THE PRACTICAL CARPENTER AND JOINER

ILLUSTRATED

A COMPLETE GUIDE TO EVERY BRANCH OF THE TRADE FOR ALL THOSE ENGAGED IN THE CRAFTS OF CARPENTRY AND JOINERY

Edited by

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Reprinted 1946

ODHAMS PRESS LIMITED, LONG ACRE, LONDON, W.C.2

JOINERY PRODUCTION IN THE MODERN WORKSHOP

There is a distinct difference between the work of the Joiner and that of the Carpenter. The Joiner is concerned with the woodwork fittings and finishings of the building, such as doors, windows, panelling, stairs, skirtings and architraves, both in their preparation in the workshop and in fixing on the building site.

CONTENTS

STRUCTURAL CARPENTRY WORK IN PROGRESS

The Carpenter is primarily concerned with the structural woodwork of buildings such as roofs and floors, and with all woodwork necessary for the erection of the building, such as shuttering for concrete and centering for arches. The illustration shows typical activities connected with outside structural carpentry.,

CHAPTER 1

CRAFTSMANSHIP

TRADITIONAL METHODS. EVOLUTION OF WOODWORKING. PRESENT-DAY INFLUENCES. FUNDAMENTAL PRINCIPLES. TECHNICAL EDUCATION. KNOWLEDGE OF MATERIAL. MACHINE PRODUCTION. CARPENTRY AND JOINERY DEFINED. AVOIDING DEFECTS. WORKSHOP ASSEMBLY METHODS. FIXING JOINERY. HALL-MARK OF CRAFTSMANSHIP.

CRAFTSMANSHIP is the skill employed in making a thing properly, and a good craftsman is one who has complete mastery over tools and material, and who uses them with skill and honesty. The efficiency of the modern building still depends upon the sincerity of its builders.

A good craftsman does not do a thing anyhow. Practical experience of trial and error, perseverance and thought, extending over many centuries, have taught him the best way. The accumulated results of such experience have been handed down from craftsman to apprentice through generation after generation. Fig. 1 illustrates the evolution of tools through the ages, and shows how their shapes are the result of centuries of experience.

Making things in wood is one of the oldest industries in the world, and the craft of the carpenter and joiner has behind it a real and tangible tradition.

Just as craftsmanship is the basis of civilisation, so are the old methods and traditional processes the foundation of modern commercial production. Contemporary methods of jointing wood were used over 4,000 years ago, while the hand tools of today have much in common with those of the past.

The old forms and customs are retained because they are fundamentally sound, and because progress depends entirely upon the work of our predecessors. It follows that if we are to understand the present conditions we must know something of the past.

Development of Technique

Discoveries and changes have greatly influenced the trend of woodwork technique, but discoveries have been slow in effect and changes have been gradual.

These changes are illustrated by the everyday tools of the craftsman shown in Fig. 2.

The reluctance of certain sections of industry to accept any change is emphasised by the fact that while sawmills were first introduced over three centuries ago, hand-sawyers were still employed at the saw pit less than eighty years ago.

Despite this conservatism, the thinking craftsman will never do hours of monotonous work without finding means to shorten or lighten the task. Hence the many jigs and the patterns made by the craftsman for repetition work.

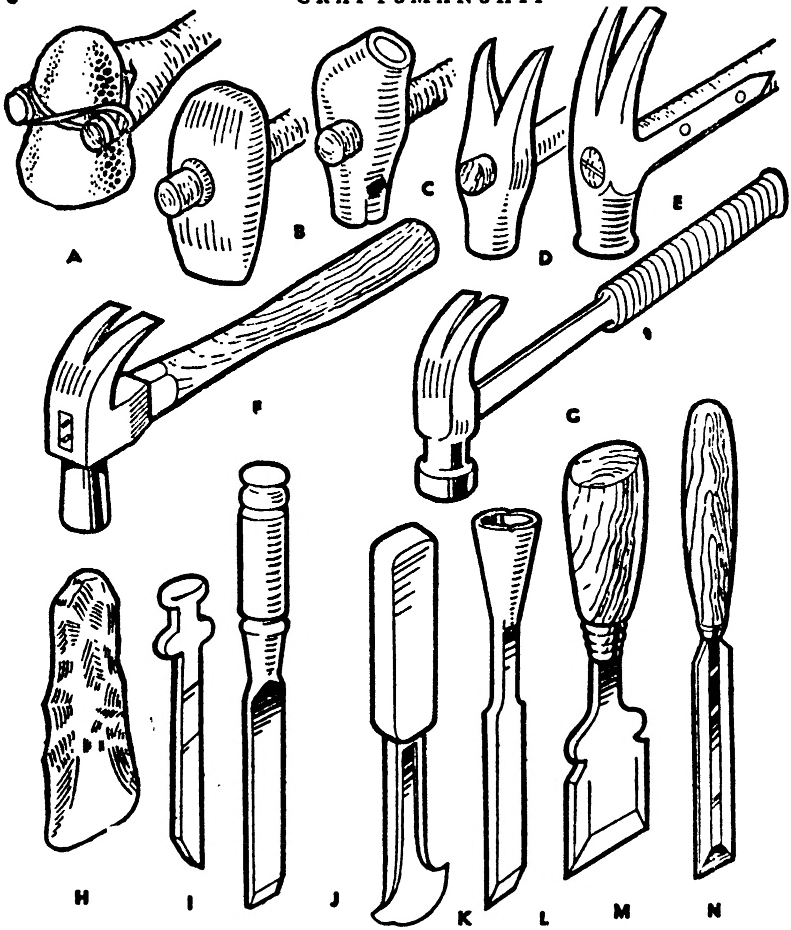


Fig. 1. Evolution of the Hammer and Chisel. HAMMERS. *A.* Shaped stone ; *B.* stone drilled ; *C.* deer horn ; *D.* bronze ; *E.* iron (Roman) ; *F.* adze eye claw (20th C.) ; *G.* all steel (modern). CHISELS. *H.* flint ; *I.* Roman ; *J.* Roman bronze ; *K.* bronze ; *L.* iron, socket ; *M.* 16th C. ; *N.* modern. (*Based on exhibits at the Science Museum, London.*)

Carpentry in the Middle Ages covered every conceivable kind of building work. The carpenter was the designer, builder and furnisher of the houses ; he cut his material from the standing tree and fashioned it to shape on the building site. The material had to be at hand ; the use made of it depended upon the experience of the individual and the tools at his disposal. Tools were crude and only suitable for the heaviest of work, while the carpenters suffered fatigue and strain from sheer toil which made them prematurely old. Nevertheless, many beautiful structures were erected. The splendid timberwork shown in Fig. 3 is a typical

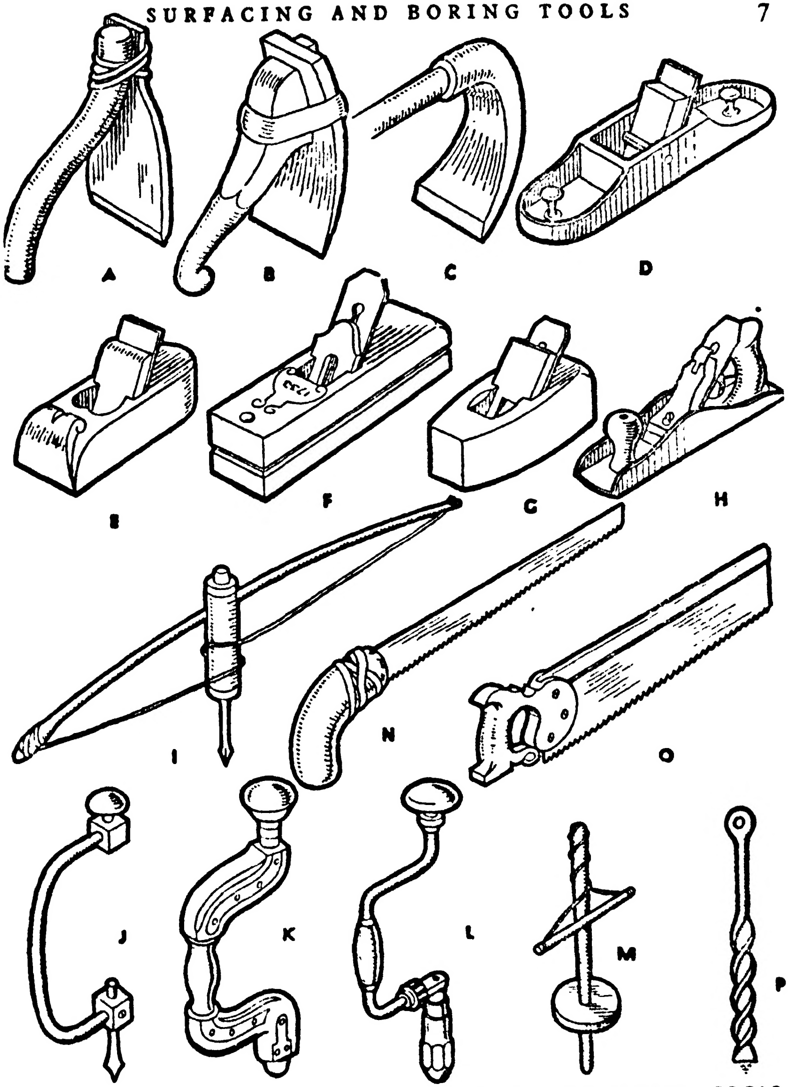


Fig. 2. Evolution of Surfacing and Boring Tools. SURFACING TOOLS: A. Adze (Egyptian); *B.* adze (16th C.); *C.* adze (18th C.); *D.* bronze plane (Roman); *E.* plane (17th C.); *F.* plane (18th C.); *G.* plane (19th C.); *H.* plane (Modern). BORING TOOLS: *I.* bow drill (Egyptian); *J.* brace (17th C.); *K.* brace (19th C.); *L.* brace (Modern); *M.* pump drill (Mediæval); *P.* auger bit (invented 1770). SAWS: *N.* Egyptian saw; *O.* handsaw (Modern).
(Based on exhibits at the Science Museum, London.)

example of mediæval carpentry, made at a time when craftsmanship was encouraged, first by religious bodies and then by guilds.

The evolution of woodworking to its present highly efficient state is characterised by the increasing practice of craftsmen to specialise

Fig. 3. This magnificent example of the mediæval craftsman's art embodies principles which are still used in modern joinery. The illustration shows the beautifully constructed 14th century timber roof of Penshurst Place, Kent. *(Reproduced by courtesy of C. H. Hayward.)*

in particular sections. Specialisation makes for economic production, and this factor alone is responsible for the segregation of sections of the building industry.

Some of the chief influences which affect present-day craftsmanship in wood are due to :—

(1) *Progress in Social and Economic Life.* The gradual levelling up of the standards of living has led to a demand for better building. Furthermore, the recognition of the worker as an individual has established greater material security for the craftsman.

(2) *Introduction of other Structural Materials.* The use of steel and concrete as constructional materials has caused very great

changes in carpentry work. Steelwork has limited the use of timber as a structural material, while concrete has created additional work for the carpenter in the preparation of moulds in which to cast the concrete.

(3) *Scientific Research on Materials and Methods of Construction*. This not only implies a further knowledge of the properties of traditional materials, but includes the introduction of new materials. Improvements in cementing materials have resulted in a more extensive use of plywood and laminated boards. The technique in the use of these materials is totally different from that of solid timber. Fig. 4 illustrates a few examples of this work.

Boards composed of many plies have eliminated the evil tendency of wood to split, warp and twist. Modern ply-boards can be used for almost any purpose for which solid wood is used, externally as well as internally.

Research has also made it possible to assess safe stress on various timbers, and has instigated a working system of grading timber for strength, resulting in a reduction in sizes of structural timbers.

(4) *Development of Woodworking Machinery* has brought into being the skilled machinist, the joiner setter-out, and the specialist firms of joinery manufacturers. Precision and accuracy hitherto unattainable are now possible.

Machinery has effected vast alterations in normal practice without entirely eliminating the need of the traditional methods adopted by the hand worker. With few exceptions, machine-made joinery still typifies the hand processes, instead of being deliberately designed for the economic exploitation of the machine. Fig. 5 shows the effects of machinery on some items of joinery. Note the tendency in construction to use smaller members with many complicated joints.

The machine encourages repetition work and standard sizes, and has made possible—

(5) *Mass Production, the Standardisation of Stock Joinery, and Prefabrication.*

Mass production is in keeping with the present age. When properly controlled it means efficient well-designed joinery at low prices, high wages and short hours, better working conditions and leisure for the operatives. It also means economy in labour and materials in the smaller domestic building.

If only a few joinery items are required, or a short length of wood is to be shaped, it is not economical to use machinery, as the expense in preparing the cutters would be relatively too great. Hence, the use of stock patterns and standard sizes, which are recognised throughout the industry, is essential for machine-made, mass-produced joinery.

