Boards. There are two forms of shooting boards, one for shooting mitres Fig. 116, known as *mitre shoot*, and one for jointing. The construction of the board is the same in both cases. The piece *a* is mortised for the battens *b*, then the piece *d* is screwed from the underside of the battens. The usual size of *d* is about 3 ft. by 10 in. by $1\frac{1}{2}$ in.; and *a* is about 4 in. by $1\frac{1}{4}$ in. The fences form an angle of 45° with the edge of *d*. The stuff is held firmly against the fences whilst the mitres are planed by the try plane running sideways on *a*, which is about $\frac{1}{2}$ in. below *d*.

Jointing Boards are made and used in the same way as shooting boards, but the fences *c* are omitted and a hardwood stop is fixed at *s*. They are used for making butt joints for short stuff; the piece rests on *d* with the edge pressed up to the try plane running on *a*. This method is quicker and easier than straightening the edges in the vice, and more certain of producing a square edge. A space should be left between *a* and *d* to allow the shavings to fall through.

Panel Boards are usually one piece of well seasoned pine, about 3 ft. by 12 in. by 2 in., with a hardwood stop. They are used for planing up thin stuff such as panels. Sometimes they are framed up to prevent warping; and instead of the hardwood stop two or three screws may be used for the stop. A *sticking board* is also useful for sticking mouldings by hand, but they are very varied in sizes and details, and seldom required. The ingenuity of the joiner will quickly devise a convenient type when it is required.

Mitres. The *trimmer*, or mitreing machine, shown in Fig. 117, is a useful machine for the

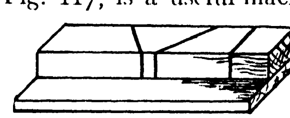


Fig. 118. Mitre Block

joiner's shop. The fences can be adjusted for different angles and fixed to the required position by the lever handles *a*. The table is graduated and marked as shown at *b*. The knives *k*, actuated by the lever *l*, make a clean cut because of the shearing action; and the machine if kept in condition usually dispenses with the mitre shoot. The screw-holes *s* are to fix the trimmer to the bench.

Mitre Blocks. The mitre block, Fig. 118, is a simple and efficient device for sawing mitres on small stuff. Although it is usually made for angles of 45°, the saw cuts may be made for any desired angle. There is usually a right angle cut as shown in the illustration. The size depends upon the work it has to do, but usually the bottom piece is about 6 in. by 1 in.,

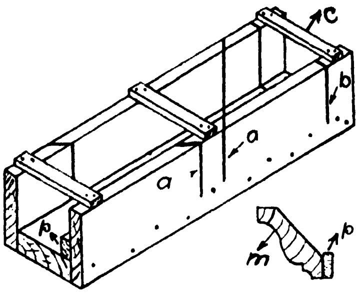


FIG. 119. MITRE BOX

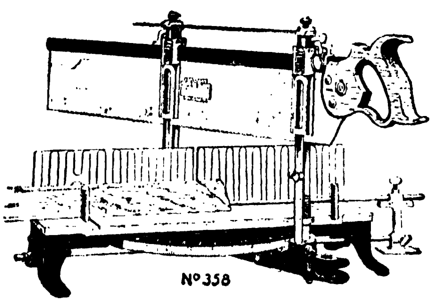


FIG. 120. STANLEY MITRE BOX

and the fence which is nailed to the base board is about 3 in. by 1½ in.

The Mitre Box is an extension of the mitre block for bigger stuff. The cuts are the same, as shown in Fig. 119, and the sides are strengthened by the pieces *c*. A 45° cut is shown at *a* and a 90° cut at *b*. When cornice or bed mouldings *m* are being cut, it is necessary to pack the moulding as shown in the small sketch. This also applies to bolection mouldings, when the back is kept clear of the panels, as shown by the small sketch in Fig. 116. The packing *p* is also used whilst shooting the mitre.

There are many forms of metal adjustable mitre boxes, but the joiner usually prefers the home-made box. Fig. 120 shows a Stanley adjustable mitre box. The saw is held above

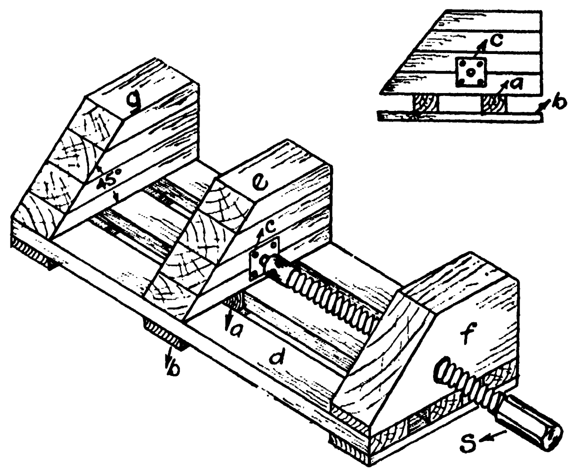


FIG. 121. SCREW MITRE SHOOT

the box, as shown, when not in use, and the angle can easily be adjusted and locked for any angle between 30° and 90°.

Screw Mitre Shoot. This is a device for shooting the mitres of small stuff (see Fig. 121). A block plane is used, running on the bevels *e* and *g*, but care must be exercised so as not to damage those faces. The blocks *f* and *g* are fixed; *f* carries the handscrew *s*, which actuates the movable block *e*, to fix the stuff between *g* and *e*. Blocks are fixed under *e* to run in the spaces between the base board *d*, which is built up on the battens *b*. An end view of the movable block *e* is shown in the small sketch. The fixed block *f* can be any shape, so that it is sufficiently rigid to carry the handscrew.

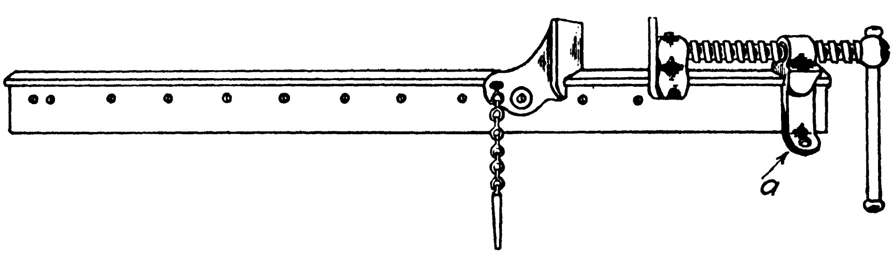


FIG. 122. CRAMP

Cramps. A good variety of cramps is a time-saver to the joiners. There should be several sizes from 2 ft. 6 in. to 6 ft., and also extension pieces for the latter. It is an advantage to have the cramps in pairs, because two cramps are usually required for cramping up. Fig. 122 illustrates the heavy type of cramp, which is usually 4 ft. to 6 ft. in length. The lug *a* is useful for screwing to the bench. If two similar cramps are fixed to the bench in this way, they are very convenient for cramping up sashes, etc., as the work is clear for squaring, pinning and wedging. Sometimes wooden cramps are used for this purpose and hardwood wedges take the place of the screws.

Bench Clamps. The bench clamp, or holdfast, shown in Fig. 123 fixes the work to the bench whilst the joiner performs the various tool operations. A hole is bored in the bench

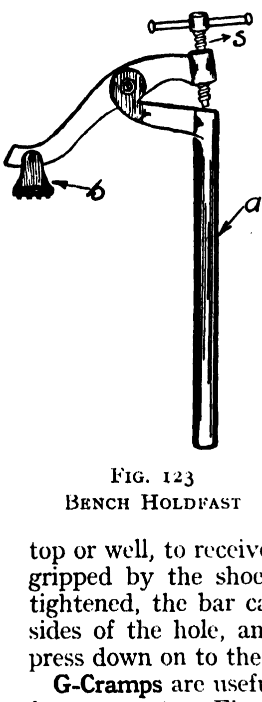


FIG. 123
BENCH HOLDFAST

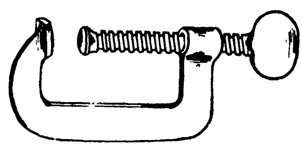


FIG. 124. G-CRAMP

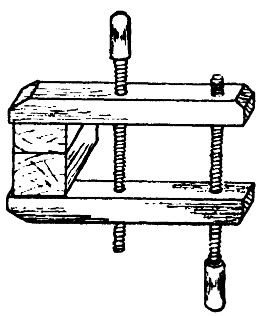


FIG. 125
HANDSCREWS

top or well, to receive the bar *a*, and the stuff is gripped by the shoe *b*. When the screw *s* is tightened, the bar cants over and grips on the sides of the hole, and then the shoe begins to press down on to the stuff.

G-Cramps are useful for small work, repairing fractures, etc. Fig. 124 shows a small type, but larger ones may be obtained with lever handles. *Handscrews* as shown in Fig. 125 are also used for light work, and for holding together several pieces of stuff whilst they are being worked, or after they have been glued. The various parts are of beech.

Cleats. These are used for holding the work after jointing until the glue sets. They may be of wood or iron. The wooden type shown in Fig. 126 consists of two pieces about 3 in. by $\frac{7}{8}$ in., and long enough to take the work for which they are required. Holes are bored to

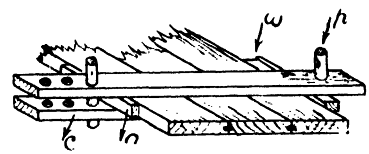


FIG. 126. CLEATS

receive the pins *p*. On one edge of the stuff a protecting piece *a* is placed, whilst at the other edge fox wedges are used to cramp up the joints. The cleats are left on the stuff until the glue sets. The advantage of this type is that the stuff is kept straight whilst drying.

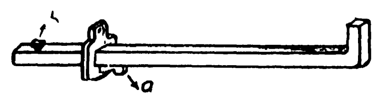


FIG. 127. IRON CLEAT

Fig. 127 shows a metal cleat, which is very useful because it is easily applied whilst the stuff is in the vice. The wedge *a* fixes the shoe in position. A small set screw *b* is put in the end of the bar to prevent the shoe from falling off when the wedge is slackened and for

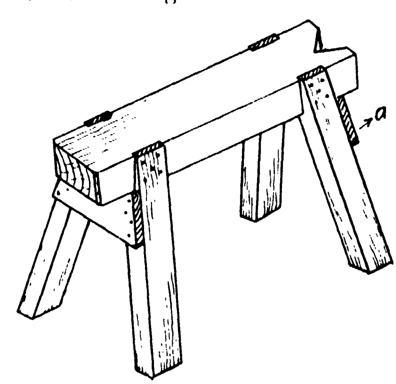


FIG. 128. SAWING STOOL

fixing an extension piece to the bar, if required. The size is usually about 3 ft. long and $\frac{3}{4}$ in. square.

Sawing Stools, as shown in Fig. 128 are necessary both in the shop and on the job. The *vee* cut in the end of the top is for gripping the work, such as doors, whilst the edges are being planed or worked. The top is usually $4\frac{1}{2}$ in. by 3 in. The legs, which are splayed outwards in both directions, are 3 in. by $2\frac{1}{2}$ in ; they are strengthened by the pieces *a*.

Tool Chests. Many joiners are not satisfied with the tool accommodation and security provided by the bench drawer, and have their own tool chest. Fig. 129 illustrates the usual type,

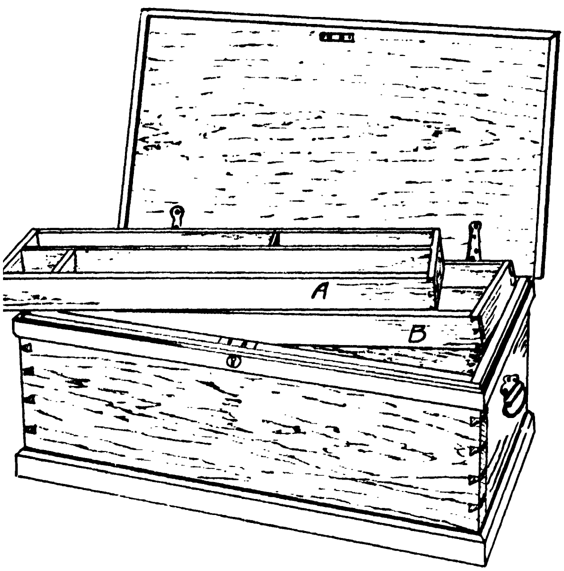


FIG. 129. TOOL CHEST

which has two sliding trays *A* and *B* for the lighter tools. The planes and heavy tools are placed on the bottom of the chest, and the saws are fixed to the inside of the lid by buttons. A common size is about 2 ft. 6 in. by 1 ft. 6 in. by 1 ft. 6 in., and they are made from 1 in. stuff. For outside work, a small portable tool box is often used instead of the *bass*, because it keeps the tools in better condition and more secure.

Glue. When the usual form of cake glue is used, whether Scotch, English, or French, it is necessary to have some form of heating arrangement. The glue kettle consists of an inner and an outer pot, so that the glue in the inner pot is heated by the water in the outer pot. If the outer pot is allowed to boil dry the glue is quickly burnt and made useless. It is usual, in joiners' shops, to have a ***heater*** containing several pots, the frame containing water and heated by gas or steam. Fig. 130 shows a gas heater containing three pots, but the same form may be obtained with one or two pots. The cake glue is broken into small pieces and covered with water; then it is allowed to steep for a night before being heated. The glue should be very hot when being used, and just thick enough to drip off the brush. It should be used in a warm dry atmosphere for good results, and the stuff must be dry and preferably warm. The glued joint should harden in a warm and dry room.

In many shops, some form of patent liquid glue, which only requires to be warm, is used. It is nearly always ready for use, except in cold weather. Whatever kind of glue is used,

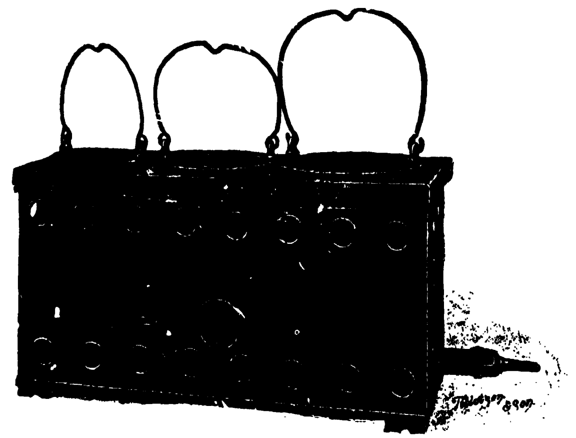


FIG. 130. GLUE HEATER

especially cake glue, it should be rubbed and squeezed out of the joint as much as possible, both for strength and appearance after cleaning up. *Cold water glue* is rapidly coming into favour. It has to be mixed fresh daily, or as required, from a white powder made by the *Croid* firm.

BRICKWORK

By William Blaber
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LESSON VIII

WALLS AND PIERS

Purpose of Walls. Walls are required to enclose a space, and for the division of a structure into a number of apartments; or as supports to carry the weight of secondary structures, such as floors and their loads, partitions, and roofs.

Before walls are built many conditions affecting their stability have to be considered : the materials of construction, their thickness, height, and length ; the nature of their loading and its distribution.

In considering their loads, the weight of the walls themselves, and the weight of interior parts that are transmitted to the walls, must be included ; also the thrust of arches, corbels, flights of stairs, etc.

Thickness of Walls. The thickness of walls largely depends, apart from their loads, upon the relation of their height to their length, and to the spread of their bases to prevent overturning. An isolated wall, such as a boundary or parapet wall, would require a greater thickness, and consequently a wider spread of foundation, than the walls of a residence, which receive much support from intersecting, joining, and returned walls.

The length of a wall, in relation to its height, is that part of the wall between any joining wall connecting at an angle, and which receives no intermediate support from an abutting or intersecting wall.

Thickness is also dependent upon the weather-resisting properties of the materials with which the walls are built. The walls should be sufficiently thick to prevent the too rapid conduction of heat, both artificial and natural ; also to prevent the passage of sound from apartment to apartment.

The Thickness of External Walls should not be less than one-sixteenth of the height of the story in the case of residences, and not less than one-fourteenth in the case of warehouses.

The following particulars are a good guide for the requisite thickness of walls under ordinary circumstances—

Walls of two stories not exceeding a total height of 25 ft., one brick thick.

Three stories in height: top story, one brick thick ; lower stories, 1½ bricks thick.

Forty feet to 50 ft. in height: top story, one brick thick ; lowest story, two bricks thick ; and the intermediate stories, 1½ bricks thick.

Fifty feet to 60 ft. high: two bottom stories, two bricks thick, and the upper stories 1½ bricks thick.

Pipe chases are frequently cut into existing walls, without any thought as to the weakening effect they may have upon the wall ; in the case of a heavily loaded wall, the result may prove serious, and should never be allowed without the sanction of someone in authority sufficiently experienced to decide whether it would be safe to do so.

Piers. In forming window or door openings or recesses, a wall is divided into a number of piers, which become the subject of concentrated loads. The openings between the piers are spanned by girders, lintels, or arches, which carry the weight of the work above and transmit it to the piers ; the various thrusts at the abutments of arches have also to be considered.

The sectional area of the piers, that is, their length multiplied by their breadth, must be sufficient to carry the concentrated loads, and it frequently becomes necessary to thicken the wall at these points.

Isolated Piers receiving no support from abutting walls need to be of a greater sectional area than connected piers. Their height is relative to their sectional area, and varies with different materials to a point, where it gradually becomes weaker owing to its liability to buckle under its own weight, apart from its load. No isolated pier should be built higher than from ten to twelve times its least diameter.

A pier 10 ft. high will only carry half the weight that it will carry when only 1 ft. in height.

The density and hardness of the material with which a pier is constructed affect its stability.

Stock brickwork crushes under a load of about 30 tons per sq. ft. ; half this load will cause failure by cracking, which will eventually destroy the structure. A *safe load* would be one-fifth of that which causes fracture, and one-half of this result for a pier 10 ft. in height.

The vertical joints in brick piers are a decided source of weakness, much of which can be eliminated by the skill and knowledge of the bricklayer in arranging his bond to produce the greatest strength, and by using a reasonably strong cement mortar.

The foregoing will assist the craftsman to realize the importance of a good knowledge of the principles underlying brickwork construction, and materially help him at any time he is employed in a supervisory capacity where the responsibility for a satisfactory job is his.

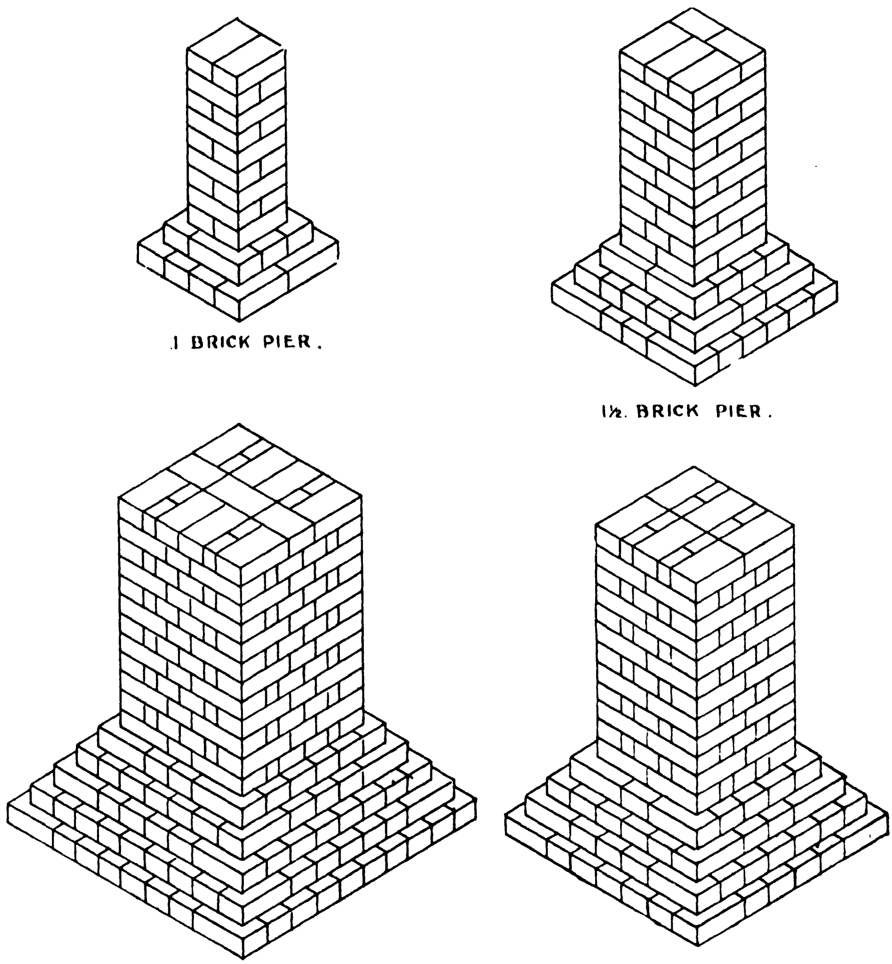


FIG. 46. PIERS

The *foundations* for brick piers in the ordinary way are the same as for walls, the spread of the footings being equal to twice the least thickness of the pier. This again depends upon the load it is called upon to support. Special treatment in this respect is a matter for the architect; in this section it is therefore only necessary to consider ordinary foundation. A number of examples are illustrated in Fig. 46.

An easy rule for calculating the number of courses of footings for any thickness of wall, is to reckon one course of footings for every half-brick in the thickness of the wall, the bottom course of which will be twice the thickness of the wall; as an example, a one-brick wall has two half-bricks in its thickness, therefore there will be two courses of footings, and the bottom course will be two bricks wide.

Again, a two-brick wall has four half-bricks in its thickness; there will be four courses of footings, the bottom course being four bricks wide.

Each course of footings is set back 2¼ in. from the face of the course below, forming a series of steps on each side of the wall. These steps are called *offsets*.

DAMP-PROOF COURSES

Reasons for Damp-proof Courses. Damp and ground air not only rise through the spaces in the lower floors, but will penetrate and find entrance by rising through the pores of the bricks and mortar, unless a layer of some impervious material is inserted in the brickwork to prevent it. The movement of warmed air in a building tends to draw dampness into the interior.

In cases where there are no apartments below ground level, the rise of moisture can be obviated by inserting a horizontal layer of impervious material in all the walls at a level of not less than 6 in. above the ground, preferably 9 in. to 12 in., and necessarily below all timbers, which would otherwise be destroyed by decay from the penetrating dampness.

In cases where there are apartments below ground level, all walls that abut the face of the earth must be provided with a vertical layer, in addition to the horizontal layer. Where the level of the subsoil water rises at any time above the level of the lowest floor, it frequently becomes necessary for the whole level surface between the enclosing walls to be covered in the same manner (see Fig. 47).

Varieties of Damp-proof Courses. *Asphalt* is undoubtedly the best material for damp-proof courses, as it is absolutely impervious to moisture, practically indestructible, and not likely to fracture, owing to its elastic nature. It is easily laid, particularly in the case of vertical layers, where other materials would be difficult to fix.

There are two kinds of asphalt—*natural* and *artificial*. The former is far and away the best, but is practically twice the cost of the latter, which may contain oil, coal tar, pitch, and lime. The principal objection to their use is that they soften to such an extent during hot weather, and then compression, due to the weight of the building, squeezes the material out of the joints between the bricks, until the layer becomes so thin that the bricks come into contact with each

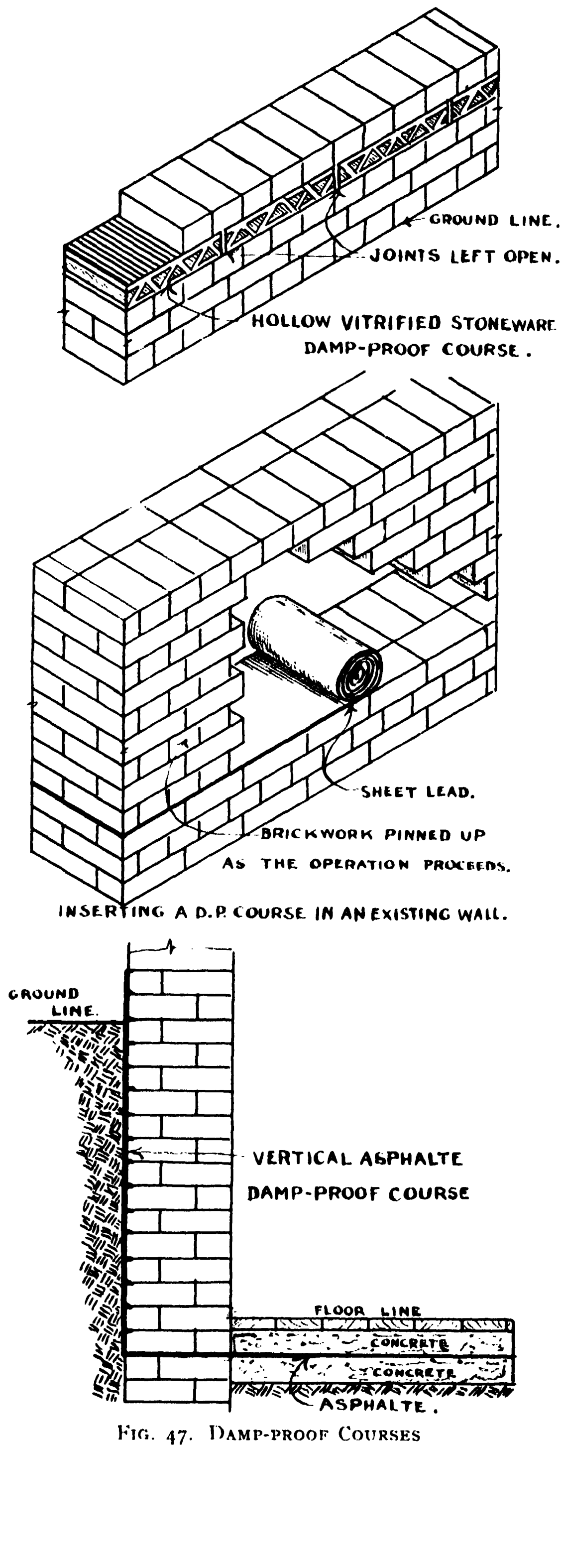


FIG. 47. DAMP-PROOF COURSES

other where their bedding surfaces are irregular, and the insulation is thereby seriously impaired.

Bituminous sheets are manufactured by several firms, which are extremely satisfactory as damp-resisting courses. Messrs. Callenders make such sheets in lengths of 24 ft. by any width that may be required. The sheets are unrolled on the surface of the walls, and joined up by forming the seam with hot irons, the damp-proof layer being continuous round the walls of the whole building.

Vulcanite, Ltd. is another maker of an excellent bituminous sheeting, their "Reliance" brand being composed of two outer sheets, with an intermediate layer of lead foil. A number of bituminous felts are also on the market, which are principally used for temporary structures.

Two courses of *roofing slates* bedded in cement mortar and half bonded form an excellent damp-proof course, but any settlement that causes fracture destroys its continuity and perfect insulation.

Hollow vitrified stoneware blocks, the width of the wall and made in short lengths, form a good damp-resisting layer, and at the same time the perforations provide ample ventilation for under the floors; in fact, in the latter respect, there is the objection that the amount of air may be too great during the winter months, making the building too cold. In fixing these blocks, the bricklayer should not make the common mistake of making the vertical joints between the blocks solid with mortar. These joints should be left open, as the joints, if of porous material, form a communication between the work above and below the impervious layer. Even were the jointing material impervious, any fine crack caused by settlement or shrinkage of the material itself would attract damp by what is known as capillary attraction.

Sheet lead has been used in the past and forms an excellent damp-resisting layer, but its cost is almost prohibitive, particularly at the present time. It can be used with advantage where a damp-proof course has to be inserted in an existing building, as it can be unrolled as the short lengths of the wall are cut away, and the underpinning proceeded with. The lengths are soldered together as the work proceeds.

LAND SURVEYING AND LEVELLING

By Professor Henry Adams, M.Inst.C.E., F.R.I.B.A., F.S.I., etc.

LESSON V

SCALES, ETC.

Surveying Lakes and Woods—Representations of Trees—Scales for Building Plots and Engineering Surveys—Ordnance Scales—Copying Plans

Surveying Outside a Boundary. Lakes and woods can be surveyed by the chain if the lines be run outside the boundary. They must be sufficiently tied, but can hardly get so good a check as a field with outer boundaries, where the chain lines can all be put inside. Without giving the field book, it will be enough to show the chain lines for two such surveys with the features sketched in. Fig. 26 shows the lines used for a lake, and Fig. 27 the lines for a wood. Representations of trees may be shown in the survey of the wood, but it is essential to bear in mind the scale. The writer once saw the survey of an ornamental lake, shown with some ducks and patches of bullrushes. One of the ducks scaled two chains long through inattention to the above note. A magnified view of the conventional forms given to the trees and bushes by surveyors is shown in Fig. 28. An elm may be 60 ft. high, other trees 30 ft. to 40 ft. Stencils of trees may be purchased if the surveyor mistrusts his skill in sketching.

Scales Used. A common scale for land surveyors is 1 in. to 1 chain, but for building plots it is rather small, being 66 ft. to 1 in. Engineering surveys with a 100 ft. chain are often plotted to 40 ft. to 1 in. It is a pity the ordnance scale of 41·66 ft. to 1 in. was not made 40 ft.; engineers have to sacrifice their convenience so that the Ordnance Survey Department might use a scale of $\frac{1}{500}$ instead of $\frac{1}{480}$. It may be useful to give a list of the various scales to which ordnance maps are drawn—

$\frac{1}{63360}$ = 1 in. to a mile, is known as the small scale.

$\frac{1}{10560}$ = 6 in. to a mile, is the medium scale.

$\frac{1}{2500}$ = 25·344 in. to a mile, is the large scale.

$\frac{1}{1056}$ = 5 ft. to a mile = 88 ft. to an inch, is a special scale for towns.

$\frac{1}{528}$ = 10 ft. to a mile = 44 ft. to an inch, is the larger scale for towns.

$\frac{1}{500}$ = 10·56 ft. to a mile = 41·66 ft. to an inch, is the new ordnance scale for towns.

The first of these is very useful for county maps, but hardly large enough for marking the sites of estates. The second one is the most generally useful for transfering portions to serve for site maps. The 5 ft. and 10 ft. scales will in many cases give the required plots and boundaries, but it is always wise to test them on the ground. In addition to marking the scale upon a survey plan, the area should be shown on the centre of each plot, or a table made at the side where the separate enclosures may be listed and the total made up.

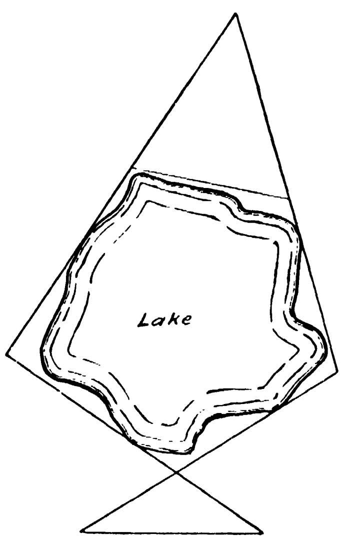


FIG. 26. SURVEY OF LAKE

Copying Plans. Portions of an ordnance map may be traced off and then transferred to another plan by carbon paper. Copies of plans to scale may be made in black lines on a white ground by means of photo-printing. An enlargement may be made by ruling the required portion with small squares by lines, say $\frac{1}{8}$ in. or $\frac{1}{4}$ in. apart, then ruling lines on the required drawing as much farther apart as the plan requires to be enlarged. The outlines may then be put in by hand, noting at what distances they cross the respective lines. Proportional compasses may be used to give these distances exactly if great accuracy is required. An instrument, called a *pantograph*, may be used for enlarging, but it is not worth while, as the method of squares is perfectly satisfactory; the *eidograph* is a still more expensive instrument for the same purpose. Suppose the enlargement required be from the 25·344 ordnance map (usually called the 25 in.) to a scale of 20 ft. to 1 in., then squares of $\frac{1}{4}$ in. side on the ordnance map would be replaced by squares of, say, 2·6 in. sides on the survey plan.

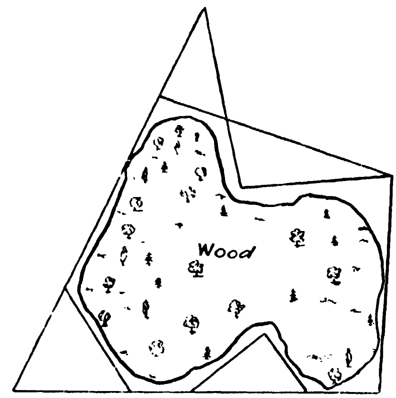


FIG. 27. SURVEY OF WOOD

FIG. 28. ENLARGED SKETCHES OF TREES AND BUSHES ON SURVEY PLANS

Calculated thus—

$$\frac{5280 \times \frac{1}{4}}{25\cdot344 \times 20} = 2\cdot604$$

The size of the squares on the ordnance map will depend upon the amount of detail shown, but $\frac{1}{8}$ in. to $\frac{1}{4}$ in. are most usual.

ARCHITECTURAL DRAWING

By Walter M. Keesey, A.R.I.B.A., A.R.C.A.

LESSON II

PRELIMINARY WORK

An understanding of the main principles of geometry and mathematics should form part of every young architect's training. Geometry is the foundation of all projection, and as much exercise as possible should be gained for precision in handling drawing instruments and the constructional value of pattern.

Geometrical Problems. A sound knowledge of plane geometry is necessary for the architectural student. This subject is dealt with at considerable length in the section on "Builders' Geometry," but the following examples indicate typical geometrical constructions useful for the architectural student—

Within a regular pentagon describe a square (see Fig. 1).

To inscribe seven equal circles within a circle (see Fig. 2).

In a given equilateral triangle inscribe three equal circles, each touching two others and two sides of the triangle (see Fig. 3).

In a given equilateral triangle inscribe three equal semicircles, each to touch two sides of the triangle and their diameters to be adjacent (see Fig. 4).

Given plan and elevation of an octagonal pyramid, to obtain projected sections (see Fig. 5).

Geometrical tracing based on Problem 3 (see Fig. 6).

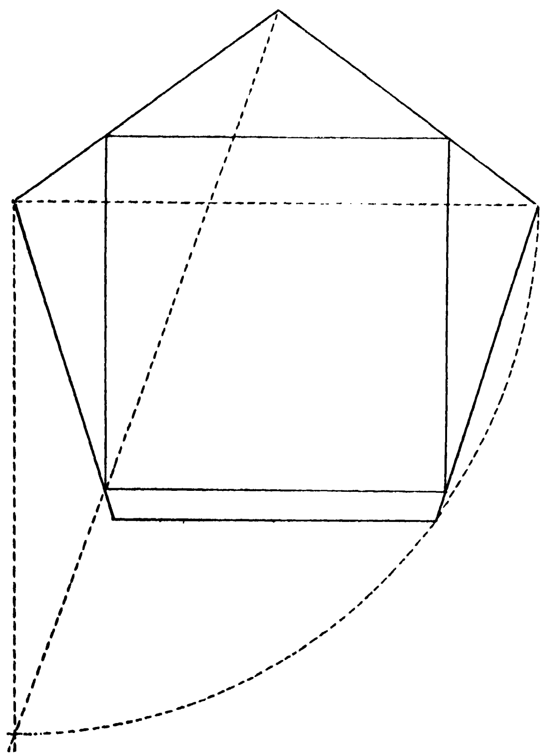


Fig. 1

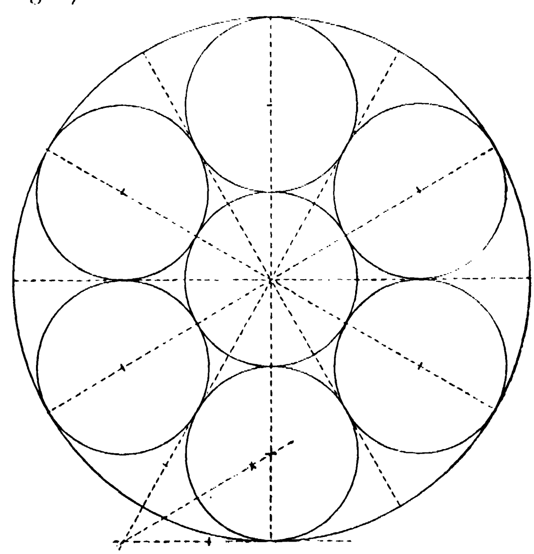


Fig. 2

Construction of pattern taken from Egyptian pottery (see Fig. 7).

Construction of pattern taken from Moorish ornament (see Fig. 8).

Exercises such as these should be worked out with great care, and when sufficient precision has been obtained, inked in carefully with ruling pen and compasses. Contiguous circles offer many difficulties, and it is advisable to adjust the scale of thicknesses by trying the thin dotted lines first. Use ink which is well strained; if in bottles do not shake while in use. Apply the ink to the instrument by means of a pen or knife blade; a little and often is better than a

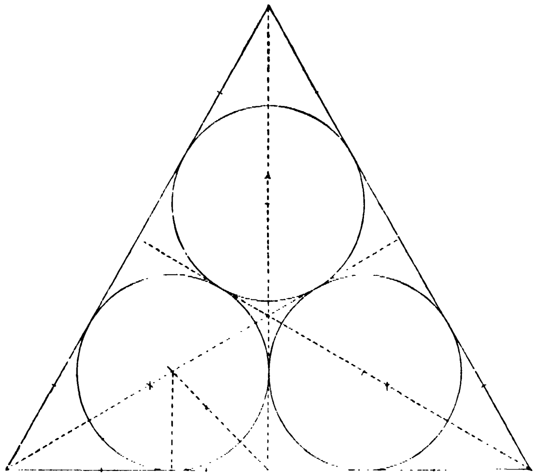


FIG. 3

full pen which may flood. Clean the pen frequently with a piece of hard thin paper and do not alter the adjustment more than necessary. Always bend compass points so that the points of needle and pen are perpendicular to the paper, otherwise the pen will scratch and wear unevenly

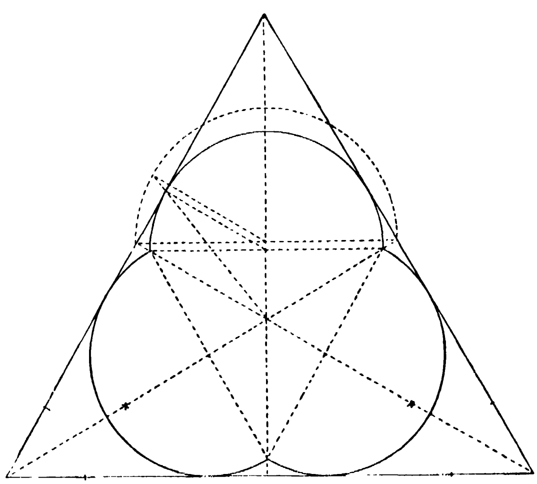


FIG. 4

and the needle hole will be wide and ugly. The "patterns" are frequently most difficult to keep quite consistent in width, and all main stems should be carefully gauged with spring dividers. Photos of Arabic geometrical tile patterns provide excellent examples for study; window tracery is equally interesting, apart from the fact that it provides a knowledge of stonework

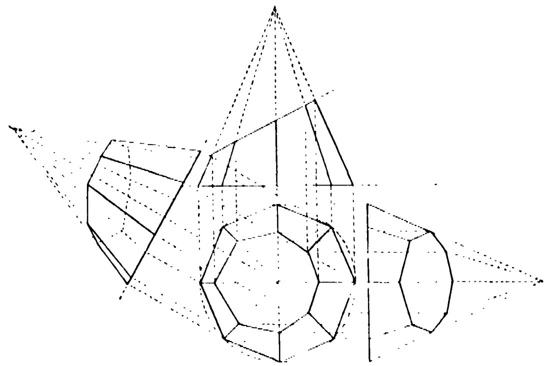


FIG. 5

and jointing. Lines may be thickened according to their importance, and "inking in" generally should be practised whenever possible.

Geometrical Patterns. A great deal of instruction can be gained from the making of patterns; most architectural decoration has a

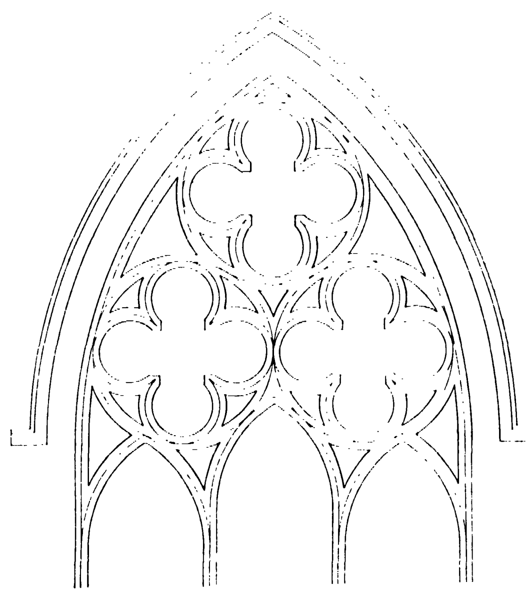


FIG. 6

geometrical basis, and many patterns can be made on a simple construction. Figs. 7 and 8 give samples of these types, which if used as a background for experiments in colour, become extremely interesting and informative. The colour box can be explored, and blending and harmonious arrangements made, which are sometimes very fascinating and technically of value in manipulation.

Scales and Attainment of Precision, Conventions, etc. Scale drawings are those which, when the object represented is actually too

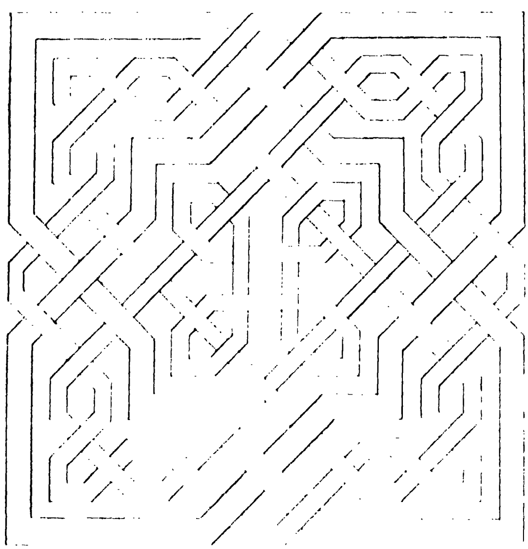


Fig. 7

large (or too small) to be adequately shown on convenient paper, is reduced (or enlarged) to some defined ratio, e.g. $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, etc. In all such regular cases, scales may be obtained already formed. The usual practice is $\frac{1}{16}$ for sketch or large schemes, $\frac{1}{8}$ for general purposes, $\frac{1}{4}$ for small work, and $\frac{1}{2}$ for detail; in every case here given the fraction is the part of an inch that represents 1 ft.; thus a $\frac{1}{2}$ in. scale is a scale of $\frac{1}{2}''$ = 1′ 0″ (1 tick feet; 2 ticks inch).

A $\frac{1}{8}$ scale is large enough to show all general details and planning, but is not sufficiently accurate for scaling off dimensions which are usually figured on the drawings (see Museum Work under "Dimensions"). The scale of a drawing should always be drawn upon the paper, so that dimensions may be readily taken, even though the paper has shrunk or expanded with straining, or has been reproduced photographically. Numerous scales are on the market, but for most practical purposes those showing $\frac{1}{8}''$ and $\frac{1}{4}''$, $\frac{1}{2}''$ and 1″, $1\frac{1}{2}''$ and 3″, and $\frac{3}{8}''$ and $\frac{3}{4}''$, on their respective sides are best. Paper scales are also obtainable in boxes of about twelve different sorts. They are more fragile, however, and rapidly get dirty, whereas a boxwood or ivory scale can be readily cleaned.

Constructed Scale. When the drawing has to be to an unusual scale, say, 2 in. to represent 5′ 0″, a scale must be constructed, and when once made accurately should be transferred to a "tick strip" (odd strip of paper), and used in a similar way to the others.

To construct this type of scale, draw an indefinite line *AB*, Fig. 9, and mark off 2 in., as at *AC*.

Draw *AK* at any convenient angle and set out on it from *A* five equal parts to any convenient scale. Join *K* to *C* and draw lines from *H*, *G*, *F*, *E* parallel to *KC*, cutting *AC*. This will divide *AC* into five parts, and one part can be readily divided again into twelve parts for inches; produce the divisions as far along *AB* as may be desired.

Diagonal Scale. These are most useful where the scale is small, such as in block plans, surveys,

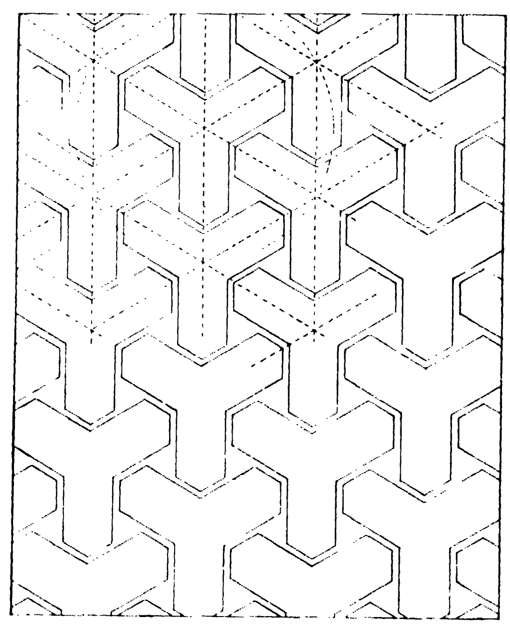


Fig. 8

etc., or for minutely accurate dimensions. Let it be required to draw a diagonal scale of 2 in. to the chain, constructed to measure links, or one-hundredths of the chain. We must take two measurements, which will produce 100, e.g. 10 and 10. Divide the 2 in. line, Fig. 10, into ten parts as before described. Erect convenient

(*Continued on page* 386)

PLUMBING

By Percy Manser, R.P., A.R.S.I.
Honours Silver Medallist

LESSON V

PIPES

JOINTING IRON PIPES

Iron pipes are joined by means of screw threads and sockets, flanges, rings and bolts, and caulking in a variety of ways, according to the size of the pipe and the nature of the job.

Wrought-iron Pipe. The method chiefly used at the present time for wrought-iron pipes is the *screwed thread* and *socket joint*. The pipe can be obtained in lengths varying from 1 ft. to 20 ft. Each length is supplied with a socket, and is threaded both ends to the standard gauge. However, in carrying out screwed iron-pipe work, it is found that a great number of threads must be cut owing to the many different lengths that are necessary; to carry this out efficiently a good set of *stocks and dies* are required, or, better still, a *threadscrewing machine*. Although the latter is an expensive item, its cost will be fully recovered if large quantities of threads are required; and this is generally the case on, say, a heating job of any size.

The pipe to be screwed is first cut by means of a *pipe cutter*. The burr left by the cutter is removed from the interior by means of a *reamer*, and from the exterior by a file, which at the same time removes the outer coating of oxide, leaving a clean surface the length of the thread to be cut. The dies are then run up the pipe to the required distance, a lubricant of lard oil being used to protect the cutting edges of the dies. If solid dies are used, the thread is cut in one operation. When adjustable dies are used it is usual to run them twice to complete the thread. The thread is next smeared with a mixture or solution; this may be obtained in powder or paste form, a very good one being *manganesite*. A few strands of very fine hemp is wound into the threads; this hemp in turn is smeared with the solution, and the socket is run on and screwed home tight by means of tongs or chain grips, Stillson wrench, etc. If hemp of a very fine nature is used and properly wound into the threads, practically the whole of it will be found to have been screwed into the joint, thus making it secure.

Fig. 39 shows what is termed a *connector*; it consists of a running thread and socket with a back-nut and a thread on the tail end to screw into a socket or other fitting; a connector is necessary where two free ends of pipe are required to be joined up. A glance at the illustration will show how this is done; the pipe

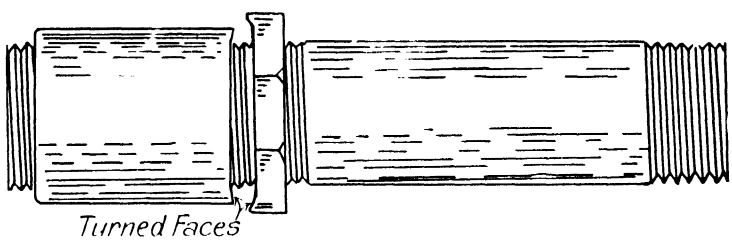


Fig. 39. Connector

to be connected has the thread butted against the running thread of the connector. Solution and hemp is applied; the socket is run on and screwed home tight; a *grummet* of hemp, smeared with solution, is placed between the back edge of socket and back-nut, and the latter is then screwed home tight, thus making a sound joint with the grummet as a packing medium. It will be noticed that the tail end of the socket and face of the back-nut are turned to enable the packing of hemp to be held in position.

Cast-iron Pipe. Fig. 40 shows a section of a lead-caulked joint; it is used chiefly for water and gas mains, also cast-iron drain pipes. A few strands of *gasket* (or *yarn*, as it is sometimes called) is first caulked well into the socket; molten lead or lead wool is then used as the jointing medium. For molten lead on horizontal joints a band of clay is first placed around the edge of the collar, with a lipped opening on the upper side for pouring in the lead; a more up-to-date method is to use an asbestos collar to retain the lead as it is poured in. The band is now removed and the lead well caulked into

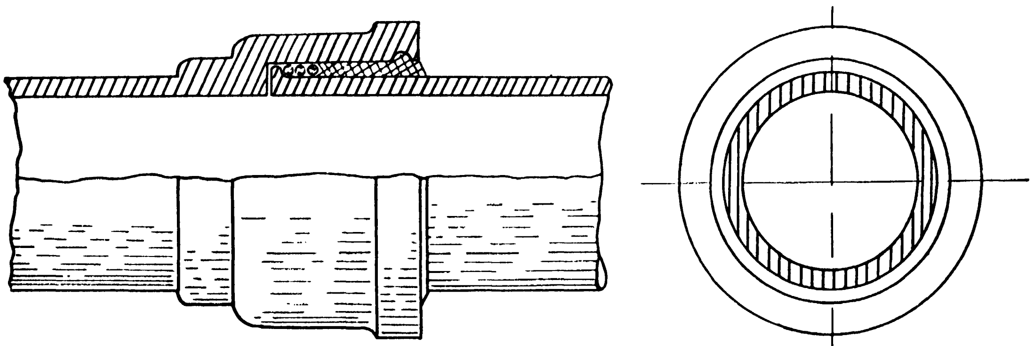


Fig. 40. Caulked Lead Joint

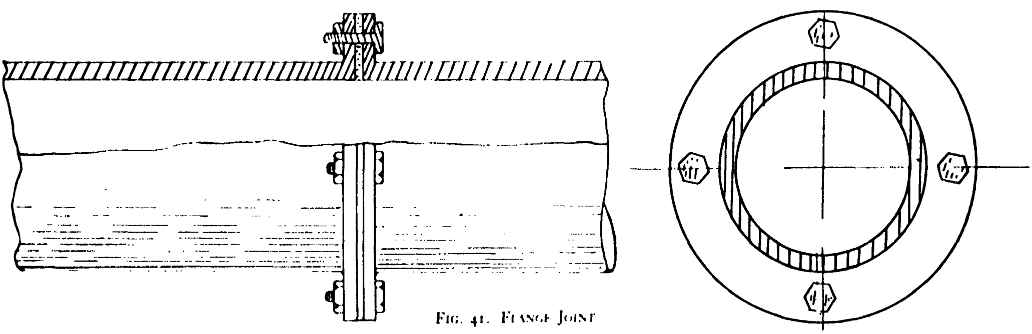


Fig. 41. Flange Joint

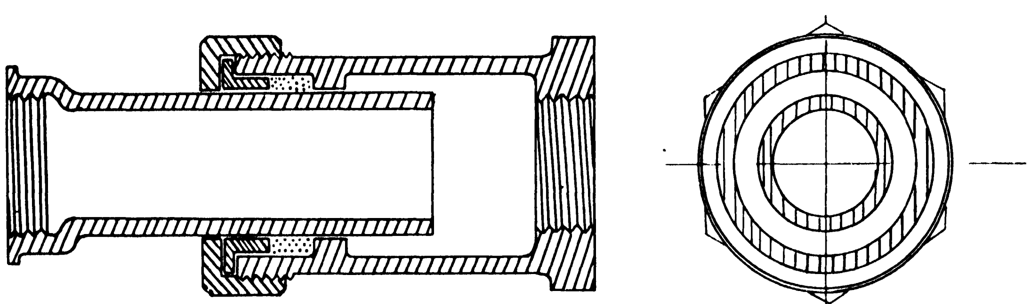


Fig. 42. Expansion Joint for Screwed Barrel

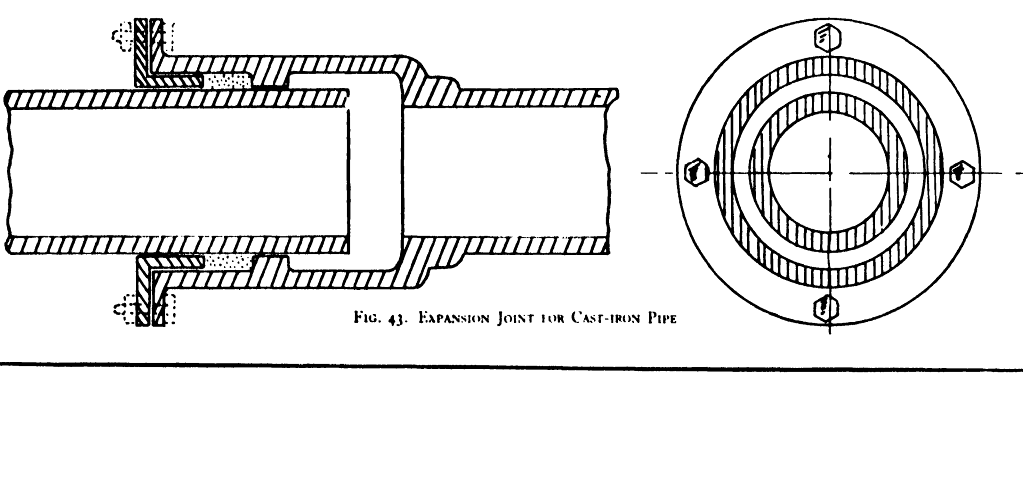


Fig. 43. Expansion Joint for Cast-iron Pipe

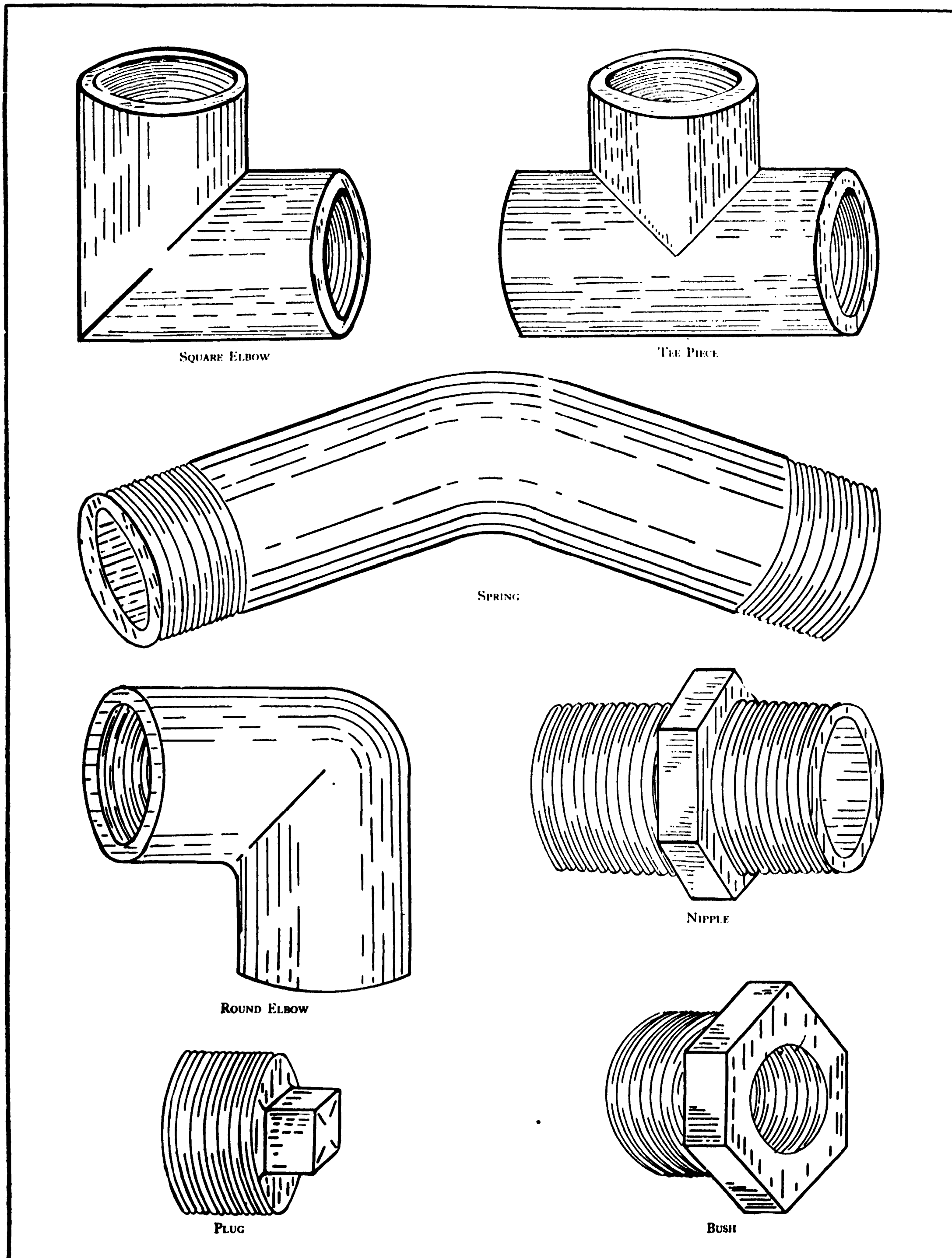


Fig. 44. Fittings for Screwed Iron Barrel

the socket; the surplus being neatly trimmed with a sharp chisel.