Prefabrication

Prefabrication is the logical extension of the principle of mass-production, and consists of preparing completely finished articles in the factory ready for installation on the building site. The joinery is produced as a planned unit, and is merely assembled on the job. Timber houses, prepared in standard sections, and floor sections and roofs, may be constructed in this manner; while doors, completed in the factory

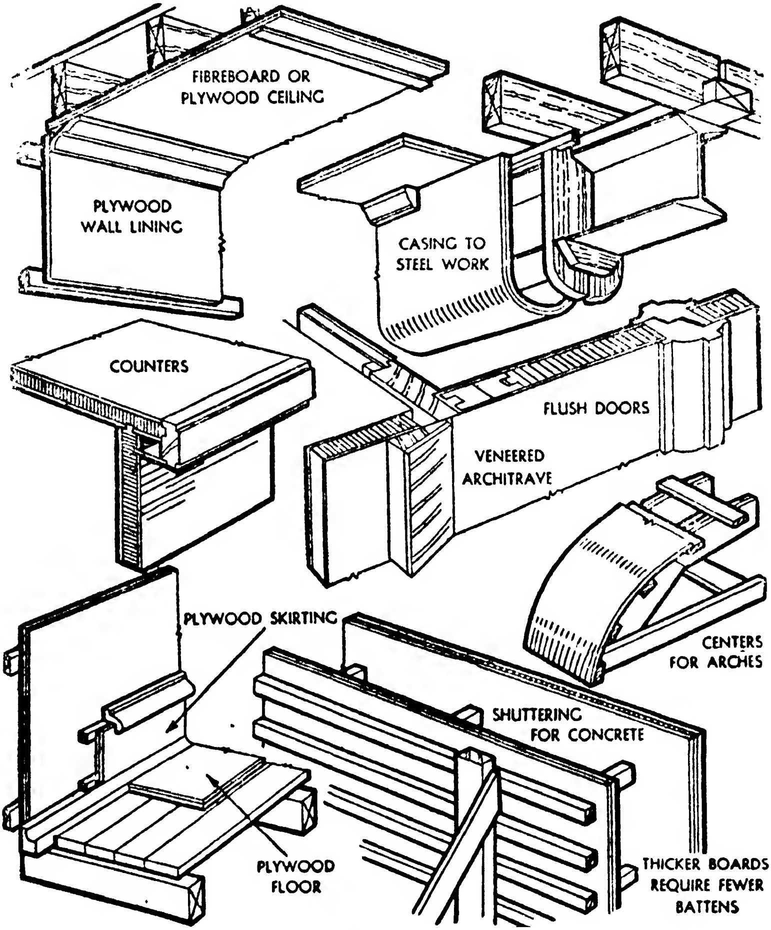


Fig. 4. Illustrating a few of the many uses of plywood and laminboard. The material will not swell or shrink; if the plys are resin-bonded, plywood can be employed as an external covering, centers for arches, or shuttering.

with all fittings and furniture and hung to their frames or linings, are excellent examples of organised production created by standardisation.

Such treatment of joinery demands better organisation on the building site, and more careful planning with the allocation of more supervisory duties. Fig. 6 shows one simple item in carefully thought-out planning; the cutting and preparation of roof rafters by machinery in the workshop before delivery to the site.

(6) *Methods of Training Craftsmen.* Recruitment and the training of personnel for carpentry and joinery are somewhat haphazard at the present time. The apprenticeship system of learning the craft, whereby a youth is

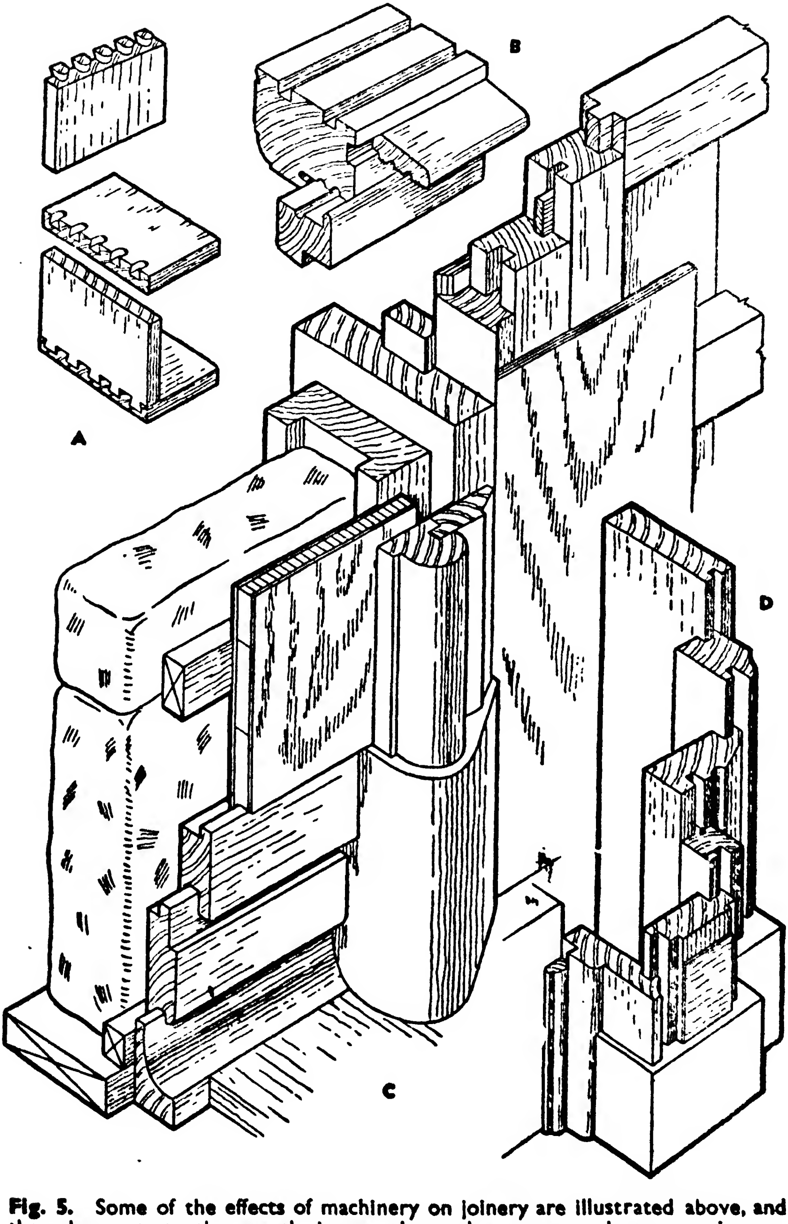


Fig. 5. Some of the effects of machinery on joinery are illustrated above, and they demonstrate the greatly increased speed, accuracy and economy in production. *A.* Machine dovetails ; *B.* window construction—smaller members with many throatings ; *C.* joinery finishings to door opening ; *D.* portion of 'built-up' architrave, consisting of small members with many joints.

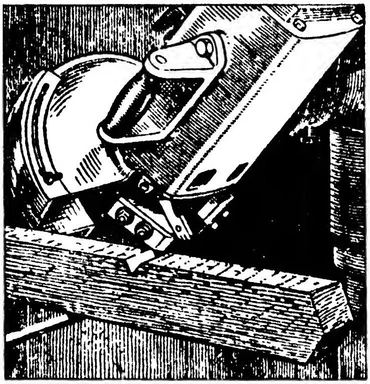


Fig. 6. Preparing roof rafters in the workshop. As much work as is possible should be done in the shop, where every convenience is available.

indentured for seven years, is gradually falling into disuse. It is impossible for the specialist firms to provide sufficient all-round experience required by the ambitious youth. Industrialists and education authorities are fully aware of the need for maintaining an adequate supply of skilled craftsmen, and realise that good craftsmen are not made without good training.

In an attempt to improve the training of apprentices, many large firms have arranged part-time day training in local technical schools. The provision of Junior Technical schools for the building industry also seems to point to a solution to the problem. Boys are admitted to the schools at the age of 13 plus, and follow a three-year course of instruction founded on a broad, scientific and realistic basis.

There are excellent opportunities for the trained craftsman to secure executive and supervisory appointments. A wide, practical experience is essential, and certificates issued as the result of examinations, are accepted qualifications. The intermediate and final certificates of the City and Guilds of London Institute denote a high degree of competency for the carpenter and joiner. They are concrete evidence of a comprehensive technical training, craft ability, and an all-round knowledge of trade processes.

There are three ways of obtaining technical training: (1) private study; (2) correspondence courses; (3) attendance at the nearest technical school.

Undoubtedly the best training is obtained by attending a technical school. Most schools cater for the carpenter and joiner, and hold evening classes; their syllabus is based on present-day needs, and facilities are available for practical experience.

Fundamental Principles

There are certain fundamental principles of craftsmanship which are vital to all good work:—

(1) An understanding of material.
(2) A complete mastery of tools.
(3) Knowledge of construction.
(4) Appreciation of good design.

A craftsman must know his material, and have an almost instinctive 'feel' of it, a sense of what can be made with it, and a recognition of its limitations and shortcomings. This is imperative because the entire work of the carpenter and joiner is controlled by the nature of the material. Wood is limited to certain dimensions dictated by custom and the sizes of trees. Joinery softwood averages 9 in. in width, and rarely exceeds 27 ft. in length; a sixteenth of an inch is always allowed for each planed surface; thus the joiner has to deal with two different sets of sizes, the nominal or sawn size, and the finished or planed size.

An important feature of wood is that it will swell and shrink according to the changes of humidity in the surrounding atmosphere. This tendency of wood to change must be taken into consideration. Fig. 7 shows how the skill of the craftsman is employed to combat this tendency of wood to move.

Under certain conditions wood will decay, and provision must be made to prevent this by the use of the right kind of wood.

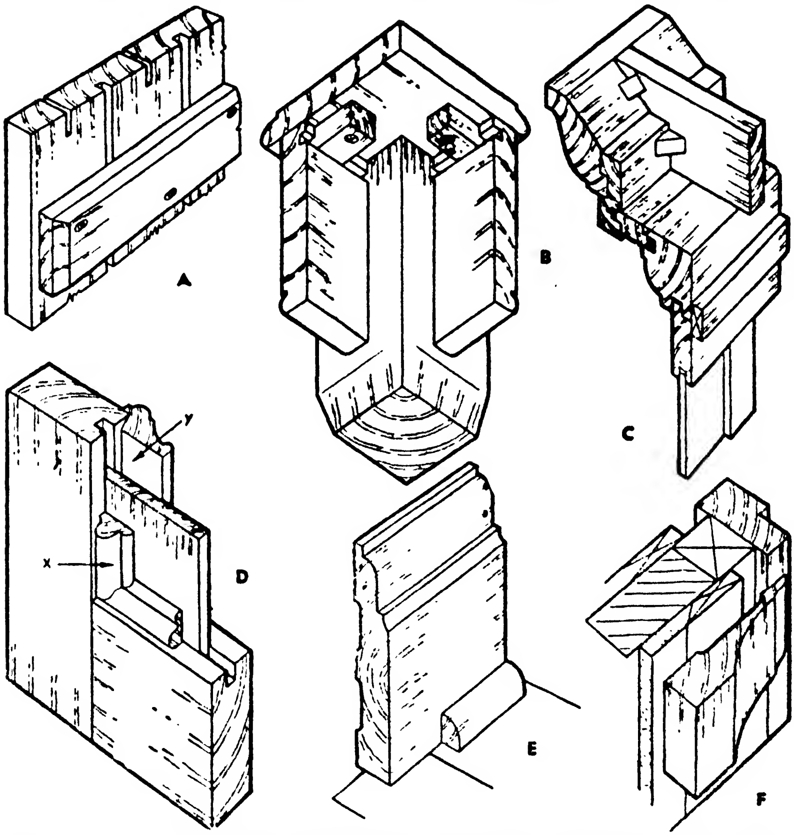


Fig. 7. A. Portion of drawing-board with slot screws to maintain a flat surface, saw kerfs and grooves to counteract shrinkage; B. portion of table showing use of buttons to hold large surfaces; C. cornice composed of small members to eliminate distortion; D. portion of panelled door. Note allowance for panel to swell. Planted moulding X is nailed to the frame and not to the panel; bolection moulding Y is slot screwed and undercut to avoid curling due to shrinkage; E. portion of skirting board with 'heart' on face to balance the tendency of the wood to warp. Note strip to cover shrinkage of floor joists; F. portion of architrave 'backed out,' i.e., grooved to reduce the sectional area so as to minimise warping. All these drawings illustrate the methods employed by the craftsman to combat the movement of wood.

To the craftsman, tools are symbols of a great heritage. He handles them with loving care, with deep respect, with skill and economy of effort.

Craftsmanship is not associated exclusively with handwork. The fact that we live on machine production must be acknowledged. A machine is only a tool, and it needs the hand and brain of a craftsman for guidance, control and maintenance. It does not matter if the craftsman uses a chisel or a spindle moulder, it is the quality of the work that counts; good work is still good, whether made by hand or machinery, whether made a thousand years ago or yesterday.

We emphasize with all possible vigour that the standard of craftsmanship to-day is better than ever. There are innumerable instances of good craftsmanship in the modern building, good because of their fitness for their purpose, their ingenuity and their growth under the craftsman's perseverance and thought.

It is obvious that the purpose and design, as well as the material, must decide the form of construction. Every item of carpentry or joinery must serve some useful purpose.

Carpentry and Joinery Defined

Carpentry may be defined as the structural work on a building. It is almost exclusively employed for the support of weight or pressure; thus, strength, durability and rigidity are the chief considerations. The work may be a permanent feature of the building, or it may be only of a temporary nature. In carpentry, wood is invariably referred to as *timber*.

Joinery may be defined as the woodwork fittings to a building. As a pleasing appearance is important, end grain, joints, and fixings should be concealed whereever possible, and the finish of the work should receive special consideration.

The chief features of good joinery are:—(*a*) Clean, flat surfaces; (*b*) straight, sharp arrises; (*c*) close-fitting joints; (*d*) accurate dimensions; (*e*) proper selection and use of material.

Joinery may develop faults by: (*a*) Excessive shrinkage causing warping, checking and the exposure of joints; (*b*) insufficient care during transit to the site and storage on the building; (*c*) decay of the material; (*d*) improper fixing.

To avoid defects occurring in joinery, the material should be selected from well-seasoned stock, and wherever possible should be dried to the required moisture content of the building (see Fig. 8, Chapter 2) and maintained in that condition throughout.

In joinery, wood is referred to as *stuff*.

Joinery work is divided into two distinct classes:—(*a*) Preparation and assembling of the joinery in the workshop; and (*b*) fitting and fixing of the joinery on the building site.

(*a*) Shopwork is divided into further sections according to the type and methods employed in preparing the joinery.

(1) The manufacture or mass-production of standardised units of joinery. In this case, all processes are executed on the machine, even the marking-out is done by the machine with the aid of jigs and patterns. The

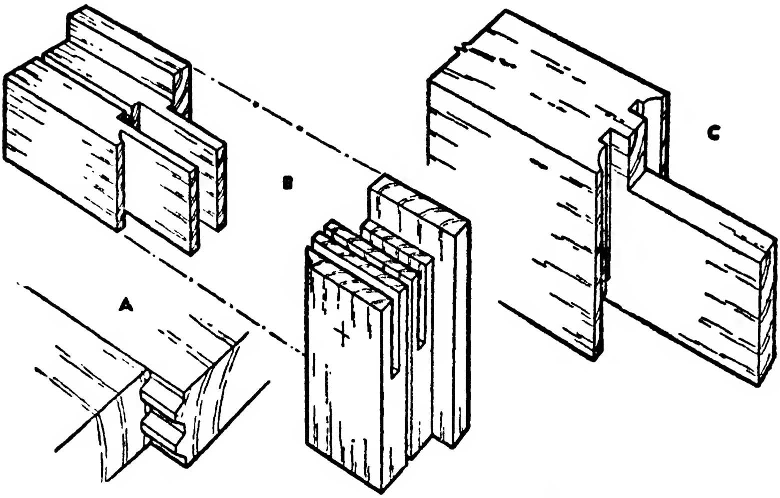


Fig. 8. Typical examples of machine-produced joinery. A. Typical machine joint to wide surfaces ; B. joint between rail and stile of a mass-produced window sash ; C. rail of a panelled door, machine-scribed ready for assembling.

assembling of the parts is the only operation done by hand labour which is regarded as a necessary evil to be tolerated until the machine can replace it. Fig. 8 shows a few details of machine-produced joinery.

(2) Individual work to a special requirement. It is sometimes more economical to do some of the work by hand methods, as the expense involved in preparing cutters and setting up the machine is too costly.

(3) Good class joinery. This invariably means individual work. The greatest difference between high-class joinery and domestic joinery is that more attention must be given to the larger pieces of wood in order to persuade them to remain stable in the positions in which they are fixed.

(*b*) Fixing joinery on the building site is also divided into two general classes. (1) First fixing, which includes the installation of all fixings not completed by the carpenter in carcassing; and (2) second fixing, which includes the final completion of the joinery and the fitting and fixing of all metal fittings.

Craftsmanship implies a great deal more than technical knowledge, though technique is naturally an important element in it. A craftsman must be prepared to give of his very best at all times, to strive for perfection, and to cherish an ideal, however difficult it may seem at the time. His work is judged solely by his efforts, by the tangible things he does.

A beginner may be chagrined at his lack of opportunity as he essays his chosen task, and must be prepared for disappointments.

But despite the scepticism of many, the human desire to achieve and do good is still the mainspring of human endeavour. It is the hallmark of true craftsmanship.

CHAPTER 2

TIMBER

CLASSIFICATION. STRUCTURE. HOW TREES GROW. PROPERTIES OF TIMBER. SEASONING. METHODS OF CONVERSION. FUNGAL DECAY AND INSECT DAMAGE. DEFECTS. PRESERVATION. TIMBER SIZES. GRADING. PLYWOOD AND VENEER. HARDWOOD AND SOFTWOOD SELECTION CHARTS.

TIMBERS of commerce fall naturally into two main botanical classes: 1. Angiosperms; 2. Gymnosperms. Angiosperms include Dicotyledons, or the broad-leaf trees; the timber trade knows these trees as hardwoods, and they include such trees as oak, ash, elm, mahogany, teak, etc.

The Dicotyledons are characterised by comparatively broad leaves and complicated flowers, with the seeds enclosed in seed cases. Gymnosperms include the great family of *Coniferæ*, or the softwoods. These are characterised by needle-shaped (or sometimes scale-like) leaves; and simple flowers, and fruit in the form of a cone in which the seeds are born naked, i.e., not enclosed in a seed-case.

These main groups of trees are further divided into families, e.g., *Salicaceæ* (consisting of all the poplars and willows), and the families in their turn are subdivided into genera and species. Every timber is given two botanical names, e.g., *Pinus sylvestris* (Scots pine); the first name is the genus, and in this case *Pinus* includes all the true pines, and the second is the specific name which only one tree possesses.

Frequently it will be seen that after the name a letter or an abbreviated word is placed, e.g., *Pinus sylvestris* L. This refers to the botanist who named the species, in this case the famous Swedish botanist Linnæus.

Structure of Timber

Timber, in common with all other living organisms, is made up of a multitude of microscopic cells. They may be compared with the cells of a honeycomb, but are of various shapes, some square, others rounded in the nature of a balloon, others long and tapering like a needle, as shown in Fig. 1. The cells are, of course, closely joined together and form a compact whole. They may be isolated by dissolving the substance which cements them together. It is convenient to consider the two main classes of timbers (i.e., softwoods and hardwoods) separately, as their structure is quite distinct.

SOFTWOODS. The softwoods are very simple in structure and consist of only two main types of cells. The first and most important of these is the so-called tracheid which makes up the most of the wood substance. The tracheid is a spindle-shaped or cylindrical cell, often bluntly pointed at both ends. The tracheids are arranged in the timber in radial rows of almost

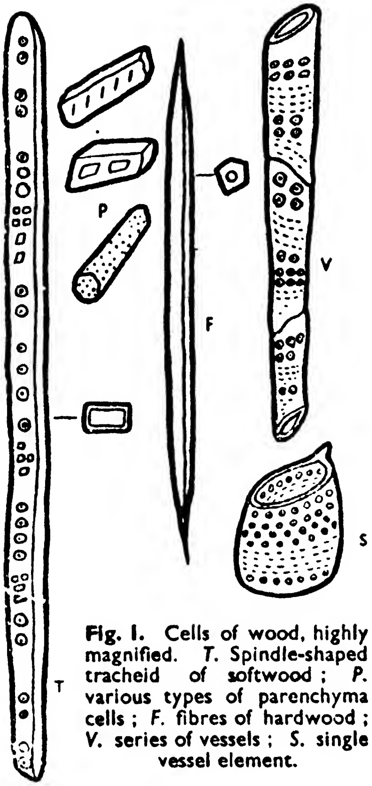


Fig. 1. Cells of wood, highly magnified. *T.* Spindle-shaped tracheid of softwood ; *P.* various types of parenchyma cells ; *F.* fibres of hardwood ; *V.* series of vessels ; *S.* single vessel element.

geometrical precision as may be seen in Fig. 2 A and B, and they vary in shape and the thickness of the wall according to whether they are formed in the spring or later in the summer.

In the spring the walls are thin and the cross-section of the tracheid is almost square. The summer-formed tracheids, however, are much flattened radially, and have much thicker cells. This is due to the fact that in the early spring, growth is vigorous, the shoots are elongating and call for rapid supplies of sap, so that the conducting tissues of the stem, i.e., the tracheids, must have as large cavities as possible.

This brings us to the functions of the tracheid, which are dual; first, giving mechanical strength to the trunk of the tree or the branch, and secondly, acting as a conductor of sap from the roots to the crown. The latter function can be carried out because the various tracheids communicate with one another by a series of pits, which are of two kinds :

(1) *The simple pit*—which is a slit-like, rounded or squareish hole in the cell wall, extending as far as the middle lamella (the cementing substance which joins two cells together). Usually there is a corresponding pit in the adjoining cell, so that the two cells are only divided by the very thin middle lamella.

(2) *The bordered pit*—this, also, is an area of unthickened wall, and is circular, but it differs from the simple pit in that from the edge of the unthickened area a dome-like wall protrudes covering the actual pit except for a small hole in the centre of the dome. In the surface view a bordered pit appears as two concentric circles, the smaller being the aperture in the dome, and the larger, the edge of the thickened area. There are various modifications of these two main types.

Cell 'Rays'

The second type of cell found in softwoods is the *parenchyma* cell, which is thin, small and more or less rectangular. It is furnished with pits connecting it with the tracheids; these are usually of the simple type. A vast majority of the *parenchyma* cells form 'rays' which appear on a cross section as lines arranged radially (Fig. 2). The rays are

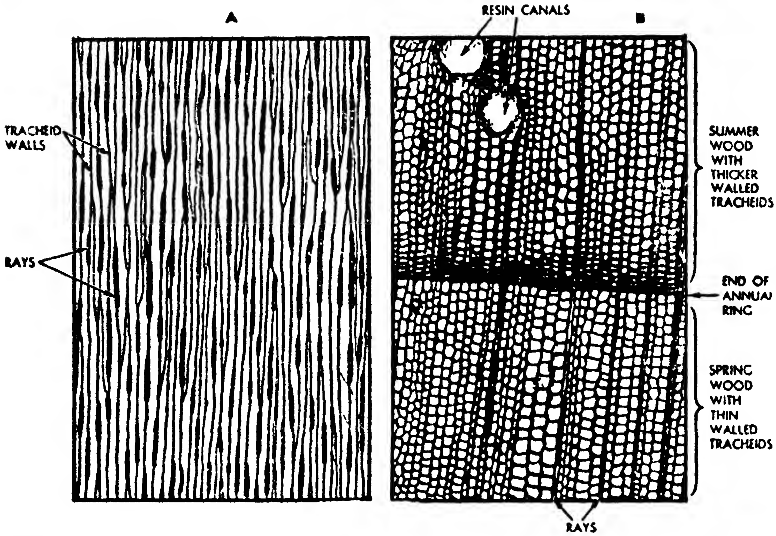


Fig. 2. Softwood Structure. *A*. Longitudinal (tangential) section through a softwood, highly magnified ; *B*. transverse or cross-section of a softwood, highly magnified. Note the symmetrical arrangement of the tracheids in radial rows.

usually one cell wide, and their function is to store foods and sometimes resin, although the majority of the resin is contained in specialised resin canals, or resin cells.

Hardwoods. The structure of the hardwoods is more complex than that of softwoods. The majority of the timber consists of *fibres* which are similar to tracheids, but are seldom arranged in strict radial rows ; they are usually shorter and very sharply pointed ; also they are only comparatively rarely pitted, as their function is mechanical.

Other cells not seen in softwoods are the 'vessels' or 'pores.' These are comparatively wide cells and are superimposed one on the other to form a continuous tube, the end walls being either absent, or heavily perforated.

These vessels can be seen as continuous tubes on the longitudinal section (Fig. 3). They may be either large, e.g., as in oak and elm, when they can be seen with the naked eye in the solid timber as fine scratches, or minute as in poplar and willow. The function of the vessels is to conduct the sap from the roots to the crown.

Parenchyma is also present in hardwoods, and this may be in the form of complicated rays consisting of hundreds of cells ; it may surround the vessels or be scattered throughout the fibres.

How Trees Grow

Annual rings. The well-known annual rings are formed by the early spring wood having finer cell walls and larger cell cavities than the later firm summer-wood. In the case of hardwoods, the ring is often accentuated by the presence of very much larger vessels at the commencement of a season's growth (Fig. 3).

The underlying principle of tree growth is that water with various salts dissolved in it is absorbed by the roots and travels up the trunk to the leaves. Here the leaves form sugars from the carbon-dioxide of the air in conjunction with the water from the roots by the action of sunlight (known as photosynthesis).

The food, when made, is passed down the trunk where it causes growth in diameter to take place; some also passes to the roots and enables them to grow. The tree grows in two directions, i.e., in height and diameter. In the former case the actual growth takes place in the bud at the end of the twig, where the cells divide and expand, forming a new shoot.

Growth in diameter is caused by the dividing of a layer of cells which extends like a skin over the entire tree, including the trunk, branches, twigs, and roots, and is situated immediately beneath the bark. This layer, known as the *Cambium* (Fig. 4), cuts off cells on either side of it.

On the inside, the cells become wood, and act as conductors for the sap going up the tree, while the cells cut off on the outside become 'bast' or 'phlœm,' and it is this that conducts the foodstuffs from the leaves down the trunk. The bast layer is very much thinner than the wood layer; in fact, the whole bast is included in the term 'bark.'