Cast-iron hot-water pipes for low pressure work, such as warming for horticultural purposes, are sometimes jointed by caulking in gasket and red and white lead; this is a very good jointing medium, providing that due regard has been given to expansion and contraction.

Fig. 41 shows a simple type of **flange joint,** the packing being either of rubber or asbestos rings for hot-water work, but for steam work what is known as *copper asbestos rings* should be used.

Figs. 42 and 43 show two types of *expansion joint* for use with either screwed iron pipe or cast-iron pipe.

Fig. 44 shows various types of fittings used in connection with screwed iron barrel.

Malleable Fittings. In addition to the ordinary wrought-iron fittings used in connection with screwed iron barrel, there may be obtained fittings of all descriptions in malleable iron. At the present time this type of fitting is extensively used; they are lighter and make a much neater finish to the work. There is also a larger variety of shapes and patterns, which enables almost any awkward position to be overcome without making sharp turns and so checking the free flow of water, which would happen if sharp elbows and square junction tees were used.

The methods of using these fittings and running the pipes will be dealt with more fully under "Hot-water Fitting."

JOINTING BRASS AND COPPER PIPES

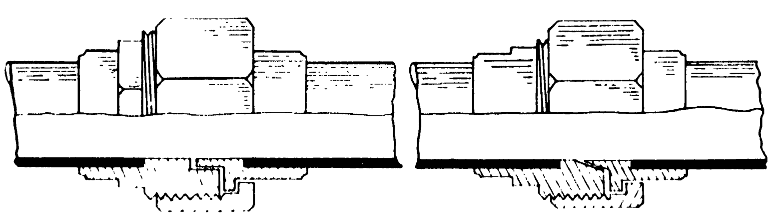
Until a few years ago, the method of jointing brass and copper pipes was brazing or fine soldering and by screw threads. Now, however, there are on the market various types of compression joints, which are very simple and effective. A brief description of the various methods of jointing, both by the old and more modern methods, will not be out of place.

The type of joint depends on the substance of the pipe. If screw thread and socket joints are required, the pipe must be of a very stout character, although the threads are of a much finer gauge than those used for iron pipe. The pipe is cut with a hack-saw, and what are known as *brass dies* are used for cutting the thread. On some work it is usual to tin the threads on the pipe and inside the socket and screw them together whilst hot, thereby obtaining a screwed joint that is also soft soldered.

Another type of joint is the *screw coupling*; a union or bush piece is either soldered or brazed to the ends of the pipes, one forming a lining and the other with a cap or nut; by means of a grummet a sound joint is formed when the cap is screwed home. A very great number of these couplings, or unions, are now made with ground-in seatings; with these a grummet is not required, a metal to metal seating being obtained.

Fig. 45 shows one type of coupling joint with grummet packing.

Fig. 46 shows another type with ground-in, or turned, seating joint.



Figs. 45 and 46. Joints in Copper Pipe

Fig. 47 shows a very good type of solderless joint known as the "Kongrip"; special fittings are obtainable for making these joints. The union, or bush, pieces are slipped over the pipe; the ends of the latter are filed square and opened by means of a tapering steel mandril; the nipple is then placed into the opened ends and the cap screwed on and tightened up. The operation is very simple, and another distinct advantage is that each fitting is a connector in itself. Fig. 48 (*A*) shows an *elbow*, or *bend*; (*B*) a *connector to iron*; (*C*) a *steel mandril* for expanding the ends of the pipe.

TABLE V

Weight of Lead Pipe

Internal Diameter in Inches	Weight per Yard in Pounds	Remarks
½	6	As required by the Metropolitan Water Board.
¾	9	
1	12	
1¼	16	
1½	21	
2	27	
½	7	As required by some of the Provincial Water Supply Authorities.
⅝	9	
¾	12	
1	16	
1¼	21	
1½	25	
2	36	

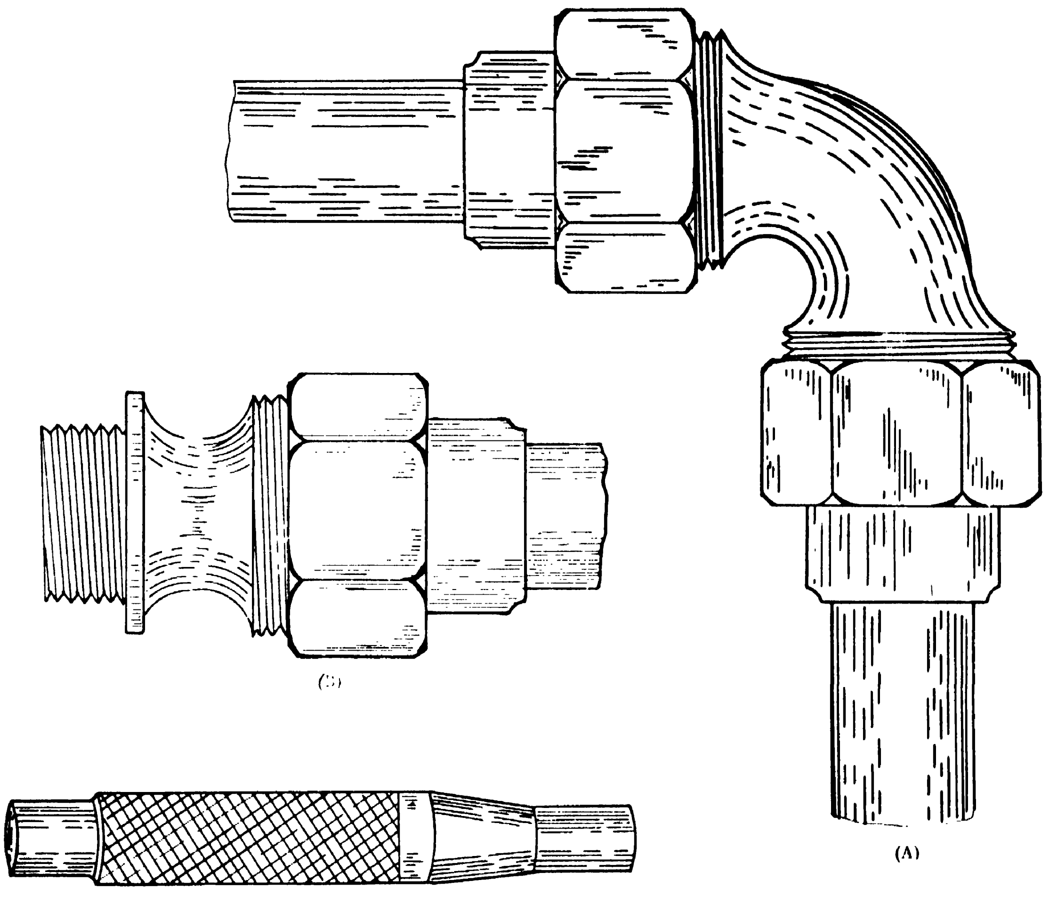


FIG. 48. (A) ELBOW; (B) CONNECTION TO IRON; (C) STEEL MANDRIL

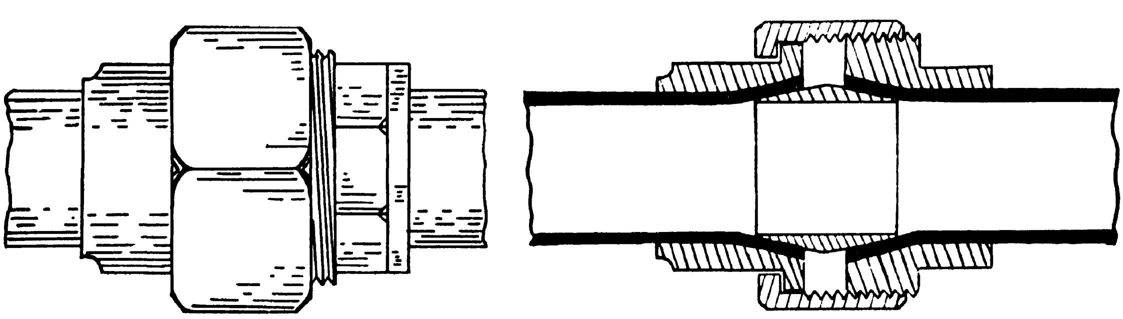


FIG. 47. COMPRESSION JOINT, COPPER PIPE WORK

TABLE VI

STANDARD GAUGES FOR LIGHT COPPER TUBES

Bore of Tube in Inches	Pressures in Pounds per Square Inch					
	Pressures up to 50 lb.		Pressures over 50 lb. up to 125 lb.		Pressures over 125 lb. up to 200 lb	
	Thickness S.W.G.	Lb. per Foot	Thickness S.W.G.	Lb. per Foot	Thickness S.W.G.	Lb. per Foot
⅛	19	0·08	19	0·08	17	0·12
¼	18	0·17	17	0·21	16	0·24
⅜	18	0·25	17	0·29	16	0·34
½	18	0·32	17	0·38	15	0·50
⅝	18	0·39	17	0·46	14	0·68
¾	18	0·46	16	0·63	14	0·80
⅞	18	0·54	16	0·73	14	0·92
1	17	0·71	15	0·93	13	1·21
1¼	17	0·88	15	1·15	12	1·70
1½	17	1·05	15	1·37	12	2·02
1¾	16	1·40	15	1·59	12	2·33
2	16	1·60	15	1·80	12	2·65
2½	16	1·98	14	2·50	10	4·07
3	15	2·68	13	3·44	9	5·48
4	13	4·55	11	5·78	7	8·89

Table V gives the regulation weights of lead pipe required for water services; Table VI gives the weights and standard gauge for light copper tubing; and Table VII gives the gauge, etc., for screwed wrought-iron barrel.

TABLE VII

WROUGHT-IRON PIPE

Nominal Bore in Inches	Approx. Outside Diam. in Inches	S.W.G.	Weight in Lb. per Foot
⅛	13/32	13	0·300
¼	17/32	13	0·425
⅜	11/16	12	0·640
½	27/32	11	0·900
¾	1 1/16	10	1·270
1	1 11/32	9	1·780
1¼	1 11/16	8	2·600
1½	1 29/32	7	3·250
1¾	2 5/32	7	3·800
2	2⅜	6	4·500
2¼	2⅝	6	4·980
2½	3	6	5·775
2¾	3¼	6	6·325
3	3½	6	6·850
3½	4	6	7·750
4	4⅜	6	8·700

ARCHITECTURAL DRAWING

(*Continued from page 380*)

perpendiculars from either side of 2 in. line and divide into ten equal divisions; through these divisions draw lines parallel to the 2 in. line. Join 90 to left top corner of rectangle and draw

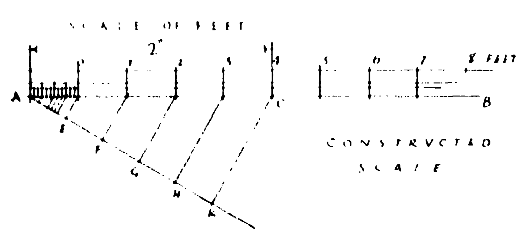


FIG. 9

lines from other numbers parallel to it. Any measure of distance up to a 100 chains can now be obtained from the line agreeing with its last figure, e.g. 67 links could be measured on line 7, as shown by strong line.

Vernier Scale. For very minute measurements another scale is in use, called the *Vernier scale.* This is usually found on measuring instruments,

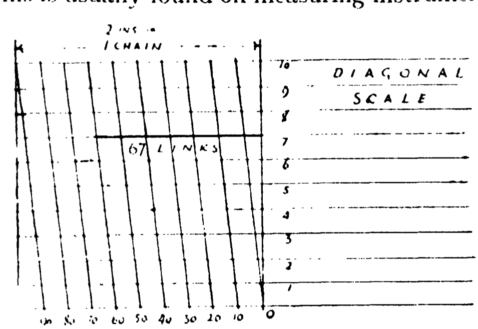


FIG. 10

particularly those used by surveyors, and is described in the section on "Land Surveying and Levelling."

ROOF COVERINGS

By John Millar, P.A.S.I., M.I.Struct.E.

LESSON IV

SLATING—(*contd.*)

Ridge Course. The last course of slates at the ridge has to be cut to about the same length as the eaves course, so that the last full course will come within $1\frac{1}{2}$ in. from the ridge (see Fig. 19). To obtain this result, the gauge as set out may, if necessary, be slightly modified. As an illustration, suppose a roof slope measures 25 ft. 8 in., and is covered with Countess slates laid to a 3 in. lap. To obtain the exact gauge, reduce the length of the slope to inches, deduct the length of the ridge course (12 in.), and divide by the nominal gauge ($8\frac{1}{2}$ in). This will give the number of courses, or may be stated thus—

$$\frac{\text{Length of slope - length of ridge course}}{\text{Gauge}}$$

that is—

$$\frac{308 \text{ in.} - 12 \text{ in.}}{8\frac{1}{2} \text{ in.}} = 34\frac{50}{85}$$

say 35 courses. Now divide the slope length by the number of courses, and the answer will be the gauge. Therefore—

$$\text{Gauge} = \frac{\text{slope length}}{\text{No. of courses}} = \frac{294}{35} = 8{\cdot}4 \text{ in.}$$

which is approximately $8\frac{3}{8}$ in. The lap is found thus—

$$\begin{aligned}\text{Lap} &= \text{length of slate} - \text{gauge} \times 2\\ &= 20 \text{ in.} \quad - 8{\cdot}4 \quad \times 2\\ &= 3{\cdot}2 \text{ in., or approximately } 3\tfrac{3}{16} \text{ in.}\end{aligned}$$

If 2 in. battens are used, a piece of batten cut to $6\frac{3}{8}$ in. will serve as a guide for fixing the battens.

Open or Spaced Slating is the term employed for slating laid with a horizontal space between each slate (see Fig. 20). This method gives by no means a poor and inefficient roofing, but is rather economical both in material and labour if the work is properly carried out.

A pitch of not less than 26° is recommended, and a spacing of not more than 2 in. between each slate, if a water-tight job is required. In an exposed position, this construction will not keep out driving snow. It is usually adopted for covering workshops, coal houses, etc. The saving effected on the slating alone, taking a square of 100 ft. as a basis, and using Countess slates with a 3 in. lap, is—

Ordinary Roofing—

$$\frac{10 \text{ ft.} \times 10 \text{ ft.} \times 144 \text{ in.}}{8\frac{1}{2} \text{ in.} \times 10 \text{ in.}} = 170 \text{ slates.}$$

Open Roofing—

$$\frac{10 \text{ ft.} \times 10 \text{ ft.} \times 144 \text{ in.}}{8\frac{1}{2} \text{ in.} \times 12 \text{ in.}} = 141 \text{ slates.}$$

This shows a saving of 29 slates per square or about 17 per cent. There is also a saving in

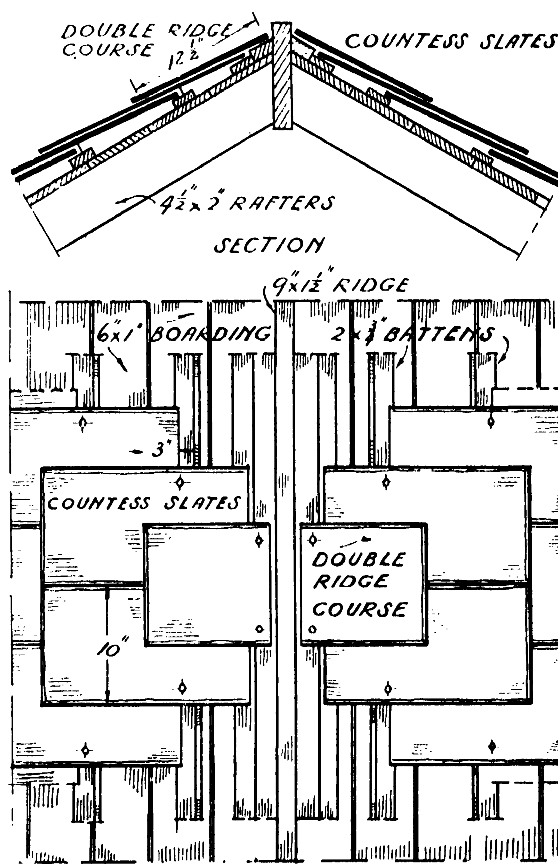


Fig. 19. Double-ridge Course

labour in fixing, also less weight to be carried by the rafters.

Glass Slates. These can be obtained of the same dimensions as the ordinary slates which

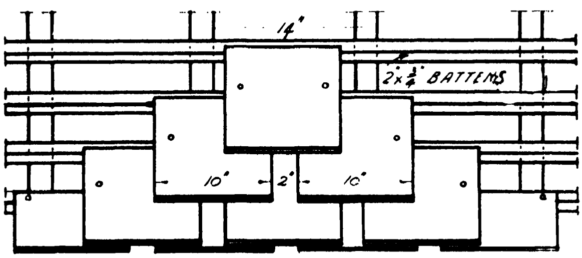


FIG. 20. OPEN SLATING

are bonded in with them, and are screwed to the battens. These are not to be recommended for large areas, but are suitable only for admitting light to roof spaces, workshops, etc.

Verges. These occur when the slating does not finish against a wall, but is carried over it. They are provided with an additional layer of slates bedded in cement on the wall, to tilt the outside courses of slates so as to divert the water

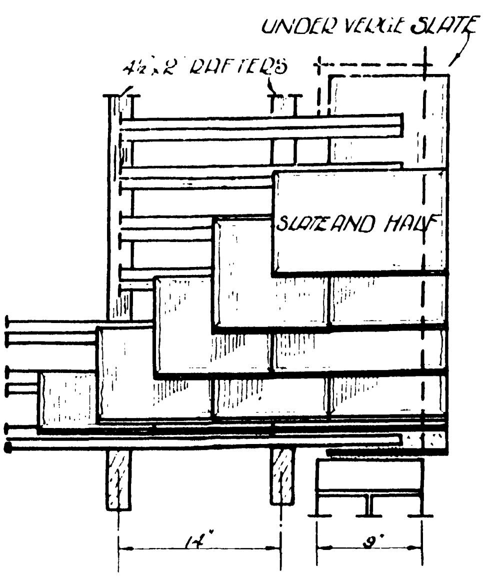


FIG. 21. VERGE

from the edge. The slates project 1½ in. beyond the face of the wall, and the outside courses are bedded and the edges pointed in cement (see Figs. 21 and 22).

Graduated Courses. In laying graduated courses (Fig. 23), the lap is kept uniform, but the gauge is varied to suit the length of the slates, which are sorted out in uniform lengths before the work is commenced. A roof of this kind presents no more difficulty in setting out than an ordinary one. All that is necessary is to put the battens at the required distances, centre to centre, to suit the gauge. The battens are set out by the slater and not by the carpenter, or the slater may supply the carpenter with a "rod" for setting out the work.

Irregularly-shaped Roofs. In roofs that are not exactly square, the courses must be kept parallel with the ridge, and any course that is short of the full course placed at the bottom (see Fig. 24). This cutting of the edges of the slates occurs where the span of

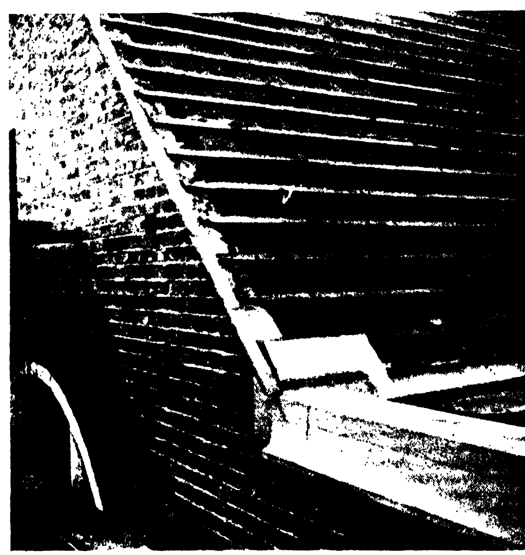


FIG. 22. FINISH TO VERGE OF SLATED ROOF

the roof varies, making one end of the roof longer than the other. The setting out should commence at the ridge, and the spacing of the battens worked towards the eaves.

Hung Slating. This is sometimes employed for protecting exposed walls from driving rains, and also as a cure for damp walls. The length of the slate selected should be such that the gauge will be a multiple of a brick in height, so that the slates may be nailed into the joints; or plugs may be driven into the joints of the brickwork to fix the battens to, which in turn carry the slates. In such cases, it is not usual to carry the slates to the ground, but

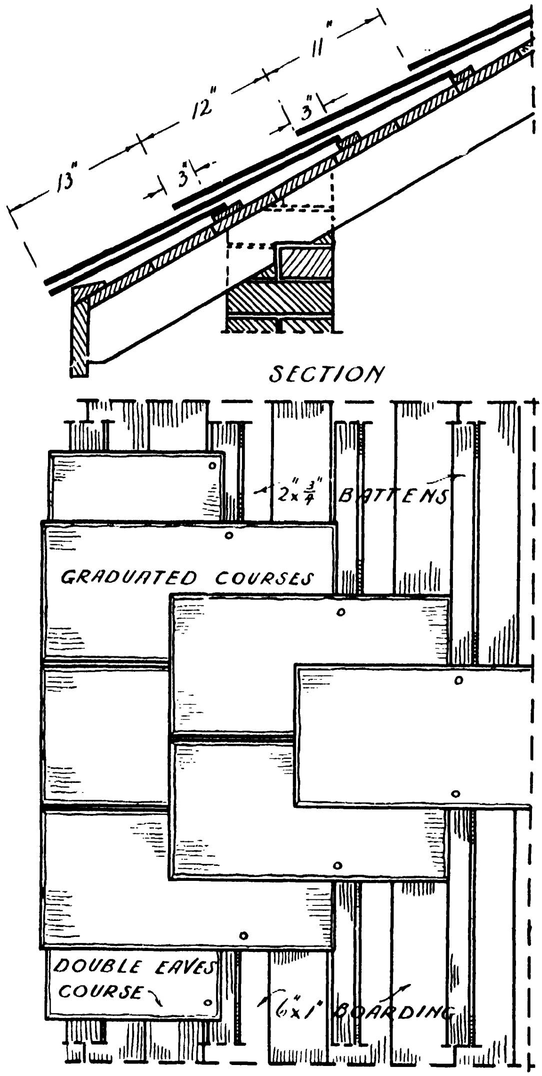


Fig. 23. Graduated Slating

to finish them with a small cornice at first floor level.

Dormer checks may be covered with slates of a size which will range so as to course in with the slates on the roof. A lap of $1\frac{1}{2}$ in. is sufficient for all vertical slating.

Ornamental Slating. To relieve the monotony of ordinary slating, the lower edges of the slates

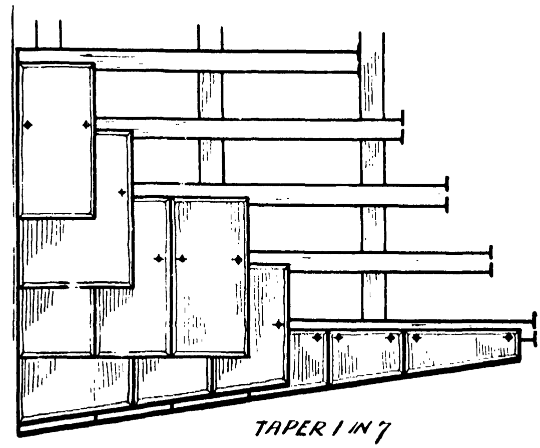


Fig. 24. Irregular-shaped Roofs

are cut to various patterns, the pattern being repeated every three to six courses, or two or

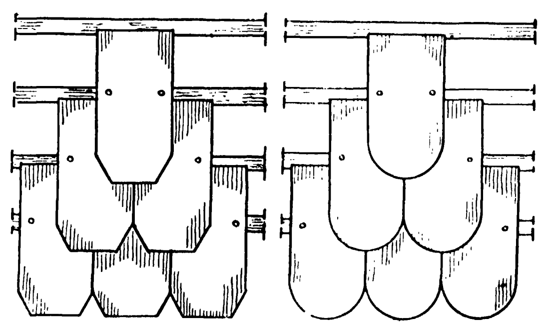


Fig. 25. Ornamental Slating

three good combinations of coloured slates may be used for the same purpose. Fig. 25 shows two examples of ornamental slating. The semi-circular ends of the example on the right-hand side are not as easy to cut neatly as the simple splayed cuts to the left.

ARCHITECT'S OFFICE AND ROUTINE

By Herbert J. Axten, A.R.I.B.A., A.I.Struct.E.
Chartered Architect

PART V

PROCEDURE BY ARCHITECT THROUGHOUT BUILDING CONTRACTS

Procedure Out of London Area. Upon the communication to the architect of a client's intention to erect a building upon a site within the administrative area of an urban district council, the following is the outline of the procedure from the initial stages to the completion of the contract, and the occupation of the premises.

Having obtained and confirmed the receipt of the client's instructions, the architect will—

1. Make a careful survey and plot the plans of old buildings—if any exist, the site and abutments.
2. Obtain from the local authority particulars as to positions and depths of sewers and drains, and position of building line.
3. Prepare sketch plans and approximate estimate, and obtain client's approval thereto.
4. Have trial holes dug.
5. Prepare working drawings, ⅛ in. and ½ in. scales. Make notes for specification during the preparation of drawings.
6. Obtain estimates from constructional engineers.
   ,, ,, ,, heating engineers.
   ,, ,, for lift.
   ,, ,, ,, lighting, sprinklers, patent flooring.
   ,, ,, ,, sanitary goods, stoves and mantles, etc.
7. Deposit copies of plans with application for permission to build and drain with the local authority.
8. Check working drawings received from specialists in item No. 6.
9. Prepare specification and form of tender; instruct quantity surveyor regarding the preparation of bill of quantities.
10. Prepare plans for and issue party wall notices.
11. Send out invitations to tender—say to selected firms.
12. Arrange for house breakers for pulling down—if any—take photographs of premises before demolition.
13. Tenders received and opened. The lowest tender examined to see that prices are run out correctly.
14. Contractor deposits his priced bill of quantities and may be given a blank copy.
15. Contracting parties sign agreement, specification, and plans.
16. Order given to commence.
17. Clerk of works appointed by architect.
18. Work to party walls, chimney stacks, etc., agreed upon with adjoining owners or their surveyors.
19. During the progress of the works—
    Notebook to be kept, recording visits to job; any instructions given with dates; notes as to progress.
    Orders given for any varied works to be confirmed in writing and copy supplied to quantity surveyor, so that work may be measured that will be afterwards hidden.
20. Make survey and issue interim certificates—certificate of completion.
21. Adjustment of contractor's account—contractor to produce receipted invoices, and to return all drawings.
22. At end of maintenance period make a survey and instruct contractor to make good any defects.
23. Issue final certificate for payment of retention money.
24. Obtain certificate of occupation from local authority.

Procedure in London County Council Area. Should, however, the site of the proposed building be within the area of administration of the London County Council, the whole of the foregoing items of procedure would be the same with slight modifications and additional requirements as follows—

Block and drainage plans, with full description in writing of materials and methods of construction, are to be deposited in duplicate with the local authority for its approval and permission to carry out the work.

Plans of new buildings must be deposited with the Superintending Architect of the L.C.C., and also with the Fire Escape Department of the L.C.C., for their approval of the escapes in case of fire and for their certificate of occupation.

There are usually some alterations, modifications, additional works or fittings necessary to put the premises into accordance with the official requirements. Every "case" is treated upon its merits, and these latter conditions are very clearly set out upon the notice sent by the superintending architect, which notice must be complied with unless alternative methods to achieve the same purposes are agreed and accepted by the Council.

Party wall notices with plans showing the existing, and the proposed, work will probably have to be served on the adjoining owners, and the conditions of the award complied with.

Light and air questions may have to be contested.

Details of Procedure.—Arising out of the foregoing, the following need explanation—

- Sketch plans.
- Contract drawings.
- Specification.
- Bill of quantities.
- Invitation to tender.
- Form to tender.
- Agreement and conditions of contract.
- Variation orders.
- Certificates.
- Adjustment of accounts.
- Application to local authority.
- Inspection by local authority.

F O R M O F T E N D E R

To

H. B. Pencille, Esq., A.R.I.B.A.,
Chartered Architect,
Bedford Square, London.

Sir,

We are willing to enter into a contract to carry out the whole of the work required in the erection and completion of a Detached House, Broad Avenue, Maidenhead, according to the Drawings, Specification, and Conditions prepared by you, and to your entire satisfaction for the sum of.................................. £............

Name......................
Address...................
....
Date......................

No Tender will be considered unless this form is used and filled in and accompanied by the Specification and Drawings and delivered by 10 o'clock on.............. the................1926.

The Employer does not bind himself to accept the lowest or any tender, nor to incur any expense in the preparation of same.

FIG. 10. FORM OF TENDER

Sketch Plans. These are prepared in pencil, frequently on tracing paper and coloured sufficient for explanation only, regardless of the conventional colouring of different kinds of building materials.

Contract Drawings. These are usually prepared to the scale of ⅛ in. to the foot together with ½ in. details of the chief elevations. These show the complete building in plans, elevations, and sections together with a small scale block and drainage plan. Complete tracings are made and photo copies obtained, both upon linen and paper, for depositing with the local authorities and for issuing to the contractor.

Specification. A specification is a document which explains in minute detail the whole of the work which is to be carried out, the materials and the labours upon same, together with the manner and position in which they are to be used from the commencement to the completion of the job. As far as possible this is set out in the order in which the work is to be carried out.

In addition to enumerating the materials and workmanship, certain clauses are embodied from the conditions of contract regarding time for completion, manner in which payment will be made, insurance of work and workmen, provisional sums and preliminary items regarding the commencement and carrying out of the work. The specification, when signed by the contracting parties, forms part of the contract, and is, therefore, a legal document.

Bill of Quantities. A bill of quantities is a document showing the detailed measurements of every item of work and materials embodied in the plans and specification, and when signed by the contracting parties forms part of the contract with the plans and specification.

Invitation to Tender. For public work, the invitation to tender takes the form of an advertisement requesting builders to submit their names if they wish to tender.

For private work, this may be either by advertisement, similar to the above, or a formal letter to selected builders asking whether they are willing to tender.

Form of Tender. Fig. 10 shows a typical example of a form of tender in use.

Agreement and Conditions of Contract. The form of contract usually adopted is the "Agreement and Schedule of Conditions of Building Contract," published by the Royal Institute of British Architects, dated 1909.

The first portion of this document is the *agreement*, which sets out the names and addresses of the contracting parties and defines the contract drawings, specification, and quantities, which when signed form part of the contract. It states the sum of money to be paid by the employer to the contractor in consideration of his performance of the work, and also gives the name of the appointed architect. This portion is executed by the contracting parties signing, in the presence of witnesses who also sign, and the document is made legally binding by the application of a sixpenny adhesive inland revenue stamp, which must be cancelled by a signature and date; where the client is a corporation or limited liability company, it must be sealed with their official seal.

The second portion of this document is the *schedule of conditions of contract* set out in 32 clauses, of which the following is a summarized list—

The works to be carried out in accordance with signed drawings and specification, and the architect's directions and explanations. Copies of all drawings, specification, and details to be supplied to contractor.

The contractor to provide everything necessary for the proper carrying out of the work.

He is to conform with any Acts of Parliament, local by-laws, and regulations relating to the work, and of any water, lighting, and any other company, and shall give all notices required by above and pay all fees.

The works are to be set out by the contractor, and the materials and workmanship to be as described in the specification.

Conditions regarding foreman, dismissal of incompetent workmen, and the appointment of clerk of works.

Variations from the drawings and payment for extras only by architect's authority.

Errors in bills of quantities and their correction. Payment for extras and omissions to be based on the original estimate.

Payment of surveyor's fees for bill of quantities.

Unfixed materials the property of the employer.

The removal of improper work and materials and reinstatement with new. Making good defects after completion of works, and conditions regarding the inspection of work already covered up.

Assignment or sub-letting only with architect's consent. Contractor to give facilities to all sub-contractors.

Liability of contractor for all damage to property and injury.

Insurance against fire.

Date of completion and damages for non-completion.

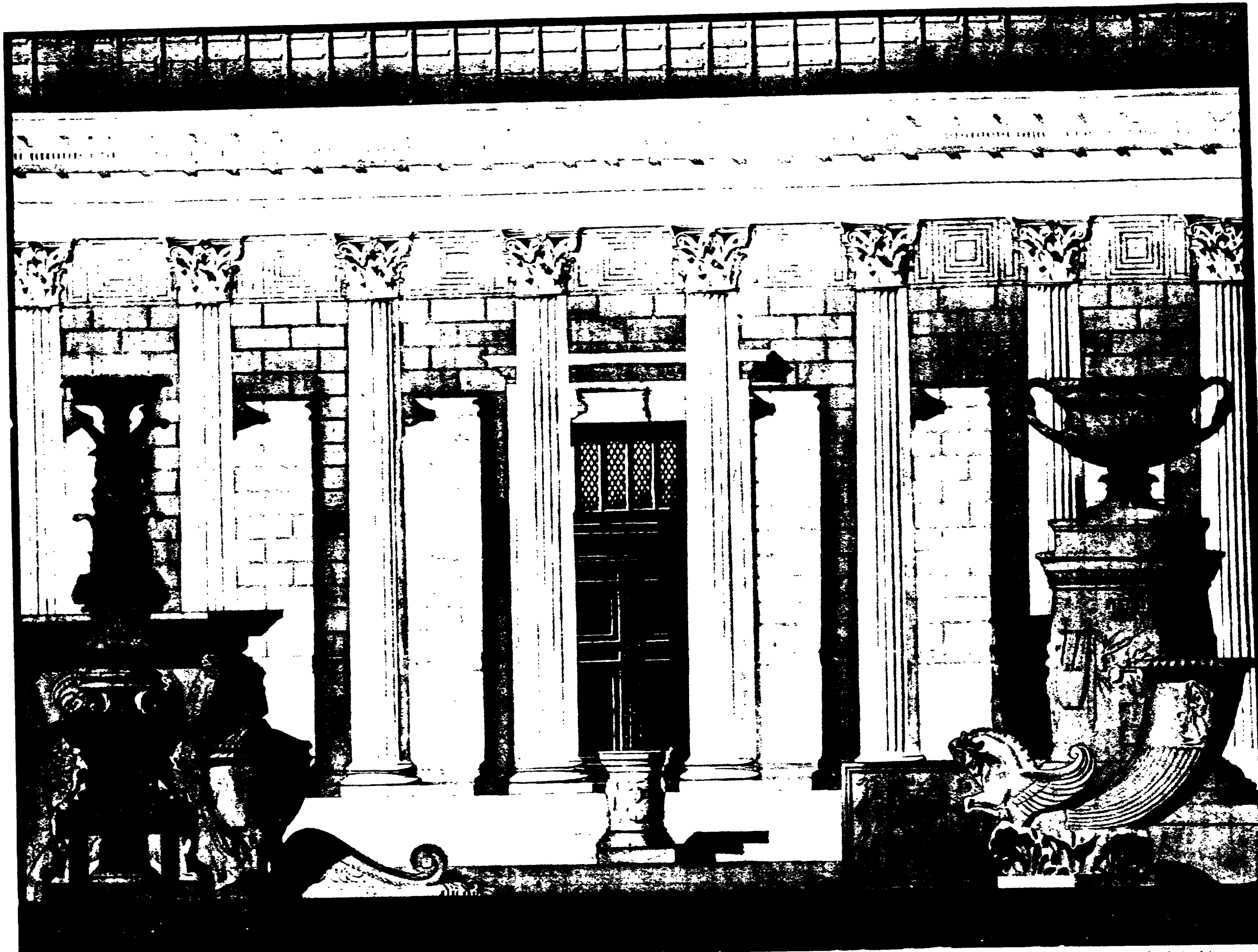
Procedure in the event of the suspension of works by contractor.

Explanation of the terms "prime cost" and "provisional sums."

Payment to contractor and issue of certificates.

The contractor's remedy in the event of non-payment by the employer.

Arbitration in case of any dispute arising between the contracting parties.



Student's Drawing, Northern Polytechnic School of Architecture

FIG. 36. A COMPOSITION OF ROMAN DETAILS

See article on "History of Architecture" which faces this page

HISTORY OF ARCHITECTURE

By Thomas E. Scott, A.R.I.B.A.

LESSON VI

ROMAN ARCHITECTURE

CONSTRUCTIONAL METHODS

Although the Romans, as a nation, were not possessed of refined artistic feeling, they were a thoroughly practical people, with unrivalled skill and inventive powers in construction.

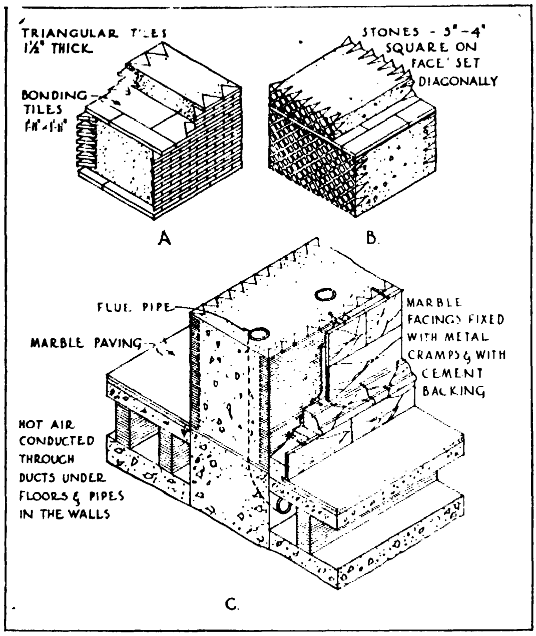


Fig. 37. Constructional Details

A = Concrete wall faced with bricks
B = Concrete wall faced with stones
C = Diagram illustrating system of heating and marble facing

Their early buildings indicate that they accepted the traditional methods of the Greeks and Etruscans, particularly in their temples, which were for the most part based on the Greek form.

Concrete. Later, however, these traditional methods were found to be too costly and too slow for the vast building schemes which the flourishing nation required, and the use of concrete became general. Although this material had been used for some time, it was from the first century B.C. onwards that it was used so extensively.

The ingredients for the manufacture of concrete were easily obtainable and, with a few supervisors to direct operations, it was possible to employ unskilled slave labour.

The concrete of the Romans owed its great strength to the qualities of certain volcanic deposits known as *pozzuolana*, found in great quantities near Rome; this was mixed with lime, and when set was exceedingly hard. Concrete was used for foundations in a manner very similar to that employed at the present day. It was cast between rows of planking, which were removed when the concrete was set. For the superstructures, walls were usually faced with stone or brick; two interesting methods are illustrated in Fig. 37. Arches were treated in a

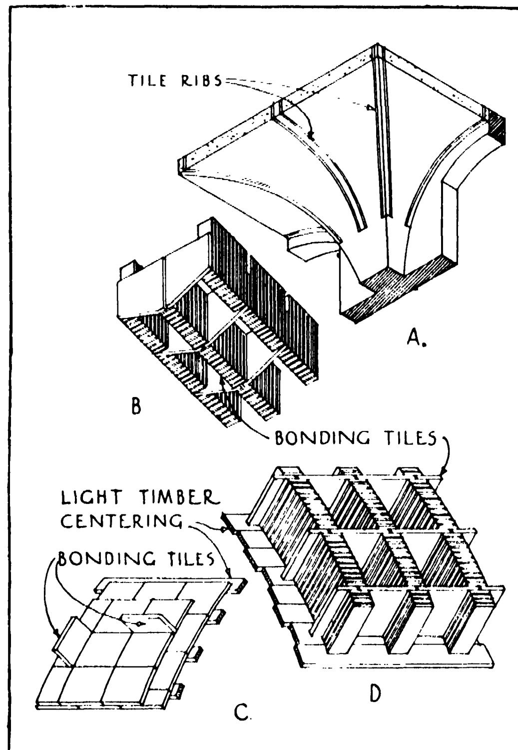


Fig. 38. Vault Details

A = Section of vault showing position of ribs
B = Detail of rib
C and *D* = Arrangements of tiles in barrel vaults

similar manner to the walls in which they were formed, with bonding courses at intervals extending right through the walls.

Vaults. Roman vaults were generally constructed of concrete, a material eminently suited for this purpose on account of its homogeneity when set. For this reason, concrete vaults exerted little thrust, a factor which simplified their use over large spans. Their construction was very largely determined by the need for economy in centering, or timber supports, during erection. Brick ribs, or arches, were formed at intervals, these being supported until completed, and the spaces, or bays, between were filled with a thin layer of concrete. When this was set, it was strong enough to support the remainder of the concrete. In some cases, layers of tiles were first placed on light centering, forming a flat type of arch. These two together formed a bed sufficiently strong to support the first layer of concrete, which was added to when set. Fig. 38 illustrates these methods.

FIG. 39. THE REMAINS OF THE BASILICA OF CONSTANTINE, ROME

Fig. 39 gives an excellent idea of the massive character of the Roman vaults.

They were of three general kinds: *barrel, cross* (or *intersecting*), and *domical*.

The first, the barrel vault, which was used generally to cover small spaces, required continuous walls for its support, whereas the cross, or intersecting, vault was used in the larger buildings, and was formed by the intersection of two vaults, usually of equal span. The lines formed at the intersections are known as *groins*. This vault, it will be seen, only required support at the four corners; when used over long halls, bays were formed by piers, as in Figs. 32 and 34, each bay being covered by a cross vault. This arrangement permitted the placing of windows in the upper part of the walls; see Fig. 34.

Domical vaults, or domes, were used over circular buildings, such as the Pantheon, and in the form of semi-domes over recesses, such as those in the Basilicas.

Although it is safe to say that without concrete the great buildings of the Romans would never have existed, it must not be supposed that no other materials were used. It will have been observed that brick and stone were employed as a facing for concrete walls, but they were also used in the traditional manner.

Brickwork. There are no remains in Rome of walls built entirely of bricks, although some have been found in the provinces. This is largely accounted for by the fact that many bricks were sun-dried; those which were burnt in kilns are found in a very good state of preservation, with the maker's name impressed.

Masonry. The building stones of the Romans were Tufa, Peperino, and Travertine, the first two being of volcanic origin. Tufa was used in the early buildings; it has poor weathering qualities, and was usually stuccoed. Peperino, a harder stone, was next in general use, while later, Travertine, a hard limestone, was employed, particularly in positions where great strength was required. The Romans accepted the Greek practice of using large blocks of stone, a length of 15 ft. being quite common. Masonry was sometimes built in mortar, and at others, where a sufficiently fine joint could be worked, metal cramps only were used. Stones frequently had a chiselled margin on the face, a decorative finish which was possibly evolved out of the methods of stone dressing used by the Greeks. In some later work, vaults were built of stone; the custom in many cases was to build the arched ribs first, using one centre and moving it along as each rib was completed, and then to fill in between these ribs with thin slabs.

Marble. It was the boast of Augustus that he found Rome brick and left it marble. But although, during the great Augustan age, many temples were constructed of solid marble, the general practice was to face the concrete walls and piers with a veneer of this material. In the early days of the Empire, Grecian marbles were used, but later, Italian quarries were opened and Carrara, Pavonazzo, Cipollino, and other varieties were used. Marble facings were at first extremely thick—about 6 in.—but later, they were reduced to about 1 in. They were secured by metal cramps with a backing of cement (see Fig. 37). Columns were usually monolithic (of one stone), and it is interesting to note that the Romans showed an appreciation of the decorative qualities of coloured marble, by omitting the fluting, thereby showing the full beauty of the colour. Granite, alabaster, porphyries, and many of the rarer materials of decorative value were imported and used to add to the richness and splendour of their buildings.

Stucco. Although this material was so frequently employed as a facing to walls of concrete or rough stone, it was applied with considerable care and skill. Marble dust was an important ingredient, the presence of which made it possible to polish the surface. Stucco also provided an excellent surface for decoration in colour, which will be referred to later.

Bronze was used to a large extent, both constructionally and for decorative purposes. The coffered ceilings and roof tiles of the Pantheon, Rome, were of bronze, in some places plated with gold.

Timber. There are practically no remains of Roman carpentry, but it is almost certain that the roofs over early temples and some of the later Basilicas were of timber. Apart from the scarcity of timber, its inflammability appears to have been a reason for its neglect as a building material.

Important buildings, such as the Baths, were heated by means of hot air, which was circulated from furnaces in a basement through flues in the walls and floors (see Fig. 37).

From the foregoing, it will be seen that the Roman constructional methods differed from those of the Greeks. Although it is, perhaps, too severe to say, with many writers, that the Romans employed deceptive methods, it is very evident that by their inventive genius, they made construction the servant of their civilization; they did not hesitate to adopt any methods to solve the problems which the production of their great buildings of unparalleled magnificence required.

THE ORDERS

The Romans adopted the "Orders" from the Greeks, but used them in a decorative, as well as a constructional manner. It has been pointed out that columns were frequently attached to walls, so that they were not structurally essential as supporting members, although they sometimes served as buttresses. For this reason it it will be appreciated that the spacing of the columns was not usually determined by the safe

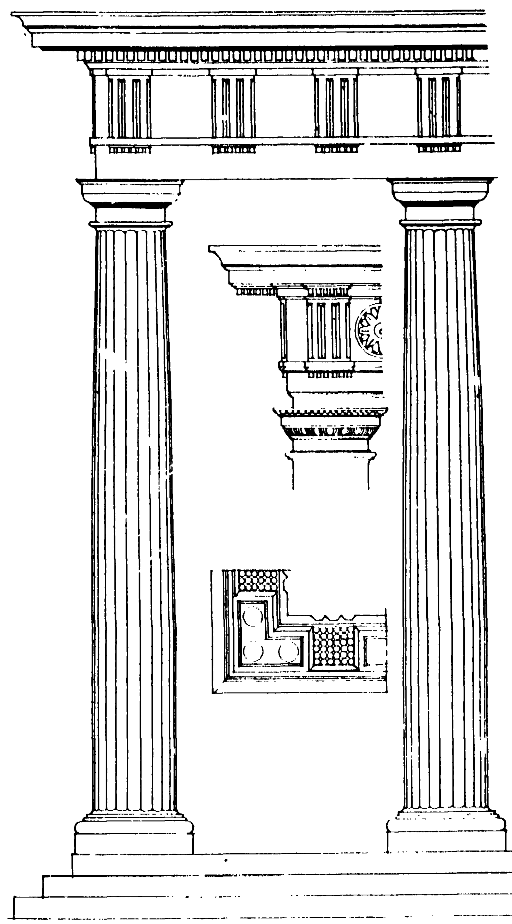


FIG. 40. THE ROMAN DORIC ORDER
The complete Order shows the "Denticulated" entablature. (Inset) Details of the "Mutular" entablature

span of a lintel, but could be modified to suit the circumstances.

The three Greek Orders were used, with many variations, and two others added, which complete the "Five" Roman Orders, to which reference is usually made. The new ones were the *Tuscan*, a form of Doric borrowed from the Etruscans, and the *Composite*, in which the capital was a combination of those of the Ionic and Corinthian Orders. The chief characteristics of the Roman Orders were as follows.

Tuscan. This was a plain sturdy form of the

Doric Order, with a simple capital and base to an unfluted column, and a rather plain entablature without triglyphs or other enrichments. It was rarely used by the Romans, but possesses

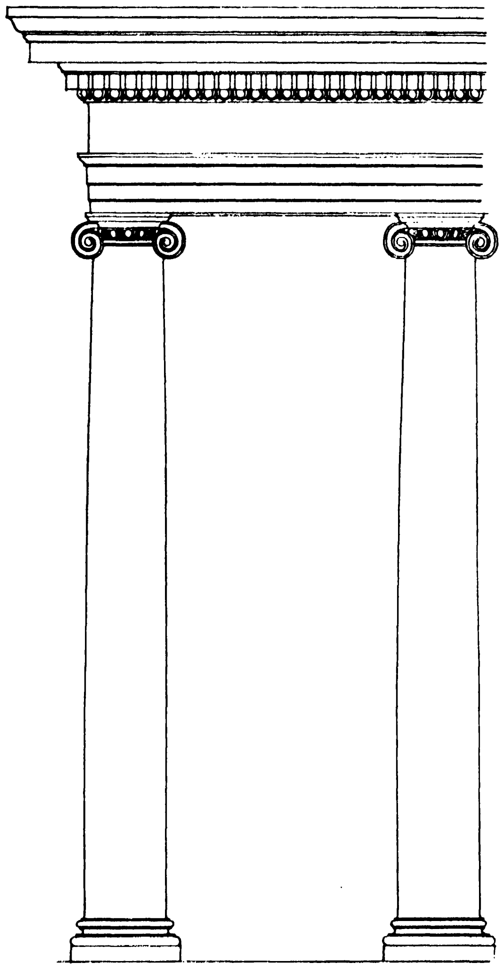


FIG. 41. THE ROMAN IONIC ORDER

great dignity, as is to be seen in the famous colonnade which leads to the Church of St. Peter, Rome.

Doric. The Roman version of this Order was less massive, but lacked the refinement and delicacy of the Greek Order from which it was derived. The column was about eight diameters high, and was used both with and without flutes. A base was added, and the capital was varied considerably (see Fig. 40). The triglyphs in the frieze were retained, but the spacing was varied, a triglyph being placed over the axis of the column at angles. A dentil course was, in some cases, introduced into the bed-mould of the cornice.

Ionic. There was little difference between the Greek and Roman examples of this Order, although the columns of the latter were more slender (Fig. 41). The volutes on the capitals of the Roman were smaller, and in later examples were sometimes angular.

Corinthian. This was the most popular Order of the Romans, and was used in most of their

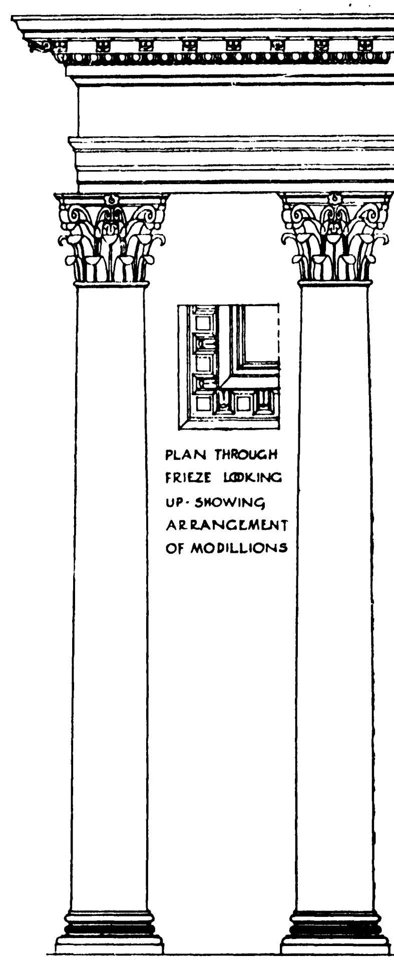


FIG. 42. THE ROMAN CORINTHIAN ORDER

temples and important buildings. The capital consisted of an abacus, angle-volutes, and rows of leaves growing out of a necking (Fig. 42).

Capitals were of great variety, and in later work were over-elaborated, rams' heads and similar motifs taking the place of the volutes.

Bases were similarly varied, but not usually enriched with carving. The shaft of the column, usually from $9\frac{1}{2}$ to $10\frac{1}{2}$ diameters in height, was fluted when stone was the material used, but generally plain when built of marble or granite. It was in the entablature, and particularly the cornice, that the Romans excelled. Although,

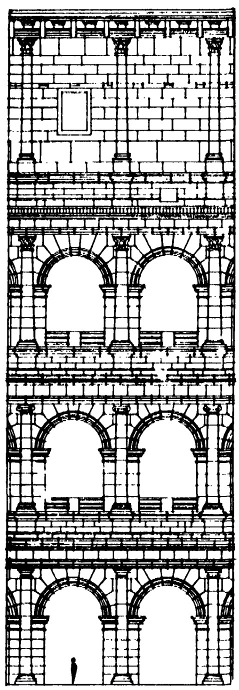


FIG. 43. THE COLOSSEUM, ROME
Part of the elevation

in the first and second centuries A.D. the entablature was fairly simple, it was later greatly enriched, sometimes, perhaps, to excess. Brackets, known as *modillions*, were introduced immediately below the upper members of the cornice, and the various mouldings were enriched with carving. The frieze sometimes contained ornament in relief.

Composite. This Order, which was employed in many of the triumphal arches, differs chiefly from the Corinthian in the details of the capital, in which the volutes are increased in size ; this variation does not appear to be an improvement. Modillions, if employed, are usually simple blocks, and the columns are more slender than those of the previous Order.

There are many excellent works which illustrate the great variety of detail in the Orders of Roman and Renaissance architecture, which should be studied by all who wish to appreciate them fully.

Application of Orders by the Romans. Although the Romans used the Orders in the traditional manner, it was their employment in combination with arches, for the decoration of wall surfaces, that produced such grand effects in the larger buildings. Another factor which influenced their arrangement was the need of the Romans for buildings of more than one story. The invariable practice was to employ a separate Order for each story, and it is of importance to note that a definite sequence was usually preserved, the sturdiest Order being used at the bottom, and the more slender at the top of the building.

Fi, 43 shows the usual arrangement of superimposed Orders.

Columns were frequently placed on pedestals, as in the Colosseum.

ROMAN DETAILS AND ORNAMENT

Openings. Window and door openings were either square or semicircular headed, the larger window openings, such as the windows in the

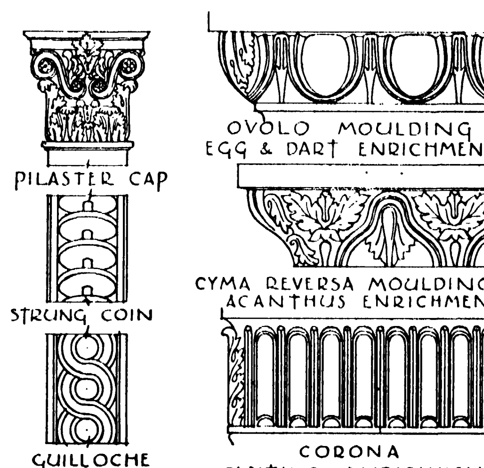


FIG. 44. ROMAN ORNAMENT

Baths (Fig. 33), being subdivided by mullions. The door of the Pantheon, a very fine example, is illustrated in Fig. 36.

Mouldings. While the Greeks usually relied upon refined profiles and delicate carving for effect, the Romans tended to enrich all possible surfaces with vigorous ornament. The sections of mouldings were bold, based generally on combinations of parts of a circle.

Ornament. Greek models were copied extensively, the Acanthus and other foliage being conventionalized and applied to all possible mouldings. Ox-skulls and garlands, frequently carved in friezes, were derived from the sacrificial rituals of the Roman religion. Characteristic Roman ornament is shown in Figs. 36 and 44.

Decoration. The decoration of wall surfaces was frequently carried out with marble panels, sometimes extending from floor to ceiling, and at others, as a dado, with stucco panels over. Vaults also were usually panelled or coffered, (Fig. 34), and richly painted and gilded. The walls of private houses were often decorated with paintings executed in *fresco, tempera, oil,* or *caustic.* The latter, a most durable form of decoration, was obtained by the use of hot liquid wax as a medium, with the colouring pigments added as required.

Pavements. Floors were frequently paved with marble in square, circular, and geometrical panels; these were in many cases taken up and used for a similar purpose in the early Christian churches, which will be referred to in the next lesson. Mosaics of coloured marble and tiles were also used, generally in simple patterns, although remains of examples of a pictorial nature are to be seen in Pompeii and in museums.

Pompeiian Decoration. This is one of the most important phases of Roman art. Its importance is largely due to the fine state of preservation in which it was found during the excavations in the eighteenth century; Pompeii, it will be remembered, was buried during the violent eruptions of Vesuvius in A.D. 79. Although based on Roman motifs, the work shows a delicacy and refinement which was, no doubt, largely due to the influence of the Greek element in the population of southern Italy. Of particular interest are the pictorial wall decorations in colour, and the delicate relief ornament to ceilings and vaults. Its influence is to be seen in the Adam style of decoration in England, and in French work of the same period.

Town Planning. No history of the architecture of the Romans is complete without some reference to the planning of their cities. In the old established towns, such as Rome, many old buildings were cleared away from time to time to make room for fine civic centres, in which important buildings were grouped around an open space, already referred to as a Forum. The conjectural restorations by Piranesi, and by many Rome students, are a valuable and interesting source of study. Many of the ruins of towns founded by the Romans in their colonies, are evidence of their fine sense of civic beauty. One of the finest was probably the rarely mentioned little town of Tigmad, in North Africa, the ruins of which suggest that once the strategic lines of the fortifications were settled, the streets were laid out in a regular manner, and the important buildings provided with a setting worthy of their purpose.

The architectures of Greece and Rome, constituting what is known as "classical architecture," are inseparable, and yet it will be evident to all that they are as widely different as are the histories of the two empires, and as the temperaments of their peoples. Although Roman work cannot be said to possess the refinement and beautiful proportions of that of the Greeks, it must always be studied for the power, grandeur, and richness which are so expressive of the great nation that was Rome.

JOINERY

By T. Corkhill, F.B.I.C.C., M.I.Struct.E., *Double Medallist*

LESSON IX

WORKSHOP PRACTICE

Grinding and Sharpening. The grinding and sharpening angles of chisels and plane irons vary with the work they have to do. Fig. 14 shows the usual angles, but they may vary considerably. The action of a blade when cutting is similar to that of a wedge. Hence the thinner the edge of the chisel the easier it will cut. It is necessary, however, to support the cutting edge to withstand the shock when cutting knots or anything that offers much resistance. It has been found by experience that the given angles are satisfactory for average work. Paring chisels may be ground much thinner because they are only used for light work, and are not driven by the mallet. Some of the irons for metal planes are also ground very thin, when they are only used for light work. A thin grinding angle makes the tool easy to sharpen, but after a few sharpenings the cutting angle becomes stumpy and it is then necessary to regrind. The shop joiner has always the grindstone at hand, which gives him a great advantage over the outside worker for producing good work.

Fig. 131 shows the method of holding the plane iron when it is being sharpened. After rubbing firmly to and fro, and keeping the hands steady to avoid a rocking motion, the iron is turned over and the back rubbed gently on the stone to remove the burr, or wire edge. For this operation the back of the tool must be perfectly flat on the stone. The best way to test for sharpness is to hold the edge against the light, and if a white edge can be seen it is not sharp.

Oilstones. There are many variations of oilstones, and a good stone pays for itself in a very short time. Some stones are much *quicker*, or *keener*, in their action than others, and the joiner requires a fairly keen stone. The most useful kind, considering the cost, is a *Washita* stone. They are so varied in quality, however, being a natural stone, that it requires an experienced man to select a good one. The stone should be tested by drawing the thumb nail along it. If there is a keen, dragging feeling, it is a good stone, unless there are flaws such as cracks, etc. The size should be about 9 in. by 1½ in. by 1½ in., so that it can be turned over in the box to use any edge in turn. If the stone is too wide it is soon worn hollow, and then it is difficult to keep the cutting edge straight. The carpenter requires a keener stone than the bench hand, because he has not the same facilities for grinding. The stone

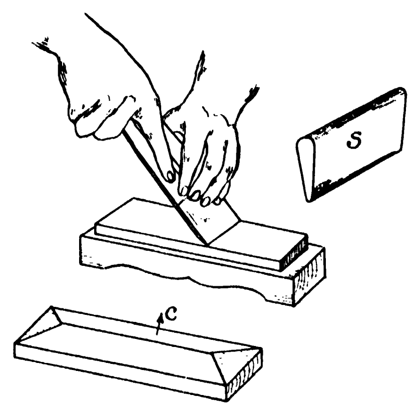


Fig. 131. Sharpening Plane Iron

should be mounted in a box and bedded in white lead. It should be covered when not in use by the cover *c*, Fig. 131, otherwise the oil is inclined to harden and spoil the surface of the stone. After a time the stone requires straightening, which may be done by holding it to the side of the grindstone; or by rubbing on a straight stone surface with a mixture of sand and water.

A good oil is necessary to keep the stone in condition, and a mixture of neatsfoot oil and sweet oil is satisfactory. Poor oils form a skin on the surface of the stone, and although the oil may be burned out it is better to avoid burning if possible. Washing with paraffin is generally satisfactory for removing the poor oil, or the stone may be rubbed with an emery cloth.

The Turkey stone is a very good stone, but the cost makes it prohibitive to many joiners; also the quality varies considerably. The same remarks apply to the Arkansas stones. Artificial oilstones, such as the Indian and the

Carborundum, are made in various grades, and are generally uniform in quality. They are very keen and have a quicker action than other stones, but they do not produce quite so good an edge. They are the most useful for machine irons and are usually "two-faced" with two different grades.

Sharpening Gouges. The *finger slip*, Fig. 131 *s*, is necessary for curved edges. It is made from the same materials as the oilstones just described. The inside ground gouge is sharpened on the

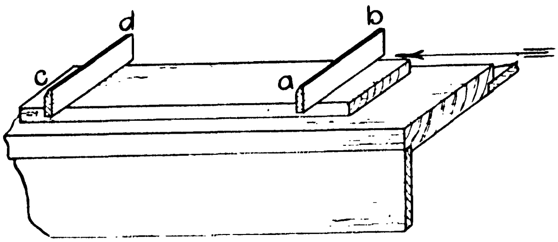


FIG. 132. USE OF WINDING STRIPS

inside with the slip; and the wire edge on the outside is removed by a gentle rocking motion on the oilstone. The outside gouge is sharpened by a rotary motion on the oilstone, and the wire edge on the inside is removed by the slip.

Sharpening sticks are about 4 in. to 6 in. long and are of different sections, such as circular, square, triangular, etc. They are made from the same materials as the other stones.

Planing by Hand. The first step in the preparation of stuff, by hand, is to straighten the

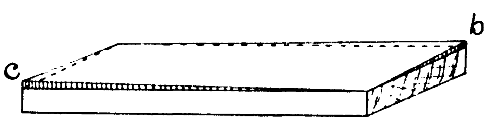


FIG. 133. TWISTED SURFACE

better side. Very often the stuff will warp, after sawing, and for most jobs it will have to be straightened. Fig. 132 shows the method of testing the stuff to see whether the face is twisted or not. Two short straight-edges, or *winding strips*, *ab* and *cd*, are placed on the stuff and sighted by the eye, as shown by the arrow. The eye is brought on to the same level as the edges of the strips. If the edge *ab* coincides with the edge *cd*, then there is no twist in the board. It is then necessary to see if the board is straight, both across and lengthwise. The strips will test the board for across; but it will have to be tested lengthwise either by sighting with the eye, or by using a long straight-edge. Fig. 133 shows a board which the strips have shown to be twisted so that the corners *b* and *c* are raised. The next step is to plane off these *hard* corners with the jack plane.

When the board has been straightened by the jack plane and try plane, it is marked as

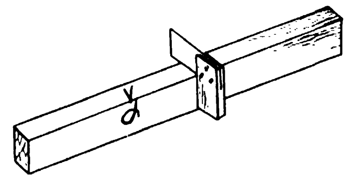


FIG. 134. TESTING FACE EDGE

the *face side*. The method of marking the board is shown in Fig. 134, the mark being placed against the *better edge*. The next step is to straighten and square this edge. Fig. 135 shows the method of straightening the edge with the try plane, the stuff being fixed in the vice. The stuff is tested with the try square as shown in Fig. 134, which also shows the method of marking the face side and front edge. The board is then *gauged* to width and the other edge planed down to the gauge mark and square to the face side. The board is then gauged for thickness and planed down to the gauge marks.

It is necessary to plane *with the grain*, and the stuff should be examined for the grain, *before* planing, otherwise the plane may pluck up the

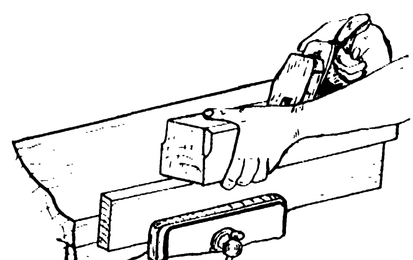


FIG. 135. STRAIGHTENING FACE EDGE

grain and cause a lot of trouble to remedy. Hardwoods require special care with regard to the grain, and the plane irons should have less *set* than for softwoods. The sole and cutting edge should be oiled occasionally when planing resinous pitch pine. The smoothing plane is used to finish off the surface preparatory to scraping or sand-papering.

Scrapers. The scraper is a piece of steel about 5 in. by 3 in. by $\frac{1}{16}$. It very often proves a difficult tool to the beginner, especially the sharpening. To sharpen the scraper, the edge is first filed straight and then rubbed on the oilstone to remove the file marks, as shown in Fig. 136. It is then wetted, placed flat on the bench, and rubbed as shown in Fig. 137. The sharpening tool is a cylindrical piece of steel or a gouge, and it is kept nearly on the same level as the scraper. The scraper is then placed on end (Fig. 138) and the sharpener is pulled up the edge sharply and firmly several times, at an angle of about 80° with the face of the scraper. It is then turned upside down and the process repeated for the other corner of the edge. This turns up the corners as shown by the end view of the scraper in Fig. 139, which also illustrates the method of using the scraper. The scraper should be kept wet, usually by the mouth, whilst sharpening. For curved work, scrapers may be obtained as shown in Fig. 140; but the joiner generally rounds off two corners of the rectangular scraper to different radii.

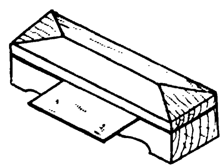


FIG. 136. PREPARING SCRAPER

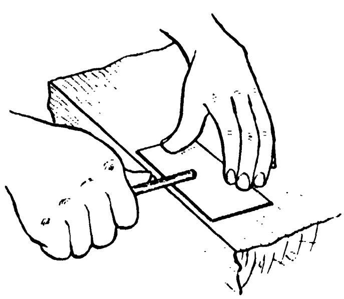


FIG. 137. SHARPENING SCRAPER

Sand-papering. Planed surfaces are always sand-papered for good work, to remove the plane marks and to make the surface more regular. The sand-paper, which is really *glass-paper*, may be obtained in about seven different strengths, or grades. The finer grades are used to finish off the surface. The glass-paper is wrapped round a *rubber*, which for straight work is a rectangular block of cork, or a piece of wood faced with cork linoleum. To sand-paper mouldings, it is necessary to make a rubber (preferably of yellow pine) to the reverse shape of the moulding. The glass-paper should be bent round the rubber and held very tightly, otherwise it will rub off the sharp arrises of the moulding. For varnished or polished work the glass-paper should be used with the grain, as the scratches across the grain are very difficult to remove. In some cases a circular motion may be used with the finer grades of paper, before the final rub-down. For painted work the paper is usually used across the grain at an angle of about 45° and then *finished off* with the grain. Sand-paper must be dry when being used, because of the glue which fixes the particles of glass to the paper. Woolly grain, as in Honduras mahogany, is pressed down by the sand-papering, and is apt to rise again when it is being polished. To avoid this it is usual to damp the surface a little with hot water, to *raise the grain*, before the final rub.

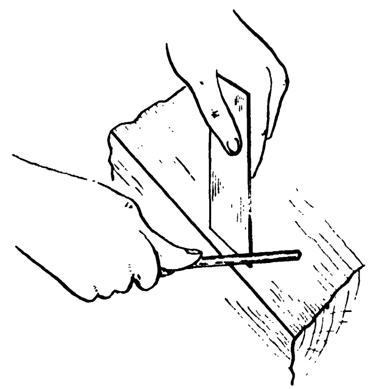


FIG. 138. SHARPENING SCRAPER

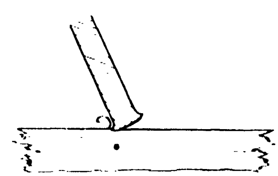


FIG. 139. ACTION OF SCRAPER

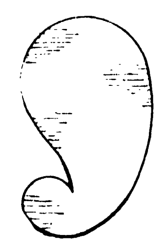


FIG. 140 CURVED SCRAPER

To Remedy Defects. It is an important part of the joiner's work to remedy defects so often found in timber. Fig. 141 shows three different forms of "little joiners." In every case

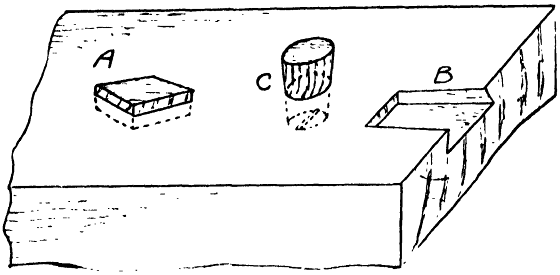


FIG. 141. "LITTLE JOINERS"

the grain of the timber should be *matched* as near as possible, especially for varnished and polished work. The usual method for filling in for loose or dead knots, etc., is shown at *A*, which is a diamond-shaped piece glued and driven in tightly. A very slight bevel on the edges will ensure a tight fit on the surface. A good method when the defect is at the shoulder of a rail is shown at *B*. In this case the "little joiner" is driven in from the end and is dovetailed to prevent it lifting afterwards. For covering up screw heads, or filling in for loose knots a pellet *C* is very convenient.

Straightening Boards. Hollow boards should be planed up on the round side, and then wetted on the hollow side and placed with the wet side downwards in a warm room. This swells the fibres on the hollow side, and dries them on the round side, thus pulling the board straight. The planing may then be completed.

Bruises, such as the dents made by the hammer, may be raised by wetting the damaged fibres. This will raise them so that they may be sand-papered level again when they are dry.

ESTIMATING

By HENRY A. MACKMIN, F.S.I., M.R.SAN.I., M.I.STRUCT.E.

LESSON V

CARPENTER

BEGINNERS frequently experience difficulty in separating the work of the carpenter from that of the joiner, and in many cases it is difficult to draw a hard and fast line. It is often stated that the joiner's work is in connection with timber that requires the use of a plane, while carpentry work is unwrought; but this is not strictly correct, for occasionally the plane is used upon carpenter's work, such as exposed faces of roof timbers. Actually the carpenter erects the carcass of the structure, i.e. plates, joists, roof timbers, and rough boardings, while the joiner prepares the finishings, such as floors skirtings, doors, windows, cupboards, and all fitments. It is usual to have separate bills prepared for the carpenter and for the joiner, but occasionally these trades are included in one bill.

Timber. Before prices for carpentry or joinery work can be compiled, it is necessary to find the cost of the timber delivered to the site or to the contractor's works. The principal timber used in construction is described as *fir*, and is imported from the northern ports of Europe and from America. The unit in common use is the "Petrograd" standard of 165 ft. cube, although other standards are used occasionally by certain timber merchants. If the builder is in a substantial way of business, and can purchase timber at the docks in bulk, he can quote much lower prices than competitors who are not so fortunate. To the price of the timber as purchased, it is necessary to add the cost of cartage, unloading, stacking, and converting to useful sizes; it is also necessary to make some allowance for waste. As the unit for pricing purposes is the foot cube, it is not difficult to divide the price per standard by 165, to find the price per foot cube; therefore it is desirable to add the various costs to the price per standard before finding a basic price per foot cube.

Price of Timber. The prices naturally vary from time to time, and at the time of writing the price per standard varies from £23 to £35, in accordance with the quality and the scantlings; but when delivered, sawn, and roughly converted to suitable sizes the price at present will average about 4s. 6d. per foot cube, and this figure will be used for the purpose of preparing many examples herein. For actual pricing, costs must be worked out locally; and in adding for cartage, it must be remembered that the weight of timber is computed at the rate of 50 cub. ft. to the ton.

TEMPORARY WORK

A considerable amount of work carried out by the carpenter consists of temporary work for other trades, and this usually consists of centering, shoring, and shuttering. Planking and strutting is usually included in the bill for "excavator." All temporary work is difficult to price, for the units used in a bill are not the most convenient for the estimating surveyor.

Centres for Arches. This item is usually given per foot super, and the quantity is the superficial area of the portion of the arch supported by the centre. The student is therefore advised to copy an example from a good textbook on building construction, or, better still, measure up and sketch a centre actually in use and "take off" the quantities of the material. The timber can then be priced at current rates, and for the labour it will be found that a centre for a segmental arch will take about two hours of a carpenter's time, for every foot of span. After use the centre has some value as old material, and this value can be deducted, say, 25 per cent. The student will find that in typical cases the cost of a centre for one arch will work out at 4s. per foot super, but if it can be used for several occasions, the price can be reduced accordingly.

Shoring. This is a speculative item and the costs for an actual shore are necessary to arrive at a price. Textbook data have little value here, and the student is strongly advised to measure up an actual shore and take off the quantities carefully, as suggested for centres. For labour it is suggested that one hour per foot cube for labourer's time, and one-tenth of one hour per foot cube for carpenter's and bricklayer's time will give average prices. If the timber is credited at half cost, the price of a typical shore will amount to 9s. per foot cube.

Shuttering. In reinforced concrete work, this is a very important item and difficult to price. It is impossible to give data applicable for all cases, for actual costs are necessary. The measurement given is the net area of the concrete supported by the shuttering, and the price per foot super must include all supporting timbers. Obviously, the number of occasions upon which it is possible to use the timbering is the important factor, but at present the price varies from 6d. to 9d. per foot super.

PERMANENT WORK

Timber for permanent work can usually be classed either as "framed" or simply "fixed." Timbers requiring joints are known as "framed" even if the joint is a simple one; but timbers which are only placed in position, such as plates and lintels, require no allowance for carpenter's time, except for roughly sawing to the requisite sizes.

Typical Items

"Fir in Plates and Lintels." To the price of the timber delivered to the job, say 3s. 6d. per foot cube, allow for carpenter one-sixth of an hour, and labourer one-twelfth of an hour per foot cube; this, at London rates and plus 12½ per cent for profit, etc., amounts to 4s. 6d. per foot cube.

"Fir in Ground Floor Joists." This item can be priced in a similar manner to the last item, with equal allowances, and the cost will be the same, viz., 4s. 6d. per foot cube.

"Fir Framed in Upper Floors." The timber itself will be more expensive, at the present time about 4s. 3d. per foot cube, and there will be a certain amount of waste, for which 5 per cent will be a fair allowance. A labourer's time must be allowed for carrying the timber to the room and the carpenter's time must allow for forming any tusk tenons required. It is suggested for carpenter twenty minutes and for labourer seven minutes per foot cube, but with heavy timbers allow ten minutes for labourer.

Detailed Example

"Fir Framed in Floors."

	s.	d.
Fir joists, 9 in. by 2 in. and 9 in. by 3 in. per 1 ft. cube	4	3
Waste, 5 per cent		2¾
Carpenter, 20 minutes at 1s. 9½d. per hour		7¼
Labourer, 7 minutes at 1s. 4½d. per hour		2¼
	5	3½
Profit and Establishment, 12½ per cent		8
Price per foot cube	5	11½

"Fir Framed in Roof." The rafters and similar timbers will cost about 3s. 6d. per foot cube, but the purlins and heavy timbers may cost as much as 4s. 6d., so for the purpose of our example we will assume timber at an average price of 3s. 9d. per foot cube. It is suggested for carpenter's time one hour, and for labourer's time twelve minutes per foot cube be allowed. An allowance must be made for waste as in the last item, and for nails allow ⅕ lb. per foot cube.

DETAILED EXAMPLE

	s.	d.
Fir rafters, collars, purlins, etc., per 1 ft. cube	3	9
Waste, 5 per cent		2¼
Carpenter, 1 hour at 1s. 9½d.	1	9½
Labourer, 12 minutes at 1s. 4½d. per hour		3½
Nails, one-fifth of 1 lb. at 5d.		1
	6	1¼
Profit and Establishment, 12½ per cent .		9¼
Price per foot cube	6	10½

"**Fir Framed in Stud Partitions.**" The timbers may be 4 in. by 3 in. and 4 in. by 2 in., and will not cost more than 3s. 6d. per foot cube. Allow one hour per foot cube for carpenter, and ⅖ lb. of nails, and for waste as in previous examples.

DETAILED EXAMPLE

	s.	d.
Fir in sills, uprights, head, etc., 1 ft. cube	3	6
Waste, 5 per cent		2¼
Two-fifths of 1 lb. nails at 4d. . . .		1⅗
Carpenter, 1 hour at 1s. 9½d.	1	9½
	5	7¼
Profit and Establishment, 12½ per cent .		8¾
Price per foot cube	6	4

"**Nogging Pieces.**" These are billed separately, and the item is worth about 3d. to 4½d. per foot run.

"**Fir Framed in Roof Truss.**" This item is not so frequent as in former years owing to modern methods of construction. With timber at £33 per standard, the price per foot cube is 4s. Add for waste as before, and allow for carpenter's time 2¼ hours per foot cube.

DETAILED EXAMPLE

	s.	d.
Fir in tie-beam, principals, post, and struts per 1 ft. cube	4	0
Waste, 5 per cent		2½
Carpenter, 2¼ hours at 1s. 9½d. . . .	4	2
	8	4½
Profit and Establishment, 12½ per cent .	1	0½
Price per foot cube	9	5

The ironmongery for the above item will be billed separately in the "Smith and Founder." Hoisting is a separate item. It is suggested that for labourer's time twenty minutes per foot cube be allowed for a height of 30 ft., and that other heights be priced in proportion.

"**Rough Boarding**" (as laid to roofs, etc.). This material is sold by the square of 100 ft. super, and 1 in. boarding at present is worth about 23s. per square. For waste it is necessary to allow 10 per cent, and about 4 lb. of nails per square are required.

DETAILED EXAMPLE

	£	s.	d.
One square 1 in. rough boarding .	1	3	0
Waste, 10 per cent		2	3½
Carpenter, 4¼ hours at 1s. 9½d. . .		7	7¼
Labourer, 1½ hours at 1s. 4½d. . .		2	0¾
Nails, 4 lb. at 4d. per lb. . . .		1	4
	1	16	3¼
Profit and Establishment, 12½ per cent		4	6½
Price per square super . .	£2	0	10

If the work in the last item is specified to be traversed for metal coverings, an allowance of two hours more should be made for carpenter's time.

If the boarding is in gutters and is to include bearers, the above price should be doubled; and as the item is priced per foot super, the amount of £2 0s. 10d. must be divided by 100, which gives the price per foot super of 5d.

EXERCISE V

1. A "Petrograd" standard of 4 in. by 3 in. timber costs £39 3s. 9d. What is the price per foot run?

2. With timber at £33 per standard, what is the price per foot cube for the item "Fir Framed in Stud Partitions"?

ANSWER TO EXERCISE IV

		ft.	in.		s.	d.		£	s.	d.
1.	Item 1.	13	8	at	18	10¾	.	12	18	3
	,, 2.	4	–	,,		5½	.		1	10
	,, 3.	10	6	,,		11¼	.		9	10
	,, 4.	4	7	,,		11¼	.		4	2
	,, 5.	6		,,	2	9¾	.		16	10½
	,, 6.	6	–	,,	7	6	.	2	5	0
	,, 7.	3	–	,,		5¾	.		1	5¼
	,, 8.	3	–	,,		½	.			1½
								£16	17	6¼

MASONRY

By E. G. Warland
Instructor in Masonry at the L.C.C. School of Building, Brixton

LESSON VIII

MACHINES

There are various types of machines now used for the production of worked stone, and much depends upon the adoption of the best type of machine, with the various devices suitable for the class of work to be executed. Proper organization and lay-out of the works is essential if the full benefits of the machines are to be obtained.

Fig. 1 (Lesson I) is a general photograph of a carefully designed masonry works capable of producing several thousand cubic feet of worked Portland stone each week. The machines are laid out or grouped in series so that a minimum amount of time is taken up in conveying the

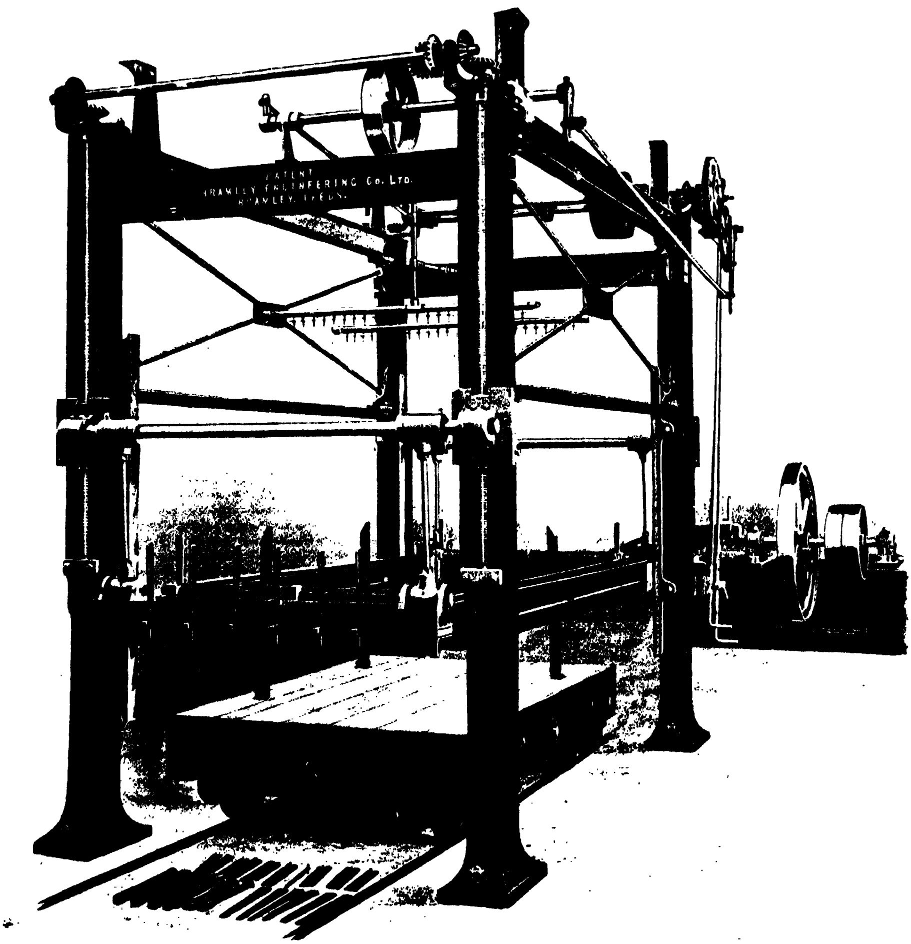


Fig. 87. Frame Saw

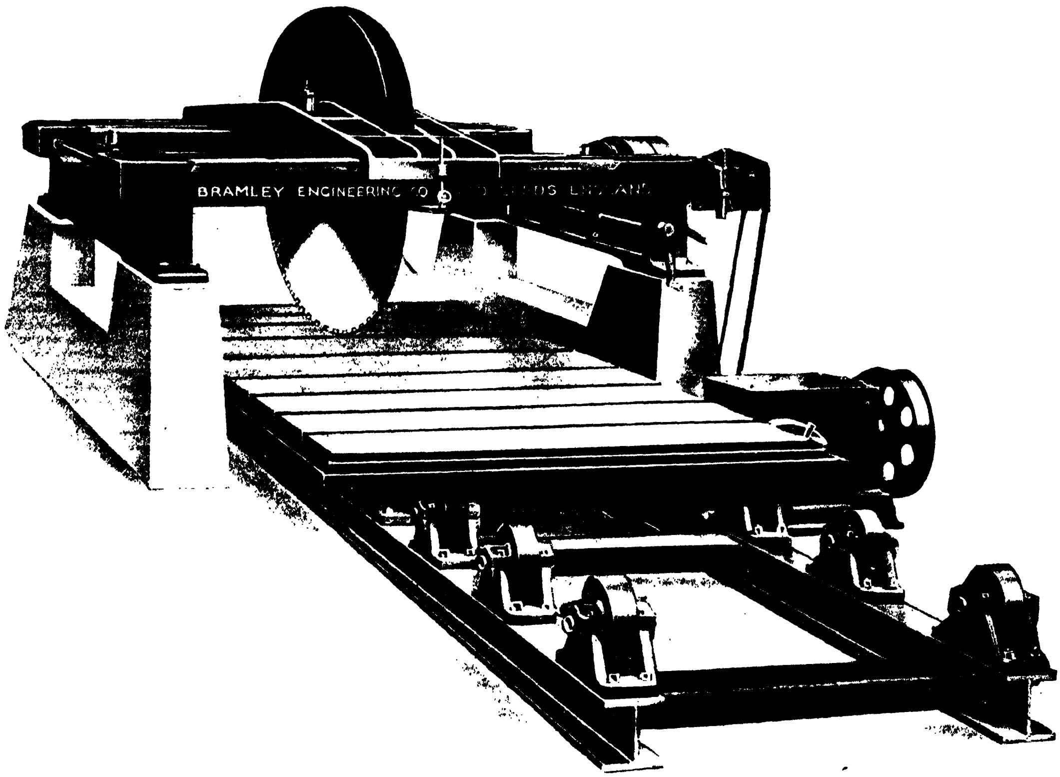


FIG. 88. AN IMPROVED PATTERN OF THE USUAL TYPE OF DIAMOND SAW

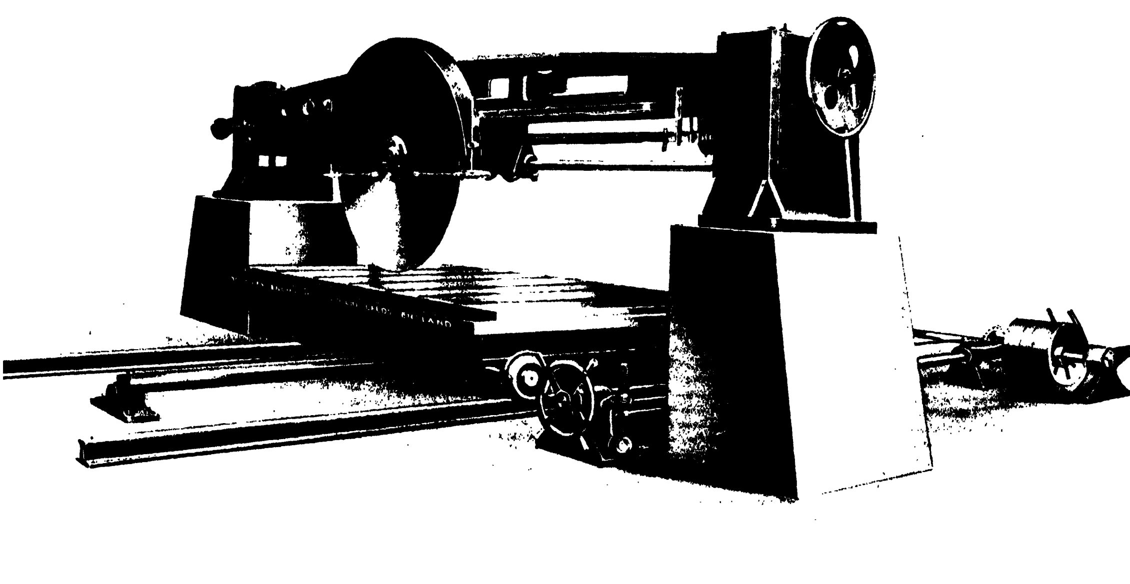


FIG. 88 (*a*). DIAMOND SAW, BEAM-TYPE

stones from one part of the works to the other. The machines and the masons' bankers are arranged so that they can be served with the electric travellers capable of lifting 10 tons, travelling at the rate of 200 ft. per min., the railway running direct into the works.

The following is a list of some of the machines in use for general masonry. It is not intended to cover the whole of the range of the machines in use, as there are many different types for the various branches, the type and grouping of the machines being quite different in marble and granite works from that of a Portland stone works.

SAWING

Frame Saw. Fig. 87 shows a good type of machine, and is an essential in all masonry works, irrespective of the class of work to be done. The table is loaded with blocks of stone, and run under the frame. *Saw blades* are fixed in the frame at the required distance apart by means of the wedges shown in the foreground. These are driven tight, making the blades rigid. The best blades for Portland stone are the "corrugated" or "ribbed" blades, about 5 in. wide. The frame is raised or lowered by means of a *worm* connected to the overhead gearing, the speed of which can be regulated or governed by means of the attachment at the side to suit the hardness of material being cut.

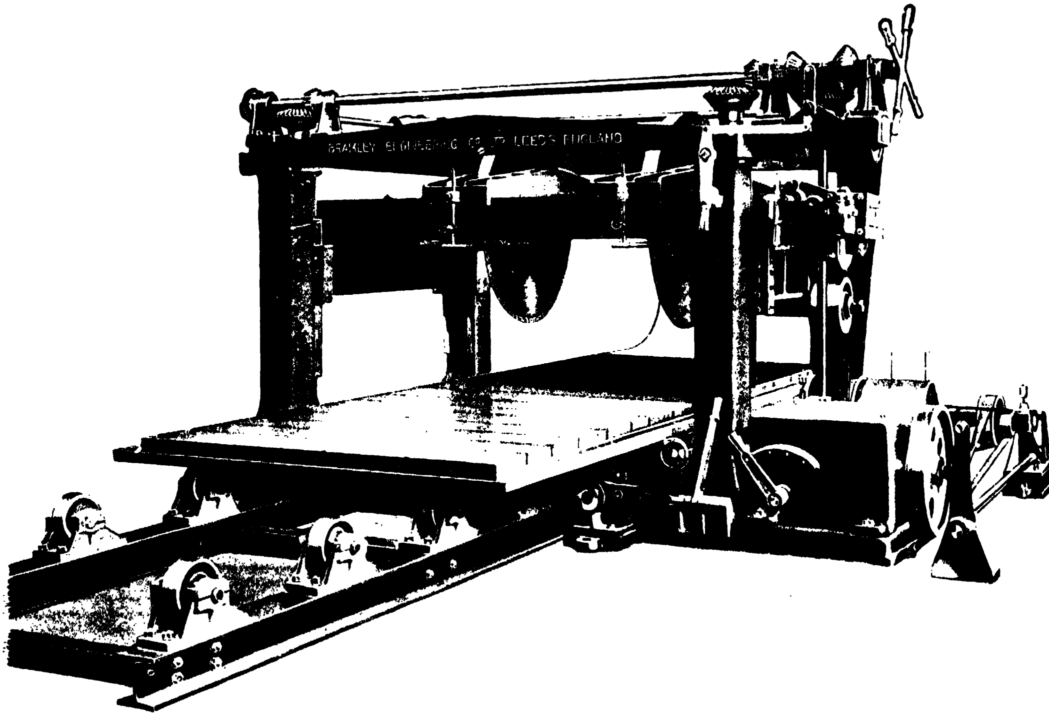


FIG. 89. THE "BRAMLEY" TWIN-BLADE DIAMOND SAW

Swinging jets are provided for the distribution of the water over the top surface of the stone.

Bridport or some other sharp sand, (and *steel grit* for granite, etc.), is placed on top of the stone; the sand must be allowed to enter freely the *kerf* made by the saw. A channel should be formed in the floor to convey the slurry resulting from the sawing into a pit. The water is allowed to drain away, the sand and other solids forming a sediment.

Diamond Circular Saw. These machines are almost essential for the equipment of a masonry works dealing with Portland or similar stones.

Fig. 88 shows the type of diamond saw in general use in masonry works. After the blocks of stone are slabbed in the frame saws they are turned over and cut to size, or possibly to shape, under the diamond saw. The resultant surface necessary. The blade, which is from 5 ft. to 6 ft. in diameter, travels laterally along the spindle, thus allowing cuts to be made at different parts of the block without shifting the stone. The stone rests on the table, which travels under

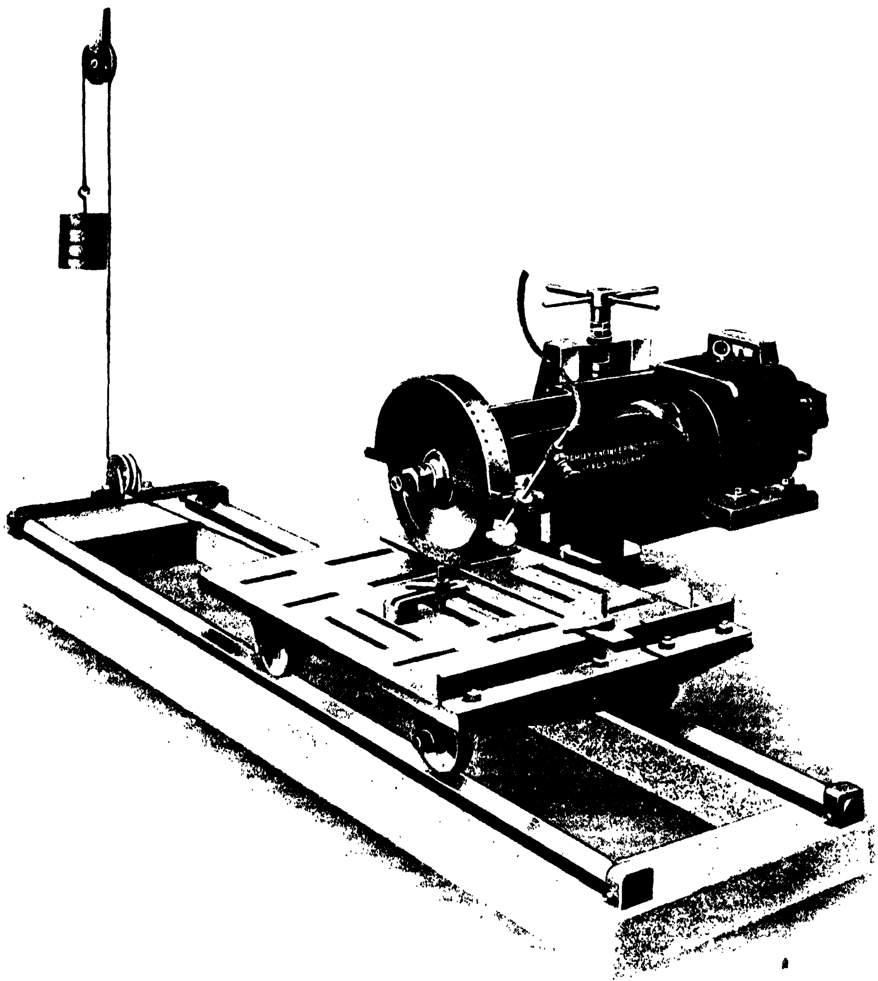


FIG. 90. JOINTER SAW

is fairly true, with very few whales, so that the surfaces only require rubbing to the finish necessary. These machines are made with rising and falling motion, so that the blade can cut at any height from the table (within the limits of the machine), thus making it possible for the saw to cut "checks" in the stone if the saw while the blade is rotating. The speed is arranged to suit the hardness of the particular stone to be cut. Water only is used as a cutting medium, apart from the *diamonds*, which are attached to the rim of the blade.

Fig. 88 (*a*) shows the beam-type diamond saw. In this type of machine the length of the stone is not limited, and the saw blade travels through the stone, cutting in both directions. It is a splendid machine for jointing large stones, such as cornices, etc.; also for slabbing, turning out extremely accurate work.

The rising and falling motion, which is incorporated in the machine, enables "checking" work to be done. To suit the cutting of material of different hardnesses and thicknesses, different speeds are provided. The "beam" has a locking device to minimize vibration while sawing.

Fig. 89 shows an improved type of saw, called the *Bramley twin-blade diamond saw.* Blades can be used up to 8 ft. 4 in. diameter, allowing a depth of cut up to 3 ft. 6 in., and having approximately 200 sockets for diamonds. The Bramley Engineering Co., supply a very good type of socket, the "Absofast Process," which is quite a reliable means for securing the diamonds. It can be readily seen that with the improved machine, twin cuts can be made at the same time at any distance apart, within the compass of the machine, thus enabling a great saving of time.

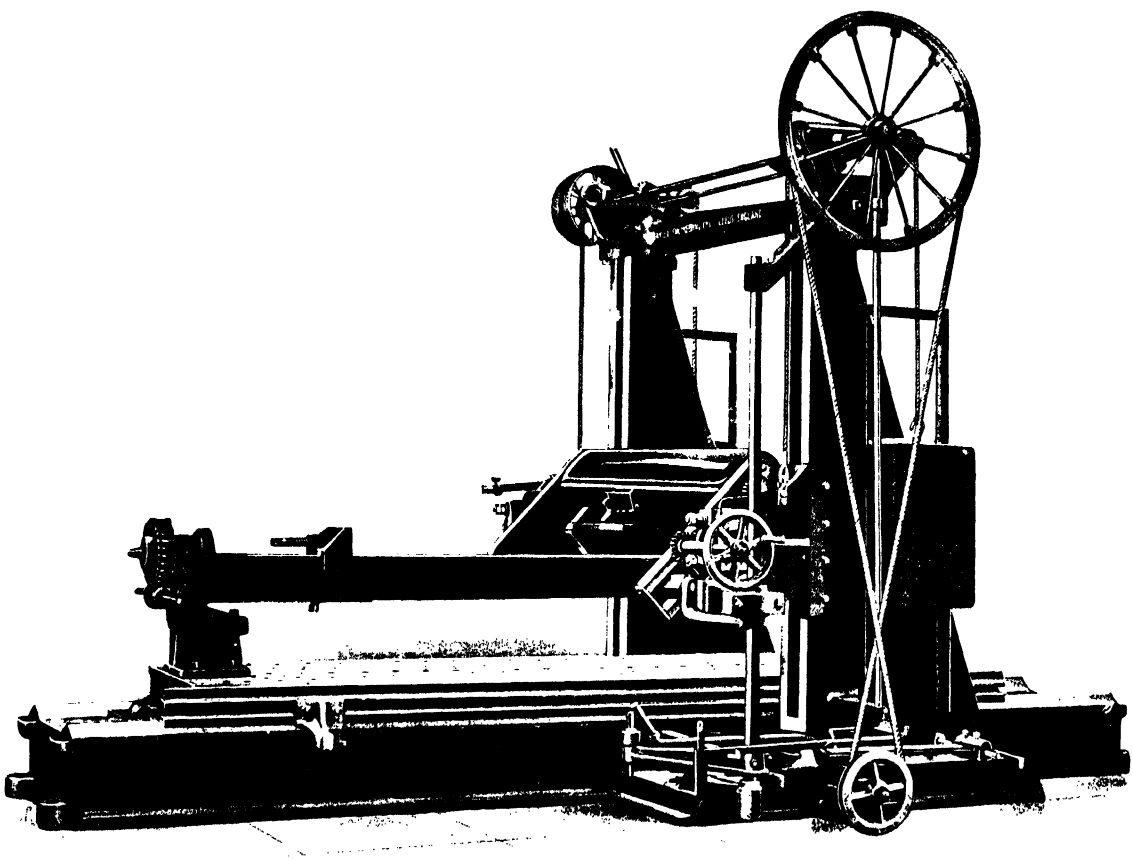


FIG. 91. MOULDING MACHINE, PROVIDED WITH TURNOVER TOOL HEAD AND ROCKING TABLE

Jointer Saw. Fig. 90 is a photograph of a *jointer saw.* This is a very handy machine and a great asset in a modern masonry works, as stones of small dimensions can be readily cut to the correct sizes required. If the machine is worked by a skilful operator, scarcely any finishing to the stone is necessary. The machines are provided with *rising* and *falling motion* and fitted with *carborundum-rimmed steel-centred blades,* which can easily be attached or detached, and wheels of other dimensions used, to suit all requirements. The carborundum is pressed on to the outside rim of the blade and slightly bevelled towards the centre, thus allowing the saw to *clear* in the cut.

PLANING AND MOULDING

Planing and Moulding Machine. Fig. 91 shows the usual type of machine used in various masonry works. For light mouldings, strings, cornices, etc., it is excellent. The *rocking* table enables the stone to be machined at top and both sides at one setting, and is specially advantageous for working deeply cut mouldings as the stone can be tilted at an angle, thus shortening the tools necessary for working the mouldings and minimizing the vibration.

The *turn-over motion* of the *tool head* enables the stone to be cut upon the return of the table.

Fig. 92 shows a *rigid head type* of planing machine which is most suitable for planing large surfaces and heavy work in general; for although this type of machine will only cut in one direction, the apparent loss of time is recovered by the quick return of the table.

Turning Lathes are used considerably for turning bases, columns, caps and balusters. They should be designed to meet the requirements of stone turning, although engineers' lathes can readily be adapted. *Gap lathes* should be installed for turning bases, etc., of large diameters. Fig. 12 (Lesson V) shows a huge granite base being turned for Messrs. A. & F. Manuelle Ltd., at Aberdeen, for Bush House, London. The cutting is performed by revolving discs of special steel which are attached to swivelling tool holders.

Fig. 2 also shows a column stone being turned in a lathe in the masonry works of the Bath & Portland Stone Firms Ltd., at Portland. This lathe is capable of turning stones up to 8 ft. in diameter. The gap of the lathe is 5 ft. It is also capable of turning a shaft 12 ft. long, by 4 ft. 6 in. diameter. A diamond saw is also shown at work.

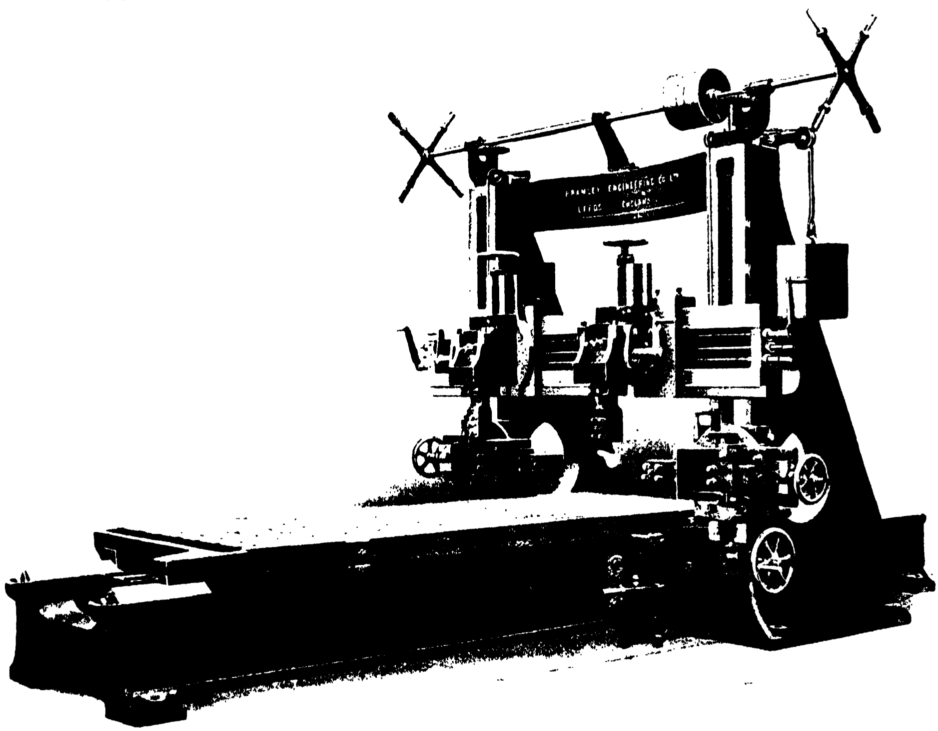


FIG. 92. PLANING MACHINE

BUILDER'S OFFICE AND ROUTINE

By R. F. Galbraith, B.Sc.

PART V

ACCOUNTANT AND CASHIER

The accountant and cashier will undertake the following duties—

Financial Books. All necessary entries in the cash book, ledgers, and journals. (See section on "Book-keeping.")

Payments of Accounts. Every month, or at convenient intervals when money is available, a list of all accounts due should be prepared by the cashier. Special note should be made of any accounts that are overdue, and of any discrepancies in the invoices that have not been agreed. This list is then scrutinized by the manager, or director in charge of the finance, who will decide what accounts to pay; probably accounts which have not been agreed would be held over pending settlement.

Cheques are now issued and forwarded. A cheque slip (see Fig. 6, which shows the slip about two-thirds size) is of great convenience, and should always be used.

The cashier is responsible that properly signed and stamped receipts are received in due course for all moneys sent, unless a receipt form is printed in the cheque itself, in which case the bank will not make payment until the receipt is signed, and stamped if required.

Payment of Wages is one of the most important items of routine in the cashier's department. In the building trade, the pay week ends at 5 o'clock on Friday evening, and payment is made at 12 noon on Saturday. A wage sheet (see Fig. 7, the actual size of the wage sheet being foolscap), showing the trade and name of every man employed on the jobs, together with total hours worked each day and total for the week, rate of pay, and deductions for insurance, is filled in by the timekeeper of each job, and forwarded to the builder's office on Friday evening. On Saturday morning these wage sheets must be checked, the exact number of £1 notes, 10s. notes, silver, and copper required abstracted, the money obtained from the bank, and made up ready for each separate job. A pay clerk is sent from the office to the job, and it is his duty to pay each man individually. If a man is absent and desires another man to draw his money, he should send a note to that effect by the man drawing the money, who must sign a receipt for the same. Any money not paid out on Saturday should be returned to the office, and obtained from there by the owner on returning to work.

J. SMITH & CO.

Builders and Contractors

123 CITY ROAD, LONDON, E.C.

Phone—Rodney 2962

.... 192....

TO..

....

Dear Sir,

We enclose herewith cheque value £..............

in payment of......................*account*

....

....

....

Your receipt will oblige.

Yours truly,

J. SMITH & CO.

Fig. 6

Petty Cash. Sundry payments, both on the jobs and at the office, are made from *petty cash.* The cashier is in charge of this money, at the office, and is responsible for checking the payments made on a job, by means of receipted bills returned each week. It is convenient to have the back of the wage sheets ruled with two sets of cash columns, one for receipts and the other for expenditure. This statement should be filled in by the timekeeper or foreman.

In a builder's business, money is usually received at irregular intervals in more or less large sums. Owing to the variation in terms of payment on various jobs, it is sometimes a matter of some difficulty to arrange for an even flow of money. The cashier should carefully watch the balance in hand and the rate of receipt of money, together with the wages requirements of the future. Wages *must* be paid when earned; accounts due for material *can* sometimes be put off by arrangement. A good cashier will watch all these points, and always have money available for wages.

Assistance to the Auditors. When the auditors make their yearly examination of the builder's books, the cashier must assist them by preparing lists of creditors and debtors, and a list of the value of all work in progress, but not completed. The value of the *work in progress* is usually taken as cost plus establishment charges. The cashier must also produce the necessary receipts and vouchers required by the auditors.

CONTRACTS

Kinds of Contracts. Three classes of contracts are dealt with in a builder's office—

(*a*) The contract between the building owner and the builder, for the erection of a particular building or the execution of certain works or repairs.

(*b*) The contract between the builder and another firm for the execution of certain works included in the main contract (*a*), but not undertaken by the builder. This type of contract is usually called a "Sub-contract," and has been dealt with under "Buying."

(*c*) The contract between the builder and a merchant, agent, or manufacturer for the supply of materials. (See "Buying.")

General Contract. The following are the chief

WAGES SHEET

For the Week ending..............................192.......

of work at..............................*in the employ of*

J. SMITH & CO.

123 CITY ROAD, LONDON, E.C.

NAME	S.	M.	T.	W.	T.	Fri.	Total.	@	Insurance Deducted	£	s.	d.

NOTE.—All delivery tickets for goods received during the week to be sent in to the office with pay-sheet on the Monday following the week-end.

FIG. 7

points incorporated into a general contract between a building owner and the builder—

1. The general scope of the work, together with the agreed contract price.

2. The time within which the builder undertakes to complete the work, and the "agreed and liquidated damages" payable for delay. The wording of this clause is most important. Delay may, and often does, occur through causes absolutely outside the control of the builder, and yet many builders will sign a contract containing a clause which saddles them with responsibility for delay, no matter what causes it. A clause of this nature should be altered before the contract is signed, or endless trouble and litigation will ensue.

3. Conditions under which the time limit mentioned above will be *extended*.

Usually, an allowance is made for wet and inclement weather, including frost, strikes, lock-outs and trade disputes, additional work, shortage of labour and materials, and alterations in design other than minor ones.

4. *Terms of Payment.* It is customary in the building trade for builders to receive 80 per cent to 90 per cent of the value of the work completed, either at stated intervals or when a certain minimum amount of work has been done. The remaining 20 per cent or 10 per cent, as the case may be, is called the *retention money*, and is retained by the employer until the work is finally completed and with an agreed interval.

For example, a contract might stipulate that 20 per cent of the value of the work would be paid monthly, while in another case 90 per cent of the value would be paid with a minimum advance of £1,500. Sometimes, when expressly provided, the value of unused materials lying on the site are included in the value of work executed for purposes of payment.

The retention money is often held till the end of the maintenance period.

The terms of payment are of great importance to a builder, and if very stringent terms are involved, an allowance to cover interest and use of capital should be included in the tender, or else the contract refused.

5. *Maintenance Period.* A contract usually provides that the builder shall make good any defects that occur during a stated period (three to twelve months), called the *maintenance period*, due to faulty materials or defective workmanship. Of course, faulty design is not the responsibility of the builder.

6. *Arbitration.* An arbitrator should be appointed under the contract to settle all disputes occurring, in accordance with the Arbitration Act, 1894, excepting those specially mentioned to be settled by the architect.

Subsidiary Points in Contract. The following minor points should be included either in the main contract, or in the conditions of contract—

Fire Insurance. Whether building is to be insured, or whether the building owners will cover the fire risks. All builder's plant should be insured in any case.

The architect should specifically mention *alterations or additions*, the extent to which additions and omissions shall be allowed, and the basis of pricing these variations. The value of day-work rates, and any other details connected with the variation, should be set out in this clause.

The Architect's Power. Usually, the architect has the absolute authority in judging the quality of materials and workmanship, also the manner in which the work shall be executed.

Subletting. Usually, permission to sublet work is required from the architect. Conditions as to customary rates of wages and conditions are imposed on the sub-contractor.

Wages Variations. A clause covering variations in the rates of wages should be included.

Default of the Builder. The right of the building owner in the event of bankruptcy, or other default of the builder, should be set out in detail. Usually, the right to determine the contract, after due notice, and to enter into new contracts to complete the work, is granted to the building owner, in addition to any remedy against the builder for breach of contract.

BUILDING SCIENCE

By Raymond R. Butler, M.Sc., A.I.C., F.C.S.

LESSON V

CEMENTS AND PLASTERS

Cements and plasters can be classified under the following scheme, shown in Table VII.

LIMES

Non-hydraulic limes are carbonate materials which, as a result of heating, have lost their carbon dioxide and are able to recombine slowly with the CO_2 of the air, forming a hard binding material between the masonry courses.