Properties of Timber

1. MECHANICAL PROPERTIES. The strength of timber is divided into various categories for practical purposes. These categories are illustrated in Fig. 5.

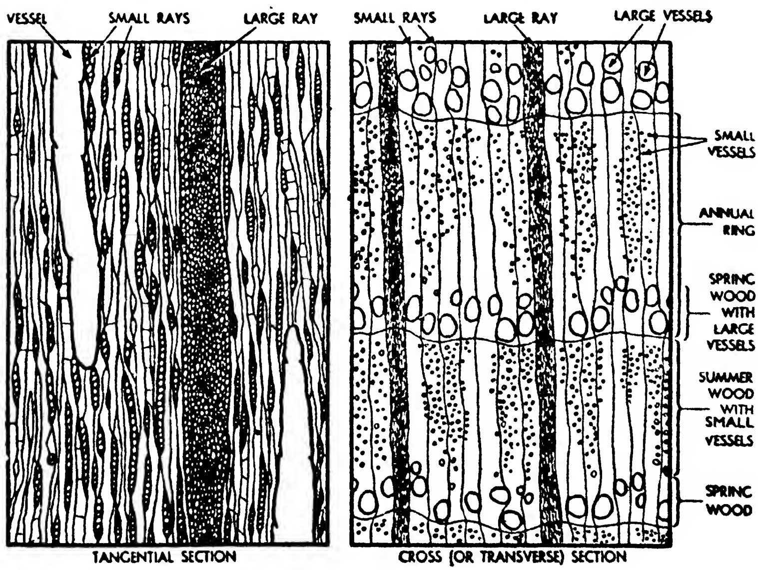


Fig. 3. Hardwood Structure: Oak (*left*) longitudinal section (tangential), highly magnified; (*right*) transverse or cross-section, highly magnified.

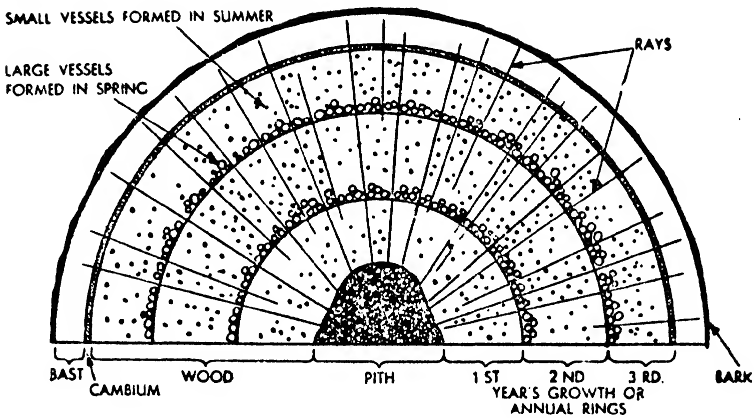


Fig. 4. Diagram of a cross-section of hardwood twig three years old. This is known as a ring porous wood because the pores are formed in concentric rings.

(a) *Bending Strength* : In determining the bending strength of timber, two tests are used : *Static bending test*, which determines the maximum bending strength and is called 'modulus of rupture.' This is used for finding the strength of joists and rafters. The stiffness of the timber is also found in this test and it is very important ; more so in such cases as joists carrying a plaster ceiling, for instance, than the ultimate bending strength.

Impact bending test which determines the ability of the timber to resist a suddenly applied load. This property is often called 'toughness' and is important for such purposes as sports goods.

(b) *Compression Strength :* The amount of crushing force which a timber will resist is important in determining the size of pit props, posts, and even air-screws.

(c) *Shearing Strength :* The resistance of timber to shearing along the grain is of importance in such cases as tenoned joints.

(d) *Hardness :* The hardness of timber, as is shown by its resistance to indentation, is obviously of great importance.

(e) *Cleavage Strength :* This is the resistance of the wood to splitting with the grain.

Tensile Strength : This is the strength which resists the timber being pulled apart in the direction of the grain. Most timbers have very high tensile strength.

When in use, timber may be subject to several kinds of force simultaneously. A beam, such as a joist, when bent under a load, has compressive forces in the upper half and tensile forces in the lower, while between the upper and lower surfaces, in horizontal planes, there are forces tending to cut or shear horizontally.

2. Heat Insulation. It is a general truth that timber that is light in weight is a better heat insulator than heavy timber. This is because the light timber has thin cell walls with large cavities in which there is air; and this

is important, for dead air spaces help to retard the transmission of heat. A heavy timber, on the other hand, has a very much smaller amount of dead air in it.

3. Fire Resistance. Although timber is regarded as highly inflammable, this depends entirely on the species and grade of timber and its size. Thus a small piece of softwood will burn easily (e.g., kindling); on the other hand, large beams of almost any timber are very difficult to burn, and certain timbers, such as jarrah, teak and padauk, are extremely resistant to fire.

It is a general truth that the denser the timber the more resistant it is to fire. The L.C.C. include the following timbers which they permit to be used as fire-resisting materials for building purposes :—oak, jarrah, karri, padauk, Burma teak, Nigerian walnut, iroko, crabwood, mora, Tasmanian myrtle, and Indian silver greywood; also softwoods (2 in. thick) impregnated with ammonium phosphate.

Seasoning

Seasoning consists of the drying out of a certain amount of moisture from the cells and cell walls.

Immediately after felling, many of the cells of timber contain free water and the cell-walls are saturated. For this reason, growing timber contains more than its own weight of water.

When timber dries, the first thing that happens is that the free water evaporates, and at the stage when the moisture appears to be dried out from the cell walls, seasoning proper begins.

The degree of seasoning is measured by the amount of moisture left in the timber at any time, and it is expressed as percentage moisture content of the dry weight of the timber. This figure is found by weighing a piece of timber, then drying it in an oven until, on repeated weighings, no further loss of weight occurs; then noting its dry weight, and using the following formula.

$$\frac{\text{loss of weight}}{\text{dry weight}} \times 100 = \begin{cases}\text{percentage} \\ \text{moisture} \\ \text{content.}\end{cases}$$

Shrinkage. Since moisture forms part of the chemical composition of the cell wall, when some of it is withdrawn the wall

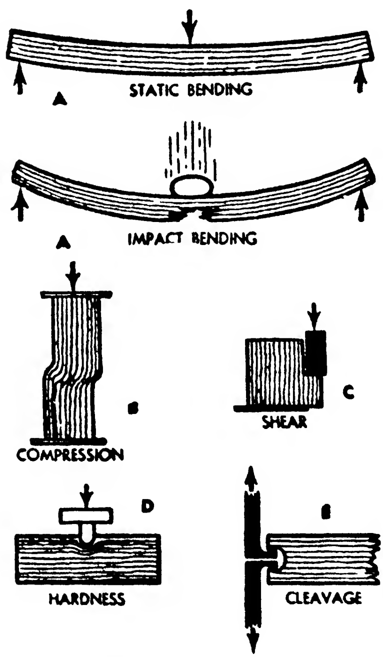


Fig. 5. The strength of timber is the resistance of the wood to external forces which tend to change its size or shape, and includes such properties as stiffness, toughness, cleavability and hardness, in addition to the power to resist compression and tension

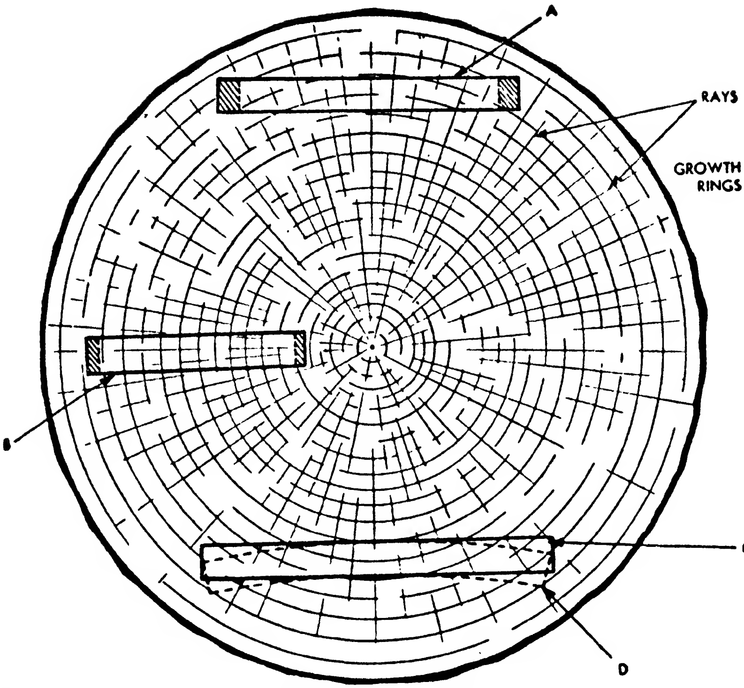


Fig. 6. The end of a log, showing shrinkage. A. Plain or slash sawn board ; B. quarter or rift sawn board, the shaded portions indicate the amount of shrinkage ; D. is the position which a plain sawn board (C) will assume in drying.

is bound to shrink; which is a brief explanation of the shrinkage when timber dries. The greatest amount of shrinkage occurs in the direction of the annual rings ; thus, in a plain-sawn board, i.e., one in which the annual rings tend to be more or less parallel to the surface of the board, shrinkage will be greater than in a quarter-sawn board where the annual rings are at right angles to the surface (Fig. 6). It also explains the phenomenon of warping ; in the case of a plain-sawn board, for instance, the side farthest from the heart tends to become concave, since this surface shrinks more than that nearest the heart ; this equal shrinkage causes various splits and cracks.

A log, for instance, will even show splits stretching from the centre to the outside. But unequal shrinkage is also caused by uneven drying ; it is obvious that in a large piece of timber the outside layers being nearest the air will normally lose moisture faster than the inner layers ; thus the outer layers will shrink more quickly than the inner layers, and a stress will be set up, and splitting will very often occur. The splitting at the ends of boards which are stacked in the open is of course, caused by the greater evaporation from the end grain.

Methods of Seasoning. There are two main methods of seasoning :—(1) Air Seasoning. (2) Kiln Seasoning.

Air Seasoning. In this method the boards are neatly stacked one above the other, and each board separated from its neighbour by narrow wooden sticks (usually ¾ in. or 1 in. square) which are known as 'stickers.' These stickers should be placed directly one above the other in order to prevent twisting.

The object of the stickers is to allow the air to flow through the piles and against each surface of the boards, and so evaporate the moisture. A rule for air seasoning is that easy drying softwoods should be piled late in the spring or early in the summer, as they are tolerant of fast drying and less likely to become stained. Hardwoods and slow-drying softwoods should best be piled in winter, as they will then dry slowly at first, and so be less liable to split or warp.

Kiln Seasoning (Fig. 7). A kiln consists principally of a brick chamber with heating pipes either in the floor or ceiling, usually fans to keep the air circulating, and a number of jets through which steam is passed into the kiln.

The timber is piled in the same way as with air seasoning (i.e., with stickers), and the doors shut, steam introduced and the heating pipes kept at a comparatively low temperature. Gradually the heat is increased and the humidity reduced until sufficiently dried.

Moisture Content for various Purposes. Fig. 8 gives the correct moisture-content for timber used in various conditions, and shows the importance of using the right moisture-content.

Conversion of Timber

The process of sawing logs into planks, boards, scantlings, etc., is known as *conversion*, and the further working of the timber into exact sizes for specific purposes ; making of mouldings, the

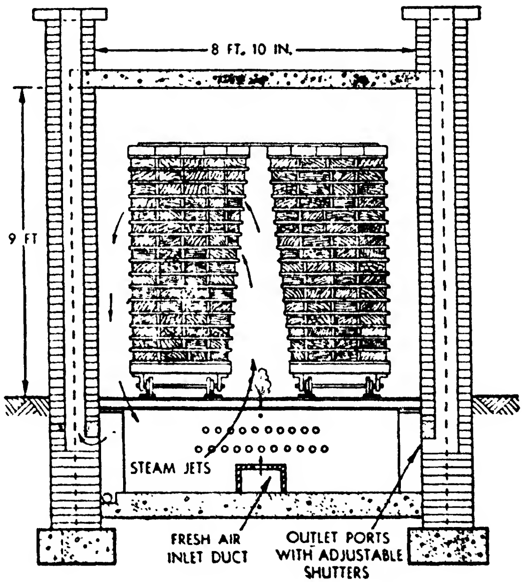


Fig. 7. Modern method of seasoning timber, illustrating a section of a natural draught kiln. Drying is accelerated without warping or checking to a predetermined moisture content. (From Forest Products Research Records No. 13 : 'Types of Timber Kilns.') *(Reproduced by permission of the Controller, H.M. Stationery Office.)*