The reaction which proceeds in the lime kiln is represented by the chemical equation—

$$\underset{\text{(limestone)}}{CaCO_3} \xrightarrow{900^\circ C.} \underset{\text{(quicklime)}}{CaO} + \underset{\text{(carbon dioxide)}}{CO_2}$$

The resulting quicklime is supplied to the builder, who "slakes" it by the addition of water. The equation is—

$$\underset{\text{(quicklime)}}{CaO} + \underset{\text{(water)}}{H_2O} \longrightarrow \underset{\text{(calcium hydroxide — slaked lime)}}{Ca(OH)_2}$$

This combination takes place with the evolution of much heat, and the resulting slaked lime, mixed with sand, constitutes the old fashioned "mortar." It depends for its binding properties on its power of absorption of carbon dioxide from the air with the resulting slow reformation of calcium carbonate; thus—

$$Ca(OH)_2 + CO_2 \xrightarrow{\text{slowly}} CaCO_3 + H_2O$$

A **fat lime** is one which contains more than 85 per cent of active lime calculated as CaO (quicklime). For example, a Buxton lime shows on analysis figures similar to these—

CaO	98·7 per cent
Total SiO_2	0·71 ,,
Alumina and Ferric Oxide	0·11 ,,
Magnesia (MgO)	0·46 ,,

A **lean lime** contains a large percentage of silica (sand), iron, and other impurities, and is the result of heating a less pure limestone. Typical figures in comparison with those of fat limes are—

CaO	71·1 per cent
Total SiO_2	23·54 ,,
Alumina and Ferric Oxide	1·64 ,,
Magnesia (MgO)	1·04 ,,

Dolomitic limes are formed by the heat decomposition of magnesian limestones or dolomites, stones which contain large percentages of magnesium carbonate ($MgCO_3$). Commercially they are known as magnesian limes, and show much higher percentages of magnesia (MgO) than other limes—

CaO	46·72 per cent
Total SiO_2	2·94 ,,
Alumina and Ferric Oxide	1·90 ,,
Magnesia (MgO)	32·60 ,,

A fat lime slakes quickly, evolves much heat on slaking, expands considerably on slaking, and sets slowly. A magnesian lime slakes

TABLE VII

Classification of Limes, Cements, and Plasters

- Binding Materials
  - → Limes
    - → Non-hydraulic
      - → Fat limes.
      - → Lean limes.
      - → Dolomitic limes.
    - → Hydraulic
      - → Feebly hydraulic.
      - → Strongly hydraulic.
  - → Cements
    - → Natural
      - → Roman cement.
      - → Natural Portland cement.
    - → Artificial
      - → Portland cement.
      - → Cement Fondu.
      - → Magnesite cements.
  - → Plasters
    - → Plaster of Paris.
    - → Flooring plaster or "hard burnt plaster of Paris."

slowly, evolves little heat on slaking, expands less on slaking, and sets more rapidly. These limes cannot set under water, since they are dependent for hardening on the CO_2 in the atmosphere.

Hydraulic limes can set under water. The "Blue Lias" limestones of this country produce hydraulic limes, and Arden lime from Scotland is hydraulic. They are valuable for "pointing" the mortar courses of buildings, since they do not draw away from the stone as Portland cement frequently does.

Hydraulic limes include all cementing materials whose clinker shall, after burning, contain sufficient calcium silicate to cause it to set in the presence of water, and also sufficient free quicklime (CaO) to slake and pulverize the mass on the addition of water. A lime containing little calcium silicate is said to be *feebly hydraulic* as compared with the *eminently hydraulic* (high calcium silicate) limes. On treatment with water eminently hydraulic limes slake slowly, evolve little heat, and expand only slightly on slaking, set after a few days, and then slowly harden to a stony consistency. Feebly hydraulic limes slake more readily, evolve more heat, and show a greater increase in volume on slaking, set in from two to three weeks, and never become stone hard.

CEMENTS

Natural cements are the result of burning clayey limestones found naturally, which on roasting produce a material capable of setting hard on the addition of water. Thus, nodules of an approximate composition—

Limestone	60–70 per cent
Clay	30–45 ,,

found in the London clay, off Sheppey, produce when burnt the material known as *Roman cement*. In the same way natural mixtures are known which on burning produce what is practically Portland cement. *Medina cement*, found in the Isle of Wight, is a similar substance.

Portland cement is by far the most important of the modern manufactured cements. It is produced by grinding together into a cream, or *slurry*, about 75 per cent limestone and 25 per cent clay, and feeding this cream into the top end of a long tubular rotating furnace. Heat from suitable firing arrangements keeps the temperature at about 1,500° C., and the slurry as it works down is first dried, then fused, and finally leaves the lower end as a clinker.

This is then ground until not less than 86 per cent passes through a sieve carrying 180 holes to the linear inch, the diameter of the wires of the gauge being ·0018 in.

The British standard specification for Portland cement requires a specific gravity of not less than 3·10 for cement four weeks old. The requirements for tensile strength are—

For *neat* cement: briquettes, dried for 24 hours, and kept under water for seven days, must have a tensile strength of not less than 450 lb. per sq. in., and after 28 days the tensile strength should be—

$$\text{Strength at 7 days} + \frac{40{,}000}{\text{The tensile strength at 7 days.}}$$

For briquettes made of one part Portland cement and three parts Leighton Buzzard (standard) sand, the figures are—

At 7 days—a tensile strength of 200 lb. per sq. in.
At 28 days—the tensile strength of 7 days

$$+ \frac{10{,}000}{\text{The tensile strength at 7 days.}}$$

Chemically, the percentage of magnesia (MgO) must not be greater than 3 per cent. Magnesia combines with silica and alumina to form silicates and aluminates, which hydrate more slowly than the calcium compounds, and may therefore cause disruption after the rest of the cement has set if present in any quantity.

The percentage of SO_3 must not be greater than 2·75 per cent. In a chemical analysis SO_3 appears as the acidic portion of calcium sulphate ($CaOSO_3 = CaSO_4$), and of magnesium sulphate ($MgOSO_3 = MgSO_4$). Small amounts of added calcium sulphate retard the setting of the cement and are beneficial; but larger quantities create a condition of weakness, due to the relative softness of the calcium sulphate, as compared with the harder cement.

Corrosion of Portland Cement. The setting of Portland cement is accompanied by the setting free of lime in the cement. *Acids* attack the lime and dissolve it, thereby destroying the coherence of the concrete. Carbonic acid gas is not harmful unless the concrete is exposed to large volumes of it, as may happen in the fermentation industries.

Acid salts, such as sodium bisulphate, and acid mineral waters slowly attack cement.

Alkalies, such as potash and soda, seem to have little effect on the cement. *Alkaline* carbonates accelerate the setting of cement, as do small quantities of calcium chloride and sodium chloride. Cement is attacked by magnesium chloride, the reaction being—

$$\underset{\text{(magnesium chloride)}}{MgCl_2} + \underset{\text{(slaked lime)}}{Ca(OH)_2} \longrightarrow \underset{\text{(magnesium hydroxide)}}{Mg(OH)_2} + \underset{\text{(calcium chloride)}}{CaCl_2}$$

The calcium chloride so produced is soluble in water, hence the destructive effect of sea water (which contains magnesium chloride) on Portland cement.

Organic fertilizers attack lean concrete (i.e. concrete containing little cement), but good concrete, at least one month old, is unaffected.

Oils and fats attack freshly laid concrete and prevent the efficient setting of the cement.

Concrete one month old is unattacked by oils.

A cement depending for its setting power not on calcium silicate (as does Portland cement) but on aluminium silicate, is now being produced under the name of *Ciment Fondu*. It is produced by burning in nearly equal proportions lime and the clayey mineral bauxite. The product when ground develops great strength in a very short time, and is claimed to be completely immune from attack by sea water, sulphurous water, water saturated with gypsum, water containing 12 per cent of magnesium sulphate, mineral and vegetable oils, and tar.

Magnesite Cements. The so-called *Sorel cement* is of this type. It has been discovered that a paste of magnesia (MgO) and a concentrated solution of magnesium chloride ($MgCl_2$) of specific gravity about 1·14 will set hard, with the formation of a hydrated oxychloride, whose formula appears to be $MgCl_2 . 5MgO . xH_2O$. The value of x is uncertain, but appears to be about 17.

It is one of the strongest cements known; and a similar material, using zinc compounds in place of magnesium compounds, is used as a dental cement.

One part of Sorel cement, with four parts of sea sand, give a material whose crushing strength is in the region of 8,000 lb. per sq. in.

It is used as the binding material in many modern jointless and composition floorings.[1] In these compositions the binding material is the magnesite cement; the aggregate is sawdust, short-fibre asbestos, wood fibre, or a similar light and porous mass; and the colour is usually reddish-brown, due to the addition of a small percentage of ferric oxide (Fe_2O_3).

PLASTERS (Plaster of Paris)

These are the result of partly dehydrating the mineral gypsum ($CaSO_4.2H_2O$). This mineral when heated in "kettles" to about 200° C. loses 1½ molecules of water, and the resulting product ($CaSO_4.\frac{1}{2}H_2O$) is known as *plaster of Paris*. On mixing with water it has the property of recombining with the water, to produce a hardened mass of the same formula as the original gypsum, $CaSO_4.2H_2O$.

This forms the basis of a number of plasters of the type of *Keene's cement*. This is practically plaster of Paris with alum. The alum accelerates the setting of the plaster of Paris and makes the result harder and more durable. It has, however, a tendency to powder after a long time. *Mack's cement*, *Martin's cement*, and *Parian cement* are similar modifications.

When gypsum is heated to from 700° C. to 900° C. it loses all its water of crystallization. In this condition, when finely powdered, it will only recombine with water very slowly, resulting in a very hard mass used largely on the Continent as a flooring plaster.

[1] For detailed classification see Author, *Journ. Soc. Chem. Ind.*, 12th October, 1923, page 980.

BUILDER'S GEOMETRY

By Richard Greenhalgh, A.I.Struct.E.
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LESSON VII

LOCI

Locus of a Point. The *locus* of a point means the *path* described by the point as it is moved; thus, an ellipse is the locus of a point which moves so that the sum of its distances from two fixed points (called the *foci* of the ellipse) is constant.

Fig. 65 shows a circle, centre *A*, a line *BC*, and another line *DE*. Suppose it is required

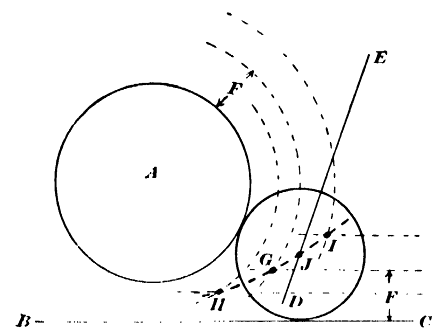

Fig. 65. Use of Locus to Solve a Problem

to draw a circle having its centre on *DE* and touching *BC* and the given circle.

Draw a line parallel to *BC* and an arc concentric with the given circle, the distances *F* being equal. The point *G*, where the arc and line intersect, is obviously equidistant from the given line and the given circle, and a circle could be drawn with this point as centre to touch the given circle and line.

Obtain other points, as *H* and *I*, in a similar manner. Then a line drawn through these points is the locus of a point that moves, so that it is always equidistant from circle *A* and line *BC*. The locus cuts the line *DE* at *J*, and this is the centre from which the required circle can be drawn.

A practical problem where a locus is required is shown in Fig. 66, where a circle has to be fitted into a tracery window, so that it is underneath the large Gothic head and over the two small lights.

It is obvious that the required circle will have its centre on the centre line of the window, and that the centre will also be equidistant from the arcs *AB* (centre *E*) and *CD* (centre *B*). Draw a locus, as shown, through points equidistant from these two arcs. The locus cuts the centre line at *F*, the centre of the circle required.

MOULDINGS

The geometrical methods of drawing a number of the common mouldings used in building work are shown in Figs. 67–91. *Roman* mouldings are usually made up of arcs of circles, but *Grecian* mouldings are often made up of elliptic or parabolic curves.

Beads, Reeds, and Flutes. A *common bead* moulding is simply a semicircle in section, as

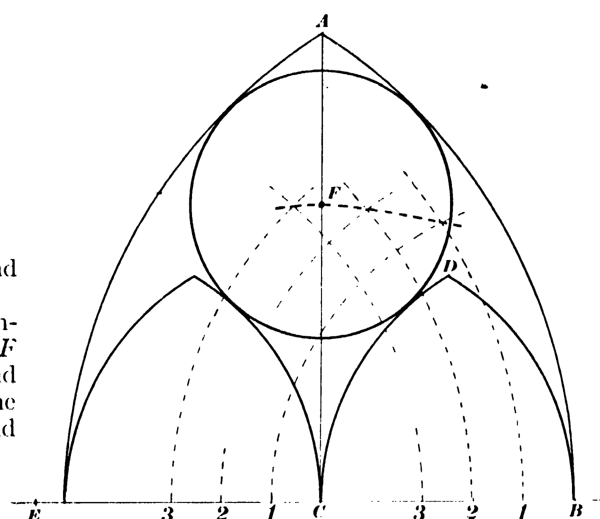

Fig. 66. Use of Locus in Drawing Tracery Window

shown in Fig. 67. The *return bead* is three-quarters of a circle, Fig. 68. *Reeding*, Fig. 69, consists of a number of semicircles separated by small quirks, or fillets. *Fluting*, Fig. 70, is the reverse of reeding. The fluting to the column in Fig. 71 consists of half (approximate) ellipses struck from three centres.

Cavetto. This is a moulding having a concave curve, which may be formed of either a quadrant

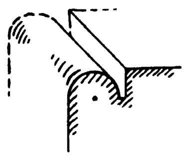
Fig. 67 Bead

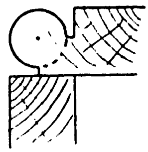
Fig. 68 Return Bead


Fig. 69. Reeding


Fig. 70. Fluting


Fig. 71. Fluting to Column

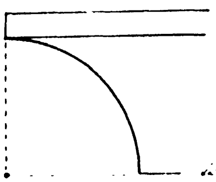
Fig. 72. Cavetto

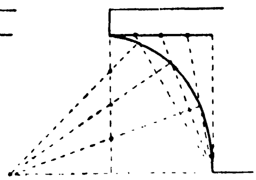
Fig. 73. Cavetto, Elliptical

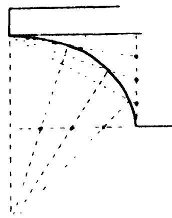
Fig. 74. Cavetto, Elliptical

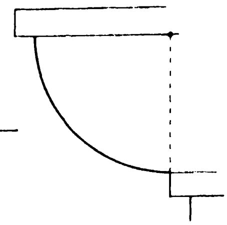
Fig. 75 Ovolo

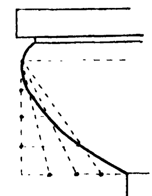
Fig. 76. Echinus, Parabolic

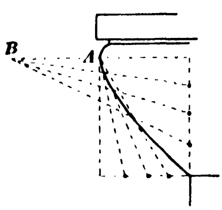

Fig. 77. Echinus, Hyperbolic

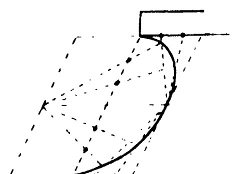
Fig. 78. Scotia, Elliptical

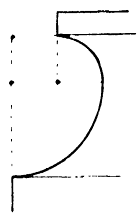
Fig. 79. Scotia

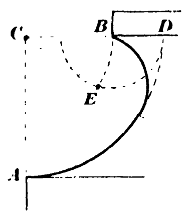

Fig. 80. Scotia

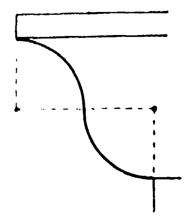
Fig. 81 Ogee (Cyma Recta)

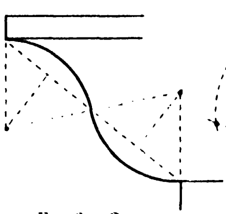
Fig. 82. Ogee

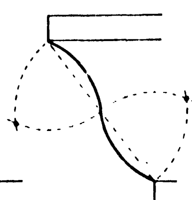
Fig. 83. Ogee

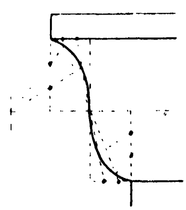
Fig. 84. Ogee, Elliptical

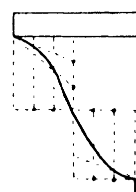
Fig. 85. Ogee, Parabolic

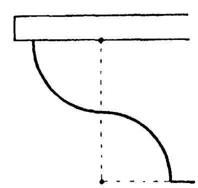
Fig. 86. Reverse Ogee (Cyma Reversa)

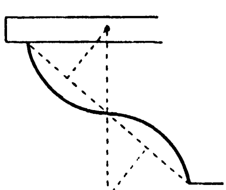
Fig. 87. Reverse Ogee

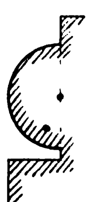
Fig. 88. Torus

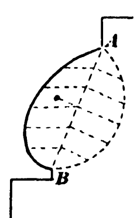

Fig. 89. Torus, Elliptical

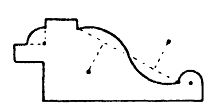
Fig. 90. Bolection Moulding

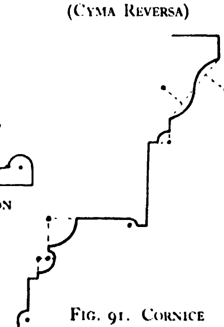
Fig. 91. Cornice

Geometrical Construction of Mouldings

of a circle, as in Fig. 72 ; or it may be composed of a quarter of an ellipse, arranged either as in Fig. 73 or as in Fig. 74.

Ovolo and Echinus. The ovolo moulding in Fig. 75 is a quadrant of a circle. The echinus moulding, shown in Fig. 76, is somewhat similar to an ovolo, and is often used at the top of columns. The curve may be either parabolic, Fig. 76, or hyperbolic, Fig. 77. In the latter case, the points on the curve are obtained by two sets of radial lines. The distance *AB* can be made any convenient length ; the position of point *B* determines the character of the curve.

Scotia. A scotia is a concave moulding and may be in the form of a simple inverted cavetto ; see Fig. 72. An undercut scotia, made of a half ellipse, is shown in Fig. 78. The simple undercut type, shown in Fig. 79, is made up of two quadrants.

The general construction for a scotia, to be drawn between two points *A* and *B*, is shown in Fig. 80. A vertical line from *A*, and a horizontal line from *B*, locate the centre *C* of the lower curve. With *C* as centre and *CA* as radius, describe the quadrant *AD*. With *B* as centre and *BD* as radius, draw the dotted semicircle shown. With *C* as centre and *CB* as radius, draw an arc from *B*, cutting the dotted semicircle in *E*. Then *E* is the centre from which the remainder of the scotia is struck.

Ogee. The ogee, or *cyma recta*, moulding is shown in its simplest form in Fig. 81, where it is composed of two quadrants. Two other methods for use where the width is greater than the height, Fig. 82, and where the width is less than the height, Fig. 83, are also given. Fig. 84 is an elliptical ogee, and Fig. 85 is a parabolic ogee.

Two methods of drawing a reverse ogee, or *cyma reversa*, are shown in Figs. 86 and 87.

Other Mouldings. Two examples of *torus* mouldings, suitable for the top edge of skirting boards, etc., are shown in Figs. 88 and 89. In drawing the latter, which is elliptical, an arc is first described on *AB*, and ordinates are drawn at right angles to *AB*. The horizontal ordinates shown are then drawn equal in length to the first ordinates, thus locating points on the curve. This method of drawing elliptic curves can be applied to other elliptic mouldings.

A *bolection* moulding as used for panelled framing is shown in Fig. 90, and Fig. 91 shows the section of a cornice. The centres of the curves are indicated.

In drawing curves made up of tangential arcs, notice that the point of junction always lies on the line joining the centres from which the arcs are struck.

ENLARGING AND REDUCING MOULDINGS

The obvious method of enlarging a figure is simply to draw the new figure by increasing the lines in the required proportion. Thus, if the small moulding, *A*, Fig. 92, has to be enlarged to twice its size, *OB* would be made twice the size of *Ob*, and the other sides enlarged in the same proportion

If, however, after drawing the large moulding, radial lines as shown dotted are drawn, it will

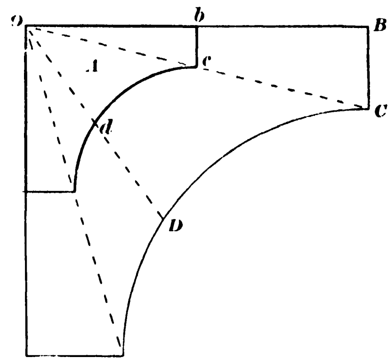

FIG. 92. ENLARGING A FIGURE

be found that corresponding radial lines in the two figures bear the same proportion to each other as the sides of the two mouldings ; thus *Oc* is half *OC*. Points on the curve can also be plotted in this way ; thus, *OD* is twice *Od*. This is called the *radial method* of enlarging or reducing figures.

Fig. 93 shows how to draw a moulding two-thirds the size of a given moulding. Draw radial lines from each corner of the figure to any point *O*. Take any radial line as *OA*, and divide it so that *Oa* is two-thirds its length. From *a* draw *ab* parallel to *AB*, and complete the figure by drawing all the lines of the required figure parallel to the corresponding lines of the given figure. Note that the extremities of the curves, or even points on the curves themselves, can be obtained by drawing lines as shown dotted.

A variation of the method is to set off two-thirds of each projector, and join up the points.

Reducing in One Direction. It is sometimes required to reduce a figure in one direction only. Thus, Fig. 94 gives a bracket as often used on the sides of cut strings in staircases. Where the string winds round the turn at the end of a well, the ends of the steps become less, though maintaining the same rise, and the brackets must be compressed, as it were, in

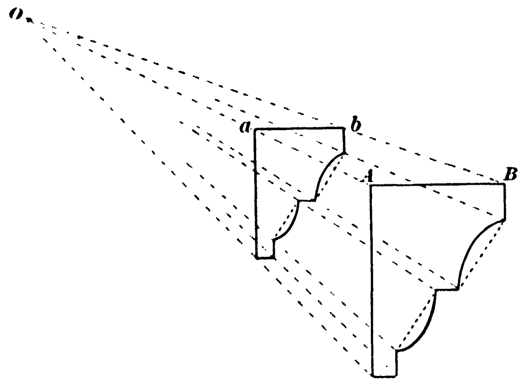

FIG. 93. REDUCING A MOULDING

length, while the vertical dimensions remain the same. A number of vertical lines, or ordinates, are drawn on the given bracket from points on its curve; draw radial lines to any point *O* from the top points of these lines, and draw a line *ab*, equal to the required compressed length of the bracket, between the extreme radial lines and parallel to *AB*. Drop ordinates from the points where the radial lines cut *ab*, and make these ordinates equal to those on the original bracket. Join the lower ends of the ordinates to give the required diminished bracket.

Linear, Superficial, and Cubic Sizes. There is much confusion about the relative sizes of things. For example, suppose there are two doors of exactly the same shape, one 8 ft. by 4 ft. and the other 4 ft. by 2 ft., how much is one bigger than the other? You will probably reply "Twice as big." But yet one door would take four times as much paint to cover it, and eight times as much timber to make it, as the smaller door. Similarly, if a man were twice the height of a boy and of exactly the same build, he would require four times as much cloth as the boy to make a suit, and he would be eight times as heavy.

The following is a useful theorem: *The surface areas and volumes of similar figures are respectively proportional to the squares and cubes of their linear dimensions.*

The truth of this theorem can be easily seen by comparing two cubes, one of 1 in. side and the other of 2 in. side. The second cube is obviously twice the linear size of the first; each surface of big cube is clearly four times the area of a side of the small cube; and eight of the little cubes would make up the volume of the big cube.

To take a practical example, suppose there are two boxes, not necessarily cubes, but of any shape yet similar in shape, and let one edge of one box be 2 ft. long and the corresponding edge of the other box 6 ft. long; that is, one box is three times the linear size of the other box.

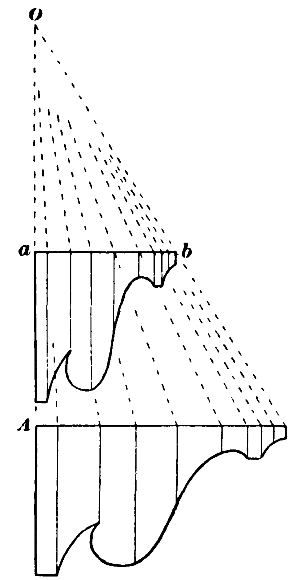

FIG. 94. DIMINISHED STAIR BRACKET

Then the amount of paint required for the large box, as compared with the small box, will be—

$$6^2 : 2^2 = 36 : 4 = 9 : 1.$$

That is, one box requires nine times as much paint as the other.

The timber required will be in the proportion of—

$$6^3 : 2^3 = 216 : 8 = 27 : 1.$$

That is, the large box requires twenty-seven times as much timber to make it as the small one.

CIVIL ENGINEERING

By Professor F. C. Lea, D.Sc., M.Inst.C.E.

LESSON III

MASONRY DAMS AND OTHER STRUCTURES SUPPORTING WATER

Water Pressure. It is shown in books on hydrostatics that in a fluid the pressure at any point is equal in all directions, and that at any

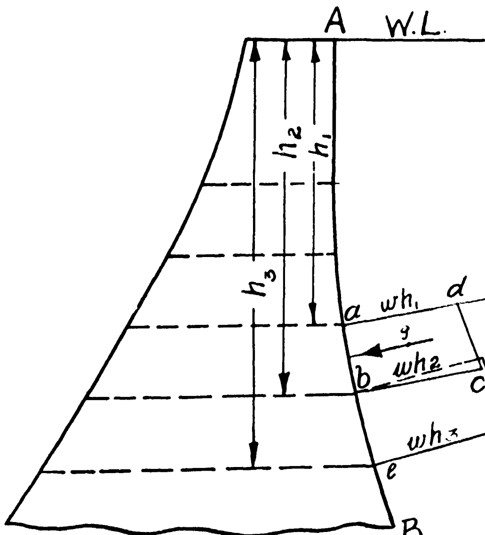

Fig. 15

depth h feet below the free surface the pressure per square foot is wh pounds, w being the weight of a cubic foot of water. The value of w for fresh water may be taken as 62·4 lb. per cub. ft., and for sea water 64 lb. per cub. ft.

Let AB (Fig. 15) be the face of a structure exposed to water pressure. At any depth h the pressure p per unit area is normal to the face of the structure, and is equal to wh lb. per sq. ft. Consider any element ab of the face, which may be considered as a straight line. At a the pressure p_1 is wh_1 lb. per sq. ft., and at b the pressure p_2 is wh_2 lb. per sq. ft. Set out at a and b, normal to ab, ordinates respectively equal to wh_1 and wh_2, on any convenient scale.

Consider 1 ft. length of the dam. Then the area $abcd$ is equal to the whole pressure on the area ab. Let g be the centre of gravity of $abcd$, then the whole pressure P_{ab} on ab acts through the centre of gravity of $abcd$ and is equal to—$wab\left(\frac{h_1 + h_2}{2}\right)$. Similarly, the whole pressure on bc is the area $bcgf$.

Example. A masonry dam (Fig. 16) has a vertical water face. The top of the dam is 10 ft. thick and the bottom 20 ft. The height of the dam is 30 ft. and the water is level with the top of the dam. The weight of masonry is 140 lb. per cub. ft. Find the resultant pressure on the

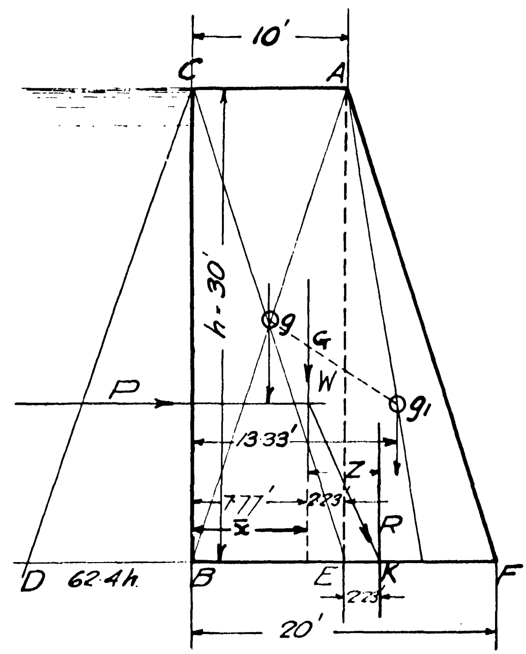

Fig. 16

water face and the resultant pressure on the base.

The water pressure diagram on the face BC is the triangle DBC, the base BD being equal to $62{\cdot}4h$. The resultant pressure—

$$P = \tfrac{1}{2}\,62{\cdot}4h^2 = 28{,}080 \text{ lb.}$$

The weight of the wall is—

$$W = \tfrac{1}{2}\,(20 + 10)\,30 \times 140 \text{ lb.}$$
$$= 63{,}000 \text{ lb.}$$

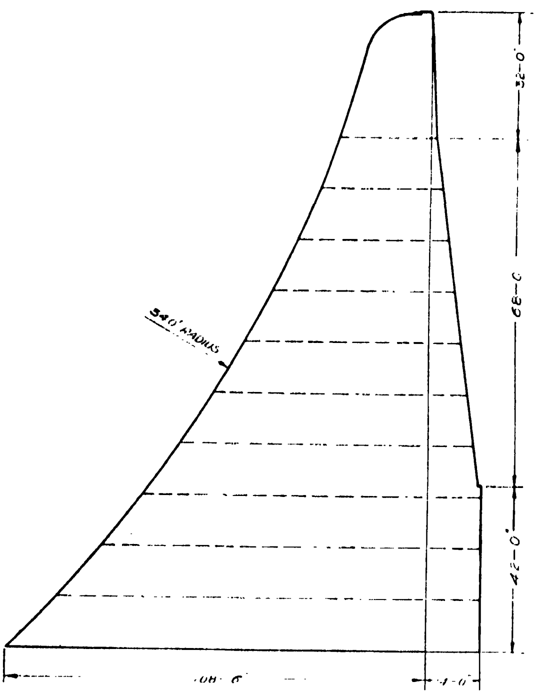

FIG. 17

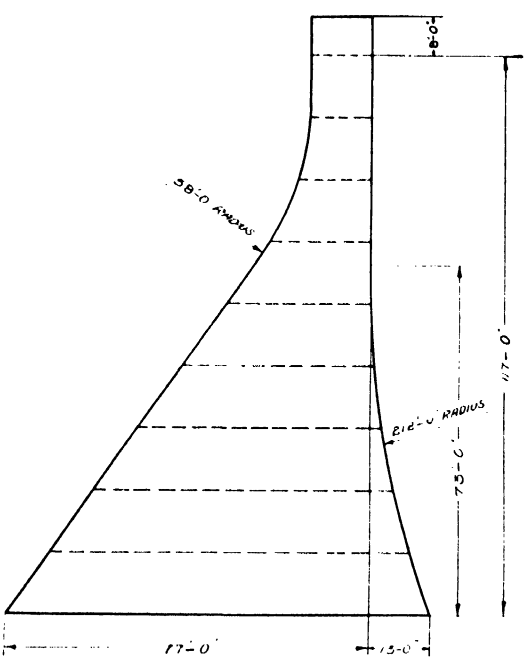

FIG. 18

Let $\bar{x}$ be the distance of the centre of gravity G of the wall from CB; g and g_1 are the centres of gravity of the rectangle $AEBC$ and the triangle FEA respectively.

Then, $\bar{x}$. 450 sq. ft.

$$= 300 \times 5 + 150 \times 13{\cdot}33$$
$$= 1{,}500 + 2{,}000$$
$$\bar{x} = \frac{3{,}500}{450} = 7{\cdot}77 \text{ ft.}$$

By combining P and W graphically, the reader can find the point K where the resultant R cuts the base FB. Or, since the moment of P about K must equal the moment of W about K—

$$WZ = P\frac{h}{3} = 10P$$

$$\text{and } Z = \frac{10 \times 28080}{63{,}000} = 4{\cdot}46 \text{ ft.}$$

i.e. the point K where R cuts the base is $7{\cdot}77 + 4{\cdot}46 - 10 = 2{\cdot}23$ ft. to the right of the centre E.

The resultant thrust is in the middle third. The normal stress at F is—

$$p_F = \frac{63{,}000}{20}\left(1 + \frac{6 \times 2{\cdot}23}{20}\right)$$
$$= 3{,}150 \times 1{\cdot}669 = 5{,}257 \text{ lb. per sq. ft.}$$

and $p_B = 1{,}042$ lb. per sq. ft.

Sections of Masonry (Gravity) Dams. Figs. 17 and 18 show sections of dams that have been constructed. A number of considerations determine the exact form of the section, the principal being the desire to economize masonry and whether the dam shall be used as an overflow weir. Fig. 17 shows the section of the Caban Coch Dam of the Birmingham Waterworks, and over the top of this the excess flood water flows when the level of the reservoir reaches the crest of the dam. Fig. 18 shows the section of a dam not used as a waste weir. Sometimes a roadway, Fig. 21, has to be carried over the top of the dam, and this may affect the design.

Types of Dams. Fig. 19 illustrates a suitable site for a dam and reservoir, and Fig. 20 shows a dam in course of construction. Figs. 21–23 show three types of dams.

STABILITY OF A DAM

Applying the simple principles discussed, it is not difficult to determine the resultant force on any section of a dam.

Line of Thrust when the Reservoir is Empty. Let the section of the dam (Fig. 24) be divided into horizontal layers of reasonable thickness, and assume the dam to be 1 ft. long. Considering any one of these layers $efdc$, its centre of gravity

Fi[illegible] Site [illegible] Ma[illegible]ry Dam and [illegible]voir

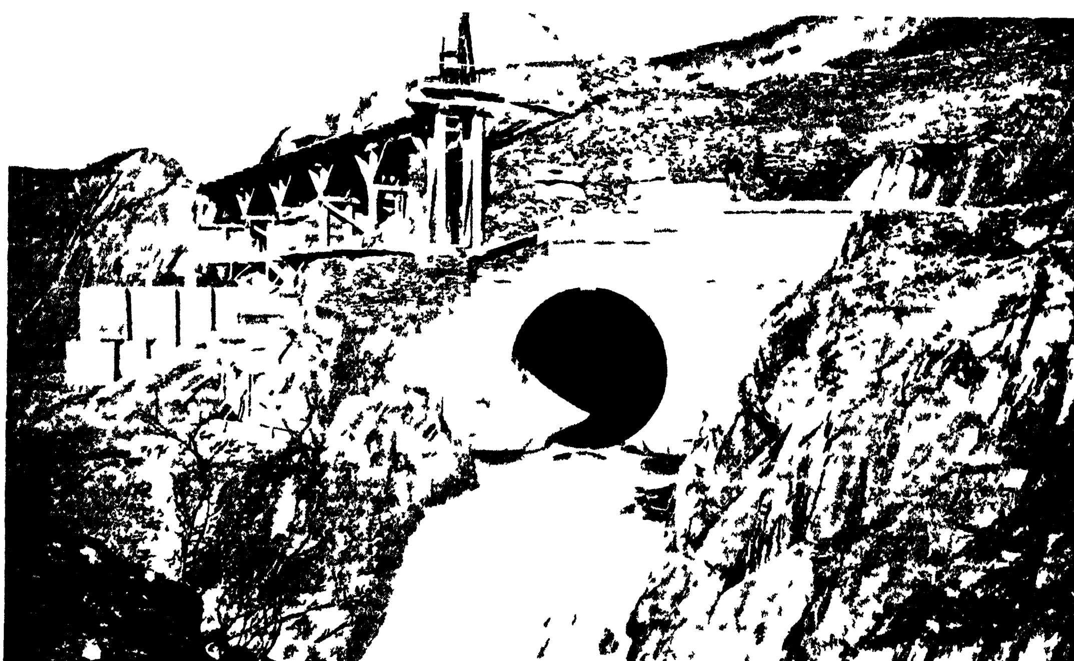

Fig. [illegible] Dam in Process of Construction

Tunnel for [illegible] the st[illegible] [illegible]. This was plugged [illegible] [illegible] work

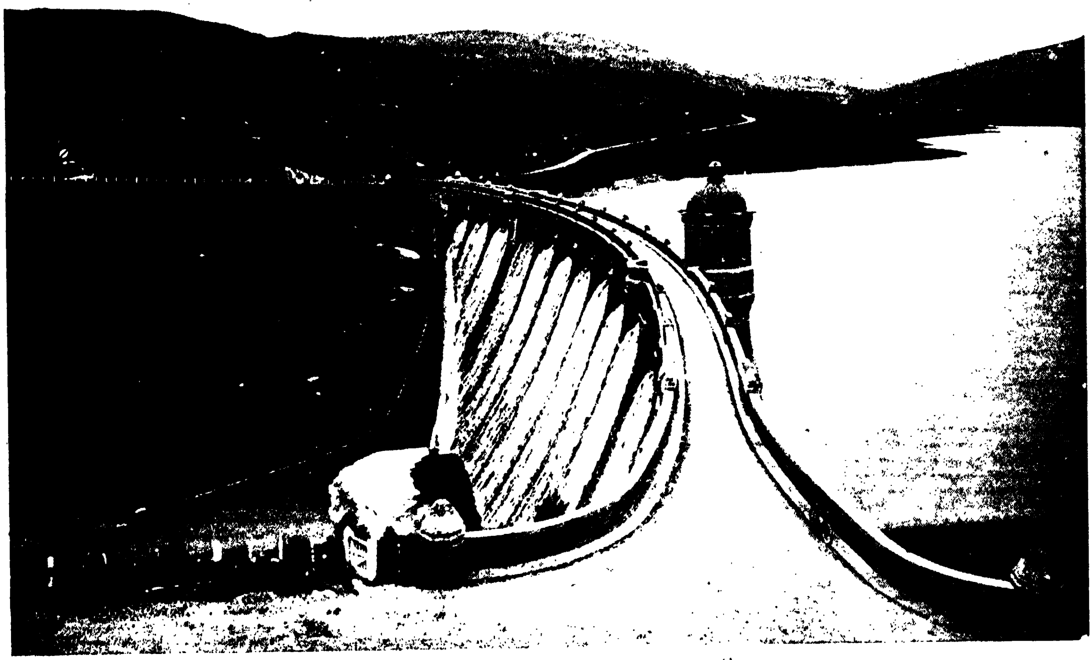

Fig. 21. Dam Constructed on the Site
Waste water flowing over the dam under the road

Fig. 22. Dam without Road over the Top

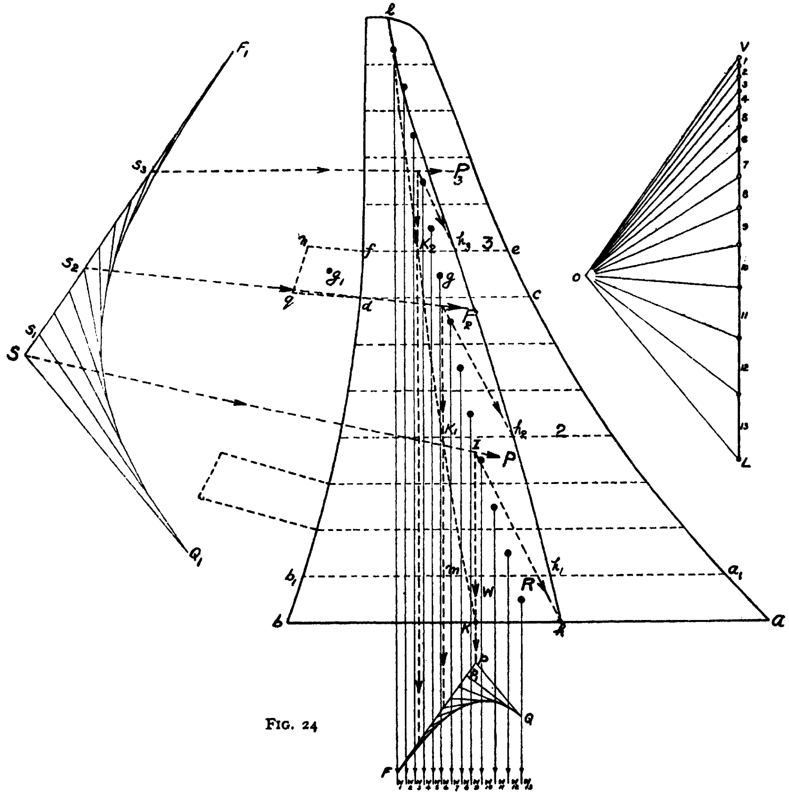

FIG. 24

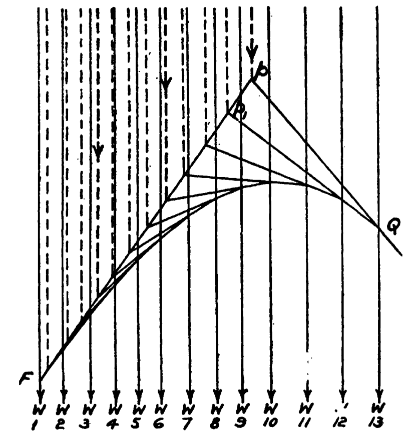

FIG. 25

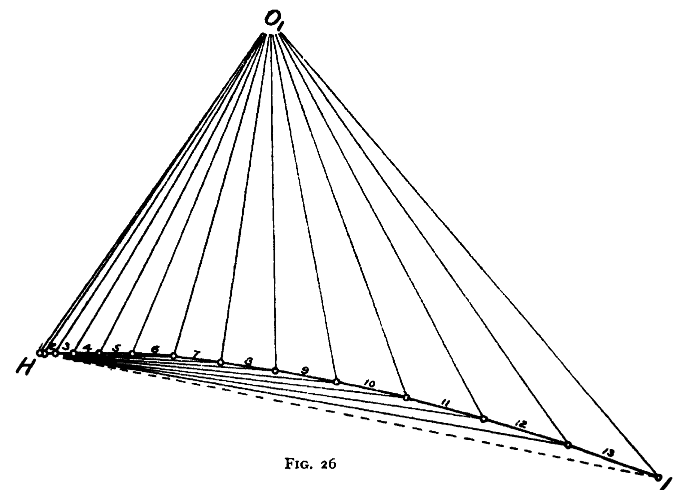

FIG. 26

FIGS. 24 to 26. OBTAINING LINES OF THRUST IN DAM

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ctive

g and its area can be found. Let w_m be the weight of a cubic foot of the masonry or concrete. Then the weight of this element of the dam is—

$$W = w_m \,.\, efdc \text{ lb.},$$

and this acts through the centre g of this area.

Let the centre of gravity and weight of each area into which the section of the dam is divided be found. Let the weights be tabulated. It is often convenient to work in cubic feet of masonry. Then above the base *ab* there are a number of parallel forces acting through the respective centres of gravity of these areas. Let the forces be plotted as 1, 2, . . . etc., in the line of loads *VL*. Taking a pole *O*, let a funicular polygon be drawn For clearness, this is drawn enlarged in Fig. 25. Where the two end lines of the polygon meet at *p*, gives a point on the line of action of the total weight above the base *ab*. A vertical through *p* cuts the base *ab* at *K*.

Now consider the second section a_1b_1. If one load, the area of the lowest layer, is dropped, the closing lines of the polygon now meet at p_1. Where these meet gives a point on the line of action of the weight above a_1b_1, and so on. The total load cuts *ab* at *K* and the load above a_1b_1 cuts it at *m*. By continuing the process, points such as K_1 and K_2, etc., at which the vertical loads above the respective horizontal planes cut these planes, are found; the curve lK_2K_1K, drawn through these points, is frequently called the *line of thrust*. What is meant is that the point where it cuts any base is the point through which the resultant vertical load, due to the weight, acts. Knowing the vertical load above any section, and its line of action, the stress diagram (see Fig. 13) for the section can be drawn.

Line of Thrust Reservoir Full. Let the water pressure diagrams on each element into which the water face is divided by the horizontal sections be drawn. For example, *dfnq* is the pressure diagram on the face *df*, *fn* being equal to wh_f and *dq* to wh_d, h_f and h_d being the depths below the water surface of *f* and *d* respectively. Let the area *dfnq*, either in pounds or cubic feet of masonry, or cubic feet of water, be found. This equals $\frac{1}{2}(fn + dq)$, *fn* and *dq* being measured on the appropriate scale. Let g_1 be the centre of gravity of *dfnq*. Then the load *P* on *df* acts normally to *df* and through g_1. Let similar diagrams be drawn for the remaining areas and the respective forces found.

The line of loads *HL* (Fig. 26) is now drawn and any pole O_1 taken. The funicular polygon F_1Q_1 (Fig. 24) can then be drawn. The resultant water pressure *P*, above the base *ab*, acts through the point *S*, where the two end lines of the polygon meet, and is equal to *HL* of the force

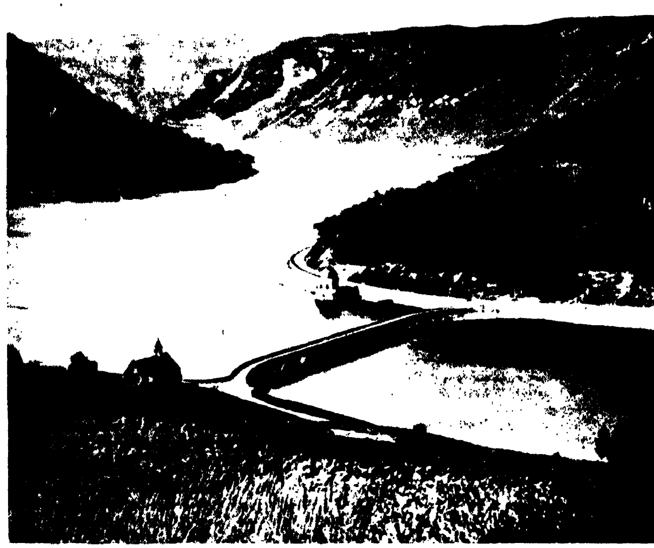


FIG. 23. SUBMERGED DAM SEPARATING TWO RESERVOIRS WITH ROAD OVER THE DAM

diagram. The resultant water pressure above the base a_1b_1 acts through the point S_1 resultant above the base 2 acts through S_2, and so on.

The Resultant Pressure on Any Base. The resultant pressure *R* on the base *ab* is then found by combining *P* and *W* (Fig. 24), i.e. by combining *VL* (Fig. 24) and *HL* (Fig. 27). Through the point *I* where *P* and *W* meet (Fig. 24), *R* is drawn parallel to the resultant of *VL* and *HL*. The tangential force *T* on *ab* is the horizontal component of *R*, which is equal to the horizontal component of *HL*; the normal component is the vertical component of *R*, which is equal to *VL* plus the vertical component of *HL*. In the same way the resultant thrusts on the sections 2 and 3 (Fig. 24) are found by combining the respective weights from the load line VL, and the respective water pressures from Fig. 26. The points h, h_1, h_2, h_3, etc., give the line of thrust lh when the reservoir is full; that is, this line gives the points at which the resultant R on any base cuts the base, but it does not give the direction of the force cutting the base.

Shear Stresses on the Base of a Retaining Wall or Dam. Let $ABDC$ (Fig. 27) be the normal stress diagram on the base AB of a masonry structure. Consider the equilibrium of the small element Aaf, which is also shown enlarged. Let it be assumed that on Af is a stress p_0 due to water pressure, and on Aa a stress p. The shear stress q, acting on af, must be equal to the shear stress on Aa.

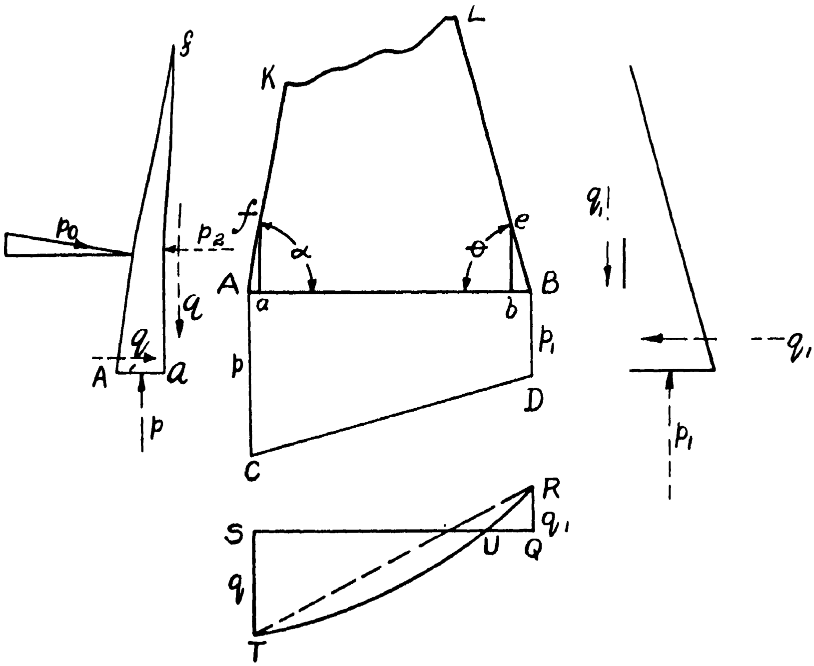


FIG. 27

The vertical forces must be equilibrium and, therefore—

$$p \cdot Aa - p_0 Af \cos \alpha = q \cdot af$$

$$\text{or } (p - p_0) = q \tan \alpha$$

$$\text{and } q = (p - p_0) \cot \alpha$$

When α is 90°, q is zero.

On af there is a normal stress p_2.

Then—

$$p_0 Af \sin \alpha + qAa = p_2 af.$$

$$\text{or } p_2 = q \cot \alpha + p_0$$

Similarly at B, assuming a normal stress p_1 on Bb, the shear stress—

$$q_1 = p_1 \cot \theta$$

and the normal stress on be is—

$$p_3 = q_1 \cot \theta = p_1 \cot^2 \theta$$

The values of q and q_1 at A and B respectively are thus known, when the normal stress diagram is known. If at A, p is greater than p_0, the shear stress on the face Aa of the element Aaf acts towards the right, and the shear stress at A on the foundation is in the opposite direction. At B the shear stress on Bb, of the element Bbe, is acting towards the left, and is opposite in sign to q at A, when p is greater than p_0. The form of the shear stress diagram $STURQ$, between T and R, is a parabola, and the area must be equal to the total tangential force on the base AB. The tangential force can be determined; and the ordinates ST and QR being known, it is easy to draw a parabolic curve so that the area $STURQ$ is equal to the tangential force. The actual stresses between S and Q are not very important, but it is desirable to consider a little further the stresses at A when the pressure p_0 is a fluid pressure. The two principal[1] stresses at A are at right angles to each other, and one principal stress is p_0. If the other principal stress can become a tensile stress, which can only possibly be the case when α has some value less than 90°, the water pressure may get into the joint and cause a movement of the resultant pressure in the manner already discussed in connection with Fig. 14. To avoid this, and particularly when p_0 is nearly equal to or greater than p, the angle α should be made a right angle.

[1] See books on strength of materials.

DRAINAGE AND SANITATION

By Henry C. Adams, M.Inst.C.E., F.R.San.I., etc.

LESSON IV

WATER CARRIAGE SYSTEM

(contd.)

DRAINS AND THEIR CONSTRUCTION

Variable Velocity of Flow. Fig. 18 shows how the velocity of a liquid varies throughout the cross-section of a drain, and was referred to in the last lesson.

Varieties of Pipes. The essential points in laying drains are that the pipes should form absolutely straight lines, and that the interior should form a perfectly true cylinder from end to end. Care in laying is, of course, necessary, but the foregoing conditions cannot be obtained unless "best" pipes are used. "Seconds" pipes, usually found with a black band painted round them, are comparatively cheap and are useful for some purposes, but they are not suitable for house drains.

The pipes should be best *stoneware* socketed pipes to the British standard specification, in lengths of 2 ft. The sockets should be conical with a slope of $\frac{1}{16}$ in., thus making the diameter $\frac{1}{8}$ in. greater at the top, or mouth, than at the bottom. The interior of the sockets should be grooved deep, the the spigot equal to one and a half times the depth of the socket should be similarly grooved. These grooved portions of the pipe should be unglazed in order that the jointing material may adhere. The bodies of the pipes are glazed by the fumes of volatilized common salt, and are said to be *salt glazed.* As the pipes are stacked in the kiln for glazing vertically, with the spigot of one pipe in the socket of the one below it, the fumes do not easily reach the interior of the socket and the end of the spigot, and thus the unglazed condition of those parts is obtained, except in the pipes in the top and bottom rows. These latter pipes should be sorted out and be put with the "seconds" pipes. The pipes, generally, should be thoroughly vitrified, salt glazed, straight in bore, true in cross-section, correct in thickness and other dimensions, smooth inside, and free from fire cracks and all other defects.

The thickness of the barrel and socket of the pipes should be $\frac{1}{2}$ in. for 4 in. pipes and $\frac{5}{8}$ in. for 6 in. pipes. The depth of the socket should be 2 in for 4 in. pipes and $2\frac{1}{4}$ in. for 6 in. pipes, while the maximum space at the back of the socket for the jointing material should be $\frac{3}{8}$ in. for 4 in. pipes and $\frac{7}{16}$ in. for 6 in. pipes. The permissible variation in the thickness of the pipes is $\frac{1}{16}$ in., while the diameter in any direction, and in any part of the pipe, should not

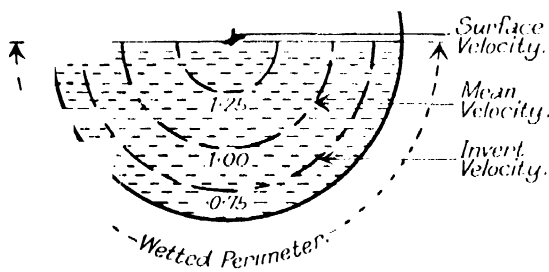


Fig. 18. Diagram showing Variable Velocity of Flowing Liquid

vary from a true circle by more than $\frac{1}{8}$ in. for 4 in. pipes, and $\frac{3}{16}$ in. for 6 in. pipes. In the straightness of the barrel there should not be a greater deviation than $\frac{3}{16}$ in. "Tested" pipes are subjected to an internal hydraulic pressure of 20 lb. per sq. in. maintained for five seconds.

The density of the material forming the pipe, and its water-tightness, are tested by an absorption test. A piece of stoneware varying from 8 in. to 20 in. super is broken from the pipe and dried at a temperature of 150° C. It is weighed and is then immersed in water, which is raised to boiling and allowed to boil for one hour. The test piece is then removed, allowed to cool, wiped, and reweighed. The increase of weight should not exceed 5 per cent. It should be noted that there are many first-class manufacturers turning out pipes better in every respect than the requirements of the foregoing specification.

Earthenware pipes are made from ordinary clays such as are used for common bricks, tiles, and field drains. They are weak and porous, and if glazed the glazing soon wears off. They are not suitable for house drain pipes. Pipes made north of Derby are made of fireclay or non-vitreous material, which is sometimes described as earthenware, but fireclay pipes would be a better definition. Midland and south country

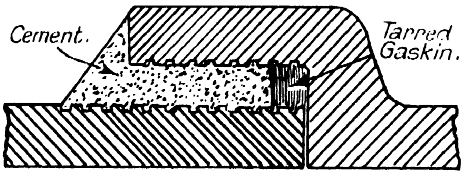


FIG. 19. ORDINARY CEMENT JOINT

pipes are made from stoneware and are stronger and more compact in texture than the northern pipes. The British Standard Committee get over the difficulty of nomenclature by specifying "ware" pipes, and any pipe complying with the specification requirements would be acceptable.

Jointing of Pipes. The joints of ordinary socketed pipes should be made by first caulking in two or three strands of tarred gaskin, and then tightly pressing in cement mortar to fill up the remainder of the socket. The outside of the joint should be finished with a neat fillet of cement mortar extending all round the pipe, as shown in Fig. 19. The cement mortar should be a strong mixture. Neat cement is undesirable, as it is liable to crack in setting and thus lead to leakage. A mixture of one or two parts of cement to one of sand will form a good sound joint.

Patent Joints. If the ground is very wet it is almost impossible to form cement joints.

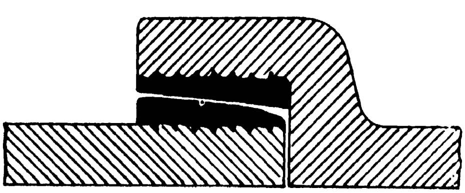


FIG. 20. ORIGINAL STANFORD JOINT

They may look all right in the upper portion, but when water reaches the underside the unset cement will disintegrate and fall off, leaving a space through which the sewage may flow out or the subsoil water may enter. In such cases *patent jointed pipes* should be used. There are many types of these joints which have been evolved from the original **Stanford joint**, made by Messrs. Doulton & Co., shown in Fig. 20. The lining of the joint is formed of black bituminous material, run into a mould to give it the required shape. These rings are covered with plastic jointing composition, which completely seals up the joint when the pipes are forced together. Another advantage of such joints is that the adjoining pipes are truly concentric, and there is no possibility of any ledge inside the pipe which would form an obstruction to the flow of the sewage.

A more reliable, and also more expensive, joint is **Hassall's double-lined joint,** shown in Fig. 21. When the pipes are put together with the bituminous rings in contact, an annular space is left around the pipe, which is filled by cement grout run through two holes in the crown of the socket. The cement forms a solid joint and it is impossible for the pipes to be separated. The inner bituminous rings in this joint are of the same wedge shape as the

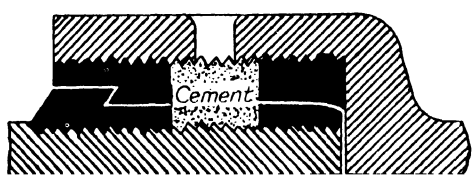


FIG. 21. HASSALL'S DOUBLE-LINED JOINT

"Stanford" joint, but instead of being close fitting, these rings, as well as the parallel outer rings at the mouth of the socket, are cast so as to allow a slight clearance space between them, which is filled up with a cushion of plastic cement to receive, embed, and render harmless any grit which may be in the way. It also fills up any flaw in the castings, besides making a temporarily water-tight joint while the Portland cement is setting. In making the joint, the plastic cement should be laid on the lining in the socket to a depth of about $\frac{1}{16}$ in., and also in the recess in the outer collar on the spigot, so that when the pipes are brought together the cement will be compressed and close the spaces, leaving only the annular ring for the cement. Before pouring the liquid cement in, a light cane should be inserted in one of the upper holes, and worked round the annular space to prove it is free from obstruction. The cement should then be poured in through one of the holes, the cane still being worked about, until the cement rises to the top of the pipe at the other hole, when the cane should be withdrawn. If a tundish or funnel is not used for pouring the cement, a small clay dam should be formed round the hole to guide the cement into it. As the grout is poured into the annular space the heavy particles of cement will sink to the bottom, causing the greater part of the water to separate and rise to the surface; so that, to ensure a solid cement joint all round the socket, a further quantity of grout should be run into the joint about a quarter of an hour after the first pouring. It is desirable to lay a good number of pipes, and then to run all the joints together afterwards so that one mixing of grout will suffice.

A pipe of another type is shown in Fig. 22. This is **Doulton's level-invert pipe** and is devised, as its name implies, to ensure the pipes being laid so that the inverts of adjoining pipes are

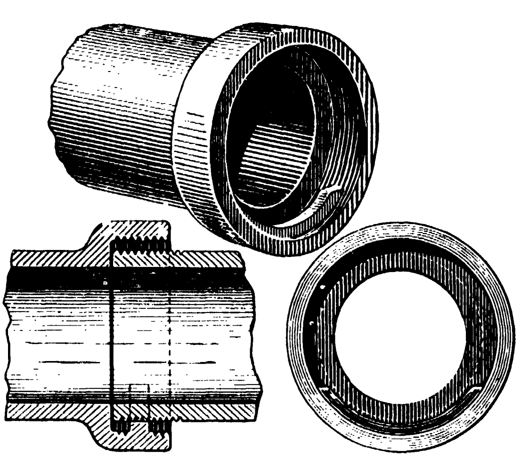
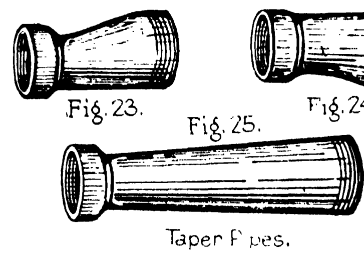


FIG. 22. DOULTON'S LEVEL-INVERT PIPE

truly in line. The spigot of one pipe, when laid on the projecting ridge in the socket of the next pipe, is in the correct position for jointing. The pipes can be laid quicker than those with ordinary sockets, but there is some difficulty in making a sound joint with gaskin all round the pipe, and if the gaskin is omitted there is a risk of cement being forced into the pipe.

When a change is made in the diameter of the drain the two sizes of pipes should be connected by a properly formed *taper pipe*. For general use the long taper (Fig. 25) is the most suitable. In using a short taper, it is preferable to lay it with the drop in the invert, as shown in Fig. 24, rather than to have the enlargement in the upper part as in Fig. 23.

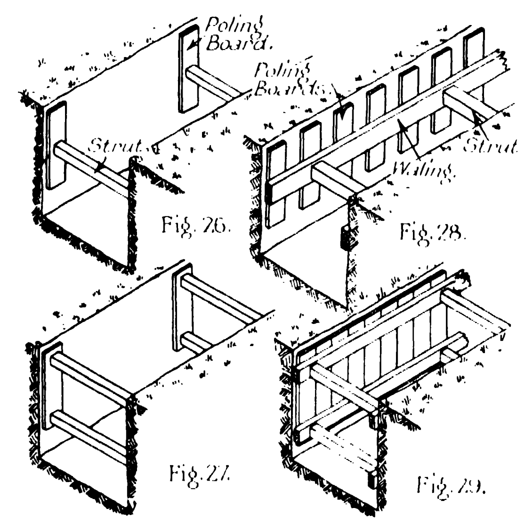
Excavation and Timbering. Trenches for the construction of drains should be made at least 2 ft. wide, to give room for a man to plant his feet on either side of the pipe without disturbing it, and to give plenty of elbow room for the pipes to be jointed. It is useless to expect good



FIGS. 23-25. TAPER PIPES

work unless the men can work under comfortable and convenient conditions. In throwing out the excavated material, the surface soil or paving should be deposited in a separate heap to the subsoil. It should be thrown so that there is a clear space along the edge of the trench for a man to walk.

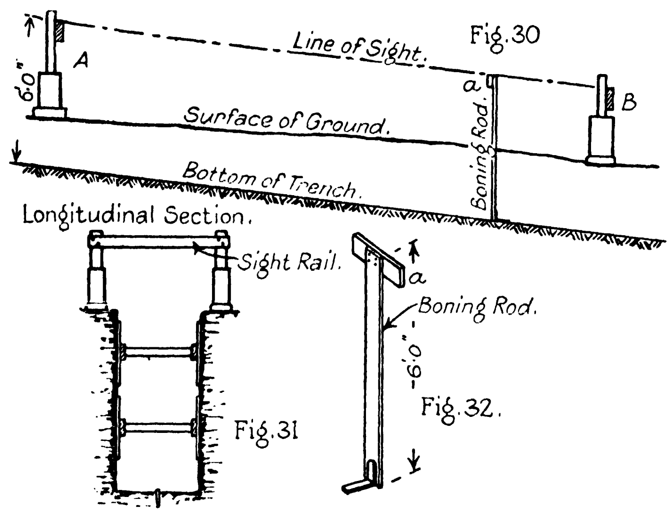
Drain trenches are usually shallow, and are open for so short a time that it is frequently unnecessary to support the sides by timbering. It is, however, bad policy to run any risk, because the contractor is responsible for any



FIGS. 26-29. TIMBERING FOR DRAIN TRENCHES

harm that may befall the workmen; and if the side of a trench collapses a great width of ground falls in, which is not only expensive to remove but the subsequent construction is made difficult. Also, if the pipes happen to have been laid, they are usually pushed out of position and the joints broken, so that a new drain has to be laid.

The style and amount of timbering required in the trench depends upon the depth of the



FIGS. 30-32. SIGHT RAILS AND BONING ROD

drain and the nature of the soil. Even if the ground is naturally firm and stable some timbering should be put in, because the weight of the excavated material heaped up at the side of the trench, and the traffic of the men up and down, tend to cause the sides to fall. The least possible amount of timbering is shown in Fig. 26. The *poling boards* of elm, $1\frac{1}{2}$ in. thick, 9 in. wide, and 2 ft. to 3 ft. long, are held in position by square or round fir struts about 4 in. thick. In deeper trenches, long poling boards, each pair held up by two struts, and possibly placed closer together, should be used, as shown in Fig. 27. When the ground is looser, the poling boards must be placed closer together, and it would then be impracticable to use struts to each pair of boards as before, because they would cause so much obstruction in the trench that it would be difficult to lay the pipes. The boards are, therefore, held back against the earth by a *waling*, that is, a fir plank 9 in. by 3 in. and possibly 12 ft. or 14 ft. long, as shown in Fig. 28. The walings are held in position by struts across the trench, generally one strut at each end, the walings on each side of the trench being laid in pairs with joints opposite to each other. In very loose ground the poling boards must form a solid shield against the side of the trench, as shown in Fig. 29, and in such case, as the timber has to withstand a great load, two rows of walings should be provided to each setting of poling boards.

Laying Drains. In setting out the work, pegs are driven over the centre line of the drain, one being at each change of direction. Then on either side of the centre pegs iron pegs are driven in at half the width of the trench away. A cord stretched from one of these iron pegs to the next one, along the line, enables the edge of the trench to be marked out ready for excavating. To enable the drain to be laid accurately to the predetermined levels, *sight rails* are fixed up, as shown in Figs. 30 and 31. Having settled upon a convenient height for the boning rod (Fig. 32), the sight rails are fixed this height above the proposed invert of the drain at the respective positions. The *invert* is the lowest point at the bottom of the interior of the pipe.

A line of sight from one rail to the next will be parallel to the drain, and at a distance above it equal to the height of the boning rod. The sight rails are secured to uprights either sunk into the ground, or set in drain pipes placed on the

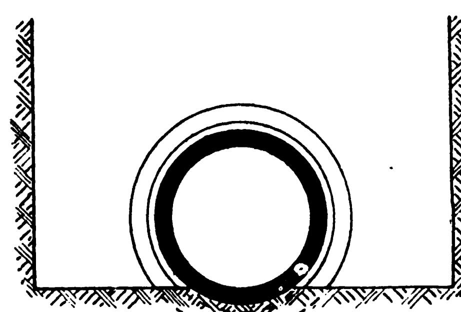


FIG. 33. BEDDING PIPES ON SOLID GROUND

ground and filled with earth. For small drainage work, where the trench is unlikely to remain open for more than a day or so, a less elaborate form of sight rail may be used, but it is essential it should be rigid.

In using the *boning rod*, one man holds it in the trench between the sight rails, while another man stands behind one of the rails and, looking over the top, signals to the other to raise or lower the rod until the cross-piece on it and the two sight rails are all in the same straight line. If no concrete is to be put under the drain, the trench should be excavated to the depth given by the boning rod, and then, just before the pipes are laid, a small quantity of earth should be removed from under the line of pipes to give a solid bed for them, as shown in Fig. 33. The bottom should be recessed for the sockets, so that the barrel only of the pipe is in contact with the ground. If the ground is excavated to the full depth at first, the trampling of the men will break up the ground, so that a firm bed is not obtainable for the pipes. In clay soils a concrete bed to the drain is essential; its thickness should be 6 in. A temporary cross-piece can be fastened to the boning rod to give the level for the bottom of the concrete.

To enable the pipes to be laid accurately, an angle bracket is fixed to the bottom of the boning rod, and this is placed in the invert at the mouth of each pipe as it is laid. If the pipe is too high some more earth should be removed from the bed, and if it is too low it should be packed with pieces of slate. Under no circumstances should a low pipe be packed with earth, as it is certain to yield when the trench is filled in and the weight comes upon it, with the result that the alignment of the pipes is destroyed. In filling the trench, small material should be put in first and packed in solidly by hand at the side of, and under the haunches of, the pipes. The filling material should then be carefully placed and gently consolidated by spading and treading, until there is a cover of about 6 in. over the pipes; the remainder of the material can then be filled in and rammed. Throwing large clods of earth and stones into the trench is very likely to break the pipe joints, by reason of the jarring which occurs.

Excavation Troubles. House drains are necessarily laid in close proximity to the buildings which they serve, and at depths near to, if not below, the level of the foundations of the walls. Foundations of heavy and important buildings are designed so as to impose a load on the ground not greater than it is assumed to be capable of bearing. The bearing capacity of a soil is estimated on the assumption that it cannot spread laterally, but will hold up to its work. When, however, a drain trench is dug adjacent to a building, particularly if it is parallel to the wall, the lateral support of the footings is taken away and precautions must be taken to prevent the settlement of the building. First of all, the building should be shored, or strutted, then the drain trench should be excavated only in short lengths, and such lengths should be firmly timbered.

If the ground is dry there is generally not much danger of damage occurring, but in wet ground arrangements will be made to pump the water out during construction, and there will be a continuous flow of water into the trench to feed the pump. If the soil is sandy, or of fine texture, as it will probably be, the flowing water will carry with it particles of soil which come from beneath the foundations, which will thereby be undermined. The length of time during which pumping takes place should be curtailed as much as possible, and in the interests of the stability of the building, the drainage work should be carried on night and day until complete.

Running Sand. Running sand is probably the greatest bugbear of the excavator. It is not a case of the sand having any specially diabolical features, but the condition is brought about by a combination of circumstances, which are in themselves separately innocuous. The digging of a trench, through sandy soil, may proceed without any difficulty until a certain depth is reached, when the sand becomes soft and unstable. This condition is always associated with the presence of water. The sand will not bear any weight, and as fast as a shovelful is removed some more sand appears and takes its place, so that although digging may proceed the trench does not get any deeper, in fact, it may get shallower.

This condition arises when the trench bottom is below the level of the subsoil water, and the water flows into the trench upwards from the bottom; or, possibly, where an impermeable stratum is penetrated and sand is discovered beneath containing water under pressure—that is, under artesian conditions. The rising water carries with it grains of sand, and keeps them in a state of flotation, the finer and lighter the sand particles, or the stronger the flow of water, the more the solidity of the sand is reduced. If the water were allowed to rise in the trench, and come to rest at its normal level, it would be found that the sand had settled down and the trench had a firm bottom beneath the water; but, of course, the pipes could not be laid in such circumstances. There is only one way of dealing effectively with running sand, and that is to lower the level of the subsoil water in the locality to below the floor of the trench.

PAINTING AND DECORATING

By Charles H. Eaton, F.I.B.D.
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LESSON IV

PIGMENTS—(*contd.*)

COLOURED PIGMENTS

The materials used by the painter and decorator for obtaining colour are many and varied; they are, as in the case of white pigments, natural and artificial. Generally, the coloured pigments produced by Nature are the most permanent as regards colour; in a few cases these are produced chemically. This, however, is a matter principally of price, it being less expensive to produce the artificial variety because of the amount of preparation frequently required to render the natural pigment fit for use. Generally, the natural pigments can be used safely when ground in either oil or water, but at all times it is most important to obtain pigments true to colour and well prepared. It is important, too, that all containers should be kept sealed, or their contents covered with oil or water, to prevent, in the latter case, hardening or drying of the pigment, due to evaporation of the water, and in the former, oxidation of the grinding oil.

Red Lead may be regarded as the most durable of the red pigments. It is an oxide of lead, and was known to the early Egyptians as *minium*; it is produced by roasting *litharge*. Its chief use is for mixing with white lead for *priming*, which is the name given to the paint generally prepared for a first application on unpainted surfaces. When made into paint it is an excellent drier, assisting in the oxidation of the oil and producing a very impervious film. It should be used thinly, and one application is usually sufficient. *If several applications were made, the film would most probably crack owing to its extreme hardness.* The pigment has excellent filling properties when applied on woodwork. Owing to its great weight the pigment settles out rapidly; priming needs constant stirring in order to keep the pigment in suspension. Manufacturers have produced a red lead paint that does not settle out quite so rapidly, which is called *non-setting red lead*. When exposed to sulphur-laden atmosphere the pigment turns brown; it is not often used for the production of colour, and it is generally sold in the form of a powder. It is very poisonous.

Ochre is known by various names, as yellow ochre, golden ochre, Italian ochre, spruce ochre, Oxford ochre; each kind is a different shade. They owe their colour to the presence of hydrated ferrous oxide. The pigment is safe in all mediums.

Sienna, another earth pigment, is obtained chiefly from Italy. The colour of the pigment is very similar to ochre, but rather more transparent. Its staining power is stronger than that of ochre, and therefore less is required. If not of good colour, but muddy, the sample should be rejected. It owes its colour to the large percentage of iron present. If the pigment is burnt its colour is changed from yellow to a low-toned red.

Venetian Red, Indian Red, and Red Oxide are earth pigments that owe their colour to the presence of iron, the colour varying according to the amount present, terra alba, or other suitable base, being mixed with it to produce standard shades and to regulate cost.

Raw Turkey and English Umber are very useful brown earth pigments. Their composition is similar to ochres, the variation in colour being due to the higher percentage of *manganese*. When burnt, the colour becomes much warmer. It is a pigment much used in graining.

Vandyke Brown is manufactured from a brown earth that is rich in organic matter. It is also largely produced artificially, and is used, ground in water, for graining. *When ground in oil, it is difficult to make vandyke brown dry satisfactorily.*

Chromes, or Chromate of Lead, is a very important pigment, *chemically produced*, ranging in colour from bright yellow to orange and red. It is a strong pigment, having most of the disadvantages of a lead pigment, i.e. it changes colour on exposure to sulphur-laden atmosphere, and is poisonous.

Zinc Chrome is a similar material to lead chrome, but it has not the disadvantages of lead. It retains its colour, and is used largely for making special pigments for *tinting distemper*, for which lead chrome is unsuitable. It is also used in conjunction with *Chinese blue* for making zinc greens. Unfortunately, the staining power of zinc chrome is not good. It is non-poisonous if of good quality.

Ultramarine Blue is a very important and useful pigment. It occurs naturally as *lapis lazuli*. Owing to the high cost of the elaborate preparation, and the great success of the chemists, practically all ultramarine is now made artificially. Individual manufacturers make a speciality of producing it. The process requires expensive plant and considerable experience; *china clay, sodium sulphate, soda carbonate, coal*, or *charcoal*, and *sulphur* are used in its production; the colour is a beautiful and permanent blue. It is prepared ground in oil, and is used extensively in distemper, being unaffected by lime. As it contains sulphur, it should not be used in conjunction with lead pigments, or lead sulphide will be formed; it has a tendency to settle out.

Lime Blue is made by reducing this pigment with *terra alba*, and is used for staining distemper.

Prussian Blue is probably the most extensively used blue pigment. It is known also as *Chinese blue* and *Berlin blue*, and is a chemical production. The latter are made, however, by another process. Prussian blue is a remarkably strong stainer, though somewhat transparent. It is fairly stable when exposed to light and air, but when in contact with white lead, chrome, or zinc oxide it is liable to lose some of its colour. It should not be used as a stainer in distemper.

Celestial Blue is Prussian blue reduced or extended.

Cobalt Blue, an *oxide of cobalt*, is a very permanent greenish blue. Being too expensive for general use, it is often reduced, or adulterated, with ultramarine blue.

Brunswick Green is the most important green pigment, and is a combination of Prussian blue and chrome, considerably reduced with barytes. The quantity of barytes is regulated by the quality of the pigment required. Brunswick green is made in a very wide range of shades, from a very bright colour to almost black. Its covering power is excellent, and its durability, when mixed with a suitable vehicle, is very good. If, however, it is of poor quality, or is not properly protected by varnish, it loses colour and becomes a dirty grey.

The trade has not much use for pure Brunswick green, hence the use of a reducing agent. It is usually sold in three shades, pale, middle, and deep.

Zinc Green is composed of zinc chrome and Chinese blue. It is frequently sold in its pure state, though there are many uses for it in the cheaper grades (i.e. reduced with barytes), as it provides a range of clean, bright shades, and is much more permanent than similar pigments made from lead chromes. Its density is not so great as Brunswick green, and the price is higher. It cannot be used with distemper.

Black Pigments. The principal black pigments are *ivory black, drop black, carbon black, lamp black*, and *vegetable black*. These pigments are produced by burning different types of matter, such as gas, ivory, and bone, vegetable matter, and animal matter. They are, almost without exception, bad drying pigments, and require special consideration in this connection.

Lake Pigments. These are a range of pigments produced by fixing on an inorganic base an organic dye. They are *crimson lake, scarlet lake, purple lake, carmine lake, madder lakes, rose pink, Dutch pink*, and *black lake*. Great progress has been made in recent years in the manufacture of these pigments, and lake colours are now produced having very good body and covering power. This is accomplished by the use of barytes and other bases.

Quality of Pigment. The inexperienced student will not find it easy to differentiate between pure pigment and that variety which has been reduced. He should not conclude too readily that a pigment which has a fair proportion of reducing material, introduced for purposes of extending some otherwise too strong or too expensive a material, will not make a good paint. There are many legitimate uses for paints that contain quite a big percentage of other matter. The chief object is to obtain a pigment that is properly prepared, and suitable for the purpose for which it is required. Points to look for are *fineness of grinding, purity of colour, strength of colour, opacity*, etc.

GAS-FITTING

By R. J. Rogers
Chief Superintendent, Fittings Department, City of Birmingham Gas Department

LESSON V

GAS AS AN ILLUMINANT

Great progress has been made in recent years in the design of gas lighting fittings, and there is now no difficulty in obtaining pendants and brackets to harmonize with any scheme of decoration or period of architecture.

The Bunsen Flame. Successful results from gas as an illuminant are most readily obtained if one possesses an elementary knowledge of the theory of the bunsen flame. Gas requires for its complete combustion an admixture of four or five times its own volume of air. With the old flat-flame burner, the gas, issuing through a narrow, spreading aperture, obtained the oxygen it needed at the point of combustion, and a large area of luminous flame was obtained. The bunsen burner, however, utilizes the injecting effect of the gas issuing from a small nipple to draw in air from ports spaced radially alongside the nipple. The mixture of gas and in-drawn air then passes through a suitable tube, or *mixing chamber*, and is ignited at a nozzle, where it burns with a non-luminous flame.

Primary and Secondary Air. When gas is distributed at ordinary pressure, the force at the nipple is insufficient to draw in all the air required for combustion, and at the same time to keep the velocity of the mixture sufficiently high to prevent the mixture *lighting back*. In practice, we find that about two volumes of air per volume of gas are drawn in around the injector. This is known as *primary* air.

The remaining two volumes of air per volume of gas required to complete the combustion are obtained from the air surrounding the actual flame. This is known as *secondary* air.

High-pressure Gas. The object of high-pressure gas, or the use of air blast, is to increase the velocity of the mixture, so that the whole of the air required for complete combustion is supplied as primary air, thus ensuring a very homogeneous mixture of air and gas and a higher flame temperature combined with a smaller flame area. It is, of course, obvious that no increase of pressure, or arrangement of air supply, can alter the total amount of heat given out when a definite quantity of gas is completely burned, but it is possible to secure a more complete mixture of gas and air, and so reduce the flame area and increase the flame temperature.

The Gas Mantle. The usefulness of this increased flame temperature is apparent when we consider the physical properties of the gas mantle.

The mantle consists of a fabric which is dipped in a solution of the salts of the rare earths, cerium and thorium. These have the property of becoming very highly incandescent when raised to a high temperature; also, having reached incandescence, a very slight further rise in temperature results in a very large increase in the illumination given out from the combustion of a stated quantity of gas. Some idea of the extent to which illumination is dependent upon temperature can be gauged by the fact that an increase of 400° C. will treble the power of the illumination given out by the mantle.

Measurement of Illumination. Some standard is required for calculating intensity of illumination. The unit usually adopted is the "foot candle." A foot candle is the intensity of illumination obtaining at a distance of 1 ft. from a "standard candle." The standard candle, as defined in the Metropolitan Gas Act of 1860, was a sperm candle, six to the pound, and which consumed 120 grains of spermaceti per hour. In practice this standard candle was not found to be very satisfactory, and Mr. A. G. Vernon Harcourt, one of the Gas Referees, devised a specially constructed lamp known as "Harcourt's Pentane Lamp," burning the volatile spirit pentane, and emitting from a definite area at the base of the flame a light equal to ten standard candles.

The intensity of illumination naturally decreases as we get farther and farther from the source of light. It is found that this decrease varies with the square of the distance from the light source.

This principle is embodied in the *Law of Inverse Squares*, which states: "The illumination falling upon two equal surfaces at different distances from a light source is inversely proportional to the square of the distances of the surfaces from the source." That is to say, if the intensity of illumination at a point 1 ft. from the light source were 1 ft. candle, then at 2 ft. away it would be $\frac{1}{4}$ ft. candle, or at 3 ft. away it would be $\frac{1}{9}$ ft. candle.

Intrinsic Brilliancy. If the intrinsic brilliancy of a light exceeds a certain figure, the human eye cannot look at it without distress or injury. Intrinsic brilliancy may be defined as the candle-power emitted per square inch of effective illuminating surface. The maximum permissible brilliancy may be taken as the brightness of the light from the open sky in June or July, and this is usually equal to about 4·35 candles per square inch. The intrinsic brilliancy of artificial light sources is often much higher than this, as the following list shows—

Intrinsic Brilliancy of Sources of Light

	Candles per Square Inch.
Ordinary Candle	2·5
Paraffin Lamp Flame	4·9
Gas Mantle, Low Pressure, Upright	23
Gas Mantle, Low Pressure, Inverted	50
Gas Mantle, High Pressure	300
Tungsten Vacuum Electric Lamp	1,000
Tungsten Gas-filled Electric Lamp	5,250

It will be seen, therefore, that most forms of artificial illuminants, and especially all types of electric lamps, in order to avoid injury to the eyesight, should be placed well out of the line of vision, or the light diffused by means of globes or shades.

Reflection. It must be remembered that adequate illumination is not entirely dependent on the quantity of light given out by the light source, but is very largely influenced by the position of that illuminant and the manner in which it is shaded, also by the colour of the wall-paper or surrounding decorations. The power of reflection of various substances varies greatly, as may be seen from the following figures—

White blotting paper reflects about 82 per cent of the light falling upon it.
Deal wood reflects about 40 per cent of the light falling upon it.
Yellow wall paper reflects about 40 per cent of the light falling upon it.
Dark brown paper reflects about 13 per cent of the light falling upon it.

The position of lighting points requires careful consideration. It should be remembered that a central pendant position gives a better distribution of light than brackets. Where brackets are used for inverted burners the positions should be at least 6 ft. from the floor. Kitchen or scullery lights should be placed so as to give a good light into the oven and on to the sink. Bedroom lights should be placed where they will not throw shadows on the blind. A pendant position over the dressing table is very useful.

Amount of Light Required for Different Purposes. What one considers a good or bad light depends very largely upon the purpose for which the room is to be used. Table II gives the average intensity of illumination in foot candles required for different purposes and situations.

TABLE II

Amounts of Light Required

Situation	Illumination Required in Foot Candles.
Art Gallery—Walls	5·0
Swimming Baths	2·0
Billiard Room (General)	1·0
Billiard Table	15·0
Church	3·0
Desk	4·0
Drawing Office	8·0
Factory (General Illumination Only, where Additional Special Lighting of Machine or Bench is Provided)	1·5
Local Bench Illumination	4·0
Complete (no Local Illumination)	4·0
Garage	2·0
Hospital—	
Corridors	0·5
Wards (with no Local Illumination Supplied)	1·5
Wards (with Local Illumination Supplied)	0·5
Operating Table	12·0
Laundry—Ironing Table	4·0
Library—Reading Room (with no Local Illumination)	4·0
Office (General)	4·0
Railway Carriage	2·0
Reading (Ordinary Print)	4·0
Reading (Fine Print)	6·0
Residences—	
Porch	0·5
Hall	1·0
Drawing Room	1·5
Sitting Room	1·5
Dining Room (General)	0·5
Dining Room (Local on Table)	4·0
Kitchen	2·0
Bedroom (General)	1·0
Dressing Table	4·0
School (Classroom)	3·0
Shop Window—Light Goods	8·0
Medium Goods	16·0
Dark Goods	20·0
Shops (Interior)—	
Light Goods	5·0
Dark Goods	10·0
Station (Railway)	2·0
Studio	4·0

Consumption of Burners. With regard to the consumption of gas for lighting purposes, there are three different sizes of inverted incandescent

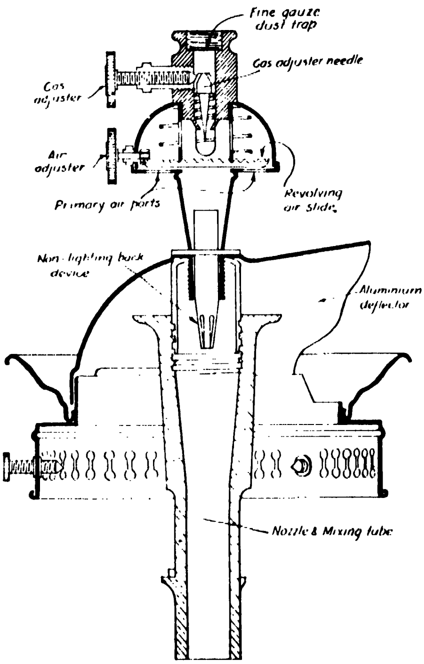


FIG. 14. SECTION THROUGH INVERTED BURNER

mantles in general use—*bijou*, *medium*, and *ordinary*. When properly adjusted, the maximum hourly consumption of these should not exceed—

Bijou . 2·5 cu. ft. per hour.
Medium . 3·5 cu. ft. per hour.
Ordinary . 4·5 cu. ft. per hour.

The Inverted Burner. Fig. 14 shows a section through an inverted burner, and is self-explanatory. The purpose of the gas and air adjusters is to ensure as perfect a mixture of gas and air as possible at the nozzle, always remembering that the larger the proportion of primary air that can be drawn in at the air ports, the hotter will be the flame and the greater the illumination from the mantle.

Multiple Superheated Burner. This desire for a higher flame temperature has led to the adoption of the *cluster burner*. In this type a metal chamber is arranged above the burner nozzles. The products of combustion passing around this chamber heat the gas and air mixture before ignition. The burner nozzles are *bijou* size, and are screwed directly into the preheater. This type of burner gives a greater candle-power per cubic foot of gas than does the single mantle burner, and the life of the smaller mantle is longer than that of the larger type.

Ventilation. One of the advantages of gas as an illuminant is the assistance it renders in the ventilation of an apartment. The products of combustion, carbon-dioxide, and water vapour being at a high temperature, rise immediately to ceiling level, and owing to their high specific heat are not readily cooled. The air fouled by the breathing of persons in the room, which would otherwise fall again to breathing level, is thus kept near the ceiling until disposed of through the usual channels of ventilation, and the air of the room is kept in gentle movement.

In order to take advantage more fully of the ventilating effect of gas burners, special lamps, Fig. 15, have been designed in which the products of combustion and the foul air from the ceiling level are removed through a duct into a

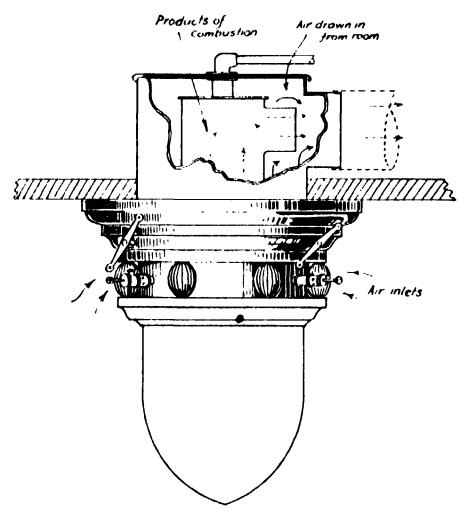


FIG. 15. VENTILATING LAMP

brick chimney, or shaft, or into the outside air. By this means the number of air changes per hour can be increased, and the ventilation of the room is effected from near the ceiling level; any possibility of the vitiated air dropping to the breathing level is thus avoided.

BUILDING CALCULATIONS

By T. Corkhill, M.I.Struct.E., M.Coll.H.

LESSON IV

REDUCTION AND COMPOUND RULES

24. **Reduction.** When we have compound quantities in multiplication, i.e. 3 ft. 4 in., £2 6s., 2 tons 5 cwt. 10 lb., etc., we often reduce the **compound** quantity to a **simple** quantity of one unit, i.e. 40 in., 46s., 5,050 lb., etc., or we reduce them to decimal or vulgar fractions, i.e. $3\frac{1}{3}$ ft. or $3\cdot\dot{3}$ ft., £$2\frac{3}{10}$ or £2·3, $45\frac{9}{100}$ cwt. or 45·09 cwt.

Note. The term "reduction" applies to conversion in either direction, from farthings to pounds or from pounds to farthings.

Example 1. Reduce 3 tons 7 cwt. $3\frac{1}{2}$ qrs. to quarters.

3 tons
20 cwt.

60 + 7 = 67 cwt.
4 qrs.

268 + $3\frac{1}{2}$ = $271\frac{1}{2}$ qrs. *Ans.*

Example 2. Reduce £3 9s. $6\frac{1}{2}$d. to pence.

£3
20

69 shillings
12

$834\frac{1}{2}$d. *Ans.*

25. **Compound Quantities.** The following two examples show how to add and subtract compound quantities.

Example 1. Add together 5 cwt. 3 qrs. 7 lb.; 13 cwt. 2 qrs. 21 lb.; 9 cwt. 19 lb.

Solution.

	5 cwt.	3 qrs.	7 lb.
	13	2	21
	9	—	19
1 ton	8 cwt.	2 qrs.	19 lb. *Ans.*

Explanation. 47 lb. = 1 qr. + 19 lb.
6 qrs. = 1 cwt. + 2 qrs.

Example 2. Subtract £123 19s. 6d. from £135 2s. 3d.

Solution.

£	s.	d.
135	2	3
123	19	6
£11	2	9 *Ans.*

Explanation. 6d. from 3d. will not go, borrow 1s., then 6d. from 15d. = 9d. (2) Borrow £1 for shillings' column.

26. To **multiply** a compound quantity by a number, factorize the number.

Example. Multiply £26 10s. 3d. by 16.

Solution. The convenient factors of 16 are 4 and 4.

£	s.	d.
26	10	3
		4
106	1	
		4
£424	4	— *Ans.*

When we are unable to factorize, we use the method given in the following example.

Example. Find the cost of 265 rods of brickwork at £43 7s. 6d. per rod.

Solution.

	£	s.	d.	
(1)	43	7	6	= cost per rod = *A*
			10	
(2)	433	15	—	= *A* × 10 rods
			10	
(3)	4,337	10	—	= *A* × 100 rods
			2	
(4)	8,675	—	—	= *A* × 200 rods
	2,602	10	—	= (2) × 6 = *A* × 60 rods
	216	17	6	= (1) × 5 = *A* × 5 rods
Total	£11,494	7	6	= *A* × 265 rods

∴ Cost = £11,494 7s. 6d. *Ans.*

27. **Division.** Factorize the divisor if possible.

Example. Fifteen joists support an evenly distributed load of 5 tons 8 cwt. 24 lb. Find the load on each joist.

Solution. The factors of 15 are 5 and 3.

	tons	cwt.	lb.
5	5	8	24
3	1	1	72
	0	7	24 = load on each joist.

When unable to factorize, proceed as follows—

EXAMPLE. A builder decides to erect 35 detached villas on 5 acres, 3 roods, 22 sq. poles of ground. How much ground should he allow for each villa ?

SOLUTION.

		a.	r.	sq. ps.		a.	r.	sq. ps.	sq. yd.
	35)	5	3	22	(	0	0	26	$27\frac{23}{35}$
Reduce 5a. to rs.		4							
		23 roods							
Reduce to sq. ps. and divide by 35		40							
		)942 sq. ps.							
		70							
		242							
		210							
Reduce to sq. yd. and divide by 35		32							
		$30\frac{1}{4}$							
		)968 sq. yds.							
		70							
		268							
		245							
		23							

∴ Ground for each villa = 26 sq. poles $27\frac{23}{35}$ yd. *Ans.*

PRACTICE

28. **Simple Practice** is an alternative method for compound multiplication. When finding the cost of 265 rods in a previous example, instead of taking sub-multiples of 265, we could have taken sub-multiples of £43 7s. 6d.

EXAMPLE. What is the cost of 756 squares of flooring at £2 4s. 6d. per square ?

SOLUTION. Note that £2 4s. 6d. can be split up into £2 + 4s. + 6d., or £2 + 2s. + 2s. 6d. ; the latter = £2 + £$\frac{1}{10}$ + £$\frac{1}{8}$.

	£	s.	d.	
	756	–	–	= cost of 756 sqs. at £1 per sq.
			2	
	1,512	–	–	= ,, ,, ,, £2 ,,
2/– = £$\frac{1}{10}$	75	12	–	= ,, ,, ,, 2/– ,,
2/6 = £$\frac{1}{8}$	94	10	–	= ,, ,, ,, 2/6 ,,
	£1,682	2	–	= cost of 756 sqs. at £2/4/6 per sq.

EXPLANATION. $\frac{1}{10}$th of £756 = £75 12s.
$\frac{1}{8}$th of £756 = £94 10s.

Compound Practice.

EXAMPLE. What is the cost of 3 tons 17 cwt. 2 qrs. of plaster at £4 12s. per ton ?

		£	s.	d.		Tons	cwt.	qrs.
		4	12	–	= cost of	1		
				3				
		13	16	–	= ,,	3	–	–
10 cwt. =	$\frac{1}{2}$ ton	2	6	–	= ,,	–	10	–
5 ,, =	$\frac{1}{2}$ of 10 cwt.	1	3	–	= ,,		5	–
$2\frac{1}{2}$,, =	$\frac{1}{2}$ of 5 cwt.		11	6	,,	–	2	2
		£17	16	6		3	17	2

EXERCISE IV

1. Add together

Tons	cwt.	qrs.	lb.
4	17	3	16
1	13	-	6
3	4	4	9
	7	6	3

2. A plot of ground has a total area of 58 acres 3 roods 21 sq. poles $14\frac{3}{4}$ sq. yards. The following portions have been sold—
100 yd. × 75 yd., 200 yd. × 175 yd., 250 yd. × 50 yd., and 250 yd. × 75 yd.
How much ground remains to be sold, after taking away 155,000 sq. yards for an open space ?

3. A plot of land is valued at £1,936 per acre. Find the value in francs per square metre, when £1 is equal in value to $25\frac{1}{4}$ francs and 1 metre = $39\frac{3}{8}$ in.

ANSWERS TO EXERCISE III

(1) $34\frac{18}{25}$ inches.

(2) $62\frac{113}{148}$ = $62\frac{3}{4}$ cwt. approx.

(3) $6\frac{17}{18}$.

SUPERINTENDENCE

By P. J. Luxton
Member of the Incorporated Clerks of Works Association

PART VI
PRELIMINARY WORK

Major Harry Barnes, V.P.R.I.B.A., in his book, *The Architect in Practice*, says that: "He (the clerk of works) should be the first man on the job and the last man off," and if his architect has adopted this practice, the clerk of works, on first taking up his appointment, will be able to spend a good part of his time in the office, and become acquainted with the details of his job. Usually, at the outset, the contractor's men are engaged in clearing the site or on demolitions, the exception being a cleared site where underpinning has to be proceeded with immediately.

Checking Drawings. The drawings supplied to him may be fully dimensioned or only partly so, but in any case the clerk of works should carefully go through them. He must see that all the minor dimensions, widths of rooms, lobbies, or corridors, and the thicknesses of the walls in any given stretch, equals the overall length of the external wall for that part, and this check must be extended to the whole of the boundaries of the building. If some dimensions only are given, the missing ones should be inserted after using the scale, and in the event of any doubtful point arising, it should be referred to the architect at the first opportunity. Inside dimensions are taken between the bare walls, exclusive of any allowance for plaster or other finishings, and bricks are called their theoretical length: a one-brick wall is taken as 9 in. thick, although the bricks may be 8¾ in. or even 9¼ in.

The sizes of doors and frames will probably be given in the specification, and the brick opening, if the frames are not built in, should be built at least ¼ in. wider than the overall of the frame. These can be dimensioned on the plan, assuming that they have not been inserted already, and the distance from the nearest room angle or opening also inserted. The dimensions of stair wells will probably be given, but the question of head-room should always be investigated, and a check made. It is advisable to take these steps at the outset, because a ⅛ in. scale is a small one, and a thick inked line may scale as much as 3 in. In some cases it is not of much consequence whether a doorway, for instance, is in any particular exact position, but it is best to assume that *every* dimension is important.

Flues, etc. Chimney breasts, fire-places, and flues should be followed up the building, and observation made as to whether the arrangement on the ground floor fits in with the position of the stack shown on the roof plan. The two are not necessarily in alignment; gathering over, either by corbelling, or arching, may have to be resorted to, but it is often possible, by adjusting flue positions at the start, to avoid "snags" higher up the building.

As windows form one of the principal features of the elevation, their location will be clearly indicated, the disposal of the openings probably being symmetrical about a centre point.

An essential precaution is to measure the boundaries of the site; if in an open field, from one or more frontages; if between existing buildings, on all boundaries. Angles must also be taken and any offsets. This is sometimes a difficulty when the site is encumbered with materials, such as brick, or stone in a stone district, which formed part of the demolished structure and have to be re-used. In such cases salient points will have to be plumbed up, and recorded in a way that will permit exact measurement above the obstructions.

Tapes. A steel tape should, of course, be used. If by any chance a linen tape only is available, it must be checked throughout its length by carefully marking with a 2 ft. rule a given length, say 20 ft., on a wall or other plane surface. Any variation will probably prove constant along the whole tape, and can be allowed for. When it is due to stretching, the measurement recorded by the tape will be less than the real length, and the variation must be added, not deducted. For instance, a 60 ft. tape, which has stretched 1 in. in 10 ft. will actually cover 60 ft. 6 in., not 59 ft. 6 in. Mistakes have been made before now—by deducting instead of adding the error of the tape—that have not been discovered until too late to be remedied.

Points of the Compass. Sometimes the position of the points of the compass in relation to the plan is an important matter, as in the case of a church, although usually these are marked on the drawings, and a difference of a few degrees is of very little consequence. A compass is not reliable because the true north is not the magnetic north; further, the needle of a compass may be deflected by adjacent iron, the influence of which may easily be overlooked. Iron on a tool, such as a pick, is a case in point.

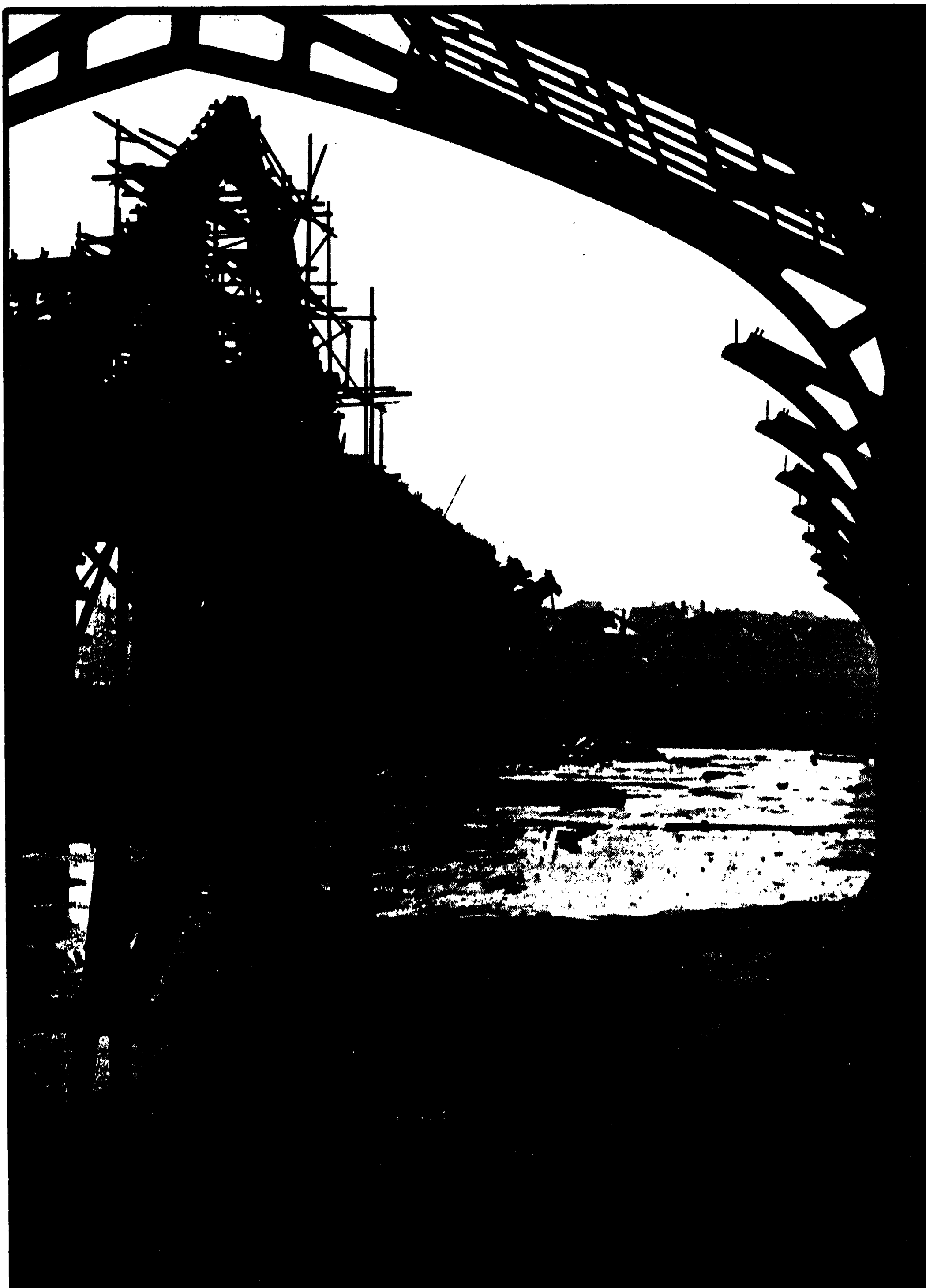
At midday—noon—the shadow cast by the sun gives a north and south direction, which is correct enough for all practical purposes. If a rod, say a straight piece of iron barrel, is placed in the ground, and the shadow about half an hour before midday is carefully marked at its extreme end, the true north can be ascertained by the following method. With the rod as a centre, strike an arc of a radius equal to the distance between the rod and the end of the shadow. Carefully observe the movement of the shadow after noon, and when it has lengthened again just sufficiently to touch the arc, make another mark. Find the centre of the distance between the two marks recorded—the end of the two shadows—and a line drawn from this to the rod gives a direction as near to true north as is likely to be required.

Memorizing Details. Such preliminary investigations as described will occupy the clerk of works' time at the commencement of the work. He will read the specification several times, index it if necessary, make notes classifying special features such as the proportions of concretes, mortars and plasters, weights of lead for soakers, aprons, valleys, flats, etc., and other things which can be conveniently tabulated. If he has the time, the clerk of works can get the main plan dimensions fixed in his memory by drawing, in pencil, to ¼ in. scale, the ground floor plan. The information required during the erection of walls, fixing steelwork, etc., can be included on this drawing, finishings being ignored. Basements would be indicated and beams over; generally, the drawing would be one that could be used by the foreman bricklayer, mason or other type of wall builder, and no one else.

To what extent this procedure can be adopted, the clerk of works must judge. He may not have time, or he may be able to visualize things so clearly, and so easily remember dimensions, etc., that expedients to assist those mental processes are not necessary. But in the case of the novitiate, for whom this advice is meant, there certainly should not be a lack of inclination. An alternative device is to trace the plan in indian ink upon tracing cloth. In marking a series of dimensions in figures for transference to a rod or wall, the best method is to record each separate width, and also to insert the running dimensions. Any local error in setting out, due, for instance, to using a thick pencil, will not recur if this is done.

System of Inspection. With regard to any particular system of inspection, time-tabling his day's activities, the clerk of works will find it difficult to make hard and fast rules. In a very general way he can be systematic, such as making a tour of the job soon after arriving in the morning, and late in the afternoon, or writing up the diary at a particular time. But as the job develops, his system will be continually upset; there will be visitors, telephone, special points to consider, and so on. Consequently, it is best to regard each day's activities as separate, and not to have any fixed system. Even if there were more than one site requiring attention, it would be wisest not to visit them at regular times. He may have to call on the architect, if the latter's office is within easy reach, at a definite time each week to report, but that is a different matter.

Relative Sizes of Jobs. It should be noted that the amount of work a clerk of works may have to do on a job does not necessarily depend on its size, nor on its cost. The plan of a steel-frame building is defined by the stanchions. When these are fixed in their correct positions and at their right levels, the rest of the structure follows in sequence. The steelwork is set out at the sub-contractor's works, and the eye can see at a glance whether the principal and subsidiary girders are of the right length. It is necessary, of course, to check sizes, see that the openings are in their right positions, that there is true bearing on the cleats and stanchion joints, holes the right size, and members level and upright, but the principal dimensions have all been fixed, and do not require further checking. There are probably few internal walls; the floors are big areas, afterwards divided by partitions. A brick building, on the other hand, may have many interior walls and piers, each with its separate foundation, and the size, angles, and levels of all require watching. Although the steel-framed building may be much the larger of the two, it will not call for the same amount of supervision.



Photograph by F. R. Yerbury

WEMBLEY EXHIBITION BUILDINGS IN CONSTRUCTION

SCHOOLS OF ARCHITECTURE

By PROFESSOR C. H. REILLY

ONE of the most interesting phenomena in England in connection with the professions, learned and artistic, during the last quarter of a century has been the rise of the great schools of architecture in the chief centres of population. The architect himself only emerged from the mass of artists, craftsmen and mere labourers to take the position of the man with the directing mind, thus giving unity and expression to the whole building, at the time of the Renaissance. From then onwards till almost the beginning of the present century, he invariably received his training in this country as an apprentice in the office or studio of an established architect. Indeed, a proportion ever growing less still do so, especially in country districts. There are those living to-day who can remember the country doctor taking pupils in the same way. Other countries had broken away from this system much earlier. France had had her schools of architecture, like the Ecole des Beaux Arts at Paris and her school at Rome, for two hundred and fifty years; and America had had her schools for the last fifty years. As the most conservative nation in the world next to the Chinese, we were content to go on with the old method right through the industrial revolution, although with that upheaval all sorts of new problems in building had had to be faced. As long as the buildings required from the designer were of the general type which had always been required, such as houses and places of worship, the national tradition in architecture, gradually evolving all the while, was equal to the occasion. All the master had to do was to initiate the pupil into the mysteries or rules of that tradition. Every building which came along had its prototype. Architecture progressed, and progressed very well, as our old towns and villages bear witness, as furniture design did by slow degrees and minute variations. Ship designing in the main progresses in this way to-day. The mystery to be imparted might be the intricacies of Gothic architecture, or the more subtle proportions of classical work, though both methods of expression never had equal weight at the same time; that is, the architect had not usually to make a choice. The whole history of the Renais-ance is the shifting of the weight from one to another.

PROFESSOR C. H. REILLY, O.B.E., M.A.CANTAB. F.R.I.B.A.

Professor of Architecture, University of Liverpool; Member of the Council of the Royal Institute of British Architects; Member of the Faculty of the British School at Rome; Joint Architect of the New Devonshire House with Mr. Thomas Hastings of New York; Author of "Some Architectural Problems of To-day," etc.

The real upheaval which upset all men's minds, and destroyed the form of tradition, was when, with the Gothic revival in the nineteenth century, the weights for a time became equal. Neither tradition was strong enough to outweigh the other, with the result that both lost their binding power. Such a moment, one would have imagined, combined with the emergence of the new problems industrialism had brought about, should have given rise to a new and modern style. This would probably have been the case had schools of architecture existed, and had architects been taught to take a wide and philosophic view of their art and its problems. The happy solutions of the aesthetic problems connected with tall buildings in

America have come about in the school of architecture era in that country.

DANGERS OF SPECIALIZATION

As it was, the new problems in England received individual solutions which belonged to no past style, Gothic or Classical, and yet had not sufficient virility and logic to make a new one. A widespread manner, worthy of the name "style," can only come about when a mode of expression is sufficiently real to become widely accepted. When each master produced his own highly individualized manner, our growing towns began to take on the restless character which we have begun to think inevitable in modern building. We made endless experiments in hybrid styles, which satisfied no one, because they stood for no national or rational need. As the complexities and diversities of our building problems increased, architects began to specialize in the problems they attacked. A man became known as an ecclesiastical architect, a domestic architect, even an asylum or baths and washhouse one. The pupil or apprentice trained in such an office, instead of learning a universal manner, or even a logical method of approach to be applied equally to all problems, learned instead a highly individualized manner, which he had only seen applied to a particular class of buildings. No wonder the debacle into which English architecture as a whole fell. No wonder it was seen at last that we must follow the lead of other countries, and establish schools which should be capable, by their broader outlook, of producing architects equal to the new conditions. Geniuses would always look after themselves, but the mass of the profession required a better education than the pupilage system could, and did, provide.

THE ARCHITECTURAL SCHOOLS

The first school of architecture in this country to provide continuous day courses was that of the University of Liverpool. Evening classes had been held at the Royal Academy, the University and King's Colleges, London, and elsewhere. Such courses, however, did not pretend to be, and could not aim at giving, a complete professional training. Even the Liverpool course in those days, thirty years ago, was only a two-year one. Since then its courses and those of all the schools of architecture recognized by the Royal Institute of British Architects for its associate membership (A.R.I.B.A.) are five-year ones, including within them a period of office work, comparable to the time when the medical student walks the hospitals. The first schools of architecture to have these longer courses recognized were that of the University of Liverpool again and the great school of the Architectural Association which had grown up in London to meet the new demands. Of the big schools to-day, with recognized five-year courses qualifying for practice, that of the Architectural Association is the only school not attached to a university or university college. Obviously, it was easier to start schools of architecture in the latter places, where there were allied schools, such as those of applied science and engineering, which could assist certain sides of the work. There is also the advantage, from an educational and practical point of view, of students for one profession being trained alongside those for other professions. The student's outlook is widened and he, or she, makes friends who may be useful in later life. On the other hand, the Architectural Association School in London, by being under the direction of an energetic group of young architects, gains, or should gain, by its closer contact with actual practice, even if current architectural fashions become too closely and quickly reflected in the student's work.

INFLUENCE OF THE R.I.B.A.

Besides the larger schools mentioned, which have each from one to two hundred students, and those at University College, London, and at Manchester, Edinburgh, and Glasgow, which have slightly less, there are a number of smaller schools of architecture at Cambridge University, Cardiff, Leeds, Sheffield, Bristol, and elsewhere, which provide three-year courses, and receive recognition for them from the R.I.B.A., as far as exemption from that body's intermediate examination. It must be understood that the R.I.B.A. all the while conducts its own system of qualifying examinations for membership, besides approving those in certain schools, and will probably do so for many years to come; indeed, until the pupilage system has, as in medicine, entirely died out. The R.I.B.A., however, has very wisely established a Board of Architectural Education to control these examinations, and to maintain standards in the various schools of architecture, and has given seats on this Board to representatives from each school it recognizes. There is, therefore, no cast-iron centralized system such as the old South Kensington one for art students, in which inspection and examination were entirely divorced from teaching. In the architectural profession, as organized by the Royal Institute, those responsible for teaching in the various schools, and who know of what students are capable, are largely responsible, too, for the demands the Institute makes. When, further, it is remembered that these teachers have all to be practising architects themselves, within the limits their teaching permits, and that on the Board of Architectural Education they sit side by side with some of the best architects in practice, it will be seen that architectural education, as far as it has been organized by the Institute has been organized on very liberal lines.

ARCHITECTURAL STUDY AND ENTHUSIASM

With regard to the student life in the schools of architecture, there is probably no better life possible for the enthusiastic young man or woman having the right abilities and tastes. After the necessary drudgery in the early years, learning building technique, his work mostly consists in designing one castle in the air after another, each more elaborate and exciting than the last. The good teacher stimulates the imagination by always setting problems which, however modern and practical, permit of fine and rather idealistic solutions. These the students tackle in groups, according to their years, and finish at set times, when their drawings are hung up and judged by a jury of the school staff, to which, possibly, an outside architect of repute has been added. Then awards are made and a criticism given before the whole school, for it is very stimulating for the younger men to see the work of the senior years. Alternately, those problems are finished as *projets* in rendered drawings, or in minutely dimensioned and detailed drawings, showing all the construction, called working drawings, which are the sort of drawings architects make, or should make, in practice for their actual buildings.

It will be readily seen how this system of competitive designing, with, however, its friendly side of the younger students drawing repeats, and helping to finish the seniors' drawings, and learning an immense deal thereby, leads to scenes of great enthusiasm. When a big design subject is being finished, the studios of the larger schools are open to all hours, in order to get the work done It can be imagined what jolly scenes these studios provide—with great drawings being coloured and finished in all directions, with juniors helping and mounting, and making meals. The difficulty in a modern school of architecture is not to make the student work hard enough, but to prevent his overworking, so exciting is the life. Of course, there are plenty of lectures to be taken on all the many aspects of building work, which afford a contrast to the work in the studios, and there is in each school, what few English architectural offices possess, a big library, where all the chief buildings of the world can be investigated. If this work is compared to the pettifogging work of a pupil in a small country office, it is obvious the pull which the school-trained student has. In his fourth year, when generally he has to do his period of office work, he is ready to command a salary. A number of fourth-year Liverpool students go each year to the offices of leading New York architects, and earn sufficient money to support themselves while over there, see something of America, and pay their passages both ways; the Labour Department at Washington having issued a waiver to the Contract Labour Law to allow them to enter the country.