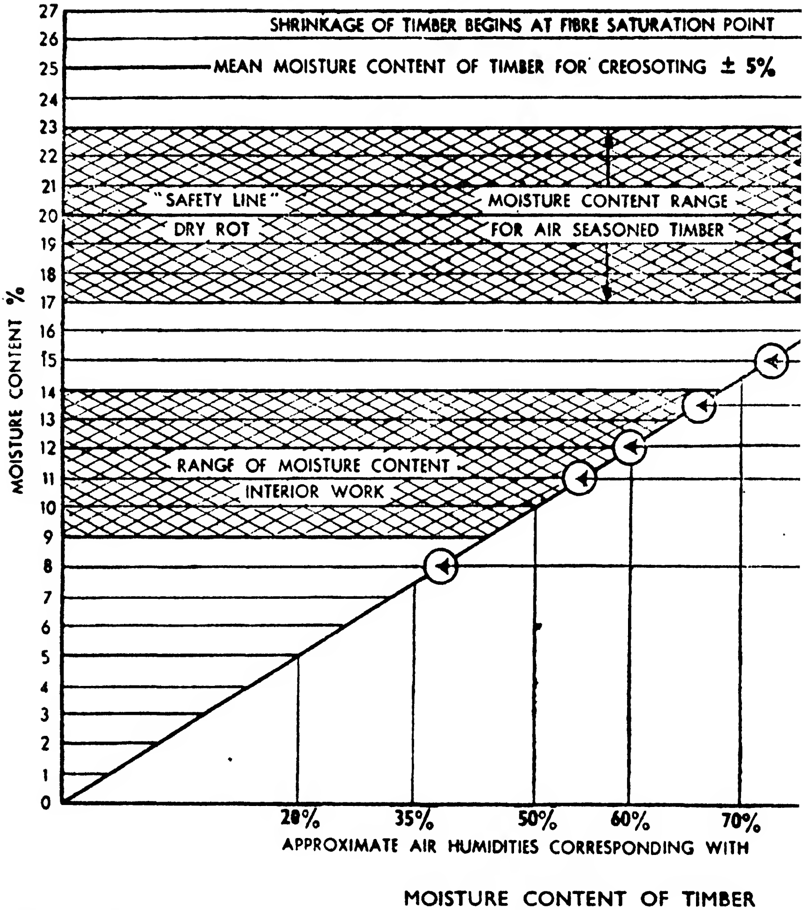


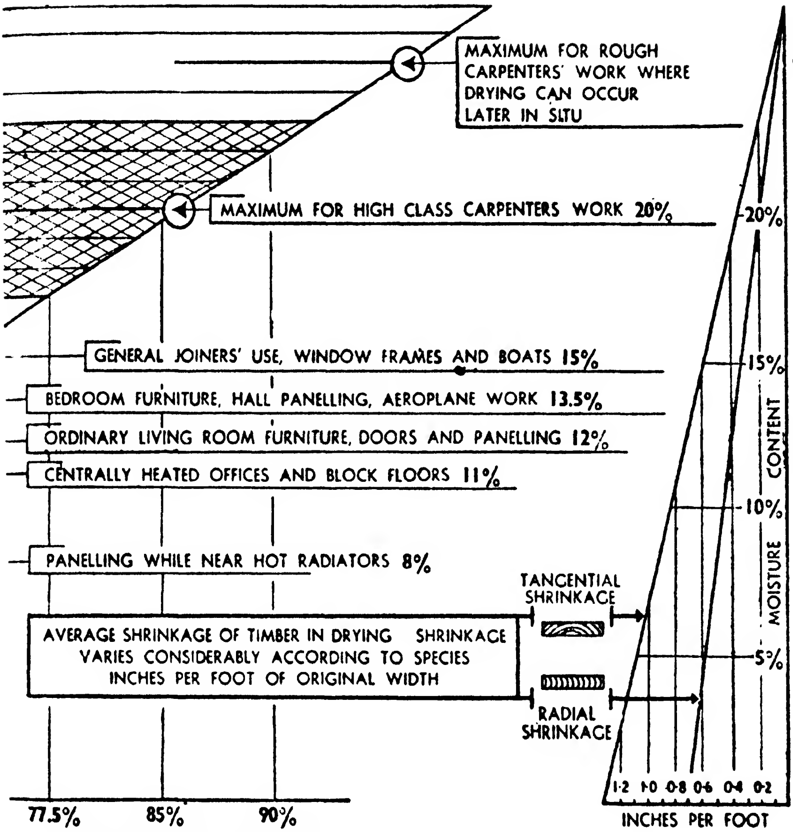
Fig. 8. Diagram showing moisture contents of timber for various purposes. (From Forest Products Research Records No. 4: 'Timber Seasoning.')

tonguing and grooving of flooring strips is known as *manufacture.*

The log on entering the saw-mill is first 'broken down' and this is done by a *rip saw* which may be either a large circular saw, or a band saw (Fig. 9).

A type of reciprocating saw which is widely used is the so-called 'frame saw,' which consists of a number of saws set vertically in a frame and parallel to each other (Fig. 10). The log is pressed against the saws and cut in one operation into a series of boards or planks.

METHODS OF CONVERSION. The simplest method of breaking down a log is by a *through-and-through* cut. This means that a series of parallel cuts is made through the entire log (this is the case with a frame saw, as at Fig. 11 A). This is not satisfactory, however,



MOISTURE CONTENTS OF TIMBER

UNDER VARIOUS CONDITIONS

The figures for different species vary, and the chart shows only average values. (*Reproduced by permission of the Controller, H.M. Stationery Office.*)

when such material as flooring is required; for this purpose quarter-sawn stock is required.

By *quarter-sawn* is meant that the annual rings are at right angles to the face side of the board. Methods of producing quarter-sawn material are indicated in Fig. 11. In order to avoid wasting timber in the log, the method of conversion is extremely important.

When the log has been broken down, the material obtained is resawn, i.e., the boards, are cut into more accurate sizes for definite purposes.

Decay of Timber

Decay of timber is caused by the action of *fungi*: the attack by insects comes in a different category and will be considered later. A fungus is a kind of plant which can only live by

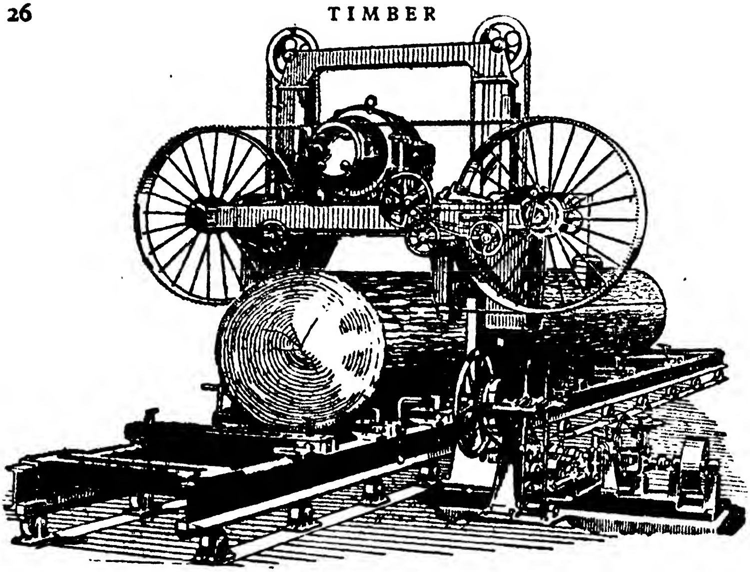


Fig. 9. The process of converting a log into 'lumber' is known as 'breaking-down.' The diagram shows a horizontal type of band saw in operation.

feeding on organic material. It cannot form food from air and water as the higher plants do. Also, unlike the higher plants, it consists of cells which are nearly all thread-like (and called '*hyphæ*'); its flowers (known as 'fructifications' or 'fruit bodies') propagate the fungus by producing *spores* which correspond to the seeds of ordinary flowering plants.

In order to live, a fungus must have (a) food—either wood or some other organic substance; (b) a certain amount of moisture. If wood is kept quite dry it is immune from fungus attack; (c) oxygen—wood, hermetically sealed or submerged in water, cannot be attacked; (d) a suitable temperature—while fungi will remain alive at comparatively extreme

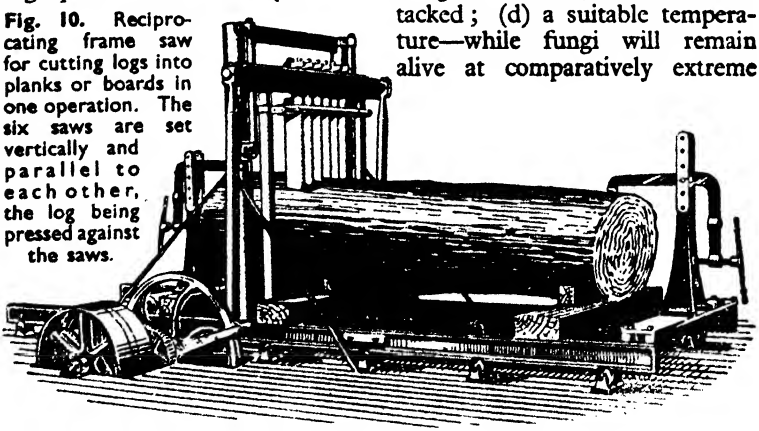


Fig. 10. Reciprocating frame saw for cutting logs into planks or boards in one operation. The six saws are set vertically and parallel to each other, the log being pressed against the saws.

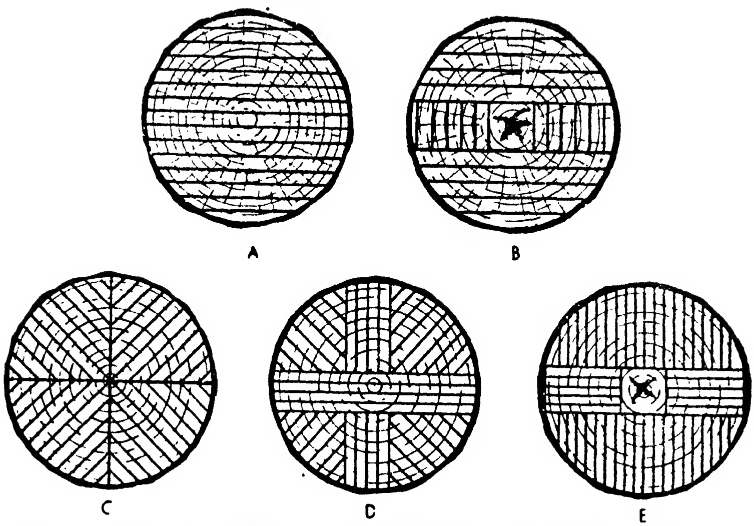


Fig. 11. Methods of converting logs. A. Plain sawn—through and through cut; B. plain sawn—method of boxing a defective heart; C. quarter sawn—gives decorative figure in oak by the exposure of rays; D. better method of quarter-sawn boards; E. quarter-sawn log with a defective heart.

temperatures, they remain immobile under low temperature. Should any of these factors be wanting the fungus will not grow. This allows for various methods of preservation (see p. 30).

How fungi decay wood. The thread-like hyphæ creep into the wood and bore minute holes in its cell-walls (Fig. 12) and absorb the substance of the wood as food. The rapidity with which the hyphæ branch out causes sufficient of the wood to be broken down to produce a softening and final disintegration of the wood—a state which is called 'decay.'

Staining fungi. Certain fungi which inhabit wood live only on the contents of the cells and not on the cell-walls; for this reason they are only found in the sapwood and do no mechanical harm to the timber, but the dark colour of the hyphæ causes the timber to become discoloured. The 'blueing' of softwoods is a common example of this process.

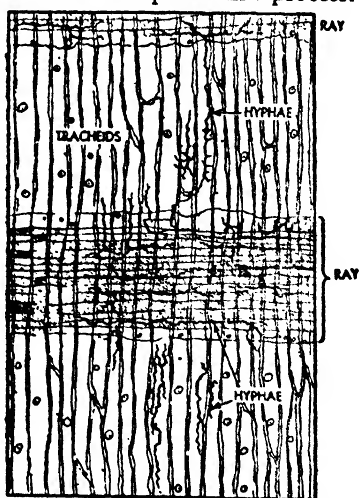


Fig. 12. How fungi destroy wood. Highly magnified radial section of softwood showing threads (*Hyphae*) of a wood-destroying fungus in the cells.

Dry Rot. The principal fungus causing dry rot is *Merulius lacrymans*. It is particularly dangerous because it can carry moisture with it as it grows in thick, root-like strands, which moisten dry timber and render it susceptible to attack. These strands can traverse considerable distances, and over (and even through) mortar, brick, etc., in search of timber.

To prevent dry rot, all timber should be kept dry, and if this is impossible, the timber should be treated with a preservative. To treat dry rot, the following are the main steps which should be taken :—(a) Remove all affected wood, and burn it ; (b) sterilise walls, etc., which have been in contact with, or near the rot, by treating with a preservative and/or flaming with a blow-lamp ; (c) treat all apparently sound timber with a preservative ; (d) treat all new wood introduced with a preservative before installing it ; (e) provide adequate ventilation.

Insect Attacks

There are three main wood-destroying insects which are found in Britain :—

Furniture Beetle (*Anobium punctatum*), often called ' wood worm.' The beetle is from $\frac{1}{10}$ in. to $\frac{1}{5}$ in. long, dark brown, the wing covers marked with a series of minute punctures (see Fig. 13 A). From June to August the beetles emerge from the wood (leaving the well-known flight-holes which are about $\frac{1}{16}$ in. across) and fly to fresh timber and lay eggs in some crack or crevice. Eggs cannot be laid on polished timber and, in the case of furniture, are generally laid on such unpolished parts as the undersides of tables.