COMPETITIONS

Then there are the great competitions, both for the prizes and studentships given by the R.I.B.A., and the great Rome Prize given by the Government, for which all the chief schools compete. The work for these prizes starts by the student being placed in a cubicle, curtained off, and remaining there for twelve, eighteen, or even thirty-six hours in the case of the final round of the Prix de Rome, during which time he makes a sketch of his design in answer to the programme set. This sketch he hands in, keeping a copy for himself, so that it is certain the idea it embodies is his own. He then spends perhaps a month, or two months, in developing it in a great series of drawings. Though these prizes are open to students all over the Empire, whether in schools of architecture or not, they have of late years almost invariably fallen to school students. Even the great external competitions for large buildings, which form one of the most interesting things in the architectural world, offering as they do the chance for the young man, like Sir Giles Scott with the Liverpool Cathedral, establishing himself and making his name, in increasing numbers these fall to school-trained men.

(*Continued on page 449*)

BRICKWORK

By William Blaber
Lecturer in Brickwork at the Northern Polytechnic, London

LESSON IX

FIREPLACES AND CHIMNEYS, ETC.

Arrangement of Flues, etc. Provision for open fires is usually made in most residential buildings (see Fig. 48). With the advent of central heating and patent gas fires, this provision is omitted in some cases. There is considerable divergence of opinion as to the merits and demerits of the open fire, but it is not proposed to discuss that matter here.

In making provision for open fires, an adequate supply of air for the purpose of combustion is necessary, otherwise the fire is not going to burn satisfactorily; an air inlet of some description must, therefore, be provided.

The position of the fireplace is of considerable importance. It should not be too near, or in a direct line with, a door, or the fire will smoke with the sudden opening or closing of the door. It is best built against an internal wall, as the flue temperature would be rapidly lowered by conduction if built against an external wall. In the latter case, the resultant dense column of cold air will need considerable heat to displace, with the result that some difficulty will be experienced in starting the fire, and the flue will always be sluggish.

Fireplace openings are formed by building piers, or *jambs*, projecting from the face of a wall a distance sufficient to provide a space in their width to form a conduit to carry off the waste products of combustion. These conduits are called *flues* and are usually rectangular in shape, and not less than 9 in. by 9 in. or greater than 9 in. by 14 in. in size for any ordinary type of stove or range.

At the top of the fireplace opening, projecting courses of brickwork are built, forming a funnel-shaped opening and closing in the space until the correct size of the flue is reached. The flue is then continued to a suitable point above the roof for the discharge of the smoke.

The sizes of fireplace openings are dependent to a great extent upon the size of the rooms. A large room will provide sufficient air for a fairly large opening, but a large opening in a small room is likely to create down draught.

The enclosing walls of a fireplace should not be less than 9 in. in thickness, the fireback being continued at the same thickness to a point 12 in. above the top of the opening.

Fireplace openings on the different floors are, where possible, arranged above one another, and the flues from the lower floors are formed in the jambs of the fireplaces on the floors above. All the flues converge to a central group, where they emerge from the roof. The upper part of the structure is termed the *chimney stack*; its termination should not be less than 3 ft. above the heighest point where it leaves the roof, this 3 ft. being built in cement mortar.

Where any flue or flues pass through a floor or roof space, the outside of the walls should be plastered with 1 in. of cement mortar, as a preventive measure against fire.

That the brickwork should be properly bonded, and the joints filled, is of the utmost importance, particularly the division walls between the flues, otherwise communication between the flues will result in retarding the up-draught, and also result in smoke being drawn down one of the flues into a room where there is no fire burning. Under no circumstances should any two flues communicate.

All wood and metal work should be kept clear of the flues. Model by-laws say that no timber shall be nearer than 6 in. or metal fastenings 2 in. to the interior of a flue, but for safety the latter should not be nearer than $4\frac{1}{2}$ in.

Thin division walls only $4\frac{1}{2}$ in. thick between the flues are an advantage, as the flues help to warm each other and increase the draught; but the external walls of the stack could with advantage be 9 in. thick, so that they can be satisfactorily bonded, also for protection of the flues from the cold outer air.

The maximum height of a stack is six times its least width at the last point of support. If this height is exceeded, iron bands and stay rods will have to be provided, and fixed to some part of the roof for added support.

The interiors of all flues are plastered with cement mortar, so as to reduce friction, and thus not retard the up-current carrying the smoke. This process is called *pargetting*.

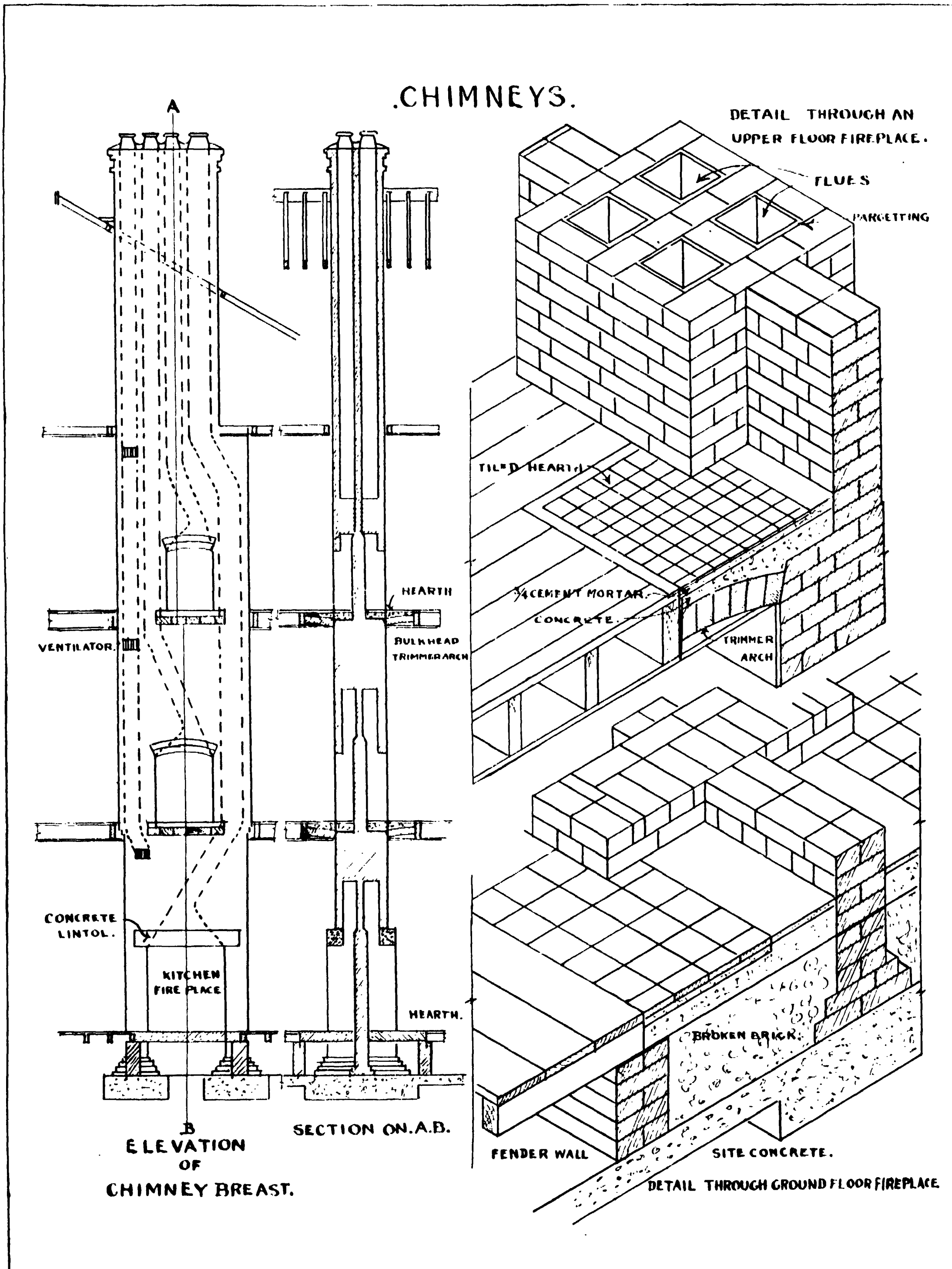


FIG. 48. CHIMNEYS

Where it is necessary to change the direction of a flue, the angle of rake of the bend should not be less than 60°. Slight bends are beneficial in preventing down draught, but do not, as many craftsmen believe, increase the draught. The fastest flue is undoubtedly the perfectly straight one, but it presents no obstacle to down draught.

Short flues are generally sluggish.

Building Flues. In building flues, care should be taken to see that mortar droppings are not allowed to accumulate at the angle of bends. A good method of preventing this is to draw a bundle of hay or straw through the flue as the work proceeds. If this is not done, holes should be left in the brickwork at places where such an accumulation is likely to occur, so that the mortar droppings can be cleared out. These holes are called *coring holes.*

Terra-cotta tubes are occasionally used on good-class work for lining the inside of flues, and make a first-class job where cost is not a primary consideration. There is, however, one objection to their use, and that is the difficulty of moving flues from their direct course. It is often necessary to move the direction of a flue with a slight twist to get it into a particular position. This is a fairly easy proposition when building in brickwork and pargetting, but would present some difficulty with tubular linings.

Foundations of Flues. The foundations of a chimney stack generally carries more weight than the wall against which it is built, and will need a greater spread of footings. It is usual to consider the projection of the jambs from the wall or the width of the jamb, whichever is the greatest, when deciding the number of courses of footings that will be required. It is better to consider the height of the stack and the width and the weight of the breast walling when deciding this matter.

Fireplaces do not always commence at ground floor level. When starting from an upper floor, projections for the jambs are built out from the main wall with oversailing courses of brickwork, each course projecting not more than 2¼ in., preferably less. Projecting stones or reinforced concrete slabs are sometimes built into the walls for this purpose. The total projection, in any case, should not exceed the thickness of the wall from which they spring, and care must be taken to see that there is sufficient weight in the structure built above them to tail them down. These projecting courses are called *corbels.*

Hearths. Level with the floor of every story a slab, or *hearth*, of non-combustible material must be fixed. This hearth slab should extend 6 in. on each side of the fireplace opening, and 18 in. beyond the face of the jambs. On the ground floor, this hearth rests on a dwarf wall 4½ in. or 9 in. thick, built up off the site concrete. These dwarf, or *fender*, walls also carry the plates supporting the floor joists. On upper floors the hearth is supported by a small brick arch, which springs from the breast walling below, and abuts the face of a timber called a *trimmer*, running parallel with the chimney breast. The arch is formed in one half-brick ring, and is contained within the depth of the floor (see Fig. 48).

In place of these trimmer arches, reinforced concrete slabs may be fixed. These slabs have two or three of their reinforcing rods sufficiently long to extend into the wall at one side, and at the other side these rods are long enough to pass through the trimmer to be screwed up with nuts.

Another method frequently used consists of tee irons built into the wall at one end, with tiles laid on the flanges to form a permanent centering for the support of the concrete to carry the hearth.

For bonding chimney stacks, which are built with half-brick walls, stretching bond is used for longitudinal strength; closers should not be used, as they are a source of weakness in half-brick walls. The dividing walls of the flues, or *withes*, as they are termed, must be bonded into the external walls every alternate course, and it will be occasionally necessary to use three-quarter bats to obtain this bond. The bats are frequently used at the quoin of the stack, but it is better to insert them away from the corner where possible, so that the corner has the benefit of a full 4½ in. lap. Chimney bond should always be carefully considered, to ensure the use of the least possible number of bats.

ARCHITECTURAL DESIGN

By T. P. Bennett, F.R.I.B.A., and T. E. Scott, A.R.I.B.A.

LESSON VI

ELEMENTS OF ARCHITECTURE

ROOFS

Besides walls, the simplest shelter will require a roof.

The object of the covering is to protect the building from the weather; its actual form is determined primarily by the method of its construction, and this in turn is closely related to the size and shape of the space covered.

Enclosed spaces, or "rooms," will be dealt with later as "Elements of Composition," but it is necessary at this stage to appreciate the interdependence between rooms and their roofs; the ceiling is usually the visible link.

Form of Roof. In all designs the form of roof must be considered from the commencement, primarily as an essential covering, but also as an element which may possibly be expressed in the external treatment. Its form may be determined by the method of spanning the enclosed spaces, or it may be desired for effect only.

In antique architecture of Greek and Roman origin, the roof rarely exists except as a protective covering, frequently used over a vault or other ceiling. In mediaeval buildings in Europe, the exigencies of the climate required a steep roof, which became a feature of importance. The Renaissance architecture of France contains many fine examples of elaborate roof treatment, and is perhaps the best period for study.

In domestic work in Europe, the relative cheapness of tiles and slates, and their efficiency as a protection against wet weather, are the factors influencing their use; consequently, the pitched roof is an essential feature in buildings of this kind. In modern practice, the roof rarely becomes an architectural feature owing to the use of concrete and asphalt, but a type of mansard is sometimes employed, both when a maximum of accommodation is required and for purposes of design.

In most districts, the provision of stories in a roof, in excess of the maximum height of building, is permitted.

The factors to be considered in roof design are the method of spanning the space, the material to be employed, and the slope at which it must be laid for efficiency in the disposal of rain-water.

Roofs may have *flat* or *curved* surfaces. The former, when suitable for the material employed, are logical, but curved surfaces are in most

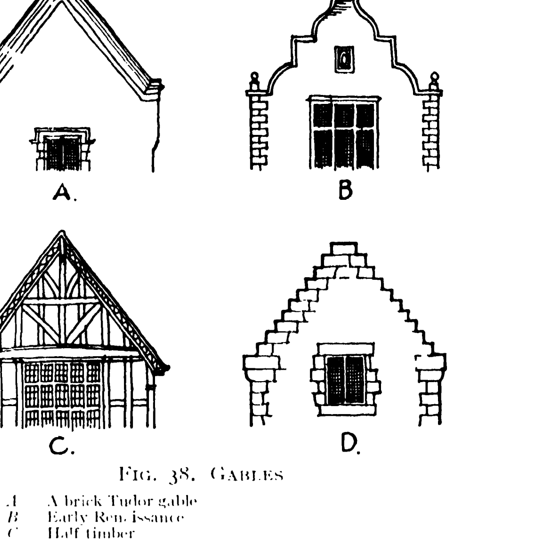


Fig. 38. Gables

A A brick Tudor gable
B Early Renaissance
C Half timber
D "Corbie," or crow steps, found in Scottish and Flemish work

cases decorative and open to criticism, because of the flatness of the upper part.

Construction. It is not possible here to enlarge upon the construction of roofs. In general, they should be simple in shape, and of consistent slope throughout a design. In a pitched roof, the ridge will normally be parallel to the longer direction of the room or building, the ends being either hipped or terminated against a wall. If the slope is not steep, there will be a pediment, characteristic of classic architecture; in other cases a gable, of which there are many interesting varieties to be found, particularly in the early Renaissance work in Western Europe (Fig. 38), will be required.

Roofs with curved surfaces are usually hipped. They were used in great variety in the later Renaissance in France, and still find favour in that country. They are usually exceedingly

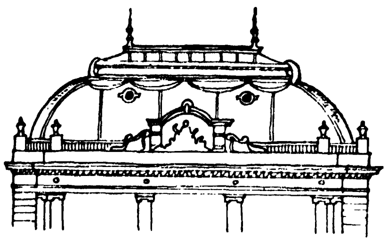


Fig. 39. Roof Over End Pavilion, Le Petit Palais, Paris

rich and ornamental, the flat part at the apex and the hips usually being covered with lead or zinc, and highly decorated with crestings and finials; see Fig. 39.

Roofs over square or polygonal plan forms are sometimes referred to as domes, but their construction does not usually justify this description. They are met with in Renaissance and modern architecture in great variety, giving interest to the silhouette of otherwise simple buildings (Fig. 40).

The roof with broken surfaces, or two slopes, is known as the *mansard*; this also is essentially

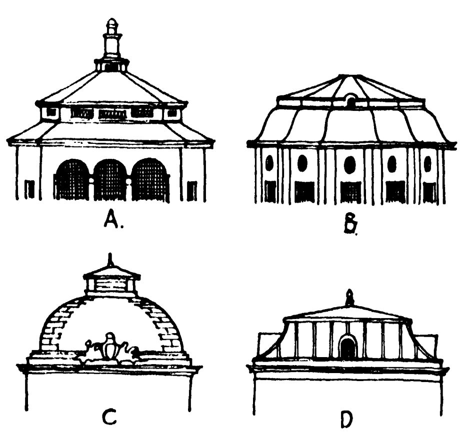


Fig. 40. Types of Roofs

A — 5th Avenue Hospital, New York
B — Theatre, Bremerhaven
C — Palais de Justice, Paris
D — Pavilion, Worthing

a French feature, and is usually richly treated in a similar manner (see Fig. 41). The mansard may consist of four distinct surfaces, or the upper part may be flat.

The Gutter is an essential accessory to the roof. In antique architecture rain-water was usually permitted to discharge from the eaves on to the pavement; in mediaeval times it was collected in a gutter and discharged through gargoyles. It is, of course, current practice to use down pipes and drains to conduct the water to a point where it cannot damage the building, or cause inconvenience. The gutter which receives the water at the base of the roof has been an important feature in historic architecture. Fig. 16 (c) illustrates a fine metal gutter formed on top of the cornice. Other methods are the projecting eaves gutter, the gutter in the slope of the roof, and the gutter behind a parapet: the first is the safest for the protection of the building, but is sometimes

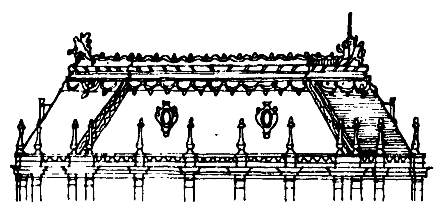


Fig. 41. Roof Over the Chapel, Versailles

dangerous and in certain cases objectionable, and is rarely used in monumental work.

Dormers. Although the steep roof had a functional origin, its subsequent use was chiefly for effect. It was natural that the space in the roof should be used, and the need for lighting produced the dormer. Dormer windows may rise from the face of the wall, as in Fig. 42 (c) and (d), but this leads to difficulties with the gutter, which ought, for economy, to be carried right round the building without frequent breaks.

The steep roofs of the French Renaissance contain many fine varieties of the dormer as a disconnected feature.

In domestic work the dormer may be a necessity, but its construction requires great attention owing to the intricate roof work involved. Careful study will show that the materials used in roofs will greatly influence the form of dormers which are formed in them. Fig. 42 (a) and (b) illustrate two simple types.

The Flèche is a feature of great beauty found in Gothic architecture. It has no material purpose, and serves chiefly as an indication of the position of a church and for architectural effect.

Chimney Stacks are of great importance to the roof. They must be anticipated in the plan, so that they project at the best position, both for the construction of the roof and for the composition of the masses.

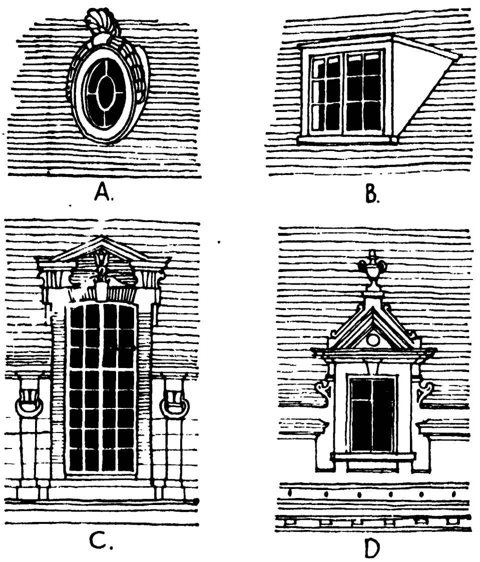


FIG. 42. DORMER WINDOWS

Structurally they are simplest at the ridge, difficult through a hip or the eaves, and impossible through a valley.

In formal design, chimneys should be arranged symmetrically if the plan permits; in picturesque schemes, a few large stacks will look better than a large number of small ones scattered about. The top of the chimney should rise above the roof, and since it is a conspicuous feature, the cap should be treated carefully. Fig. 43 illustrates a few characteristic types.

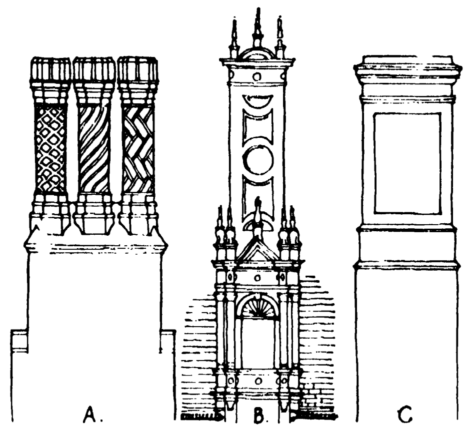


FIG. 43. CHIMNEY STACKS
A = Hampton Court
B = Chateau de Chamord
C = A modern type

SCHOOLS OF ARCHITECTURE

(*Continued from page* 443)

THE NEW AND SIMPLER ARCHITECTURE

But better than such successes, which in the course of time would naturally come to such men, is the new and simpler architecture which is everywhere appearing, from the little subsidy cottage to great office block or hotel. This can be directly traced to the training in logical design which the schools of architecture give. The only hope for a style of architecture arising which will faithfully reflect the best of our own time and do credit to our century, as the Georgian architecture did to the eighteenth century, is in an architecture which is first and foremost a logical and practical interpretation of the needs of our time. It is designing of this sort which the schools of architecture are everywhere teaching. That is why we are beginning to see better things around us, and why we may expect them to increase more rapidly every year.

FIRE-RESISTING CONSTRUCTION

By Walter R. Jaggard, F.R.I.B.A.

LESSON III

FLOORS

Classification. The floors are one of the principal features of all fire-resisting construction; many ordinary buildings, not definitely claiming to be altogether fire-resisting, are often supplied with one of the many forms of fire-resisting floors. There are very many varieties of these floors, and every year sees fresh additions to those already patented. All these floors have great merit when properly erected, and it should always be borne in mind that, whatever type is employed, the floors should be inserted with the same care with which they are prepared for tests.

It will not be possible to examine and illustrate all the many varieties of floors; selections only can be given, and the omission of any particular floor must not be taken, in any way, as a condemnation of the methods used, but is simply due to lack of space.

A waterproofed floor is very desirable, so that unnecessary damage to goods by the use of water may be avoided, as far as possible, and means for the exit of this water should also be provided.

The types of fire-resisting floors may be considered under the following classification -

1. Steel, brick, and concrete, or steel and concrete.
2. Steel, fireclay lintels, and concrete.
3. Fireclay or terra-cotta blocks and concrete.
4. Precast concrete beam units.
5. Reinforced concrete beams and slabs.
6. Solid timber.

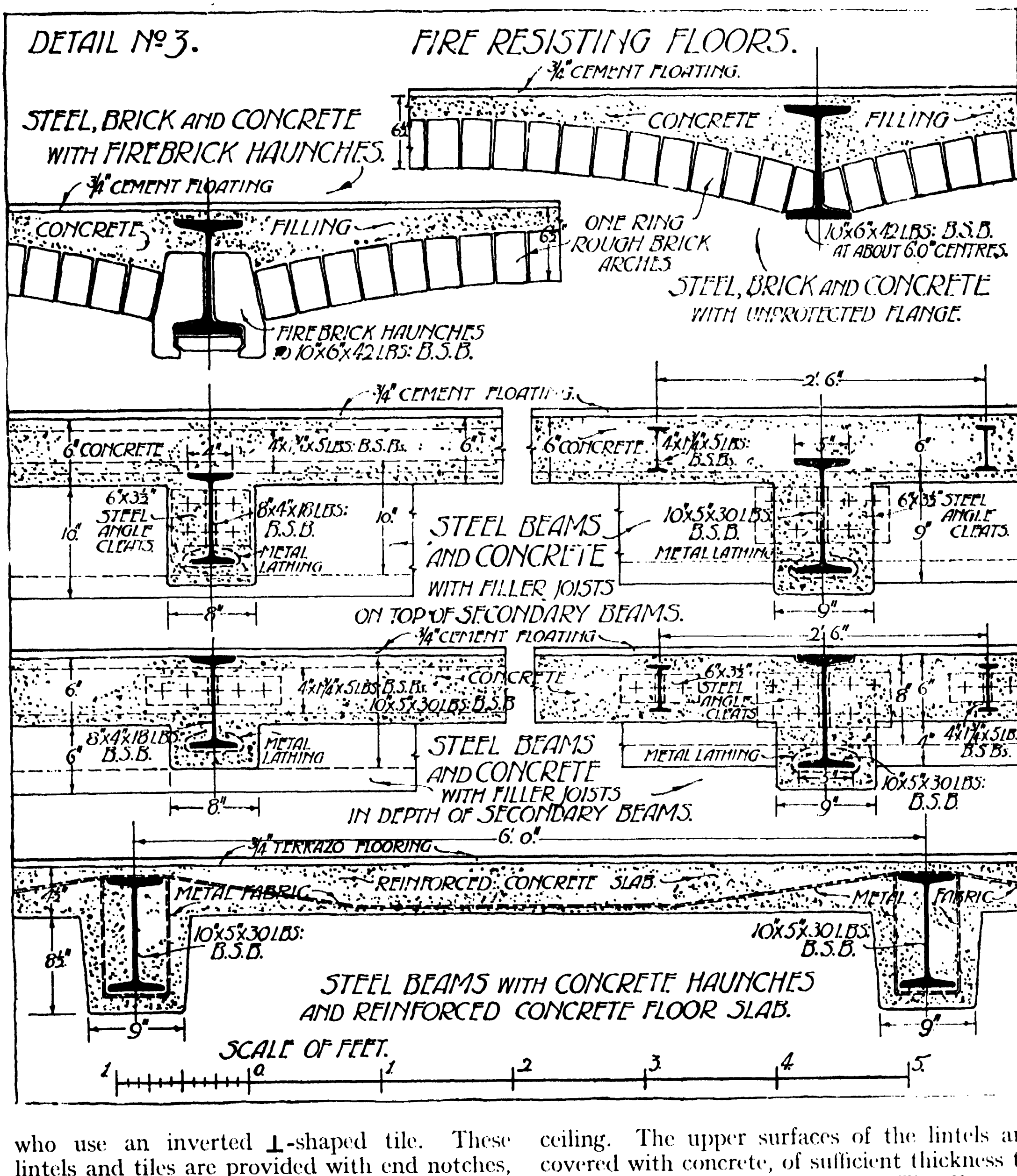
Steel, Brick, and Concrete, or Steel and Concrete. One of the oldest types of fire-resisting floors consists of iron or steel beams, spaced at about 6 ft. centres, supported by cast-iron columns, and carrying half-brick rough ring segmental arches, springing from rough cut brick skewbacks on the bottom flanges, and with the upper surfaces finished level with concrete. Iron rods about 1 in. in diameter are often threaded through the webs of the beams and embedded in the brickwork, to counteract the resultant thrust of the series of arches. The exposure of the bottom flange of the iron beam is a defect, which can, however, be remedied with specially made fireclay or terra-cotta springer blocks. The floor is heavy and is not often used, although the use of bricks for fire-resistance is good. Cross sections of the floor are shown in the upper part of Detail No. 3.

The common steel and concrete floor consists of main, secondary, and intermediate structural steel beams, which carry much smaller steel beams, known as *filler joists*, at about 2 ft. 6 in. centres; these small joists vary in size from 4 in. × $1\frac{3}{4}$ in. × 5 lb. for a span of 6 ft. to 6 in. × 3 in. × 12 lb., for a span of 10 ft., and they may rest upon the top flanges of the larger joists, or be connected with angle cleats, riveted and bolted to their webs. A wooden centering is placed or temporarily suspended below the steelwork, and concrete is then deposited thereon, entirely encasing and covering all the steelwork. It will be noted that the structural steelwork of such a floor must be calculated to carry the whole of the weight, the concrete merely acting as a solid filling material, though it also serves to maintain and enhance the stiffness and rigidity of the floor. Sections indicating these alternative methods of construction are shown in Detail No. 3, the second method being more economical in the required thickness of the floor.

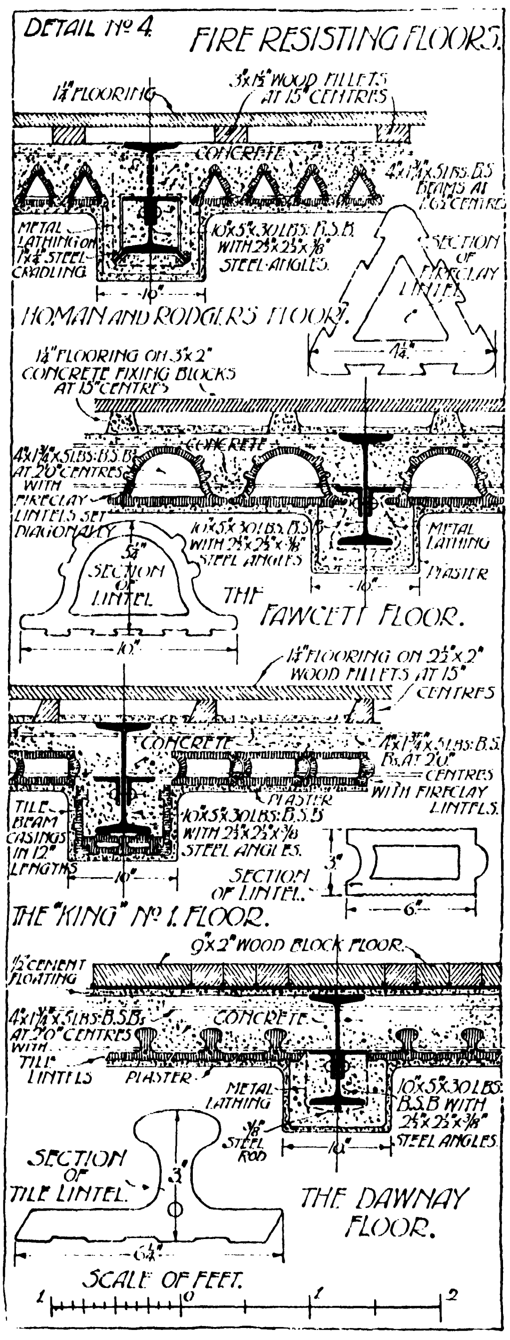
A comparatively thin concrete floor, with a thickness of about $4\frac{1}{2}$ in., can be obtained by omitting the small *filler joists* and substituting one of the many forms of metal fabrics, such as expanded metal, Hyrib, B.R.C. fabric, or Johnson's wire lattice. The structural steel beams are placed at about 6 ft. centres, and the metal fabric is then laid across from beam to beam, and finally encased in concrete placed upon temporary centering; such a floor is shown in section in the lower part of Detail No. 3.

Steel, Fireclay Lintels, and Concrete. The main object of this type of floor would appear to be the elimination of a considerable part of the heavy concrete filling together with the necessity for much of the expensive wood centering. This is accomplished in such patented floors as those of Messrs. Homan and Rodgers, The Fawcett

Construction Co., and Messrs. J. A. King & Co., who each use a special form of hollow fireclay lintel, and by Messrs. A. D. Dawnay & Sons, the small steel beams, and being mostly made with a series of rough indentations, provide a suitable key for a finishing coat of plaster for the



who use an inverted ⊥-shaped tile. These lintels and tiles are provided with end notches, which fit over and underneath the bottom flanges of the small filler joists, which are placed at centres varying from about 1 ft. 6 in. to 2 ft. or 2 ft. 3 in. They thus protect the undersides of ceiling. The upper surfaces of the lintels are covered with concrete, of sufficient thickness to entirely encase the steelwork. The Fawcett lintel is placed between the small beams at an angle, the short diameter forming a right angle with the steelwork, whilst each of the others are placed at right angles to the steelwork. Sectional illustrations of these floors are shown in Detail No. 4, which also gives some enlarged sections of the lintels and tiles.



This type of floor is very efficient, comparatively light in weight, fairly sound resisting, and being self-centering is quickly and easily erected.

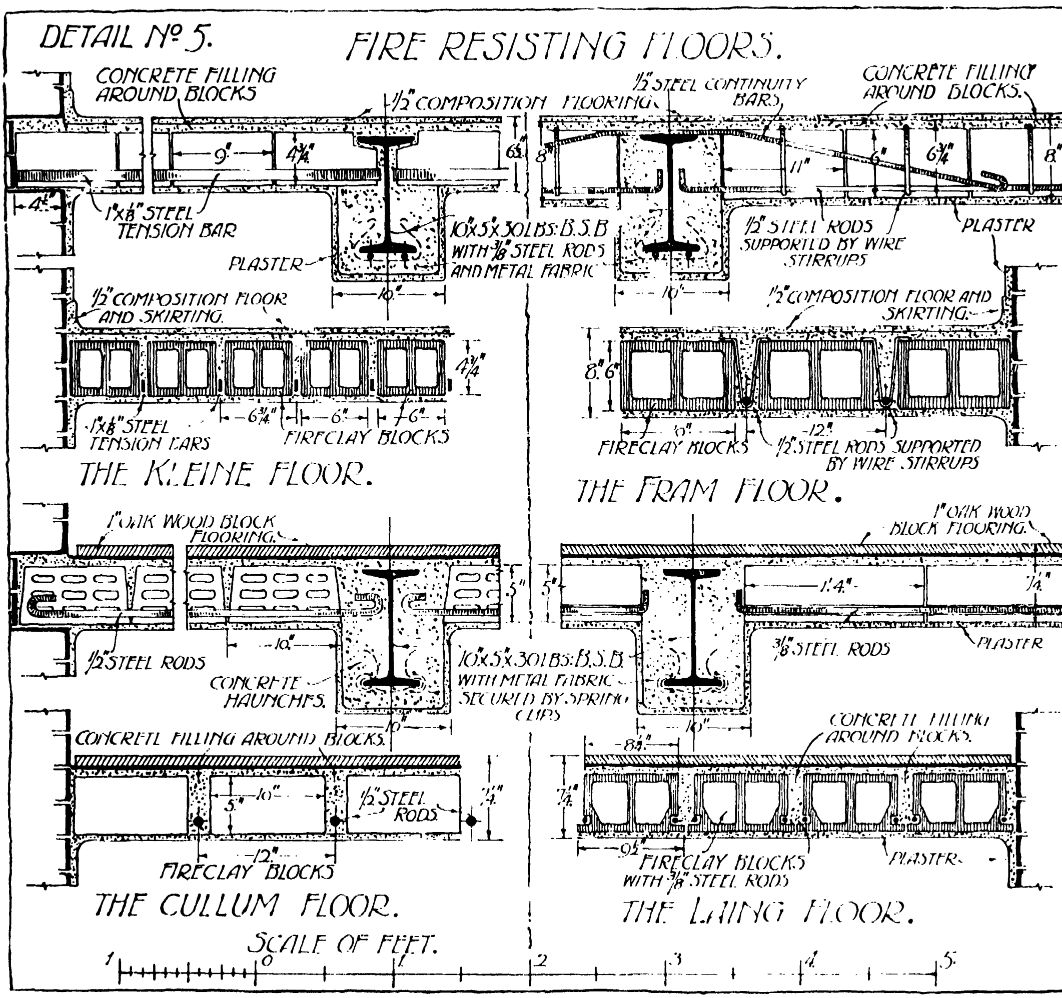
It should be noted that in the formation of the concrete haunches to the steel beams, the bottom flanges should also be encased with at least a 2 in. thickness of concrete. To ensure a good key for the concrete, the lower part of the beam should be wrapped with stout metal lathing, distanced from the soffit of the beam with metal cradling, as shown in Detail No. 4, or with one or more $\frac{3}{8}$ or $\frac{1}{2}$ in. steel rods, as in other details, to obtain a good key for the fairly moist concrete, which should be well spaded against the wood shuttering, to get true surfaces.

Fireclay or Terra-cotta Blocks and Concrete. This type of floor, of which the Kleine, Fram, Laings, Diespeker, and Cullum floors are examples, are of comparative modern introduction. They are constructed with main steel beams, which are usually spaced at about 12 ft. centres, but which may be as much as 20 ft. apart. Between these beams, and upon a temporary wood centering, are placed rows of terra-cotta or fireclay hollow blocks from 9 to 15 in. long, 6 to 10 in. wide, and 4 to 8 in. deep, with a $\frac{3}{4}$ in. space between the rows, into which are placed thin tension bands of steel, about 1 in. deep, or circular steel rods. When all the blocks and bands are assembled, fine 1 to 1 cement concrete or grout is spread over the top surface, and runs down into the spaces and around the tension bands, solidly adhering thereto, and to the roughly serrated faces of the blocks. The rows of blocks, with the steel bands, are placed across the short span of the floor, and thus, with the concrete, convert the rows of blocks into a series of beams, by reinforcing the under surface with tension rods. For ordinary use the reinforcing rods run in one direction only, have their ends bent upwards, and rest upon the walls or concrete haunches around the main beams. The rods may be kept in position by bent steel stirrups resting upon the blocks, and hooked continuity bars may be used to link adjacent panels together.

The principles underlying this type of floor construction may be stated as follows. When the panel or bay has set and the centering removed, its own weight and any super-load placed upon the floor tends to shear the units of the floor or move them vertically downwards over each other. When this is successfully resisted by the concrete, a bending action takes place, which causes compression at the upper surface and tension on the lower part of the floor. The concrete and the blocks can supply resistance to compression, but cannot supply tensile resistance, hence the steel tension bands are called upon to exert their strength, because of the intimate adhesion of the cement to the steel and terra-cotta blocks.

The method of reinforcement may be employed in both directions of the floor panel, but in that case the blocks must be solid ended to prevent the cement concrete or grout entering the open ends; the secondary reinforcing band is placed directly upon the first one, but in the opposite direction.

Some illustrations of these types of floor are shown in Detail No. 5.



SPECIFICATIONS AND QUANTITIES

By Wilfrid L. Evershed, F.S.I.
Chartered Quantity Surveyor

LESSON VI

TAKING OFF

In beginning the "taking off," start with a heading to the first sheet of dimension paper, writing across the whole column as shown in the example. See Folding Plate.

Notes only are made of preliminaries and preamble. The latter consists of the general description of the materials in the particular trade, and is written up from the specification when "billing."

On all sheets the name of the job should be written as shown.

Cube of Building. The cube of building is a note made for information purposes.

Items *ex* **Form of Contract.** The form of contract which is being used should be stated; the items from the contract, which should be mentioned, are as follows

The number of sets of drawings provided for the use of the builder.
Giving notice and paying fees to local and other authorities.
Setting out work.
Foreman.
Clerk of works' office.
Maintenance for certain period.
Damage to persons and property.
Insurance of various kinds.
Completion date.
Damages for non-completion
Form of payment, etc.
Water for works.
Particulars as to site; also trial holes.
Provision of tools, plant, etc.
Sub-letting.
Testing materials.
Watching and lighting.
Removal of rubbish.

Hoarding, Fans, etc. A linear dimension is given, stating the height, width, construction, etc.; also how long they are to be maintained, and if available for billposting.

Number gates and openings in same as extra only.

Work in Connection with Adjoining Property. This will follow the ordinary order for "taking off" as applied to the various classes of work to be executed, but is kept separate in the bill.

Pulling Down. As far as possible, work in pulling down is measured; only the small items should be numbered.

Work to Party Wall. This is kept separate and taken off complete, and follows the usual order; but special work, as temporary screens and protective work, making good to floors, decorations, etc., is measured and, if considered necessary, billed as a provisional item.

Excavation. If possible, give the nature of soil in the description, and always keep rock separate.

Surface Excavation. The excavation over the surface of the site, to remove the grass and garden mould, is taken by the superficial yard up to 12 in. deep, the depth being stated; when over 12 in. deep, it is taken by the yard cube. The surface excavation is measured over the area of the building, that is, from outside of the foundation trenches.

Surface excavation also includes work other than the removal of turf and garden mould, such as levelling the site for building, when the whole area has to be excavated to a definite level ready for building.

In measuring excavation, it is the net quantity previous to excavation that is billed, and no allowance is made for the increase in bulk.

Planking and Strutting. This should be measured; expressions such as "and including all planking and strutting required" must not be used. The area of the whole face of the excavation is measured, and it is better to treat the ordinary trench excavation in the same way, but mention should be made that both sides are measured.

It is only the face of the excavation that is measured, not struts, waling pieces, etc.; these are allowed for in the price.

Tunnels are taken as linear, giving the width and height. Where any timber has to be "left in," keep it separate.

Basement and Trench Excavations. These are cubic dimensions; the excavation is kept separate in depths of 5 ft., to allow for the extra labour in working from stages.

Basement and ordinary surface trenches are kept separate. The depth at which the basement trench excavation starts should be mentioned.

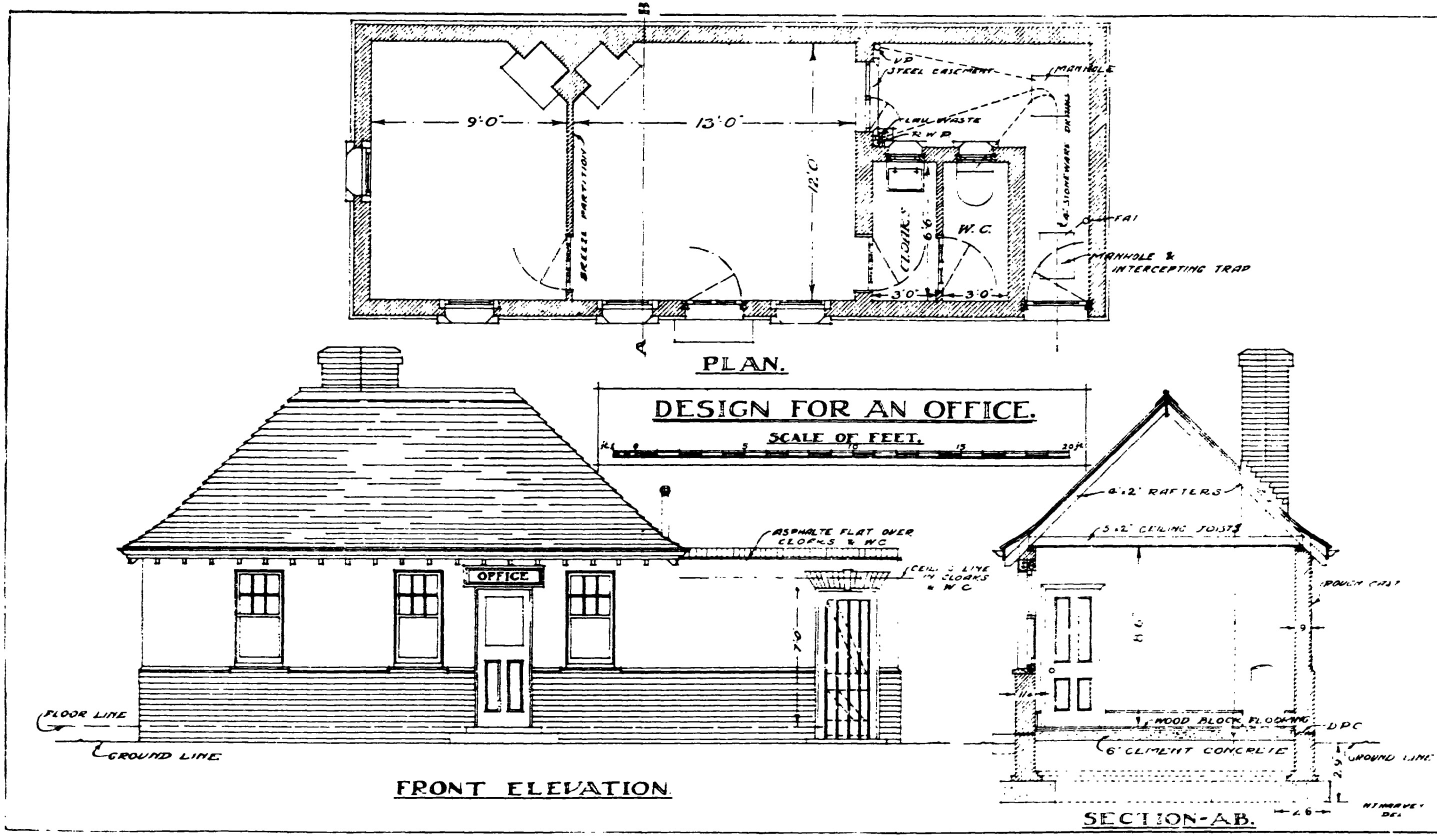


Plate I. Quantity Surveying

A certain proportion of the excavation is generally returned and filled in to the foundations, and this is kept separate.

A dimension should be taken for preparing bottom of excavation to receive concrete, or a note made that the excavation includes this; the former method is the better.

Excavation in pier holes is kept separate. In all excavation work an item is included for pumping, to keep the excavations clear of water.

Excavations to Cuttings. Excavation for cuttings, forming embankments, etc., is measured by the cubic yard, but with work of this nature state how the excavation is to be carried out.

Sides of excavations which have to be battered, and surplus soil spread and levelled over a surface, or formed into slopes, are taken by the yard superficial for the labour.

Where the work of excavation is likely to encounter trees, shrubs, roots, etc., this is mentioned, and if possible these items are numbered for removal.

Concrete in Trenches. Take this by the cubic yard, and separate the basement and surface trenches. If less than 12 in. thick, mention this in the description.

EXAMPLE I. Sheets Nos. 1, 2, and 3 show a typical example of the method of booking on dimension paper, the dimensions for excavation, concrete, and brickwork. These sheets are reproduced to a scale of half size from the actual taking off sheets, the dimensions being taken from Plate I.

It will be noticed that the dimension is written in the second column, which is called the *dimension* column; and where it is desired that the item shall stand for another similar item it is *timesed* in the first, or *timesing*, column, as will be seen on sheets Nos. 2 and 3.

The collection of different dimensions on waste, which is the fifth column, will be observed.

It will be noticed that at the bottom of the left hand principal column of sheet No. 3, an item has the word "nil" written against it; this illustrates what is done when an item is wrongly entered.

Brickwork. Brickwork in London is measured and booked as a superficial dimension of brick dimensions, and is reduced to the standard rod on the abstract. For the Midlands and the North, it is reduced to the superficial yard, one brick thick, unless over 3½ bricks thick, when it is given in cubic yards.

All brickwork is measured as being built with ordinary bricks, and work built of other bricks is deducted and added as work in these or an "extra only" item taken.

All work is kept separate after reaching 40 ft. above ground in heights of 20 ft.

Work of odd sizes or shapes is measured cube, and reduced to standard on abstract.

In measuring internal walls, the dimensions for the excavation, concrete, and footings are reduced in length by the projection of the main walls.

Work Kept Separate. The following items should be kept separate—

- One-brick walls faced both sides.
- Half-brick walls.
- Garden walls.
- Brickwork in small quantities, for making good, or for filling in old openings.
- Brickwork which is much broken up with piers; this increases the labour.

Always keep separate any work which involves additional labour, or which is of a cheaper character, such as

- Heavy work in foundations.
- Retaining walls.
- Deep foundations, or trenches.
- Brickwork in backing to masonry.
- Brickwork in cement.
- Work built off girders and in raising old walls, stating the height above datum.
- Walls built to a batter or with a battered face.
- Work circular on plan.

This last item has the radius stated as "to flat sweep" over 6 ft. radius, and "to quick sweep" under 6 ft. radius.

When an additional thickness of new work is added to an existing wall, ordinary bricks being used for bonding, a quarter brick is added to thickness; the tooth and bond is included in the superficial item for extra thickness.

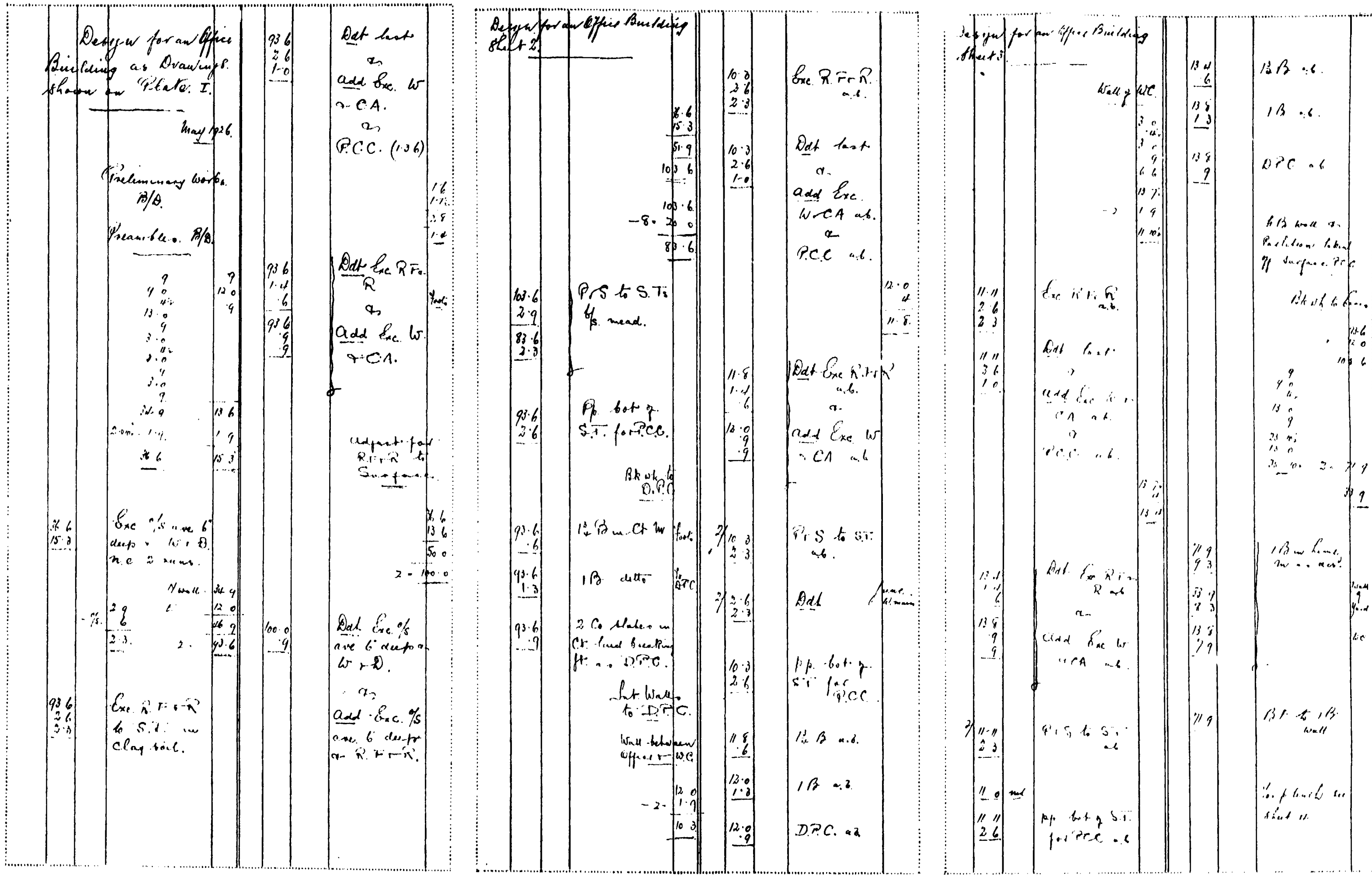
"Toothings," or "indents," left for the connection of future walls are taken as a linear dimension for the thickness of wall.

Underpinning. Work in underpinning is kept separate and described as being in "short lengths in underpinning"; the excavation and concrete are also separated.

Mention that the work is in lengths not exceeding 4 ft., and take a width of at least 3 ft. from the face of the wall for excavation. An item is also taken for wedging up to the old wall for the joint between old and new work.

Cutting off old footing courses should be taken as a linear dimension, but cutting away the old concrete can be cubed. All underpinning will require an item for the necessary shoring, needling, etc.

Hollow Walls. Take off the brickwork in the ordinary way; that is, if it is a 11 in. wall in two half-brick skins, measure a superficial dimension of one-brick wall, and the same



TAKING OFF, EXAMPLE I

dimension will answer for an item for the extra labour in building in two half-brick skins, and for the value of wall ties and building in.

Cuttings. Rough cutting is measured by the foot superficial, and is generally only measured when raking or circular. If fair cutting has also to be measured, a deduction is made from the rough cutting equal to 4½ in. wide, this being the width allowed for fair cutting. Fair cutting is a linear dimension taken to facing work.

Other rough and fair cuttings are bird's-mouth and squint quoins, both being linear dimensions.

Fair rounded, or bull-nose, angles and fair splay angles have the girth and width stated.

Damp proof Course. Measured per foot superficial, except in asphalt 9 in. and under in width, when it is taken as a linear dimension.

Vertical work is kept separate. It will require additional "excavate, return, fill, and ram" to allow for working. This is taken to make a total distance from the face of brickwork to face of excavation equal to 2 ft. Where the top edge of vertical work is turned into the brickwork, an average of 1 in. is added to the height, and an item taken for "raking out and pointing."

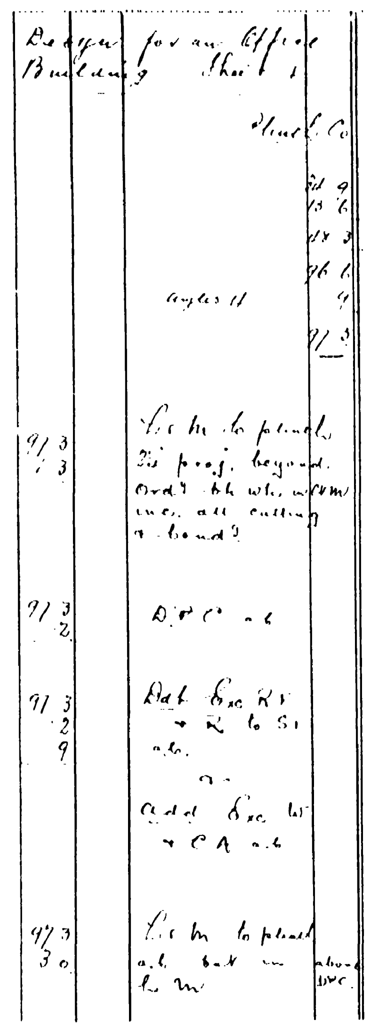
At the junction of vertical asphalt with any horizontal damp-proof course which is at lower edge of same, and which has to be joined to it, an angle fillet is measured to make a watertight joint, and unless there is an offset course of the footings to take this, a single projecting course is measured.

External angles of vertical work have a linear dimension for "labour to rounded angle."

Plinths and Similar Extra Thickness to Walls. A plinth is sometimes formed by building the lower portion of the wall of greater thickness than the general walling, but is often formed by an additional thickness of quarter-brick added at the base of a wall, and built from the topmost course of footings. This last is measured as a superficial item for additional labour and material in quarter-brick as plinth. If a multiple of half-brick, it would be added to the ordinary brickwork; but if, say, it is three-quarter-brick, then the material is added to ordinary brickwork, and a superficial item taken for the additional labour in rough cutting and waste on bricks. The splay course at the top is measured as "extra for one course purpose-made, red, sand-faced, splay bricks as plinth course including pointing"; the mitres are numbered.

EXAMPLE 2. The dimensions shown on sheet No. 4 illustrate the method of booking a plinth projection, when it is less than a half-brick in thickness, and the various adjustments in connection therewith.

Hoop-iron and Other Bonds. These are measured by the foot or yard run, and the gauge



TAKING OFF, EXAMPLE 2

and width stated; the total weight is also given.

Beam Filling. This is measured round the eaves as a linear dimension for the extra labour, stating the thickness of the walls; the brickwork is included in the height of walls.

Projections to Ordinary Walls. After measuring the ordinary wall, projections, such as piers, are measured.

STRUCTURAL ENGINEERING

By W. Arnold Green, M.A., B.Sc., A.M.Inst.C.E., M.I.Struct.E.

LESSON V

SYMBOLS

In the structural engineer's shorthand it is well, if possible, to adopt symbols (Table VI) which will be mnemonic, that is, suggest their meaning. The initial letter principle, advocated by Mr. E. F. Etchells in his *Mnemonic Notation*, is valuable, though it is not always easy to follow it when a convention has been established. E for elastic modulus is mnemonic, but the connection between $\frac{1}{n}$ and G and for what they stand is not so obvious.

The same letter may serve as a symbol for different words, but the context should make the meaning clear.

Dimensions. With the exception of velocities and accelerations, to which reference is only occasionally necessary, and of costs, which are beyond the scope of this section, all the quantities dealt with in structural engineering may be expressed in terms of weight and of length. The *dimensions* of a quantity may be defined as the power to which the weight or length must be raised to represent the quantity. Thus a volume being the cube of a length, its dimensions are 3 of length, a pressure being a weight divided by an area; its dimensions are 1 of weight and −2 of length.

The dimensions of the product of two quantities are the sum of the dimensions of the quantities. Angles and ratios are of no dimensions. In every physical equation, the dimensions of each term must be the same, and a knowledge of this fact is often helpful in avoiding mistakes.