Death-watch Beetle (*Xestobium rufovillosum*), Fig. 13 B, is similar to the furniture beetle, but is larger—$\frac{1}{4}$ in. to $\frac{1}{3}$ in. long, and has no punctures on the wing-cases. The life cycle is similar, but the beetles emerge earlier (April to June) and the larvæ may bore for several years before pupating. The flight-holes are about $\frac{1}{8}$ in. across. Damage is most common in large structural timbers (e.g., in churches, etc.) and is seldom found in softwoods.

The Powder-post Beetles (*Lyctus ssp*), Fig. 13 C, resemble furniture beetles, but are somewhat thinner and longer, being about $\frac{1}{5}$ in. long. Eggs are laid during spring and summer in the pores of the sapwood of timbers which have large pores (e.g., oak and elm). Hardwoods with small pores and softwoods are not attacked. Since the larvæ live on the starch in the wood they only attack the sapwood.

The damage may be recognised by the very fine, even powder which is ejected from the holes ; the dust from wood attacked by the furniture beetle is granular, and that from the death-watch beetle contains bun-shaped pellets.

Preventative Treatment. To prevent attack by these insects, furniture should have all cracks stopped up and unpolished parts waxed ; the avoidance of sapwood (of oak especially) will stop the powder-post beetle's attack. If damage is present, watch should be kept for the beetles during spring and summer, and these must be killed. Preservatives should be applied during early summer and for several consecu-

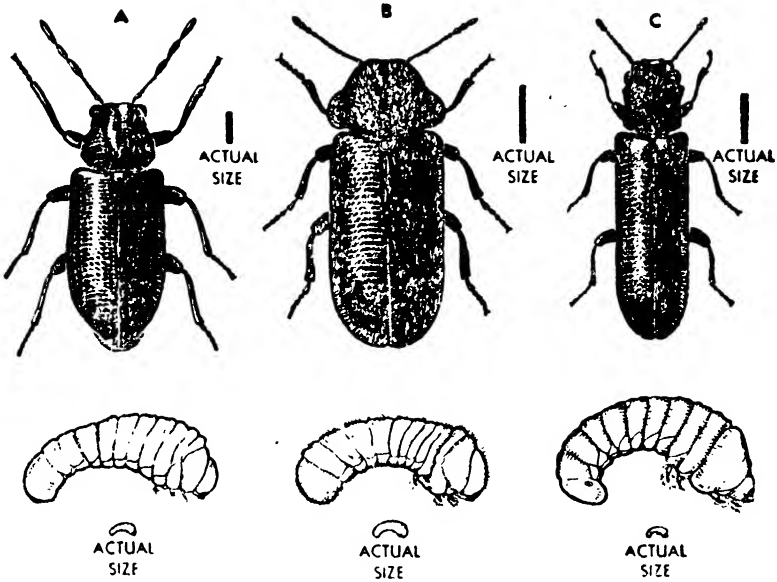


Fig. 13. The three main wood-destroying insects found in Britain and their larvæ. A. Furniture beetle (*Anobium punctatum*) ; B. death-watch beetle (*Festobium rufovillosum*) ; C. powder-post beetle (*Lyctus ssp*). The small symbols indicate the actual size of the insects and larvæ.

tive years. Turpentine, benzine, creosote, or the various proprietary compounds may be used.

Defects in Timber

Apart from fungal decay and insect damage, there are a number of defects of timber which may be natural or caused by seasoning. The presence of knots constitutes an often serious defect, as the strength of the timber is thereby impaired.

Knots may be '*live*' or '*sound*,' i.e., free from decay and firmly joined to the surrounding timber or '*dead*,' i.e., not firmly joined to the surrounding timber; dead knots are often loose and may fall out. According to the direction in which a knot is cut, it is called a 'splayed' or 'round' knot (Fig. 14). Other defects are:

Bark pockets: areas of bark enclosed in the sound timber; *pitch pockets:* pockets in the wood containing resin; similar openings along the grain are called *pitch-seams; gum veins:* similar to the above, but gums take the place of resin; *spiral grain:* in which the fibres (or tracheids) follow a spiral course round the stem.

Seasoning defects include shakes (partial or complete splitting) of various kinds, such as :—Ring shake, heart shake, star shake and cup shake (Fig. 15).

Other seasoning defects are bowing, springing, cupping, twisting (see Fig. 16); also *case-hardening*, i.e., where the timber is dried too quickly and the outer layers shrink whilst the interior is still wet and a stress is set up in the outer layers; *honeycombing*,

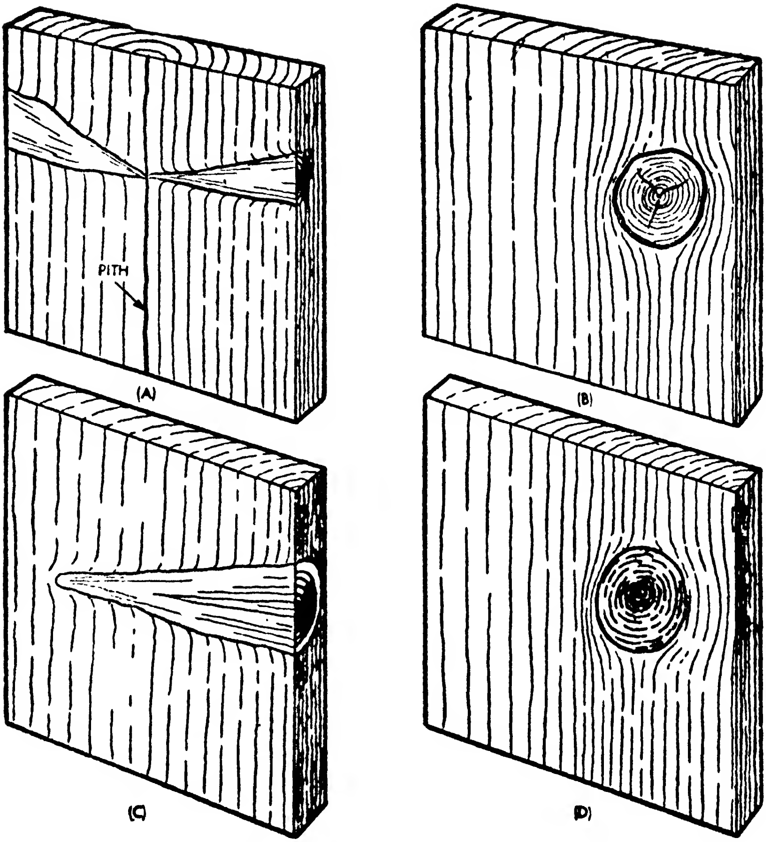


Fig. 14. Some common defects in wood. Four types of knots are shown: A. Branched knots; B. dead knot; C. splay or spike knot; D. round knot.

i.e., interior checks (see Fig. 15 D).

PRESERVATION. The main principle is the poisoning of the food on which either fungi or insects live; their food is, of course, wood. The usual method employed is to force a liquid into the timber so that it permeates the cell walls and renders them toxic to insects and fungi.

A good preservative should be toxic, permanent (that is to say, it will not leach out), safe to handle, will penetrate easily, will not affect metals, and be cheap and easily available. There are three main classes of preservative:—(a) Oils, including creosote; (b) water soluble compounds; (c) solvent types (these are mainly proprietary preservatives and while tending to be more expensive than the others, have a better penetrative power when applied by brush or spray).

The best known preservative which combines all the abovementioned advantages is creosote, and its only disadvantages are that it needs pressure to obtain good penetration, discolours the timber and may soak into and disfigure such materials as plaster. Creosote may be applied either by the open tank method, in which the timber is placed in a tank containing creosote, and heat applied until a temperature of about 200 deg. F. is reached. This is maintained for an hour or two, and then allowed to cool.

Penetration of the creosote takes place mainly during cooling. Most of the creosoting of sleepers, telegraph poles, etc., is done in a creosoting cylinder. The timber is run into the cylinder on trucks; the cylinder is then hermetically sealed, and the creosote forced in under pressure (varying from 100/200 lbs. a sq. inch.). This method results in the greatest possible penetration.

Water soluble preservatives are also best applied under pressure and in a similar type of cylinder. Some of the most effective water soluble preservatives in general use are—sodium fluoride, magnesium silico-fluoride, mercuride chloride, and zinc chloride.

Sizes of Timber

In spite of the vast number of different sizes of timber available, there are limitations for various kinds, and the sizes available should be ascertained before ordering. Thus it should be remembered that American hardwoods are seldom imported in lengths over 16 ft. and usually

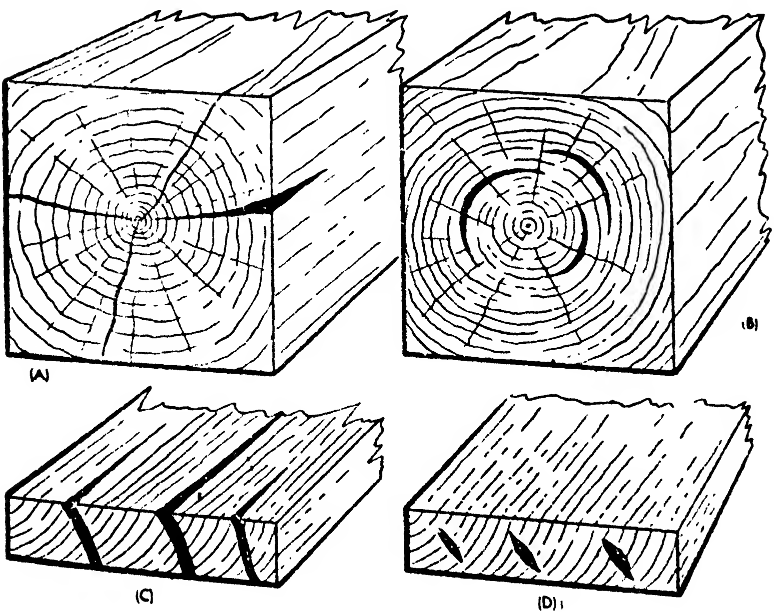


Fig. 15. Timber defects due to shrinkage; types of shakes and checks. A. Heart shakes; B. cup shakes; C. end splits or checks; D. honeycombing. The wood checks at the line of least resistance, along the growth rings or rays.

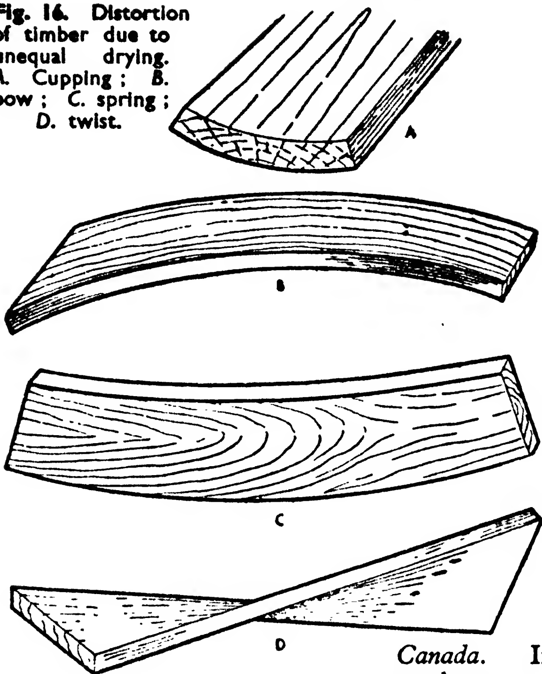


Fig. 16. Distortion of timber due to unequal drying. A. Cupping; B. bow; C. spring; D. twist.

rise from 8 to 16 ft. by even 2 ft. intervals.

Always specify whether 'sawn' or 'planed' sizes are intended, and avoid ordering sizes which are wasteful (and, therefore, expensive) to cut. For example, if only 2 in. planks are stocked it is foolish to order 1 in. finished boards if ⅞ in. will serve, as it is impossible to cut two 1 in. boards out of a single 2 in. plank.

It should be noted that prices rise very rapidly as widths increase, so the smallest widths necessary for the job should be ordered. Most of the timber trade deals in lengths of 6 to 16 ft., and widths of 6 to 10 ins.

Timber, being a natural product, is difficult to put into exact grades; it has, however, been graded on the number and kinds of defects in various ways according to the country of origin.

Grading

Baltic countries. Baltic softwoods are graded (or 'bracked') into 1sts, 2nds, 3rds, 4ths, 5ths, 6ths, and unsorted (u/s); the latter grade consists of a mixture of grades better than 5ths. The quality of timber varies with the country and port of shipment.

U. S. A. and Canada. In many cases the producers of different classes of timber have formed themselves into Associations which issue printed grading-rules. Thus most hardwoods are graded according to the rules of the National Hardwood Lumber Association.

Empire. Only recently have any rules been drawn up for grading Empire timbers; the Imperial Institute rules form, however, the basis of grading, although they are not yet well known. Some Empire timbers e.g., teak, have their own recognised grades.

STRENGTH GRADING. The Scandinavian bracking is purely arbitrary, but an advance has been made in the issue of the British Standards 'Grading Rules for Structural Timber,' in which grading is based on the strength of timber. The weight of timber and its defects are correlated directly with its safe working stress in bending.