BEAM THEORY

INTERNAL STRESSES

Section Modulus. Consider a cross-section of a structural member of any shape, such as that shown to the left of Fig. 13, called upon to resist forces due to loads acting in a direction parallel to the section, like those on the cantilever beam shown in Figs. 1 and 2. Let the sum of the loads to the right of the section be S, the *shearing force* acting on the section, and let the total leverage of the forces about the section (that is, the sum of the products of the forces and their distances from the section) be Bx, the *bending moment* at the section. Let $CDEF$ be a small longitudinal section of the unstrained beam ($CD = FE = \delta x$), where DE is the trace of the cross-section.

If the forces to the right of the section DE tend to produce clockwise rotation, the top portion will be in tension, and will be lengthened

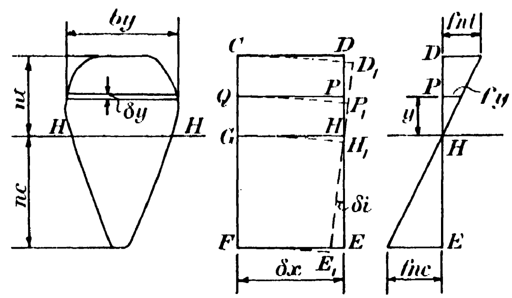


Fig. 13

from CD to CD_1, and the bottom portion will be in compression, and will be shortened from FE to FE_1. There will obviously be one portion GH, along which there will be no tension or compression, and therefore $GH = GH_1$. This is termed the *neutral axis* of the beam, HH being the neutral axis of the section.

It is usual to assume that the section DE, which is plane before bending, remains plane (D_1E_1) after bending. Thus the change in the length of QP to QP_1 will be proportional to its distance (y) from the neutral axis.

If Hooke's law holds good, an assumption (often erroneous) usually made, the stresses on the section may be represented by the horizontal lines in the triangles shown on the right of Fig. 13.

If fy is the stress on any strip of height δy and breadth by a distance y from the neutral axis, then, by similar triangles,

$$fy/y = fnt/nt \quad . \quad . \quad . \quad . \quad . \quad (19)$$

The total load on the strip $= fy \cdot by \cdot \delta y = y \cdot fnt \cdot by \cdot \delta y/nt$.

The total t nsion on the top portion

$$= \frac{fnt}{nt} \Sigma_0^e y \cdot by \cdot \delta y$$

$$= \frac{fnt}{nt} \text{(area moment of top portion of cross-section about axis } HH) \qquad (20)$$

Similarly, the total compression in the bottom portion

$$= \frac{fnc}{nc} \text{(area moment of bottom portion of cross-section about axis } HH) \qquad (21)$$

TABLE VI

SYMBOLS USED IN STRUCTURAL ENGINEERING

Symbol	Meaning	Dimensions: Weight	Dimensions: Length
A	area	0	2
a	lever arm, distance apart	0	1
a_1	lever arm ÷ depth of beam	0	0
B_a, B_x, etc.	bending moment at a point a distance a, x, etc., from a fixed point	1	1
B, b	breadths	0	1
c	compressive stress	1	−2
D, d	diameters, depths	0	1
E	modulus of elasticity	1	2
e	eccentricity, distance from centre	0	1
$e_,$	eccentricity ÷ depth	0	0
f	flexural stress, flange stress	1	−2
g	gyration radius	0	1
G	rigidity modulus	1	−2
h	height	0	1
I_x I_y, etc.	inertia moment about axis XX, YY, etc.	0	4
L, l	lengths	0	1
M	section modulus I/n	0	3
m	modular ratio, ratio of 2 elastic moduli	0	0
n	distance of edge of section from neutral axis of zero longitudinal stress	0	1
$n_,$	n/d	0	0
n	reciprocal of Poisson's ratio	0	0
P	point load	1	0
p	pressure	1	−2
R	resistance moment	1	1
r	radius	0	1
S	shear	1	0
s	shear stress	1	2
t	tensile stress	1	−2
v	volume	0	3
W	weight	1	0
w	weight per unit length	1	1
	weight per unit area	1	−2
x, y	unknown quantities; co-ordinate lengths	0	1
Δ (delta)	deflection	0	1
δx, δl, δv, etc.	(delta x, delta l, etc.) a small difference of, or a small element of, x, l, v, etc., of the same dimensions as x, l, v, etc.		
i, θ, ϕ, ψ	(iota, theta, phi, psi) angles	0	0
π (pi)	ratio of periphery (circumference) of a circle to its diameter = 3·14159, etc., = 22/7 approximately	0	0
$\Sigma_a^b y \cdot \delta x$, or $\int_a^b y dx$	the total sum of such quantities as the product of a particular value of y and a small element of x, as x varies from $x = a$ to $x = b$, the value of y in each case depending on the particular value of x. Σ (sigma) the Greek S and $\int$ the old English S are symbols of summation or integration.		

As there are no normal forces acting to the right of the section, the total tension must equal the total compression; therefore, as by similar triangles $fnt/nt = fnc/nc$, the values in the brackets of equations (20) and (21) must be equal; that is, *the neutral axis must be on the centroid of the section.*

The moment about this axis of the forces acting on the section must equal B; therefore

$$Bx = \Sigma_0^{nt} fy \cdot by \cdot \delta y \cdot y$$

$$+ \Sigma_0^{nc} fy \cdot by \cdot \delta y . y$$

$$= \frac{fnt}{nt} \Sigma_0^{nt} by \cdot y^2 \cdot \delta y$$

$$+ \frac{fnc}{nc} \Sigma_0^{nc} by \cdot y^2 \cdot \delta y$$

$$= \frac{fnt}{nt} \cdot I_{\text{HH}} = \frac{fnc}{nc} \cdot I_{\text{HH}} \qquad (22)$$

$\Sigma_0^{nt} by \cdot y^2 \cdot \delta y$ is the moment of inertia of the tension area about the axis HH. The centre of action of the tension, in equation (20), is thus the moment of inertia of the tension area about the neutral axis, divided by the area moment of the tension area about the same axis. Similarly, for the compression area. The distance between the centres of action of the tension in the top portion, and the compression in the bottom portion, is termed the *lever arm* of the section.

In equation (22) the quantity $\frac{I_{\text{HH}}}{nt}$ is termed the *section modulus* for tension, and $\frac{I_{\text{HH}}}{nc}$ the section modulus for compression. It will be noted that for sections whose neutral axis is not central, there are two values of the section modulus. For a symmetrical section of depth d, the section modulus $M = I \div \frac{1}{2}d$; and the bending moment, at any section (B), is the product of the section modulus and the stress (f) at the edge of the section, that is

$$B = f \cdot M \qquad (23)$$

If f is the maximum allowable stress, the bending moment (B) equals the *resistance moment* (R).

Deflection Due to Longitudinal Stresses. For a stress fy, the material of length δx is stretched by an amount $fy \cdot \delta x \div E$ (see equation (4)).

The angle δi between the two faces DE and D_1E_1, in Fig. 13, as measured by its tangent or circular measure, equals $fy \cdot \delta x \div E \cdot y$.

As from equation (22) $Bx/I = fnt/nt = fy/y$,

$$\delta i = Bx \cdot \delta x \div E \cdot I \qquad (24)$$

Shear Stresses in Cross-section. The total tension in the top portion PD of the section DE in Fig. 13, between two lines parallel to the neutral axis distances y and nt from it, is $\Sigma_y^{nt} by \cdot \delta y \cdot fy = Bx\Sigma_y^{nt} by \cdot \delta y \cdot \frac{y}{I}$, as from equation (22), $fy = Bx \cdot y \div I$.

If the area moment about the neutral axis of the portion of the section, a distance y and nt from it, is written AM_y^{nt}, the expression for the total tension in PD becomes

$$(AM_y^{nt}) \times Bx \div I \qquad (25)$$

If the bending moment at the section CF is $Bx + \delta Bx$, the total tension in the top portion QC of the section CF

$$= (AM_y^{nt}) \times (Bx + \delta Bx) \div I \qquad (26)$$

From equations (25) and (26) $(AM_y^{nt})(\delta Bx) \div I$ = difference in pull on sections QC and $PD = s \cdot by \cdot \delta x \qquad (27)$

as this difference must represent the total horizontal shear along the plane PQ and s, the vertical shear stress, has been shown (see Fig. 7) to have the same value as the horizontal shear stress.

If the vertical shear S is constant throughout the length δx, the bending moment at CF must be greater than the bending moment at DE by an amount $S \cdot \delta x$, that is

$$S \cdot \delta x = \delta Bx \qquad (28)$$

From equations (27) and (28), $\frac{S \cdot \delta x}{I} \cdot (AM_y^{nt}) = s \cdot by \cdot \delta x$; therefore

$$s = S \cdot (AM_y^{nt}) \div by \cdot I \qquad (29)$$

For a rectangle of area $d \times b$, $s = S\left(b \cdot \frac{d}{2} \cdot \frac{d}{4} - b \cdot y \cdot \frac{y}{2}\right) \div b \cdot \frac{b \cdot d^3}{12}$; for $y = d/2$, $s = 0$;

for $y = 0$, $s = \frac{3}{2} \cdot \frac{S}{b \cdot d}$; intermediate values being the ordinates of a parabola (see Fig. 14). As the average shear stress is $\frac{S}{b \cdot d}$, the maximum is 50 per cent more than the average.

For a rolled steel joist, if the average shear stress is calculated by dividing the total shear

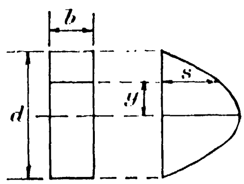


FIG. 14

by the area of the web $(d \cdot t)$, the shear at the top of the web by the fillet is approximately the same as the average, and the shear at the neutral axis is about one-eighth more than the average, the stress being distributed as indicated in Fig. 15.

Deflection Due to Shear. If the shear were constant throughout the section, the deflection DD_1 ($= \delta\Delta s$), indicated in Fig. 16, would from equation (6) equal $s \cdot \delta x \div G$.

If $s = S/A$,

$$\delta\Delta s = S \cdot \delta x / G \cdot A \quad . \quad . \quad . \quad (31)$$

For rolled steel and plate girder sections, this is approximately true if A is the web area

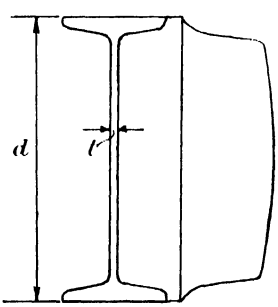


FIG. 15

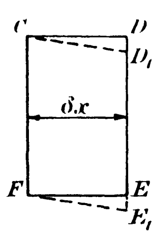


FIG. 16

$(d \cdot t)$. For a rectangular section it can be shown that equation (31) is correct, if A is five-sixths of the area of the rectangle.

Composite Beams. In members constructed of two materials, such as concrete and steel, if there is no relative movement of the two materials in contact, the unital strains must be identical; and therefore, from equation (5), the stresses must be directly proportional to their elastic moduli.

If m is the ratio of the elastic modulus of the stronger material to that of the weaker, for finding the area and other properties of the composite section, the stronger material may be considered as replaced by the weaker material of an area m times that of the stronger, acting as if condensed into the same space.

For concrete the elastic modulus is a variable and uncertain quantity, but as a basis for calculation it is usual to assume that m is constant and equals 15 for the mixture most commonly specified. As concrete is comparatively weak in tension, it is usual also to neglect its tension value entirely, and take all the tension in the steel.

If a steel joist of depth d, area As, and moment of inertia Is, is embedded in a slab of concrete of area $D \times b$ (see Fig. 17), and n is

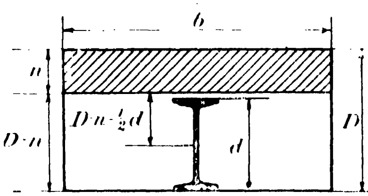


FIG. 17

the distance of the centroid of the composite section from the top compressed edge, then

$$b \cdot n \cdot n/2 = m \cdot As \cdot (D - n - d/2) \quad . \quad (32)$$

that is, $b \cdot n^2 + 2n \cdot m \cdot As = 2(D - d/2) \cdot m \cdot As$.

Dividing throughout by $b \cdot D$ and calling $\frac{m \cdot As}{b \cdot D} = r$, and $n/D = n_1$, the equation becomes

$n_1^2 + 2n_1 \cdot r = (2 - d_1) \cdot r$; therefore

$$n_1 = \sqrt{r^2 + r \cdot (2 - d_1)} - r$$

$$= \sqrt{r \cdot (r + 2 - d_1)} - r \quad . \quad . \quad (33)$$

The moment of inertia of the composite section is

$$I = \frac{bn^3}{3} + m \cdot Is + m \cdot As \cdot (D - n - \tfrac{1}{2}d)^2 \quad (34)$$

The section modulus Mc for concrete equals $I \div n$. For steel the section modulus $Mt = I \div m \cdot (D - n)$.

If the top of the joist lies above the neutral axis, the concrete area is reduced by the area displaced by the steel, but the nature of the assumptions made do not justify any further refinement in the formulae.

If the joist is replaced by rods, and if D is measured to the centre of the rods, Is and d may be neglected and equation (33) becomes

$$n_l = \sqrt{r(r+2)} - r \quad . \quad . \quad (35)$$

Then equation (34) becomes

$$I = \tfrac{1}{3}b \cdot n^3 + m \cdot As \cdot (D - n)^2 \quad . \quad (36)$$

If the allowable concrete stress is fc, and the allowable steel stress is ft (connected by the relationship $m \cdot fc/n = ft/(D - n)$), the bending moment the section can resist has two values

$$Rc = I \cdot fc/n \text{ and } Rt = I \cdot ft/m \cdot (D - n) \quad (37)$$

of which the smaller value must be taken.

From equations (36) and (37)

$$Rc = \left\{\tfrac{1}{3}b \cdot n^3 + m \cdot As \cdot (D - n)^2\right\} \cdot fc/n \quad (38)$$

As from equation (32) $\tfrac{1}{2} \cdot b \cdot n^2 = m \cdot As \cdot (D - n)$

$$Rc = \left\{\tfrac{1}{3}b \cdot n^2 + \tfrac{1}{2}b \cdot n \cdot (D - n)\right\} \cdot fc$$
$$= \tfrac{1}{2} \cdot b \cdot n \cdot fc\,(D - \tfrac{1}{3}n) \quad . \quad . \quad . \quad (39)$$

As the distance from the neutral axis of the centre of action of the compression has been shown (see equation (22), etc.) to equal (I of compression area about the neutral axis) ÷ (area moment of the same area about the same axis), this distance equals $\tfrac{1}{3}b \cdot n^3 \div \tfrac{1}{2}b \cdot n^2 = \tfrac{2}{3}n$. This is also obvious from the fact that the centroid of a triangle is two-thirds the height from the apex.

The lever arm is thus $(D - \tfrac{1}{3}n)$. As the total compression is $\tfrac{1}{2}b \cdot n \cdot fc$, Rc is obviously $\tfrac{1}{2}b \cdot n \cdot fc\,(D - \tfrac{1}{3}n)$, the result obtained another way in equation (39).

Similarly,

$$Rt = As \times ft \cdot (D - \tfrac{1}{3}n) \quad . \quad . \quad (40)$$

EXAMPLE 1. A 5 in. × 3 in. rolled steel joist (R.S.J.) has the following properties: $As = 3\cdot24$ in.^{2}, $Is = 13\cdot6$ in.^{4}

If in Fig. 17, $b = 24$ in., $D = 5$ in., and the stresses are limited to $fc = 600$ lb. per sq. in., and $ft = 18{,}000$ lb. per sq. in., find the resistance moment, assuming $m = 15$.

SOLUTION.

$r = m \cdot As \div b \cdot d = 15 \times 3\cdot24 \div 24 \times 5 = \cdot405$

$n_l = \sqrt{(\cdot405 \times 1\cdot405)} - \cdot405 = \cdot754 - \cdot405$

$n = n_l \cdot d = \cdot349 \times 5 = 1\cdot745,\ D - \tfrac{1}{2}d = 2\cdot5$

$D - \tfrac{1}{2}d - n = \cdot755,\ D - n = 3\cdot255$

$I = \tfrac{1}{3} \times 24 \times 1\cdot745^3 + 15 \times 13\cdot6 + 15 \times 3\cdot24 \times \cdot755$

$= 42\cdot5 + 204 + 27\cdot7 = 274\cdot2$

$Rc = 600 \times 274\cdot2 \div 1\cdot745 = 94{,}200$ in.-lb.

$Rt = 18{,}000 \times 274\cdot2 \div 15 \times 3\cdot258 = 101{,}000$ in.-lb.

R of joist alone

$= 18{,}000 \times 13\cdot6 \div 2\tfrac{1}{2} = 98{,}000$ in.-lb.

The R of joist alone is greater than Rc. It would not be reasonable, however, to take a lower safe load on that account.

In practice, owing to the stiffening effect of the concrete on the compression flange of the joist, it is usual to calculate the resistance moment of a floor of joists with a filling of sound concrete as if the joists acted independently of the concrete, and were stressed to, say, 9 tons per sq. in. The stress in the concrete would then be

$$\frac{9}{8} \times \frac{98{,}000}{94{,}200} \times 600 = 700 \text{ lb. per sq. in.}$$

EXAMPLE 2. What is the effect of increasing the total depth from 5 in. to 7 in.?

SOLUTION.

$r = 15 \times 3\cdot24 \div 24 \times 7 = \cdot289$

$d_l = 5 \div 7 = \cdot714$

$n_l = \sqrt{(289 \times 1\cdot575)} - \cdot289 = \cdot675 - \cdot289 = \cdot386$

$n = \cdot386 \times 7 = 2\cdot70$

$D - \tfrac{1}{2}d = 4\cdot5$

$D - \tfrac{1}{2}d - n = 1\cdot80,\ D - n = 4\cdot3$

$I = \tfrac{1}{3} \times 24 \times 2\cdot70^3 + 15 \times 13\cdot6 + 15 \times 3\cdot24 \times 1\cdot80^2$

$= 157\cdot4 + 204 + 157\cdot4 = 518\cdot8$

$Rc = 600 \times 518\cdot8 \div 2\cdot70 = 115{,}000$ in.-lb.

$Rt = 18{,}000 \times 518\cdot8 \div 15 \times 4\cdot3 = 144{,}500$ in.-lb.

This is nearly 50 per cent more than the R of joist alone, so that in this case there is justification for a rule sometimes adopted of calculating as if the joist acted alone with a stress of 10 tons per sq. in., if there is 1 in. cover of concrete to the top flange, and 11 tons per sq. in. if there is 2 in. cover, only if the concrete can safely be stressed to

$$\frac{11}{8} \times \frac{98{,}000}{115{,}000} \times 600 = 700 \text{ lb. per sq. in.}$$

EXERCISE II

1. A timber beam 12 in. deep and 4 in. wide is subjected to a bending moment of 96,000 in.-lb. What is the extreme fibre stress?
2. If the shear stress at the neutral axis of the beam at the support is 180 lb. per sq. in., what is the average shear stress across the section?
3. What is the shear stress 4 in. from the centre of the section?

JOINERY

By T. Corkhill, F.B.I.C.C., M.I.Struct.E., *Double Medallist*

LESSON X

JOINTS

This lesson will deal with the joints required for joinery. It is a difficult matter, however, to draw a hard and fast line between joinery and carpentry joints, so that examples will be given which apply equally to both. The joints which

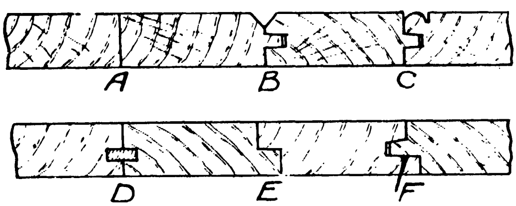


Fig. 142. Various Joints

are definitely carpentry will be dealt with in that section. Variations of the joints will be shown in the constructional details as they arise, because special circumstances often require special methods and ingenuity.

General Principles. The general principles governing the construction of joints may be summarized as follows: (*a*) Accuracy and simplicity, that is, the joint should be as simple as possible for efficiency. (*b*) The joint should be arranged and cut so as to take as little from the strength as possible. (*c*) The abutting surfaces must be sufficiently large to resist the thrust and prevent the crushing of the surface which receives the thrust. (*d*) The resisting surfaces should be at right angles to the line of pressure. (*e*) The resistance of the various members, whether wood or metal, should be equal. (*f*) The shrinkage of the timber must be taken into account.

Classification. The various types of joints may be divided into the following groups: (*a*) Lengthening of timbers, such as lapped, halving, and scarfed joints. (*b*) Jointing of timbers not in the same straight line, or angle joints. This class covers the whole range of joints: mortise and tenon, lap, housed, bridled, cogged, mitred, keyed, dovetailed, etc. (*c*) Joints for increasing the width, or surface; that is, timbers in the same plane, such as panels, counter tops, floor boards, match boarding, etc. These joints include the butt, tongued and grooved, rebated, dowelled, slot screwed, etc. (*d*) Hinging and shutting joints, as used for doors, casements, etc.

Joints for Increasing the Width. The *glued butt* joint is the most common and simplest form of joiner's joint, as shown at *A* in Fig. 142. The joint is not so easy to make as it appears to be, because the edges must be perfectly straight and square. Short lengths are usually *shot*, by means of the try plane, on the *shooting board*, but generally the edges are prepared in the vice. It is an advantage, for thin stuff, to *shoot* the two pieces together, face to face, in the vice as shown in Fig. 143. The *vee* marks on edges point to the face sides. By this method, if the edges are a little out of square, one

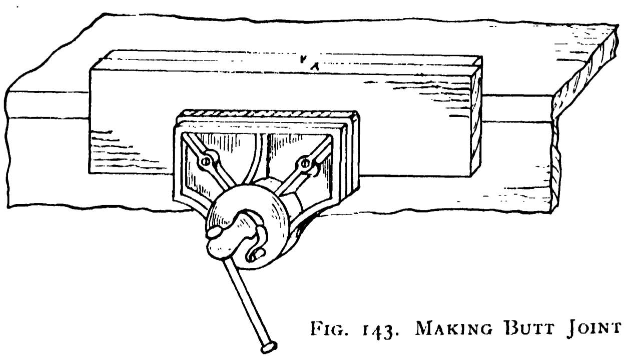


Fig. 143. Making Butt Joint

compensates for the other. The joint must fit perfectly. There must be no *riding*, or rocking, when the edges are placed together, otherwise the joint will break after it is glued up. The beginner will find that he tends to plane the edges round, but if he tries to plane the edges hollow the try plane will usually do the rest. When the joint is prepared, one piece is fixed in the vice; then both edges are glued and quickly placed together, and the top piece firmly *rubbed* to and fro until it becomes difficult to move. The rubbing is intended to squeeze out the surplus glue and air bubbles. The "joint" should be put carefully on edge until the glue is set. Sometimes dogs (Fig. 144) are driven in each end, but a well made joint with seasoned stuff does not require them.

Long boards are prepared separately, and after gluing the edges they are put in cramps or cleats, Fig. 126, and also dogged at the ends.

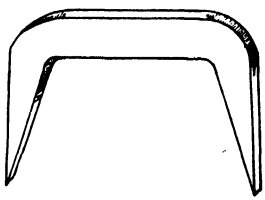


FIG. 144. DOG

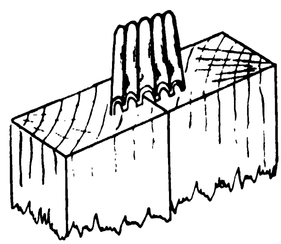


FIG. 145. JOINT FASTENER

This applies also to tongued joints as shown at *D* in Fig. 142, because they are difficult to rub together. If the boards are first cut to the required length, the *corrugated joint fasteners*, Fig. 145, are very good for driving in the ends, instead of dogs. For cheap work, especially shelving, they are often driven in the face of the joints instead of in the ends, and punched below the surface. They are so shaped that they pull the joint up.

Dowelled Joints. Sometimes the butt joint is strengthened by dowels, as shown in Fig. 146.

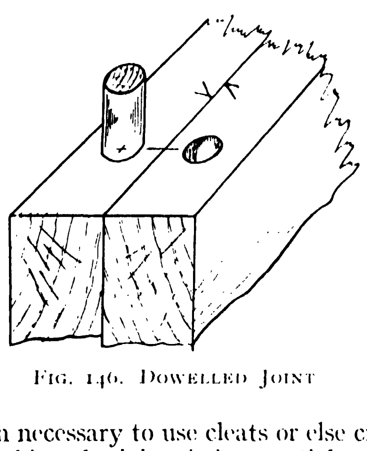


FIG. 146. DOWELLED JOINT

It is then necessary to use cleats or else cramps. When making the joint, it is essential to gauge the centre lines for boring from the face side, and to square the positions of the dowels across the two pieces together. The dowels may be bought in long lengths, in varying diameters; or they may be made by hand with the dowel plate, Fig. 147. When made by hand, it is best to cut a piece about 3 in. long, any width, but to the correct thickness, and then split the dowels into a square shaped section. These *square* dowels are then pointed and driven through the dowel plate. The holes in the plate are sometimes provided with a small triangular projection *a* which makes a small groove along the dowel to allow the air and surplus glue to be driven out, when driving in the dowel.

Secret Screw Joint. For good work the

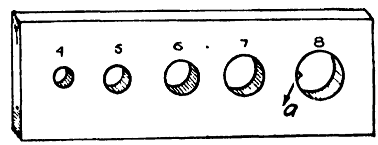


FIG. 147. DOWEL PLATE

secret screw joint is often used; see Fig. 148. This joint requires special care when making. The screws are put firmly into one board *b* and left projecting about $\frac{1}{8}$ in.; corresponding holes are bored in the other board *a*, to receive the

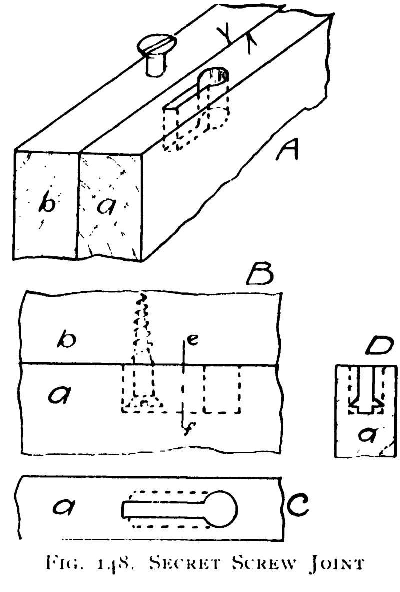


FIG. 148. SECRET SCREW JOINT

projecting heads easily. The positions for both screws and holes are squared across the edges of the two boards, and gauged from the face side as for dowelling, but an allowance is made for the slot. When the holes have been bored (slightly deeper than the projecting screw heads) slots are made the same depth as the holes and a little wider than the screw *shanks*. The slots should be about $\frac{3}{4}$ in. long. To make the method more clear, a front elevation *B*, a plan *C*, and a section *D* are shown in Fig. 148. When the joint is prepared, the piece *b* is fixed in the vice, and the piece *a* is dropped on to the screws. The two pieces are lightly cramped together and piece *a* is tapped at one end to drive the screw heads along the slots. When the joint is satisfactory, piece *a* is knocked back again and the screws are driven half a turn farther in, to pull the joint up. The joint is then ready for gluing and finally knocking together again.

Fig. 142 shows six different ways of building up the width of the boards. The *tongue and groove and vee* joint at *B* is very common for matchboarding, as is the *beaded* joint at *C*. For floor boards the *vee* is omitted in *B*. Either the *vee* or the *bead* may be on both sides of the matchboarding if required. The joint *D* is easier to make by hand than *B*, as the tongue is a loose slip. Hence both boards require ploughing only, and the joint is made true before ploughing. Sometimes hoop iron is used for the slip. Wooden tongues should be made from three-ply wood for strength. The rebated joint *E* is also a common joint. When floor boards have to be secret nailed, a joint similar to *F* is generally used; the projection under the groove is convenient for the nails as shown. For floor boards, the tongue is usually a little below the centre of the thickness to give a thicker wearing surface on the top of the floor.

It is usual to *batten* the backs when the width is built up, to keep the surface flat. Fig. 149 illustrates three different methods of preparing the battens so that the stuff is free to expand or contract, without the joints breaking or the boards splitting. The simplest method is shown at *C*; the centre screw is put in without slotting, but all the others are slotted to allow for contraction. Sometimes the fixed screw is at the edge, and then the contraction is all in one direction. A very good method for counter tops is shown at *B*. In this case the batten is usually part of the carcase framing. The *buttons b* are usually fitted so that they can be turned round without unscrewing. This allows everything to be fitted in the shop, and then taken to pieces for conveyance to the job. The *dovetailed key* shown at *A* is not so common, but makes an excellent counter cramp if fitted properly. It should be screwed at one end only, and if shrinkage takes place it should be adjusted and rescrewed.

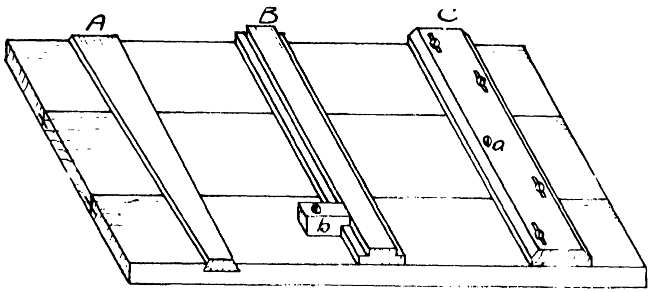


FIG. 149. COUNTER BATTENS

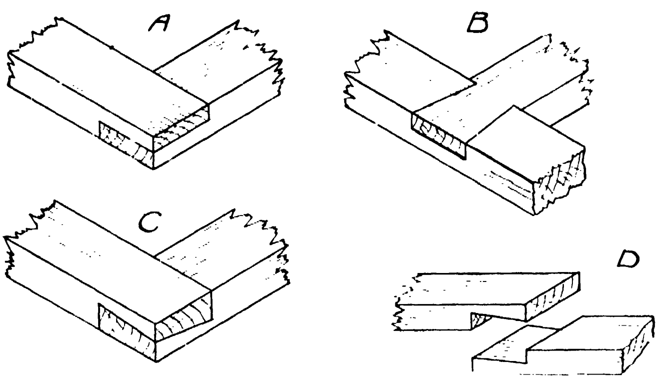


FIG. 150. HALVING JOINTS

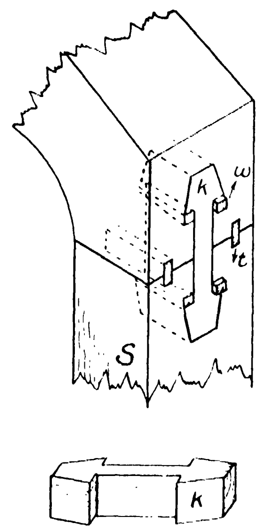


FIG. 151. HAMMER-HEADED KEY JOINT

Lengthening Joints. The carpenter is more concerned with the lengthening, or scarfing, of timbers than the joiner, hence they will be further considered in CARPENTRY. There are several joints, however, which the joiner is constantly dealing with, one of which is the *lapped halving*. Fig. 150, *A*, shows a *lapped halving* suitable for corner junctions or for lengthening timbers, and *D* shows one specially adapted for the latter purpose. The splay or bevel, is to prevent the two pieces pulling apart after they are fixed together.

A very important method of fixing two pieces together lengthways is shown in Fig. 151; this is the *hammer-headed key joint*. Sometimes the "hammer head" is made part of the stile *S*, but only when the stile is hardwood. The *key K* should be made from hardwood, so that the projecting parts will not split away when the wedges are driven home. In the sketch, two of the wedges *w* are shown projecting, and two driven home. The two tongues *t* are to keep the shoulders from twisting. This joint is generally used between the stile and the head, and at the crown, in circular headed frames.

The *handrail bolt*, shown later, is another method of lengthening timbers. The method of using the bolt will be referred to in HANDRAILING, for which purpose it is mostly used. A countercramp for pulling together the ends of the stuff, will also be illustrated in STAIRCASING because the most common application is to the strings for a circular well.

LAND SURVEYING AND LEVELLING

By PROFESSOR HENRY ADAMS, M.INST.C.E., F.R.I.B.A., F.S.I., ETC.

LESSON VI

OBSTRUCTIONS

DETOURS WITH THE CHAIN—SETTING OFF RIGHT ANGLE WITH THE CHAIN—OPTICAL SQUARE—METHOD OF TWO TRIANGLES—FINDING WIDTH OF RIVER

Gaps and Detours. A surveyor may occasionally have to make a detour round an obstruction in

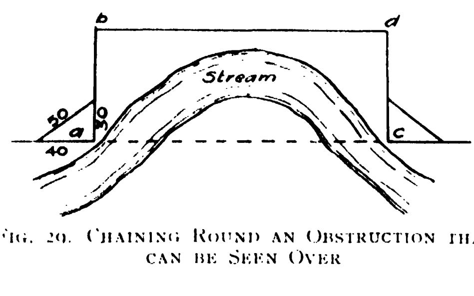


FIG. 29. CHAINING ROUND AN OBSTRUCTION THAT CAN BE SEEN OVER

running a chain line. There are two principal cases: (*a*) when the obstruction can be seen over, as the bend of a river; and (*b*) where the view is totally obstructed, as by a house or a haystack. Of course, the lines should be laid so as to clear all obstructions so far as may be possible, but there are many cases where they cannot be avoided. The base line should be the longest available on level ground, as the accuracy of the survey will greatly depend upon it; where, however, proper check lines are taken, there cannot be any great error. Fig. 29 shows how

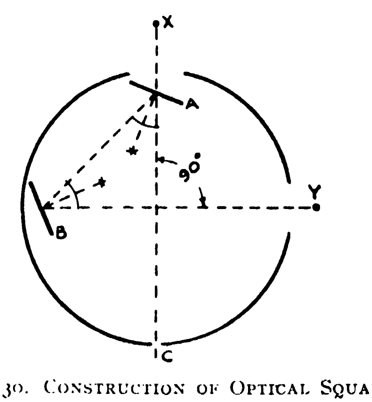


FIG. 30. CONSTRUCTION OF OPTICAL SQUARE

the chain may be carried past the bend of a stream. The chain line is sighted through from end to end, a pole being placed at *a* and another at *c*; it is required to know the distance from *a* to *c*. Set up a right angle with the chain at *a* by measuring back 40 links on the chain line; peg one end of the chain down at this point and the 80th link at *a*. Then take hold of the 50 tally and gently straighten out the two sides of the triangle. The 30 side is then to be produced to *b* far enough to clear the obstruction. A similar triangle must be set up at *c*, and *cd* made equal to *ab*, then *bd* will be the length of the omitted portion from *a* to *c*. Suppose up to *a* the chain line measured 4·32 and *bd* measures 1·12, then *c* will read 5·44. Offsets to the stream should be measured and entered on a sketch in the field book. A right angle set up by the chain cannot be depended upon nearer than one quarter link, and an optical square is sometimes used for the purpose.

Optical Square. The arrangement of the optical square is shown in Fig. 30, where *A* is a glass, silvered half-way up and left plain for the other half, set at an angle of $67\frac{1}{2}°$, with the line of sight *CX* along the chain line. *B* is a

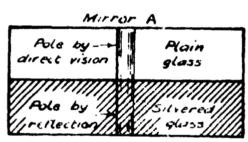


FIG. 31. REFLECTING MIRRORS IN OPTICAL SQUARE

wholly silvered glass, set at $67\frac{1}{2}°$ to the transverse line *BY*. Then, sighting along the chain line through *C*, the distant pole will be seen through the unsilvered portion of *A*, and a pole held by an assistant in the direction *BY* will first be reflected by the mirror *B*, and then into the silvered portion of *A*. When an exact right angle is obtained, the two portions of pole will appear superposed as in Fig. 31.

Obstructed Lines. Fig. 32 shows the method of procedure when the forward view of the chain line is wholly obstructed. The distance *ab* must be twice that of *bd*; perpendiculars are set up as before, and the distance *cd* checked until it is made equal to *ab*; then the two diagonals of the parallelogram must be measured and made equal. This ensures that the line *cdef* will be parallel to the chain line. From *ab* the same operation is gone through in the opposite direction, so as to make a true continuation of the chain line at *gh*; the distance *dc* will then be equal to the omitted length *bg*.

A quarry, gravel pit, or small lake may be surveyed by setting up two triangles with a common apex as in Fig. 33. From *b*, on the chain line *abc*, a line is run to clear the pit and continued so that *de* is equal to *bd*; from *c* through *d* a line is continued to *f*, making *df* = *cd*. Then, whatever the angles may be of the two triangles, the length *ef* will be equal to the omitted length *bc*.

Width of River. There are some half dozen methods of finding the width of a river by the chain, so that a line may be continued across it.

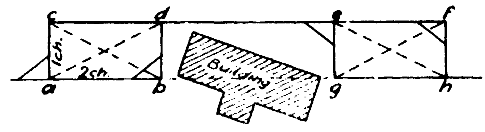


FIG. 32. CHAINING ROUND AN OBSTRUCTION WHEN IT CANNOT BE SEEN OVER

The simplest method is shown in Fig. 34, where the points *a*, *b*, and *c* are in one line. A right angle being set up at *b*, any distance *bd* is marked off and continued to *e*, so that *dc* = *bd*. Another right angle is set out at *e* and continued to any point *f*; then, with poles at *c*, *d*, *e*, and *f*, the surveyor walks backwards, keeping *dc* and *fe* in view until they all coincide at point *g*. The distance *ge* being measured, will give the required distance *bc*. Some of the textbooks say look out for a white stone, tree trunk, or something else to sight to on the far bank of the river, but there may be difficulty in seeing it from *g*; and apart from this, if *abc* represent a chain line, it

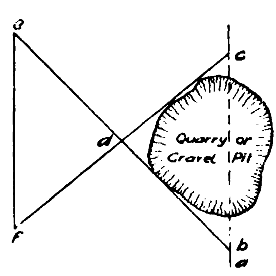


FIG. 33. PASSING GRAVEL PIT BY DOUBLE TRIANGLE

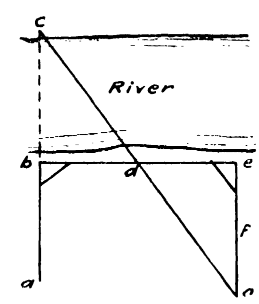


FIG. 34. FINDING WIDTH OF RIVER

will be necessary to get across the river some time or other, and therefore a pole should be planted at *c*. Where a stream is under one chain wide no construction of this kind will be necessary, as the chain can be held across it. The reading of the chain up to the near bank with the width of stream added to it, will give the reading to continue from on the far bank.

ARCHITECT'S OFFICE AND ROUTINE

By Herbert J. Axten, A.R.I.B.A., A.I.Struct.E.
Chartered Architect

PART VI

PROCEDURE BY ARCHITECT THROUGHOUT BUILDING CONTRACTS—(*contd.*)

Variation Orders. It is provided in the conditions of contract that no orders for variations shall be valid unless received in writing from the architect, and in Fig. 11 is given the form of a typical variation order.

Certificates. The contractor is paid by the employer in instalments from time to time, in accordance with the terms stated in the conditions of contract, upon the receipt of certificates, issued by the architect, stating the sum due.

For this purpose, the Royal Institute of British

Bedford Square,
London, W.C.2.
3rd February, 1926.

Messrs. Thoroughgood & Co.,
Building Contractors,
Slough.

Dear Sirs,

HOUSE, BROAD AVENUE, MAIDENHEAD

VARIATION ORDER NO. 1 - EXTRA.

I have the pleasure to confirm verbal instructions given on the job to day for the following extra works to be carried out

Form pit in garage in accordance with estimate dated 14th January last at a cost of £15 12 6.

Lay 1" oak wood block flooring in Hall in lieu of 1½" G. & T. flooring at an additional cost of £10 8 0.

Yours faithfully,

H. B. PENCILLE.

Fig. 11. Variation Order

Architects publish certificates in book form, a reproduction of a certificate being given in Fig. 12.

The certificate, when duly filled in, is sent with a covering letter to the contractor, who in due course forwards it to the employer and upon receipt of payment sends the formal contractor's receipt to the employer. At the time of sending the certificate to the contractor, it is usual to notify the employer in writing.

CONTRACT WITHOUT QUANTITIES

An outline is now given of the procedure by the architect in the adjustment of a contractor's account at the completion of a contract where

Architect's Address
Date

Certificate No.

Previous Instalments £......

Present Instalment £......

Total to date £......

I HEREBY CERTIFY that the sum of................

is due to......................of......................

on account of Works at............................

under the terms of the Contract therein dated........19...

£.........

....
Chartered Architect.

To...................

....

CONTRACTOR'S RECEIPT.

...............19...

Received from.....................................

the sum of £..........................in payment of

Certificate No.....dated..............19...

£...............

Stamp.

FIG. 12. ARCHITECT'S CERTIFICATE

there were no quantities. Upon the receipt of the contractor's detailed account, which should be accompanied by receipted bills, the architect would—

1. Go through the specification and prepare an abstract of all the provisional sums and p.c. items.

2. Go through the specification, noting items added, omitted or varied, and check with the variation orders.

3. Compare the signed contract drawings with the office copies of drawings, and note items added, omitted or varied, and check with the " variation " orders.

4. Peruse the letters sent to the builder, noting anything which may affect the account.

5. Peruse all letters from the builder and check as in No. 4.

6. Peruse the letters sent to and received from client and extract items as in No. 4.

7. Peruse the job notebooks kept, showing the progress of the work and extract items as in No. 4.

8. Prepare a schedule of " variation " orders issued under " extras " and " omissions."

9. Prepare a schedule of specialists' and sub-contractors' estimates which were excepted.

10. Ascertain whether the accounts have been paid for all provisional sums and p.c. items, such as steel-work, lifts, electrical work, stoves and mantels, sanitary goods, heating, district surveyor's fees, etc.

11. Agree or adjust every item in the account one by one; carry the amount of the omission or addition in each item to a schedule under each head; and finally carry the totals to the summary of account, an example of which is as follows

Amount of Contract (as per Tender dated) .		£
To Additions	£	
By Omissions	£	
		£
Paid on Account (as per Cert. No.) . . .		£
Add Surveyor's Fees		
2½% on £— . . .	£	
1½% on £— . . .	£	
	£	
Less Amount of Retention (as per Certificate of Completion No.) . . .		£

12. Obtain all the drawings and specifications from the builder with which he was provided for the execution of the contract.

13. Issue the certificate of completion.

14. Note any necessary reparations and making good to be done at the termination of the maintenance period —and agree these with client.

15. See that these several works are satisfactorily completed.

16. Issue final certificate for payment of retention money.

APPLICATION TO LOCAL AUTHORITY FOR PERMISSION TO BUILD AND DRAIN PROPOSED BUILDINGS

It is provided under the by-laws that every person intending to erect a building shall give due notice to the local authority in writing, accompanied by complete plans and sections of every floor on tracing cloth to a scale of not less than ⅛ in. to 1 ft., showing the position of all drains, water-closets, and all sanitary appurtenances. This must be accompanied by a written description of the materials to be used in the construction of the building and drainage, and state the means of water supply. At the same time a block plan must be deposited, drawn to a scale of not less than 44 ft. to 1 in., showing the position of the proposed building and the buildings immediately adjoining the width and level of the street, the relation of yard and lowest floor to the level of the road; also the lines of drainage, with size, depth, and inclination of each drain and method of ventilating the drains.

For the above purpose, the local authority provide application forms with all the items enumerated, and the forms require only to be filled in, signed, and deposited.

INSPECTION OF BUILDING WORK DURING PROGRESS, BY THE BUILDING INSPECTOR OF THE LOCAL AUTHORITY

The plans and application for the proposed building having been duly deposited and approved by the council, a formal approval is sent to this effect by the council surveyor to the architect; this approval is accompanied by building notices, which must be sent in by the builder from time to time—as hereunder enumerated—notifying the surveyor that the work is ready for inspection.

The work must be inspected and approved by the building inspector at the following stages before the next stage is proceeded with—

When trenches are excavated.
When foundation concrete is in.
When damp-proof course is laid.
When drains are laid.
At completion of the building.

The building inspector attends during the testing of the drains and sanitary appliances; and upon the whole of the work being completed to his satisfaction, a certificate of occupation is issued by the clerk to the council. This certificate states that the drainage has been completed to the satisfaction of the surveyor to the council, and the premises are fit for occupation.

PLUMBING

By Percy Manser, R.P., A.R.S.I.
Honours Silver Medallist

LESSON VI

WATER SUPPLY

Composition. Water is a chemical compound, two atoms of hydrogen combining with one of oxygen; it is formed when hydrogen, or a combustible substance containing hydrogen, is burned in oxygen or atmospheric air. The symbol for water, that is, the formula signifying its chemical composition, is written H_2O.

Source. The source of natural waters is from the rainfall. The sun's rays cause evaporation of water from the moist surface of the land, the sea, and rivers, which rises in the form of invisible vapour and, forming clouds, descends in the form of rain; under changes of temperature it may be in the form of dew, mist, snow, hail or sleet. The greater part of this water flows over the surface of the land or sinks through the earth until an impermeable strata is reached, where it is arrested and flows along this strata, and either issues in the form of springs or finds its way into a water-course or the sea. In other cases, where the strata is of a different formation, underground lakes are formed, from which we obtain some of our supplies by means of wells being sunk, and tapping the water-bearing stratum. A great deal depends upon the nature of the ground on which the rain falls, as to the amount which percolates into the earth. For instance, if on clay very little water will pass into the earth, whilst it will pass freely through a gravel or sandy formation. From this it will be readily understood that a clay soil is impermeable, whilst a sandy or gravel soil is permeable, or in other words, these two soils are non-porous and porous respectively. Rain-water in its natural state is soft, and if collected well away from any contaminating influences, is usually pure and wholesome; in proximity to manufacturing towns, however, many impurities are picked up, in its descent from the clouds. These impurities are the products of coal combustion, etc., and sulphurous and ammoniacal impurities are thus added to the rain, rendering it impure.

Hard and Soft Waters. In passing from the clouds and through the earth rain absorbs *carbonic acid gas*; this gas is a solvent of nearly all the rocks, and in the passage of the water over the rocky formations, salts of lime and magnesia are dissolved out and absorbed or held in solution, thereby rendering the water either *temporarily* or *permanently hard*. If, in the form of *carbonates*, the water will be temporarily hard, but if in the form of *sulphates*, then permanent hardness will result. This hardness is determined by the action of the water on soap, or in other words, on its soap-destroying properties. Water containing up to 6° or 8° of hardness, is spoken of as *soft*, whilst water containing hardness above this percentage, is known as *hard* water.

One grain of lime per gallon of water constitutes 1° of hardness.

The characteristics of a wholesome water are as follows: It should be clear, bright, and sparkling, free from odour, tasteless, soft to touch, and should dissolve soap readily.

Waters obtained from the chalk formation are clear and sparkling, and although hard, usually form a good supply. But waters from the limestone and magnesium limestone formations, sometimes containing the fixed salts, are not as a rule so good as those from the chalk. Hard water is very wasteful; this can be proved by the amount of soap that is required before a lather can be obtained.

Action of Water on Metals. Hard water has practically no action on the commoner metals, while soft water has a solvent action on most of them; for this reason, great care must be taken that pipes and cisterns, for storage and distribution, shall be of such material that will withstand the action of soft water. Lead is readily attacked by soft water; particles are dissolved out and taken up in solution, rendering the water unfit for domestic purposes, and may cause lead poisoning or paralysis. This action on lead is known as the *plumbo solvent action*, that is, the lead dissolving action. Lead pipes used for the distribution of hard waters become coated with a film, or thin crust, which acts as a protection against further action. Iron and zinc are also attacked by soft waters, which gradually destroy the metal.

Pure tin is not affected by either hard or soft waters.

Materials for Storage and Distribution. For the hard waters, pipes may be of lead, copper, cast or wrought iron; cisterns may be of slate, galvanized wrought iron, cast iron, or wood cisterns may be lined with lead; whilst on the cheaper kinds of work, wood cisterns lined with stout sheet zinc are sometimes used. Vitrified stoneware and fireclay cisterns are very good, but the chief objection is their great weight.

For the soft waters, the following materials are suitable: lead-encased tin pipe, tin-coated lead pipe, the Walker health pipe both in lead and iron, tin-lined iron and copper pipes, glass-lined and porcelain enamelled iron pipes, and pipes protected by the Bower-Barff process, and Dr. Angus Smith's solution. Cisterns may be of fireclay, stoneware, slate jointed with painters' putty and the angles protected by cement fillets, and iron cisterns coated with patent cement.

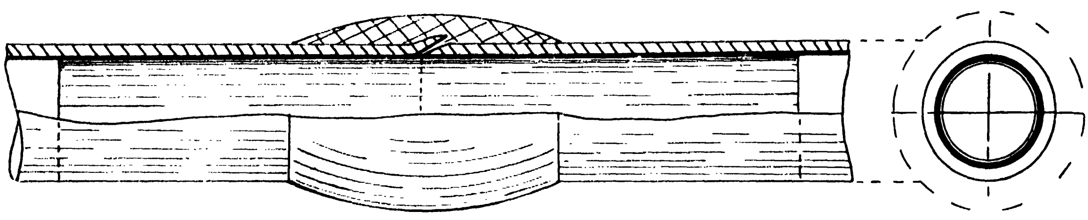


FIG. 49. SHOWING COPPER FERRULE IN POSITION IN TIN-LINED LEAD PIPE

Lead-encased tin pipes consist of a pipe of pure tin inside an outer pipe of lead; the pipe of tin is forced through the die together with the pipe of lead in one operation. Great care must be exercised in joining these pipes, owing to the low melting point of the tin; it is necessary, therefore, to make provision against the tin leaving the lead when under the heat necessary to wipe a joint, and thin copper ferrules are inserted to hold the tin in place. Fig. 49 shows a ferrule in position.

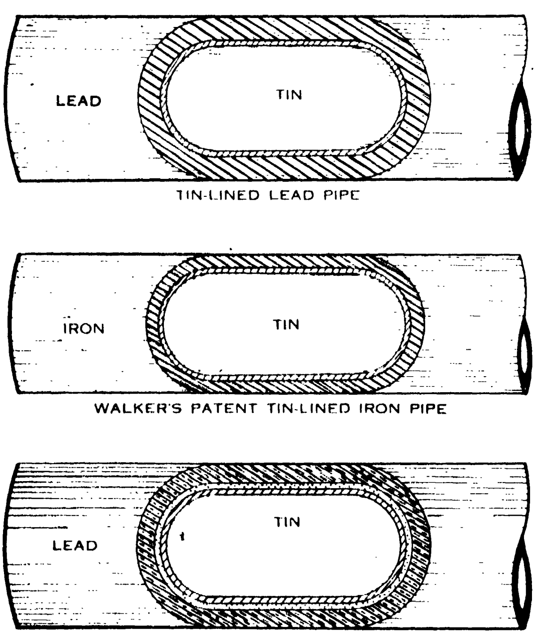


FIG. 50. TYPES OF TIN LINED PIPE

The *tin-coated pipe* is not a very satisfactory pipe to use, as it consists of only a wash of tin, which is easily damaged, thus exposing the lead to the action of the water.

The *Walker health pipe* consists of a pipe of pure tin encased in a pipe of lead; between the inner and outer pipes is a layer of heat-resisting non-fibrous material. Fig. 50 shows sectional sketches of tin-lined lead pipes, and the Walker health pipe.

Glass-lined and porcelain enamelled iron pipes are very good, though expensive; the chief objection is the ease with which the lining becomes damaged, and the consequent difficulty in cutting lengths without damage to the lining, and exposing the metal to the action of the water.

The *Bower-Barff process* of treating pipes consists of raising the pipes to a very high temperature, and exposing them to a current of superheated steam; this forms a protective coating of black oxide, which is proof against the rusting action of the water.

Dr. Angus Smith's method of coating pipes is carried out by immersing them in a hot mass composed of bitumen, resin, and coal tar at a temperature of about 400° F.; they remain in this liquid until the pipes reach the temperature of the coating mixture, after which they are withdrawn and allowed to drain and harden.

TOWN SUPPLIES

The water supply to our towns is generally from the public water company's reservoirs. These are usually placed on as high ground as possible to give height, or *head*, where the supply is to be by gravitation; in some districts the water is pumped from the storage reservoir into a high-water tower, from where it falls back through large mains to supply the surrounding district. The object of the tower is to give the necessary head and pressure to reach the highest buildings; in other districts the mains are fed direct from the pumps.

Before distribution the water is passed through filter beds of various kinds. One type is about 5 ft. 6 in. in depth and composed of approximately: 2 ft. 6 in. Thames sand, 1 ft. Barnes sand, and 2 ft. 3 in. various gravel

The bottom of the beds are laid with 6 in. pierced pipes in rows about 20 ft. apart. The rate of flow to be efficient should not exceed 540 gals. per square yard per twenty-four hours.

Quantity per Head. The quantity of water allowed per head per day varies in different parts of the country. In London approximately 30 gals. per head per day is the quantity allowed; whilst for Edinburgh 40 gals. and Glasgow 45 to 50 gals. The allowances of 30 gals. per head per day is made up approximately as follows—

Drinking	0·75 gals.
Cooking	0·35 „
House Cleaning	3·00 „
Laundry	3·00 „
Sanitary Fittings	6·50 „
Baths	9·00 „
Town Purposes	5·00 „
Allowance for Waste	2·00 „
	29·00 gals.