Plywood and Veneer

Plywood consists of three or more veneers glued together in such a way that the grain of each veneer is at right-angles to the next. There should always be an odd number of plies in any piece of plywood, so that stresses are balanced. The number of plies is 3, 5, 7, or 9 (Fig. 17).

The term 'multi-ply' is generally used for plywood with more than three plies. The thickness of any plywood depends more on the thickness of the individual plies than on the number; thus, 3 ply may vary from 3 mm. to 6 mm. or more; whereas 5 ply may be as little as 6 mm. or less.

ADVANTAGES OF PLYWOOD. The object of plywood is to minimise the effects of swelling and shrinking of timber, and by crossing the plies to give strength to wood in its weakest direction, i.e., across the grain. Other advantages are—resistance to splitting, less warping, large sizes free from defects and facility in bending to curved surfaces of simple shape.

Preparation of Logs. Most logs need to be steamed, or treated in hot water to soften them sufficiently for cutting; such timbers as European birch, Douglas fir, and European pine can, however, be cut when cold.

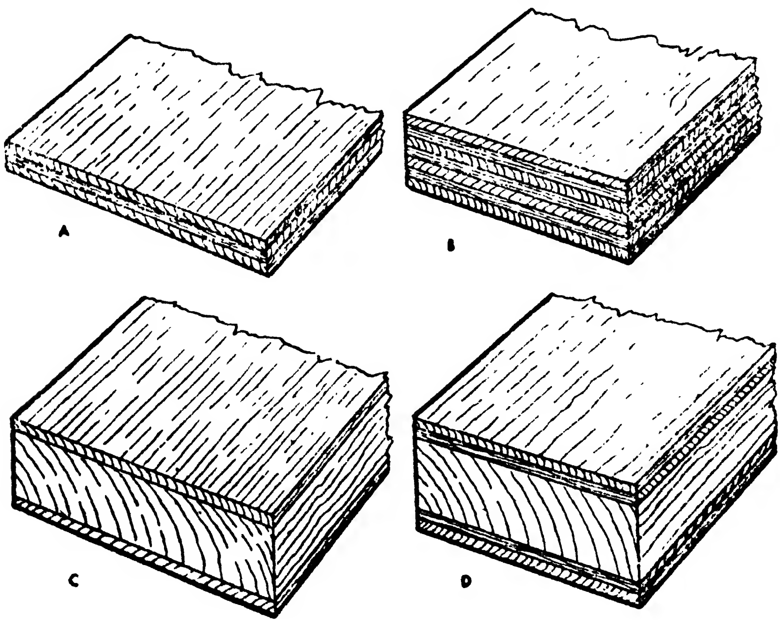


Fig. 17. Types of plywood. A. Common three-ply; B. seven-ply, each layer of equal thickness, and each layer at right angles to the next layer; C. three-ply with thick middle ply, known as 'stout heart'; D. five-ply with stout heart. Note that plies are always of an odd number, so that the stresses are balanced.

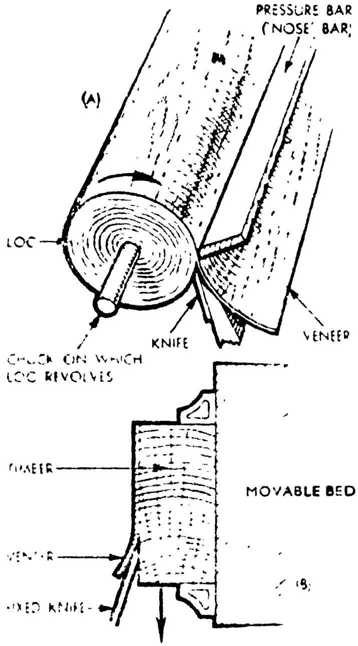


Fig. 18. Methods of cutting veneer for plywood. A. Rotary veneer cutter. By this, the most common method, an endless sheet of veneer can be peeled off ; B. slicing veneer, using a vertical slicer with movable bed.

There are two main methods of cutting the veneer.

(1) *Rotary Cutting.* This is the most common method of producing veneers for plywood. The cutters are, in effect, massive lathes, the log being held at either end by chucks and revolved against a heavy knife which runs the whole length of the log. In this way an endless sheet of veneer can be peeled off (Fig. 18 A).

(2) *Slicing.* Certain timbers, especially figured timbers such as oak and burrs, are sliced in order to obtain the maximum amount of figure. There are two types of slicing machine—the vertical slicer (Fig. 18 B); in this there is a fixed knife, on which the squared flitch of timber is brought vertically down and a thin veneer cut off; the horizontal slicer, in which the log is fixed and the knife driven horizontally across it.

Drying Plywood

Drying. Plywood comes under two categories of manufacture :—

(1) *Dry-glued plywood.* In this the veneers are dried before being made up into plywood ; (2) *wet-glued plywood:* in which the plywood is made while the veneers are still wet.

The former method is by far the superior.

Gluing. Glue is usually applied in liquid form, by a machine something like a mangle in which the bottom roller runs in a trough of glue and coats both rollers with glue. The veneer is run through this gluing machine and takes up glue on either side.

In the case of certain types of synthetic resin glue, this is in the form of thin sheets which are cut to size and placed between the plies. The heat when pressing is sufficient to liquefy the glue and cause adhesion. Synthetic resin glue is the best type for exterior work, as it is waterproof, and plywood made with it will not disintegrate under the stress of weather conditions.

Pressing. When the veneers are glued, they are assembled and put in heavy presses. These may be of two types :—

Cold Press. In which the glued plies are placed one on top of another between heavy plates which are forced together by hydraulic pressure. When sufficient pressure is reached, the plates are clamped and removed, and allowed to remain until the glue is set.

Hot Press. In this case each set of plies is placed between metal plates which are heated; these plates are forced together and so held until the glue sets, the heat being maintained. This type of press is essential when certain types of synthetic resin glue are used.

Re-drying. Following extraction from the press, the plywood is re-dried, as it picks up moisture with the glue, after which it is trimmed to size and ready for delivery.

TIMBERS USED FOR PLYWOOD. The main timbers used for plywood are:—European birch, Canadian birch, alder, gaboon, Douglas fir, pine, beech, cottonwood, obeche and lauan. Veneers may be of almost any timber, and a great number are normally available for the cabinetmaker and joiner.

BLOCKBOARD and LAMINBOARD. Blockboard consists of two or more plies enclosing a fairly thick core made up of strips of softwood (occasionally hardwood) which are more or less square in section Fig. 19 A. Laminboard is similar, but the strips are considerably thinner and frequently of hardwood (Fig. 19 B).

CARE OF PLYWOOD. Plywood will absorb moisture under humid conditions and, if this occurs, warping may take place; also plywood is not immune from decay, therefore care should be taken to store plywood in a dry place, preferably stacking it flat, one sheet on the other, without separating sticks. The ideal is to maintain the moisture content at 10 to 12%. When used in the open the exposed parts should be treated with paint or varnish to prevent absorption of moisture.

Timber Selection Chart

Essential information of the common hardwoods and softwoods is given in tabular form on pp. 36-38.

This has been specially prepared in alphabetical order for easy reference, and should prove invaluable for the selection of timber for any particular purpose.

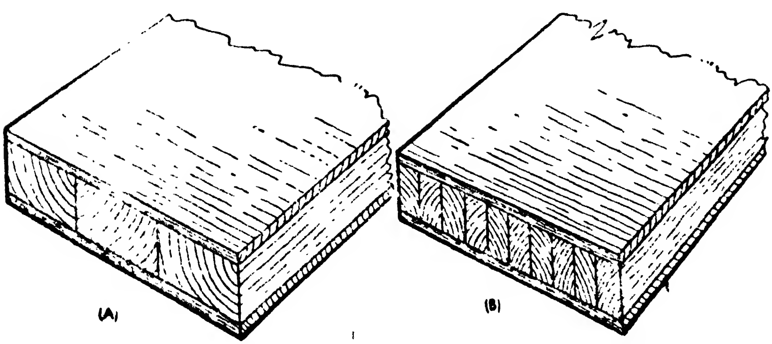


Fig. 19. Examples of built-up boards. These shrink very little and form an excellent base for expensive veneers. A. Block or joinery board; B. laminboard.

ESSENTIAL PARTICULARS REGARDING COMMON TIMBERS

The information given in the following Table (pp. 36-38) has been specially prepared, for easy reference, in alphabetical order. The selection of timber for any particular purpose can thus readily be made.

Name of Timber.	Country of Origin.	Description of Timber.	Weight per cu. ft. (seasoned) lbs.	Uses.
HARDWOODS				
ASH (*Fraxinus excelsior* L.).	Gt. Britain, Europe.	White to light brown, saws and machines well, not very durable, very tough and elastic.	44	Sports' goods, tool handles vehicles aircraft, etc.
BEECH (*Fagus sylvatica* L.).	Gt. Britain & Central Europe.	Pale brown, works and turns well, bends easily, not very durable takes creosote well.	45	Furniture, especially chairs, flooring, turned goods, cabinet work, etc.
BIRCH, Canadian Yellow (*Betula lutea* Michx.).	East Canada...	Pale brown, sometimes figured, works and veneers well, not very durable, very strong, tough	44	Flooring, panelling, furniture, turnery, plywood for aircraft, etc.
BIRCH (*Betula alba* L.).	Gt. Britain, Europe.	White to pale brown fine grained, works and veneers well, not durable	45	Mainly as plywood, also staves turned articles, etc.
CANARY WHITEWOOD (*Liriodendron tulipifera* L.)	U.S.A. ...	Pale yellow with greenish tinge, often purplish markings, soft, straight grained, very easy to work, finishes well, not durable, not very strong.	28	Joinery furniture, veneer cores turnery etc.
ELM (*Ulmus procera* Salisb.).	British Isles .	Reddish brown, coarse grained, fairly hard, tends to warp, works and glues well, fairly durable	35	Wharf construction piling, weatherboards, chair seats, coffins, wagons, etc
GABOON (*Aucoumea klaineana* Pierre).	French Equatorial Africa.	Pale red brown, resembles mahogany, straight grained, fairly soft, works and veneers easily, takes glue well	25	Mainly as plywood and laminboard, also substitute for mahogany in cabinet work
GURJUN (*Dipterocarpus* spp.).	India, Burma Siam.	Reddish brown, hard, works easily, fairly durable, strong.	46	Railway carriages, flooring, constructional use, joinery sills, etc.
IROKO (*Chlorophora excelsa* Benth. and Hook. f.).	West Africa...	Yellowish brown, hard, works well, very durable and strong.	41	High-class joinery, flooring, furniture etc.
JARRAH (*Eucalyptus marginata* Sm.).	Australia ...	Dark red brown, very hard, heavy and durable, works fairly well, fire resistant very strong.	56	Flooring heavy construction, railway sleepers, wagon building bridge decking, wharf construction, etc.
MAHOGANY, African (*Khaya ivorensis* A. Chev.).	West Africa...	Reddish brown, often figured, variable hardness, works and veneers well, stains and polishes easily.	35	Cabinet making, panelling, interior decoration, etc.

Name of Timber.	Country of Origin.	Description of Timber.	Weight per cu. ft. (seasoned) lbs.	Uses
MAHOGANY, Honduras (*Swietenia macrophylla* King).	British Honduras, Central America.	Similar to African mahogany, but finer grain, strong, less likely to warp.	34	All types of high-class joinery and furniture work, ship and boat building, air screws, veneers, etc.
MAPLE, ROCK (*Acer Saccharum* Marsh).	Canada and Eastern U.S.A.	White to light yellow brown, often figured, e.g., Bird's Eye maple, very hard and strong, hard to work, but finishes excellently, turns and veneers well	47	Flooring, furniture, sports' goods, turnery, high-class joinery, veneers, etc.
OAK (*Quercus robur* L.).	Europe, including Gt. Britain.	English oak is the hardest grown in Europe, but tends to warp unless well seasoned. Slavonian oak is softer and easier to work. Volhynian oak is fairly hard but not as well figured as English.	46/8	Furniture, flooring, construction, fences, gates, shipbuilding, barrels, turnery, joinery, etc.
OBECHE (*Triplochiton scleroxylon* K. Schum).	West Africa..	Pale yellow, soft, straight grained, works easily, veneers and glues well, not durable.	24	Interior joinery, plywood furniture, substitute for mahogany when stained, etc.
SILKY OAK (*Cardwellia sublimis* F. Muell).	Australia ...	Pale reddish brown, strongly figured when quartered, coarse grain, fairly soft, easy to work and turn, moderate strength.	38	Cabinet-making, furniture, panelling, veneers, etc.
SILVER GREY WOOD, Indian (*Terminalia bialata* Steud).	Andaman Isles.	Grey to grey brown, mottled and striped with irregular markings, very ornamental, hard, medium texture, works well	43	Furniture, interior decoration, cabinet-making, motor bodywork, etc.
SYCAMORE (*Acer pseudoplatanus* L.).	Gt. Britain and Central Europe.	White, often with ripple figure, works and veneers well, very strong, stains and polishes well.	39	Furniture and cabinet work, panelling, veneers, dairy appliances, textile and other rollers turnery etc
TASMANIAN OAK (*Eucalyptus obliqua* & spp.).	Australia ...	Resembles English oak in colour and texture but lacks 'silver grain.' Some tendency to warp, about as strong as English oak, works fairly well, stains and polishes well.	41/51	Mainly flooring furniture, also tool handles, oars etc.
TEAK (*Tectona grandis* L.f.).	Burma, India, Indo-China, Java, Siam.	Light to dark brown, hard, extremely strong, works well, exceptionally durable, fire and acid resistant.	41	Shipbuilding, joinery, furniture, interior decoration, flooring, fencing, greenhouses, etc.
WALNUT (*Juglans regia* L.).	Europe, including Gt. Britain.	Grey brown to brown, often finely figured, close grain, works very well, durable, strong, tough and elastic.	41	Furniture, interior decoration, rifle butts, etc.