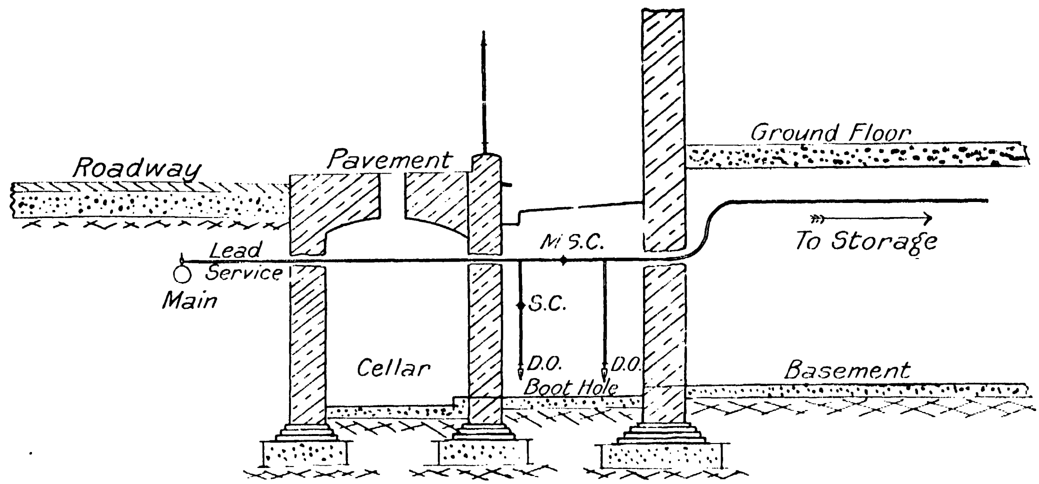


FIG. 51. ARRANGEMENT OF SERVICE PIPE FROM COMPANY'S MAIN TO HOUSE

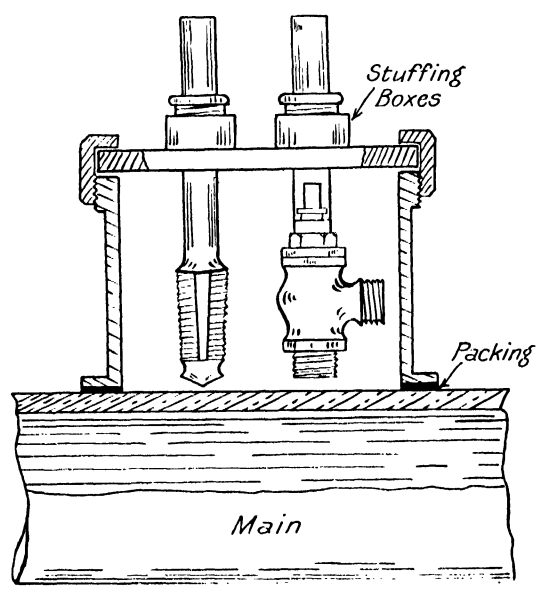


FIG. 52. APPARATUS FOR TAPPING MAIN UNDER PRESSURE

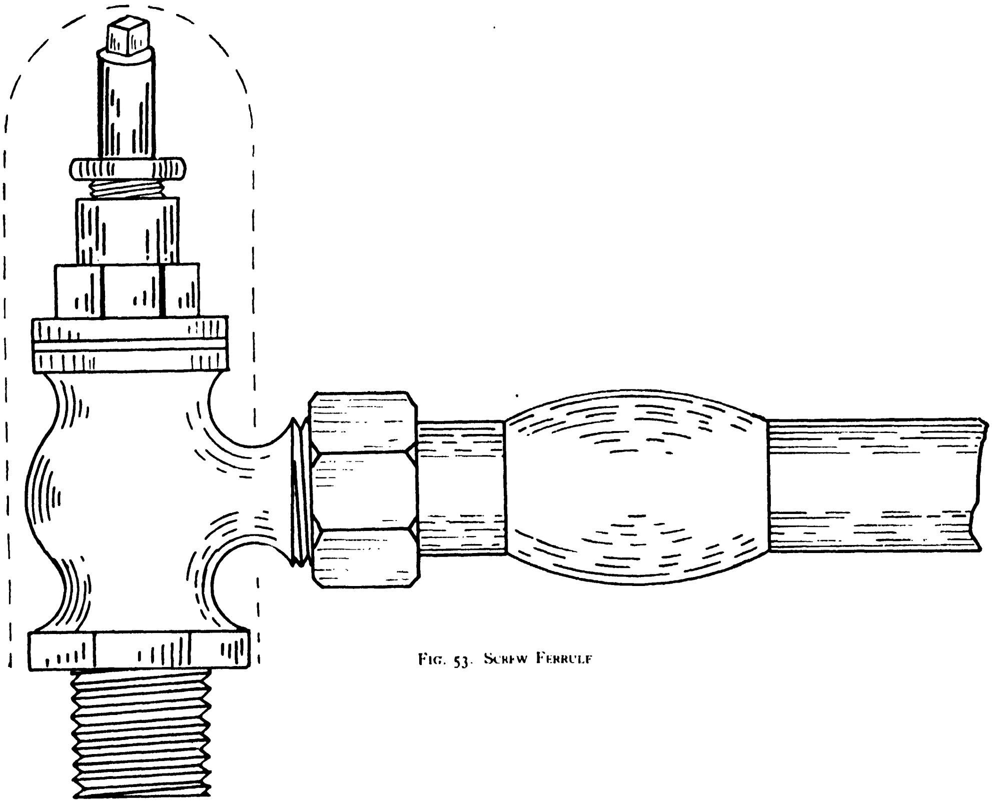


Fig. 53. Screw Ferrule

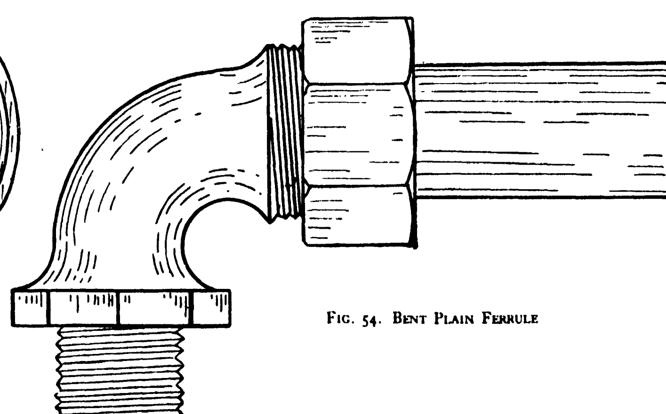


Fig. 54. Bent Plain Ferrule

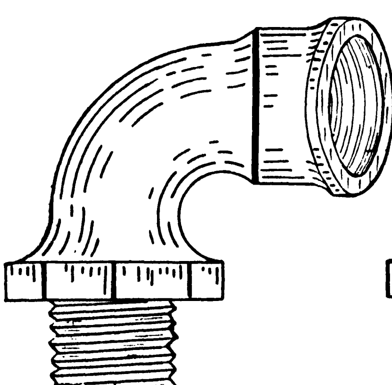


Fig. 55. Bent Ferrule for Iron Pipe

Uses. Water is required for cooking, drinking, personal cleanliness, washing clothes, utensils, cleansing of houses, sanitary fittings, drains, and sewers; also the watering and cleansing of streets.

Distribution. The present-day method of distribution from the reservoirs is by means of cast-iron mains passing under our roads, the communication between the main and the consumer's storage cistern being effected by a brass ferrule, which is tapped and screwed into the cast-iron main, the ferrule union being wiped on to the lead service pipe. The latter is then continued below the ground to the interior of the premises, whence it rises to supply the storage tank or tanks, and is termed the *rising main*; an efficient *stop-cock* must be provided at a suitable spot to control the supply pipe. Fig. 51 shows the method of communication to a town house.

The water companies' mains are fitted at various points with valves and emptying plugs, to control and drain out the pipes when new connections or repairs are required to be carried out.

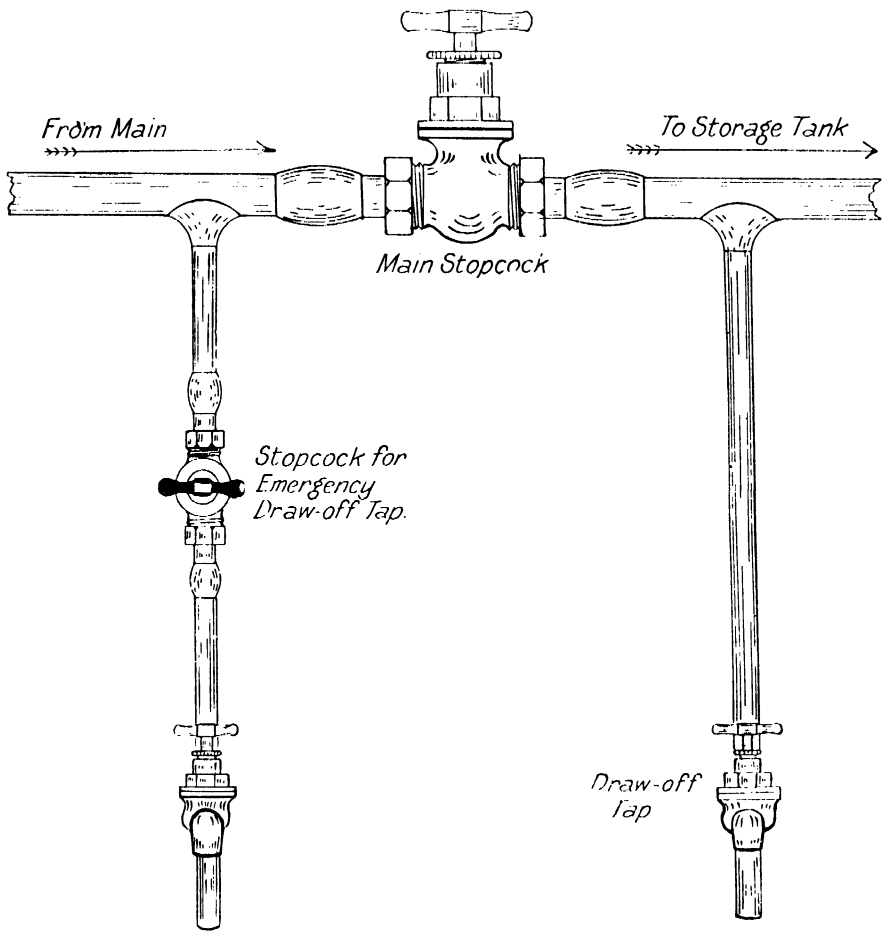


FIG. 56. ARRANGEMENT OF MAIN STOP-COCK AND DRAW-OFF TAPS

Connection to Main. The *drilling and tapping* of the cast-iron mains is usually done by the ordinary ratchet drill and tap, which necessitates the main being shut down. There is an apparatus (Fig. 52) that enables the main to be drilled and tapped and the ferrule screwed in with the water still in the main at full pressure. The operation is quite simple and very little water is wasted. The apparatus consists of a small iron body, the top of which is constructed so as to enable the plate which holds the drill and tap and the screw ferrule to revolve; the hole is drilled and tapped by a combined tool, which is then withdrawn. The top plate is given a half-turn to bring the ferrule immediately over the tapping, when the ferrule is screwed down. The chain grip, holding the apparatus to the pipe, is then released, and the operation is complete.

Fig. 53 shows a screw ferrule with wiped solder joint to union. In some cases, an ***iron key*** is fitted to the square shank of the spindle, and of a length to allow it to reach to within an inch or two of the pavement level; in others, an iron dome is covered over the body, as shown by dotted lines, and the whole buried beneath the roadway.

There are also plain ferrules used for connecting service pipes to cast-iron mains. Fig. 54 shows a plain ferrule without stop-cock; these

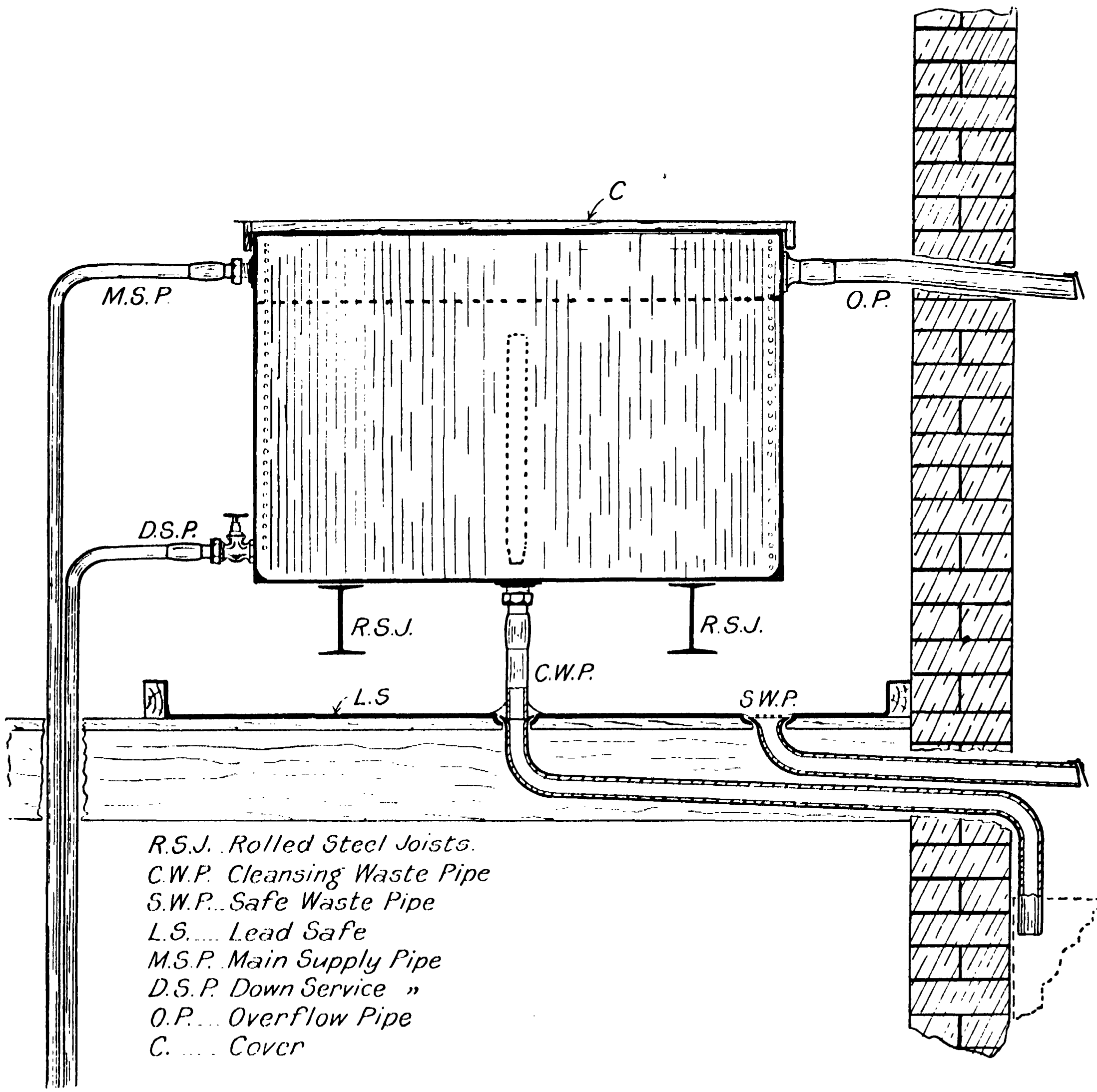


FIG. 57. STORAGE CISTERN AND CONNECTIONS

NOTE. The water level and cleansing waste plug shown by dotted lines.

are also supplied with screw threads to receive wrought-iron screwed barrel connections for main service pipes (Fig. 55).

Main Stop-cock. Fig. 56 shows the method of arranging the main stop-cock and draw-off taps. A branch pipe should be taken out on the main side of the stop-cock and fitted with a draw-off tap and control stop-cock, thus enabling water to be drawn in the event of house supply being shut down for any length of time. The draw-off tap, on the house side of the main stop-cock, enables the whole of the rising main to be emptied when the main stop-cock is shut down; this is essential, especially in times of frost, and is also a necessary item when repairs are required to the rising main.

The stop-cock and draw-off taps should be placed in a prominent and accessible position immediately inside the premises, and enamelled iron or painted tablets fixed on the wall showing their purpose. In a large number of town houses, it is sometimes convenient to fix the house draw-off tap over a sink and thus fulfil two purposes, that of a drinking water supply, and also a means of draining out the rising main.

Storage. The storage of water for domestic purposes is a matter that calls for strict attention. In large numbers of houses, it seems to be the general rule that any place will suffice for the fixing of a storage cistern; and one has only to visit a few houses, both in town and country, to find cisterns in all sorts of out-of-way positions, uncovered and exposed to filth of every description, fixed beneath floors where the open joints of the boards allow dust and floor washings to pass freely through, fixed in roofs beneath the slates, and without proper coverings, and in a host of other positions of a most unwholesome character.

It is not always possible to construct a proper cistern room, but if the following idea is carried out, the stored water would be kept free from contamination. A storage cistern should be fixed in a light, airy and accessible position, away from the direct action of the sun's rays; the overflow should terminate well away from any soil pipe or waste pipe terminal; and the cistern should be fitted with a close-fitting dustproof cover.

In larger establishments, and where the best possible results must be obtained, proper cistern rooms should be constructed; or if the cisterns are to be fixed on the roof, as is often the case, proper provision must be made for enclosing them in casings made up in sections, which are easily removable when repairs or cleansing of the cisterns are necessary. The practice of packing loose sawdust and slag wool between a wood casing and the cistern is not one to be recommended; a better method is to construct hollow casings to hold the packing medium, and if the casings are made up in sections, and held in position by clamps, they are easily taken down, and the whole of the cistern exposed in a short time.

When cisterns are fixed inside the building, *lead safes* should be provided beneath them and fitted with a waste pipe, discharging into the open, to act as a *warning pipe* in case of a leakage.

Fig. 57 shows the method of fitting up a storage cistern in a building, together with the general arrangement of the pipes; for sake of clearness, one down service only is shown. A cleansing plug and waste pipe should be provided for use when the cistern requires cleaning out; this waste should discharge into a *rain-water head*, and should be carried down separately to discharge over a properly trapped gulley. This " waste " is required when a cistern has to be cleaned; without it, the whole of the water, together with the dirt that accumulates, must be drawn off through the service pipes and fittings, which is most objectionable; whereas with this waste pipe the water, together with the washings of the cistern, can be carried away straight to the drain. The supply can afterwards be allowed to run to waste for a few moments to thoroughly wash out the bottom of the cistern, after which the plug can be refixed. It will be noticed that the cleansing plug terminates just below the water level; this is to prevent unauthorized persons from detecting its presence and tampering with it. The ends of overflow and safe waste pipes should be fitted with hinged copper flaps.

ARCHITECTURAL DRAWING

By Walter M. Keesey, A.R.I.B.A., A.R.C.A.

LESSON III

ISOMETRIC PROJECTION AND MODEL DRAWING

Projection. The student will notice, as he advances in his drawing, that it is necessary to show at least two views of an object before a clear representation may be obtained. Generally, one of these views is taken at right angles to the horizontal plane and becomes an " elevation," while the other at right angles to some vertical plane becomes a " plan." The part of a cube in contact with the ground is, of course, the plan, while of the other sides of the cube four vertical ones are elevations (N., S., E., W., etc.), and the top horizontal one might be termed the roof. These are difficult to show except in isolated drawings, but may be clearly expressed with the assistance of " isometric projection." In this method of representation all actually vertical lines are drawn vertically, whereas horizontal lines are projected at an angle of 30° to right or left, and measured to actual scale along each line. No " vanishing " is allowed for as in perspective, but while the method often distorts a large object, yet it is extremely useful in giving a three-dimensional view of any object and to a defined scale; it is particularly suitable for details of joints, penetrations, and other invisible details. When studying such forms, in connection with building construction details, the student should make a point of sketching the items in isometric, to gain added confidence both in knowledge and power to express himself easily.

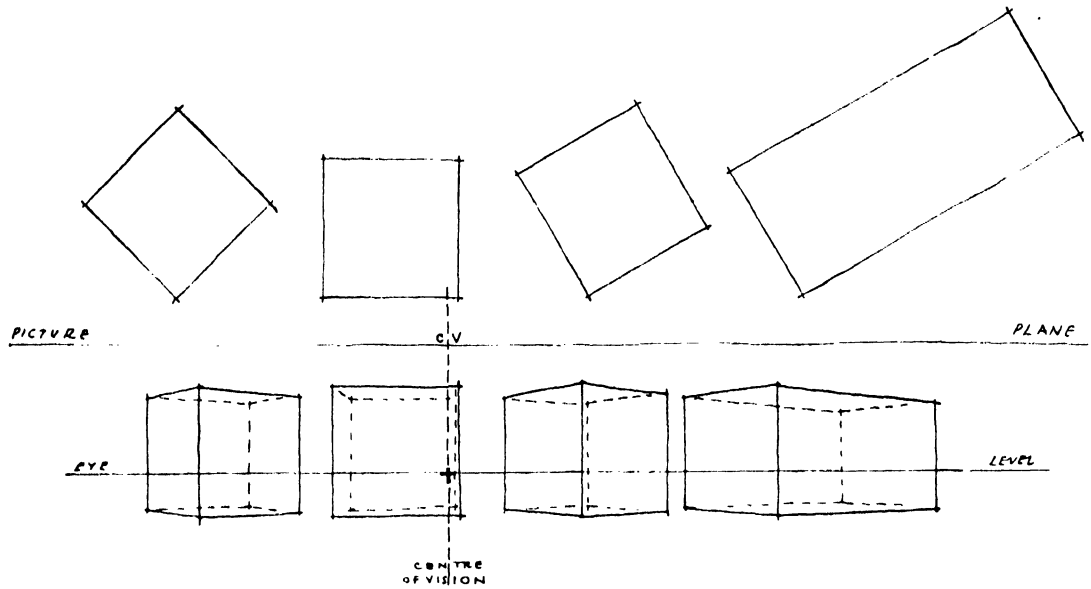


Fig. 11

Model Drawing. Included in the study of projection is model drawing. This is really a path to that happy goal of all draughtsmen, sound expression, and can be studied better under the guidance of an art master at any School of Art than by individual study. Models are essentially right forms, and should be used analytically in conjunction with projection. Freedom is rapidly gained if the student realizes that parallel lines are parallel in isometric only for convenience; and that if one stands, near a tunnel, and looks from one end towards the other end, the far end appears smaller than the near end; and all details contained in that tube, such as posters of equal sizes, follow the general inclination of vanishing. Standing facing a pair of large doors (closed), the lines are at right angles with one another; open the doors away from you and the lines now appear to vanish within the door opening. So soon, then, as one pushes a parallel plane away to right or left, the lines of that plane will *diminish* in equal relation. One cannot actually see a perfect square front of a cube and also one side. As soon as a side appears the front must be less than square, as illustrated in Fig. 11.

A certain amount of similar thought pervades all the various forms, and one's judgment necessary for its appreciation is rapidly strengthened by exercise.

The photograph of the tower, shown in Fig. 12, is an excellent example of the type of form suitable for good instructive work; the diagram, Fig. 13, of the constructive lines, explains itself, but particular attention should be paid to the various centre lines and directions of the elliptical shapes. Continuous drawing of circular shapes, at a fair height, will very rapidly teach the student the methods of drawing illustrated and explained in this lesson.

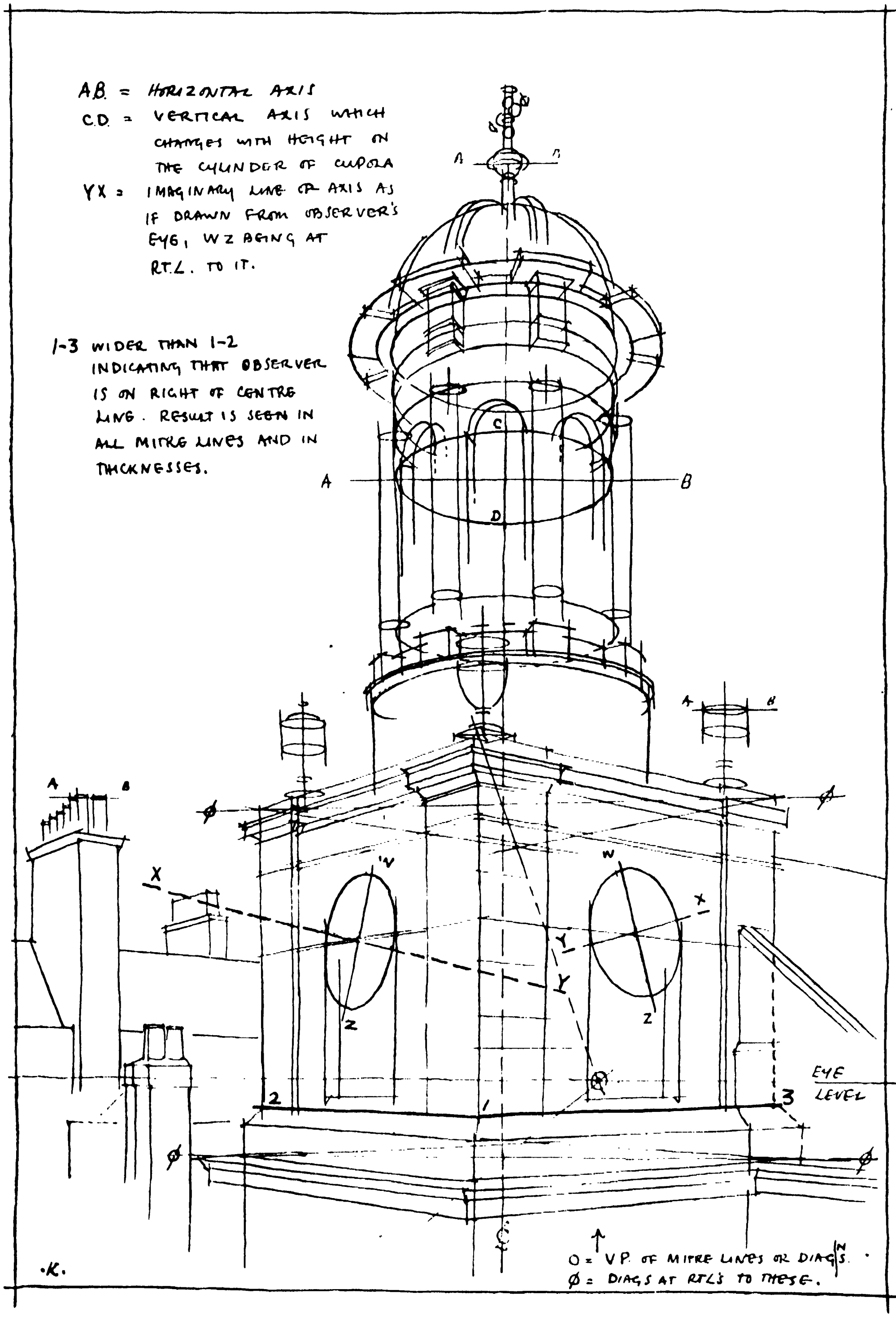
Study the diagrammatic skeleton lines of Fig. 13 and draw them over again. The base is cubical and presents the only difficulty of gauging the left side 1–2 with the right 1–3. Notice that all the horizontal lines would meet at some point on the eye level; also that the top horizontal square having been formed and the diagonal produced to the eye level, a vanishing point is made which is extremely useful for mitres of angles. When the sides are nearly equal, as in this case, the other diagonal is nearly horizontal and the profile of these mouldings is more easily seen than in the foreshortened angles. Always check main width with main height overall.

The top circular tower is an interesting exercise in ellipses. Imagine it to be a plain cylinder subdivided horizontally as indicated in diagram; notice the gradually increasing height of the vertical axis *CD* and the permanent horizontal axis *AB*. This is important to note and must always be drawn; it is more evident in the diagram than in the photo, where other forms are liable to disturb its direction, but where it can be traced consistently in the large and the small details. The columns form a convenient guide to the disposition of the centres and should be drawn in before attempting the arcading. Their architraves become simplified box forms with their centre lines to the centre of tower. If the back ones could be seen they would obviously carry through from the front.

Another interesting and generally confused problem concerns the drawing of the vertical

FIG. 12. CUPOLA, ALL-HALLOWS, LONDON WALL

ellipse, as in the louvred windows. Imagine a large circular advertisement as a street wall. Knowing it to be circular, you see it as a long thin ellipse when viewing from the same pavement close to the wall. Its greatest axis seems to tilt toward one direction, while its smallest axis seems to be in direct continuation of your "gaze." This really is so, and all vertical ellipses should be drawn (despite the perspective method, which is theoretical) as if the short axis were a line from your eye through the centre and the long axis at right angles to that line. Vertical ellipses will therefore



AB = HORIZONTAL AXIS
C.D. = VERTICAL AXIS WHICH CHANGES WITH HEIGHT ON THE CYLINDER OF CUPOLA
YX = IMAGINARY LINE OR AXIS AS IF DRAWN FROM OBSERVER'S EYE, WZ BEING AT RT.∠. TO IT.
1-3 WIDER THAN 1-2 INDICATING THAT OBSERVER IS ON RIGHT OF CENTRE LINE. RESULT IS SEEN IN ALL MITRE LINES AND IN THICKNESSES.
A
B
C
D
X
Y
W
Z
1
2
3
EYE LEVEL
O = V.P. OF MITRE LINES OR DIAGNS.
ø = DIAGS AT RT∠S TO THESE.
·K.

Fig. 13

apparently change their directions as the diagram indicates by the two *X Y* and *W-Z*. A perspective "set up" for circles can only give their apparent position, after which the ellipses should be drawn in as above. When experimenting with this problem, commence with very distorted (side) views of clocks, arches, etc., or posters, as in the street already quoted.

Freehand Work. Many drawings should be made from models or similar forms, but it is a sad mistake to "line in" every exercise. This awful phrase really means, "Now I can give up thinking and just go over my lines; in fact, I can turn my drawing upside down, and do it equally well or perhaps better!" Get away from comfort and really study each line until perfection has been reached. Lines are used to convey an impression, and correct freedom in that impression is much better than meticulous care bestowed upon the lining up of a badly set up drawing. A good line arrives by constant alteration and consideration, until the hand obeys the eye as implicitly as does the eye the brain. It will not arrive, however, with the use of a HHH pencil for free drawing, but with a B at least; nor will much fine work evolve if the pencil is coarsely sharpened or too small- or bitten at the end! Hexagonal pencils are good to learn to sharpen, and every facet should receive the knife first; after that every ridge, until a point about 1½ in. long (including wood and lead) is made. Cheap pencils break so soon that the money spent on them is soon wasted. A long swinging stroke on a board, held at arm's length on the knees and towards the group or object, is fine bodily exercise and should be encouraged. Do not hold a pencil as you would a pen for this work; it becomes too limited in range; give the lines a good "carry through" to gain precision and speed. For this reason, always make the drawing as large as is possible, and keep your eye on the shape outside as well as inside the group. A figure on a hill top against the light is easy to draw, because the brain observes shape and is not distracted by detail; choose, then, simple "shapes" to begin with, and inquire into the construction of them afterwards.

Tone. Having drawn the group, assume the light comes from one direction, and try and cover the dark planes with tone. Put them in first with a brush, if you like, and a wash or washes of tone of different strengths. Later, try and cover the same surfaces on another drawing with pencil, for the sake of the experience. If we take a square inch of paper and put lines ⅛ in. apart with a BB pencil a tone will result, i.e. eight lines to the inch; with sixteen a darker tone will be obtained, and so on. Also a harder pressure, or crossing the lines or adding dots, etc., will vary the tones. All these should be tried and, finally, when the tone is decided upon, put the selected tone in the drawing.

Some casts of simple strong shapes should now be tried out and the same principles applied. The casts which are so prevalent in schools of art are not there so much as samples of ornament as samples of shapes, and should be considered as such for our purposes. The *Egg and Dart* to a large scale is a most enlightening cast, and excellent for the study of tone and methods, being deeply modelled with contrary surfaces and strong shadows. Remember that on such rounded forms a shadow, which is drawn like the lines of a bead curtain, will surely hide all the shapes it covers instead of explaining them. Lastly, when drawing by means of shade and light, no outline is essential, and any preliminary lines should be considered only as guides to the surety of the final pencil lines. Heavy outlines only tend to bring the preceding planes up to the surface.

Penwork. Given the time, it is worth while using a pen at every opportunity; it seems to be usually considered that penmanship is only for the very last stages, and that no preliminary knowledge is necessary. With a pencil the lines tend to merge, readily producing a tone; but with a pen all lines are distinct, and need much more courage and skill to blend them. A pencil drawing can be drawn into without much trouble but, to fill in between pen lines, is a very difficult matter. Use a pen, therefore, as a matter of course, and you will cease to feel as if it were a new suit! Also use ordinary writing nibs (except, possibly, the "J" variety) instead of the deadly mapping pen, which, as its name implies, is made for a specially fine purpose. All sorts of nibs are on the market—some with two and three or more points—and should be tried out. These can be purchased from Messrs. Gillott, with steel nibs for "script" writing. If much work is anticipated, add a spring to the nib and transform it into a fountain pen. The flow will be much more regular and the work more uniform.

ROOF COVERINGS

By John Millar, P.A.S.I., M.I.Struct.E.

LESSON V

TILES AND TILING

Manufacture of Tiles. Tiles are made from clay. Ordinary clay is formed by the disintegration, or weathering, of igneous rocks, shales, and certain limestones. It contains silica, alumina, and combined water, in various proportions, with impurities in the form of oxide of iron and lime, its composition being dependent upon the character of the rock from which it is formed.

The pits are generally worked open to the sky, but in the Broseley district the clay is in the form of rock and is obtained by mining. It is generally found that the top seams are weak and the deep seams are strong; the clay, therefore, requires careful mixing and blending to make it suitable for tile-making. Owing to their comparative thinness, the material requires careful selection, handling, and burning.

If the clay is too strong, that is, contains too high a percentage of alumina, it requires the addition of, say, ground fireclay to thin it down. A refractory clay, that is, one containing a high percentage of silica, is more suitable, as it is then capable of being burnt to a higher temperature than a strong clay.

Weathering. After having been dug, the next operation is *weathering*. Clays differ greatly in the extent to which they are affected by exposure; some are completely disintegrated by standing in the open air for less than a month, whilst others are scarcely affected after years of exposure. Some tile makers consider this process unnecessary for their clay, but it is such an important operation in the production of an efficient and lasting tile, that all clays should be spread out, watered, turned over, and left to weather for at least twelve months.

The clay is next taken and tipped into hoppers containing toothed and plain rollers, which crush and reduce the material into a fine state. It is next placed in an open trough with mixing blades and afterwards thoroughly mixed in a pug-mill, water being added to obtain the required consistency. It should be sufficiently fine to pass completely a 24-mesh sieve.

Machine-moulding. The material is now ready for moulding, and may be machine-moulded or hand-moulded. In machine-moulding the clay may be in a plastic or in a semi-dry state, but in hand-moulding the material must be plastic.

From the pug-mill the clay is forced through a die, thus forming a long band thicker and wider than the width and thickness required for the finished tile. The forcing of the clay through the die means a reduction to about one-sixtieth of its original bulk, and requires an enormous pressure, which probably produces cleavage lines similar to those in slate, causing the tiles to laminate under the action of alternating frosts and thaws. In addition to this danger there is another. During the passage of the clay through the die, the portion that comes into contact with the sides travels at a different speed, due to friction, to that at and near the centre, thus foliating the tile into a series of very fine leaves.

Another method of moulding employed, and one preferable to the last, is by passing the clay through a set of rollers of the width required, and spaced apart to give the tile its proper thickness after burning. A revolving knife cuts the band of clay into pieces of regular sizes, termed *bats*. These bats are allowed to stand for a few days, after which they are placed in a machine and subjected to a pressure of 20 tons per square inch; at the same time the holes are made and the nibs formed on the tile.

Hand-moulding. For hand-moulding, a metal mould is used and it is covered with sand before being filled, to prevent the clay adhering to its sides, and to give to the tile the texture known as *sand-faced*. The mould is formed with two projecting pieces on its edge; these pieces go to form the nibs on the finished tile, and are turned up by the moulder while the clay is soft. The holes are next pierced with a small metal cylinder.

Hand-moulding has the advantage over machine-moulding, in that it gives a more homogeneous tile and one less liable to lamination.

With regard to colour, hand-made tiles quickly vegetate and become a natural colour.

Drying. The process of drying which follows takes from two weeks to eight weeks, according to the plasticity of the clay. The object of drying is to remove the surplus water and thus facilitate handling of the tile. Water is found

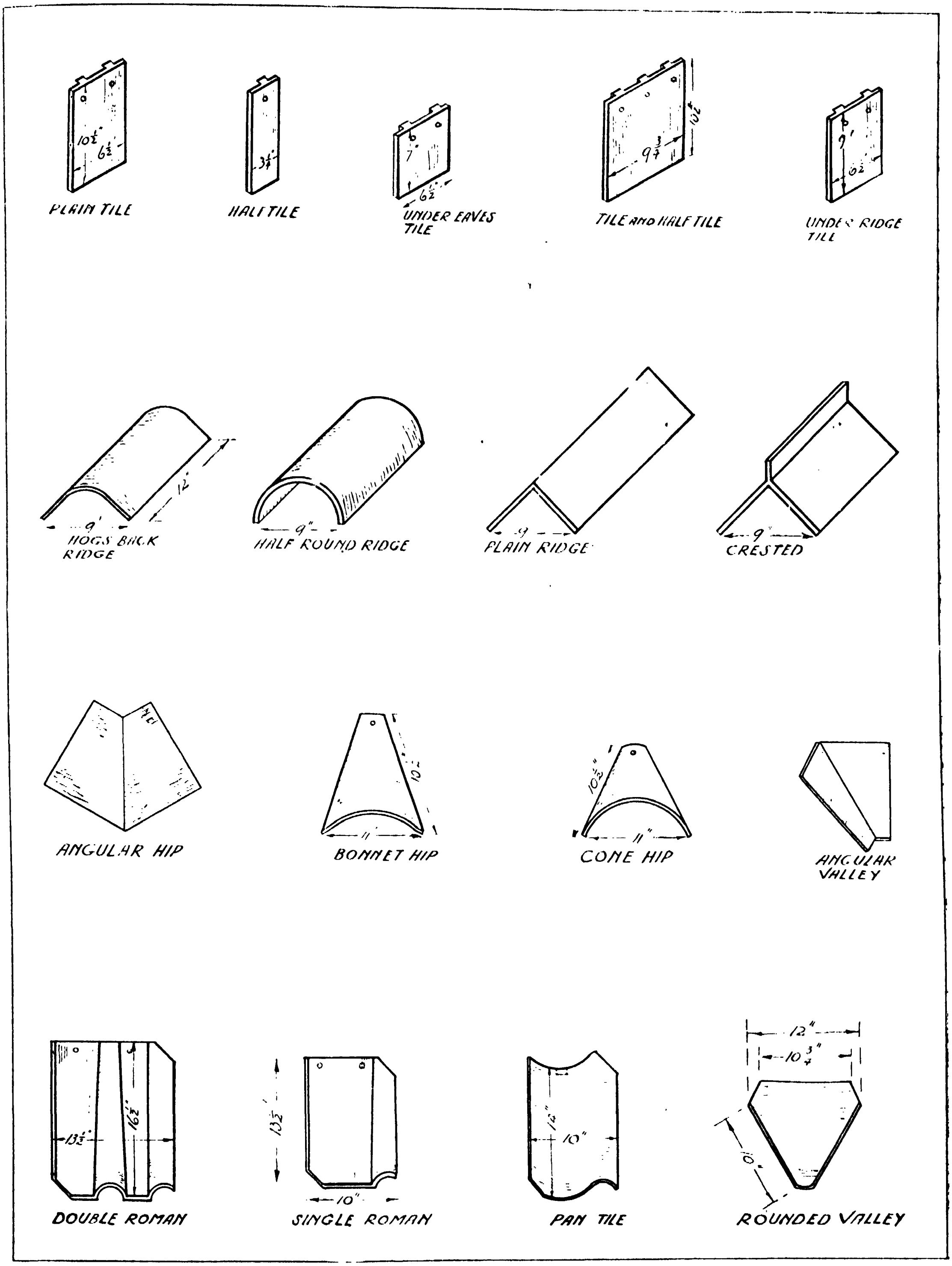


FIG. 26. VARIETIES OF TILES

in two conditions, either as moisture or mechanically mixed with the clay, or in a state of chemical combination.

Part of the former is evaporated on drying, and the remainder by heating the clay to a temperature of 220° F. The combined water is unaffected until a temperature of 1,100° F. is

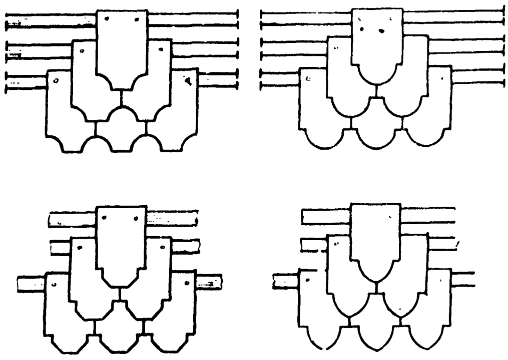


Fig. 27. Ornamental Tiling

reached; at this temperature the clay loses its plasticity and becomes a stone-like mass. The removal of this water is the cause of the shrinkage in the clay, and this should not exceed about 9 per cent. During drying, a slight "camber" is obtained in the length of the tile by placing the tile on a cambered board, or on a shaped bed of sand. This camber is an important quality, as it not only gives a good bedding for the tile, but reduces capillary attraction to a minimum, and the air spaces thus formed are valuable in assisting evaporation of moisture and in preserving the tile. Tiles are sometimes found to be curved in their width, but this is due to hard burning.

Burning. The next operation, and one of the most important in tile making, is the burning, as the weathering qualities of the tiles depend chiefly on sufficient burning. The temperature needed to secure a good roofing tile of satisfactory hardness is between 1,870° F. and 2,100° F.

The heat is applied gradually at first, but the actual burning takes about two days. The greatest heat being at the top of the kiln, the tiles in this position are burnt harder and are darker in colour; while those at the bottom, getting the least fire, are lighter in colour. There are many shades of colour between these two extremes.

The kiln is left to cool down before the tiles are withdrawn, otherwise the sudden change of temperature would cause the tiles to crack in pieces.

Colour. The colour is largely determined by the burning and the amount of oxide present in the clay. There is a wide choice of colours in tiles, ranging from light red to dusty brown, and if used with the right judgment will give variegated tints that make the roofs look very pleasing.

After the tiles are withdrawn from the kiln they are sorted out for colour and quality into three grades: *bests*, *seconds*, and *thirds*.

The principal tile-producing areas are Broseley (Shropshire), North and South Staffordshire, Loughborough (Leicestershire), Berkshire, Kent, Yorkshire, and Somersetshire.

Plain Tiles. Of the many varieties of tiles in use at the present time, *plain tiles* undoubtedly make the best and also the most picturesque roof, particularly where hand-made tiles are employed. They are used extensively, with few exceptions, for good-class work, and when properly made will be found to be practically everlasting.

The failure of a good tile roof is usually due to the corrosion of the nails, or the decay of the battens. The tiles measure 11 in. by 7 in. or 10½ in. by 6½ in. by ½ in. in thickness, the latter size being more in general use (see Fig. 26).

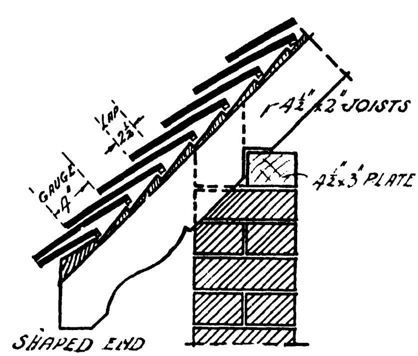


Fig. 28. Feather Edged Boarding

They have two nibs on the underside for hanging to the batten, and are laid in a similar manner to that of slates, but being smaller and more porous, they require a steeper pitch (see Table I).

Tiles are sold by the thousand (1,000 only being allowed, and not 1,200 as for slates).

Gauge and Lap. The gauge and lap for tiling are determined in a similar way to that for slating, but no deduction is made in the length on account of the nail hole as in the case of head-nailed slates, the lap being the amount by which a tile covers the next but one below it. The lap generally adopted is $2\frac{1}{2}$ in., which gives a 4 in. gauge. Each tile, therefore, has an

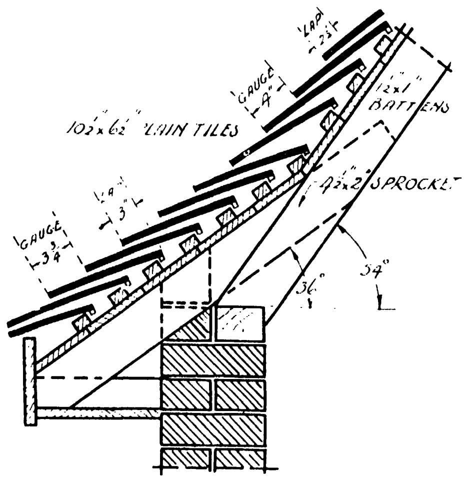


FIG. 29. EAVES FINISHED WITH SPROCKETS

effective covering area, when laid to this gauge, of $6\frac{1}{2}$ in. by 4 in., which is 26 superficial inches.

Number Required to Cover a Square. The number, therefore, laid to a gauge of 4 in., required to cover a square is given by the formula—

$$\frac{\text{Area of square}}{\text{Width of tile} \times \text{gauge}} = \frac{10 \times 10 \times 144}{6\frac{1}{2} \times 4}$$
$$= 554 \text{ tiles}$$

It is usual to allow 5 per cent for waste, which gives the total number as—

$$554 + \frac{554 \times 5}{100} = 582 \text{ tiles}$$

If the situation is an exposed one, the gauge should not be more than $3\frac{3}{4}$ in. In this case, by the above formula, the number required will be 591 tiles per square.

Variety in Tiling. Variety may be introduced into the work by slightly varying the gauge. If the gauge is, say, 4 in., the gauge rod would be marked, commencing at the eaves, say, 4 in., 4 in., $3\frac{3}{4}$ in., $3\frac{3}{4}$ in., $4\frac{1}{4}$ in., 4 in., 4 in., $3\frac{1}{2}$ in., etc., thus giving the same number of courses without affecting the efficiency of the roof covering, and eliminating the mechanical accuracy often found in modern work. Other means of obtaining variety to the surface in tiling are to use tiles of mixed light and dark shades, or by introducing tiles having their lower ends shaped, as shown in Fig. 27, in bands of three or four courses, between four to six courses of plain tiles.

Weight of Tiles. Tiles weigh, approximately, 21 cwt. per 1,000. The weight, therefore, per square, will be, where a 4 in. gauge is employed—

$$\frac{554 \times 21}{1000} = 11{\cdot}6 \text{ cwt., approx.}$$

and, if a $3\frac{3}{4}$ in. gauge be adopted, the weight will be 12·4 cwt. per square. This weight, compared with "seconds," or "mediums," in Welsh slating, is nearly double; and, a tile not being impervious to moisture, to this weight must be added the weight of moisture that may be absorbed by the tile, which is anything up to 5 per cent. Owing to this increased weight, stouter rafters are required to ensure a satisfactory roof.

Preparation for Tiling. The preparation of the roof for plain tiling is similar to that employed for slating, but tiles being a better non-conductor of heat and cold than slates, the use of battens is less objectionable. The size of battens used are $1\frac{1}{2}$ in. by 1 in., or 1 in. by $\frac{3}{4}$ in.

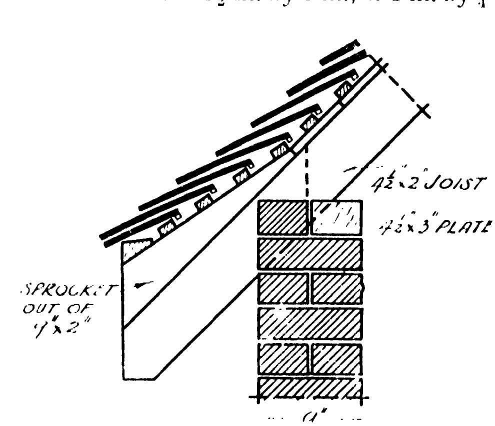


FIG. 30. ALTERNATIVE METHOD OF FINISHING EAVES WITH SPROCKETS

In addition to the methods previously described, feather-edged boarding is much in use for tiling at the present time instead of boarding and battens (see Fig. 28). It is used on the score of economy and is not to be recommended. The boards are cut out of 1 in. thickness of board, which gives approximately $\frac{3}{4}$ in. at one edge and

⅛ in. at the other. For satisfactory work, the width of the board should divide equally into the slope length, and this is obtained in the same way as that shown in Lesson III for finding the exact length of the gauge.

Sprockets. These are pieces of timber varying in length from 2 ft. to 3 ft. 6 in., and cut out of timber 9 in. by 2 in. They are placed on the top of each rafter at the eaves, or they may be of the same scantling as the rafters, say, 4 in. by 2 in., from 3 ft. to 3 ft. 6 in. long, and nailed to the side of the rafters, giving a bell-shaped eaves (see Figs. 29 and 30). For this method of eaves finish, a well-known architect, famed for his excellent designs, makes the pitch of the rafters 54°, and that for the sprockets 36°.

A set-square made to an angle of 54° for giving the roof pitch, is simply reversed for the sprocket pitch. While this looks pleasing from an architectural point of view, care must be exercised that the angle at the eaves is not too flat, which, with the increased volume of water at this point, is often the cause of lamination of the tiles.

Nailing. Plain tiles are generally specified to be nailed every third, fourth, or fifth course, and this is quite satisfactory in most cases, but if the building is in an exposed position every tile should be nailed. The nails used are 1½ in. long and preferably made of copper, but these are little employed owing to their expense. Composition and zinc nails are in more common use. The old method of fixing was by means of oak pegs.

Bedding. Bedding, torching, or rendering to the under side of the tiles should be avoided, and if provision has to be made against extremes of weather, felt and boarding should be employed.

PRELIMINARY OPERATIONS

By R. Vincent Boughton

LESSON VI

SHORING (*contd.*)

Example of More Advanced Dead Shoring. Figs. 43 and 44 depict plan and section of a two-story building, having a 4½ in. brick division wall extending through both stories. It is desired to remove such wall on ground story, and to insert a girder to support the wall over and the first floor joists, which are now carried by the wall. Fig 44 shows the section of the system of shoring that is considered better than the method shown by Fig. 45, as the 4½ in. wall on first floor, being partly carried by the joists, allows the needles being placed at a greater distance apart than if the wall was not so borne.

It will be noted that Fig. 44, and enlarged detail *A*, show the steel girder placed in position below the timber joists, which will avoid the necessity of cutting and fitting the ends of them to the girder, and also prevents interfering with the bearing of the 4½ in. partition wall. Sometimes a condition may be imposed on the builder, which will require the girder to be placed in the thickness of a floor—a rather difficult and costly matter,—and Fig. 45 and enlarged detail *B* show this condition. As the joists must be cut and fitted to the girder, the partition wall will lose its support until the girder is fixed, and consequently needles must be inserted at only short distances apart to carry the wall. A difficulty arises in getting the girders into position between the ends of joists, and this is best overcome by using two girders, the first one being quite easily fixed, as shown at *B*, and sufficient space being arranged between it and the end of the joist shown to allow, with a little manipulation, the hoisting and fixing of the second girder.

It may at first be deemed practicable to shore only the floors and allow the wall, with its superimposed roof load, to be borne by the floor joists; but such a method would not be in conformity with good principles of shoring, because (1) the dead shores must be placed at such a distance away from the centre line of wall as will allow room for working the girder into position; (2) there must be sufficient room to cut and fit the joists to the girder; and (3) a great strain would be imposed on the joists that would cantilever over the heads of shoring.

The distribution of the loads to the shoring

DETAILS OF SHORING

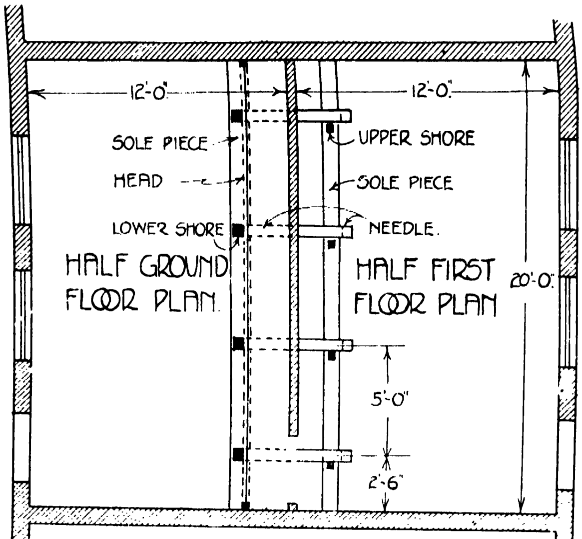
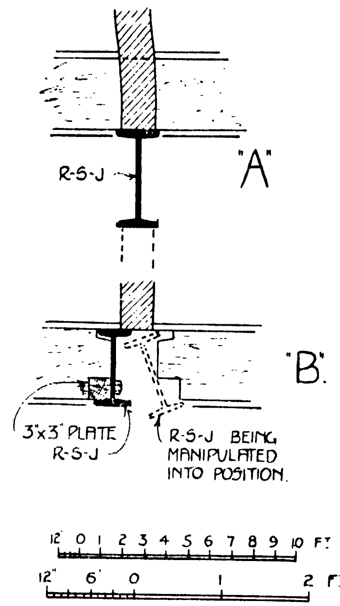
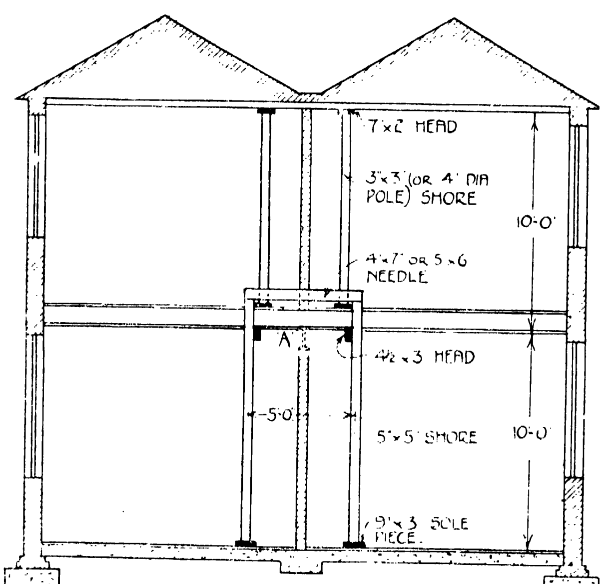


FIG. 43

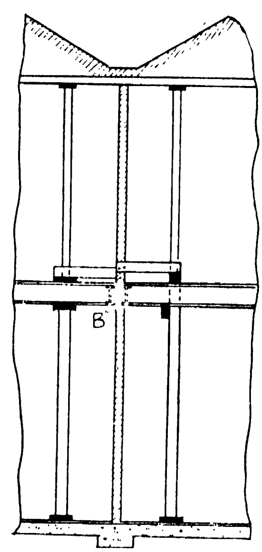


SCALES



SECTION

FIG. 44



ALTERNATIVE METHODS OF SHORING

FIG. 45

will be as follows. The roof and first story ceiling will be transmitted through the shores in the first story to the shores in the ground story, and also partly through the wall; the weight of the wall in the first story will be equally distributed, partly through the floor joists, and partly through the needles to the shores in the ground story; the first floor will be borne by the heads fixed to the shores, and consequently transmitted to the dead shores.

Calculations for Timbers. Calculate the loads, commencing from the roof and working downwards, and allow for one bay of shoring 5 ft. wide, as shown by plan, Fig. 43. Allow that half * of roof load is carried by the external walls, one-quarter by the centre wall, and one-eighth by each of shores.

Weight of 5 ft. bay of roof = total sloping lengths × width of bay = 28 ft. × 5 ft. = 140 super. ft. ÷ 2 * = 70 super. ft. × 0·5 cwt. (as Table) for slated or tiled roof = 35 cwt.

The centre wall will take 17·5 cwt., and each shore 8·75 cwt.

Weight of ceiling on each shore = 6 ft. × 5 ft. × 0·1 cwt. (as Table IV) = 3 cwt.

Weight of $4\frac{1}{2}$ in. wall (measured overall of doorway) = 5 ft. × 10 ft. × 0·375 cwt. = 18·75 cwt.

Weight of floor, timber framed, used for domestic purposes, on each shore, = 6 ft. × 5 ft. × 0·82 cwt. = 24·6 cwt.

The loads on the various members will be as follows :-

Heads Over Upper Shores, 11·75 cwt., uniformly distributed.

Upper Shores, 11·75 cwt.

Needles = weight of wall, and roof = 36·25 cwt., concentrated at centre.

Heads Under First Floor = floor only, and not including load of upper shores, which should be fixed over lower shores = 24·6 cwt., uniformly distributed.

Each Lower Shore = load from *one* upper shore plus half load of wall plus load of floor = $11·75 + \frac{36·25}{2} + 24·6$ = say, 54 cwt.

Calculations of Northern Pine Scantlings by formula as before explained :-

Heads Over Upper Shores. $11·75 = \frac{2 \times 4bd^2}{5 \times 4} = bd^2 = \frac{11·75 \times 5 \times 4}{2 \times 4} = 29·3$, or, say, 29.

A plank placed flatways against a ceiling is useful to distribute the load over a large area, so use 7 in. × 2 in., which equals $7 \times 2^2 = 28$; this is about suitable, though a little on the light side.

Heads Under First Floor. $24·6 = \frac{2 \times 4bd^2}{5 \times 4} = bd^2 = \frac{24·6 \times 5 \times 4}{2 \times 4}$ = say, 62.

$4\frac{1}{2}$ in. × 3 in. placed with greater dimension vertically will be a little on light side, but may be safely used, as $3 \times 4\frac{1}{2}^2$ = nearly 61.

Needles. $36·25 = \frac{4bd^2}{5 \times 4} = bd^2 = \frac{36·25 \times 5 \times 4}{4} = 181$. 5 in. × 6 in. needle = $5 \times 6^2 = 180$, or 4 in. × 7 in. = $4 \times 7^2 = 196$.

Upper Shores. Length = say, 9 ft., and load = 11·75 cwt. Refer to Table V and try 3 in. × 3 in.

$R = \frac{9 \times 12}{3} = 36$. $RC = 1·28$. Therefore 3 in. × 3 in. × 1·28 = 11·52 cwt., which indicates that the size is suitable. A 4 in. diameter scaffold pole would be equally efficacious.

Lower Shores. Length = say, 10 ft.; load = 5[illegible]. Try 6 in. × 6 in.

$R = \frac{10 \times 12}{6} = 20$. $RC = 3·6$ cwt. Therefore 6 in. × 6 in. × 3·6 = 129 cwt., which shows that the proposed scantling is too heavy. The nearest practical scantling is 5 in. × 5 in., as $R = \frac{10 \times 12}{5} = 24$; $RC = 2·75$. Therefore, 5 in. × 5 in. × 2·75 = 68·75 cwt.

Details of Construction. The upper heads should be secured to the ceiling joists by well spiking the upper shores to heads, and sole pieces also by well spiking; the needles must be "dogged" to lower shores, and the lower heads bolted to shores, with cleats under. The sole piece under lower shores should be 9 in. by 3 in. In some cases the upper shores might be dispensed with, and the whole of the roof and ceiling loads considered as borne by the wall; but generally this is contrary to the rule which dictates that walls should be relieved of as much weight as possible, as by so doing the needles may be placed at a maximum distance apart consistent with the greatest width that a brick wall will "hold itself together" without support. This distance is about 4 ft. and 6 ft. for work built, respectively, in lime and cement mortar, provided that the work is in good condition and properly bonded.

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