Name of Timber.	Country of Origin.	Description of Timber.	Weight per cu. ft. (seasoned) lbs.	Uses.
WALNUT, African (*Lovoa klaineana* Pierre).	West Africa...	Golden brown with occasional dark lines, medium texture, works fairly easily, veneers well, some tendency to warp.	35	Furniture and cabinet work, veneers, high-class joinery, etc.
WALNUT, Queensland. (*Endiandra palmerstonii* C. T. White).	Australia	Resembles European walnut, but more regularly striped, grain fine but interlocked, hard to work, needs sharp tools, finishes and polishes well.	46	Cabinet-work furniture, interior decoration, veneers, etc.
SOFTWOODS				
CEDAR, WESTERN RED. (*Thuya plicata* D. Don).	British Columbia and U.S.A.	Reddish brown, very light, soft, straight grained, very stable, extremely durable, easy to work, but sharp tools should be used.	24	Weatherboards, shingles, window frames, joinery, panelling, etc.
DOUGLAS FIR. (*Pseudotsuga taxifolia* Carr).	British Columbia and U.S.A.	Pale reddish yellow with strong grain markings, straight grained, free from defects, works easily but has a tendency to split on nailing.	33	Building, carpentry, joinery, interior fittings, flooring, wharves, bridges, plywood, etc.
HEMLOCK, WESTERN. (*Tsuga heterophylla* Sarg).	British Columbia and U.S.A.	Pale brown, rather soft, non-resinous, works well, and takes paint, varnish and polish well.	31	Joinery work, panelling, interior fittings, flooring, etc.
LARCH (*Larix decidua* Mill).	Europe, including Great Britain.	Pale red brown with whitish sapwood, rather heavy and hard, durable, resinous, fairly easy to work unless there are too many knots.	37	Fencing, gates, piling, rustic work, boat building, pit props, flooring, etc.
PINE, YELLOW. (*Pinus Strobu* L.).	Eastern Canada and East U.S.A	Soft, straight grained, very even textured, whitish, very easy to work, extremely stable, holds nails and screws, takes stain, polish, paint, etc., well.	26	High-class joinery, boat and yacht building, pattern making, cores for veneers interior decoration, etc.
REDWOOD (*Pinus sylvestris* L.).	Northern Europe and Russia.	Pale yellowish red, fairly soft, easy to work, takes nails and glues well, fairly stable.	32	General building including joinery, carcassing, floors, window frames, doors, etc., also paving blocks, sleepers, telegraph poles, pitwood, etc.
SPRUCE, CANADIAN. (*Picea* spp.).	Canada and Eastern U.S.A.	White, straight grained, resembles whitewood, easy to work if sharp tools are used, holds nails and screws well, glues easily.	28	Joinery, boxes, packing cases, pulp, etc.
SPRUCE, SITKA. (*Picea sitchensis* Carr).	Western Canada and U.S.A.	White, straight grained, uniform texture, good strength properties, especially elasticity.	28	Aeroplane work, spars, paddles, oars, high-class joinery, etc.
WHITEWOOD (*Picea Abies* Karst).	Northern and Central Europe.	White, hard knots tend to make working slightly difficult, stains well, fairly strong.	27	General joinery, flooring, shuttering, matchboarding, food containers, etc.

CHAPTER 3

HAND TOOLS

METHOD OF SELECTION. SAWS. PLANES. ROUTERS. CHISELS AND GOUGES. SPOKESHAVES. SCRAPERS. OILSTONES AND SLIPS. BORING TOOLS. MARKING OUT AND TESTING TOOLS. NAILING AND SCREWING. SAWING AND PLANING APPLIANCES. CRAMPS. ADHESIVES. FIXINGS.

ALTHOUGH joinery is not generally made by hand methods nowadays, there are still many operations that have to be done by hand. This is partly because it is still economical to do small jobs for which the setting up of a machine would be too great; partly because many operations have to be carried out away from the shop in which the machines are installed; and also because the machine takes no account of the individual fitting of parts. It is therefore necessary for the craftsman to have a good selection of tools and to know how to use and condition them.

The actual range and choice of tools depends mainly upon the type and class of work one expects to do. It varies for instance in carpentry as distinct from joinery or joinery fixing; and there is also the matter of personal preference, and the importance of selecting and adapting the tools to suit the individual.

Types of Saws

Saws may be conveniently divided under three headings: handsaws, back saws, and those for cutting curves. There are, however, several features common to all; these are illustrated in Fig. 1. First, a note on size. Length is always taken from the actual blade regardless of the handle. Tooth size is reckoned as so many points to the inch, including those at both ends.

It will be seen that the teeth are cut at an angle to the general line of the saw, this varying according to the particular type of saw. The lower the angle at which they are inclined the smoother the finish and slower the cut. All teeth, too, have what is known as '*set*,' that is, they are bent over alternately one way and then the other. They thus cut a kerf which gives easy clearance to the blade. This set should be kept to a minimum because, otherwise, the tool removes a great deal of sawdust unnecessarily and so absorbs power. In all good handsaws this detail is helped by the blade being taper-ground, being thinner at the back than at the tooth edge. This gives a clearance in itself and makes excessive set unnecessary, except in cutting wet material.

In use a saw should never be forced. To move it back and forth just by its own weight is scarcely enough, but a moderate pressure is all that is needed.

Handsaws are used for the preliminary cutting out of timber, and sometimes for larger joints.

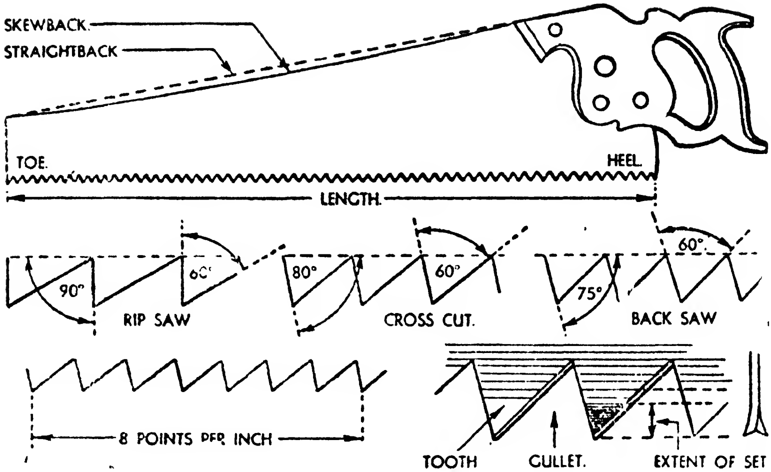


Fig. 1. Hand saw showing details of saw teeth.

First the *ripsaw* used for cutting *with* the grain. It may be 26-28 in. long with a tooth size of 3-4 points to the inch. One feature in which the ripsaw differs from all others is that the teeth are sharpened straight across at right angles to the blade so that the points present a series of chisel-like edges to the wood.

The *cross-cut* saw is used for cutting across the grain, though it *can* be used for ripping (it is slower-cutting for the latter purpose). A length of 26 in. is a good average with a tooth size of 5-8 points per inch Most workers nowadays buy a cross-cut saw instead of a ripsaw. A *panel saw* is invaluable for cutting large tenons, plywood, and for small work needing a fine cut. The length might be 18-24 in., tooth size 7-12 points to the inch.

Most handsaws are used as shown in Fig. 2 with the wood supported on trestles. The cut is started with a few short strokes, holding the left hand at the end with the thumb bearing against the blade to steady it and to prevent an accident in the event of its jumping out from its kerf. When a start has been made the saw should be worked with full strokes, the blade being held so that the line of the teeth is

Fig. 2. Method of ripping or cutting a board in the direction of the grain. The drawing shows the start of the cut.

at 45 to 60 degrees with the wood. Note how the index finger of the right hand points along the blade.

Sometimes it is more convenient to rip down on the bench, the overhand stroke being used as in Fig. 3. In this case the saw is pointed forward to make a start. Both ends of the wood must be securely cramped down. Many craftsmen consider this to be a less back-aching method than the more usual way shown in Fig. 2.

The operation of cross-cutting is similar to that of ripping on the trestles. When the cut is nearly finished, the left hand should be brought over the blade to support the wood, otherwise the weight of the projecting piece may cause it to splinter as it drops off (Fig. 4). Fig. 5 shows an alternative method of sawing with the wood held in the vice.

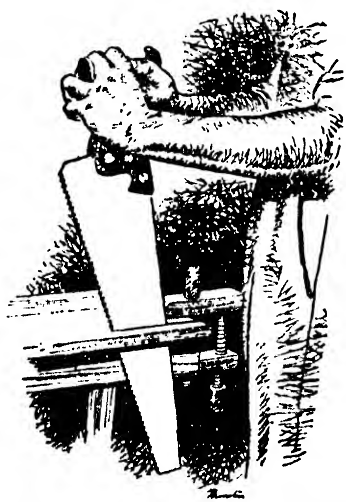


Fig. 3. Overhand ripping on the bench. This is a very convenient method of cutting boards. Both ends of the wood must be securely cramped down.

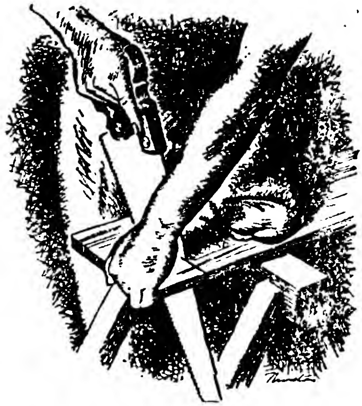


Fig. 4. Cross cutting or sawing across the grain. Method of finishing the cut, and supporting the sawn-off end.

It is important to hold the saw upright, and a good plan is to use a trysquare as a guide. Once experience has been acquired it will be unnecessary to continue it. A proper start must be made, otherwise if the cut inclines in one direction and an attempt is made to correct it, the saw will begin to drift in the opposite direction and the result will be a wandering line, and probably a buckled saw as well. It is wise to saw to one side of the line so that the full size is left with allowance for trimming.

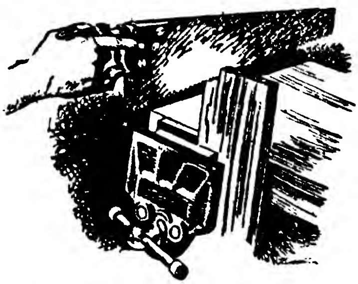


Fig. 5. An alternative method of sawing. In this case the wood is held securely in a vice.

Fig. 6. Starting the cut with a tenon saw. The work is held on a bench hook. Note specially how the thumb bears against the blade of the saw.

Fig. 7. First stage in cutting a tenon with the work held in a vice.

Backsaws. It is the stiffening strip of brass or iron that gives these saws their name. Their chief use is in cutting joints and in bench work generally; a 12 or 14 in. tenon saw with 12-14 points per inch, and a dovetail saw of 8-10 in. with 18-20 points to the inch are useful. For general bench work the wood should be supported on a bench hook to prevent it from moving (Fig. 6). This illustration shows the cut being started; note that the thumb of the left hand bears against the blade to steady it; also that the first finger of the right hand points along the blade. At the start the saw cuts the far corner of the wood only. As the cut is deepened, the hand is gradually lowered so that the saw cuts horizontally.

Cutting a tenon in the vice is a typical tenon-saw operation. The wood is fixed at an angle as shown in Fig. 7 so that it is easier to keep the saw in line with the gauge marks at both side and end. The dovetail saw is used similarly, but is suitable for fine, small work only.

Saws for Cutting Curves. Of these the *bowsaw* (Fig. 8), although not often used nowadays, is the most effective since the blade is held in tension by a cord twisted tourniquet fashion. When not in use the cord is slackened. Both hands are used to grasp the saw and both hold the handle (as distinct from the knob). The wood is held vertically in the vice and the saw held so that the blade is at right angles with it. The cut is on the forward stroke only. A 12 in. blade length is a handy size.

The only limit to the usefulness of the bowsaw is for internal holes which are at a greater distance from the edge of the wood than that between the blade and the centre bar. For these holes the *keyhole* or *padsaw* is needed (Fig. 9). It is not so

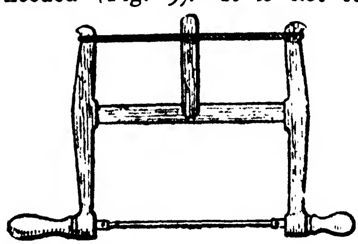


Fig 8. Bowsaw for cutting curves. The blade is held in tension by cord which is twisted tourniquet fashion.

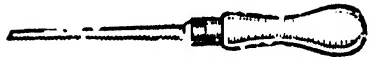


Fig. 9. Keyhole or padsaw. A convenient tool for work of second fixing.

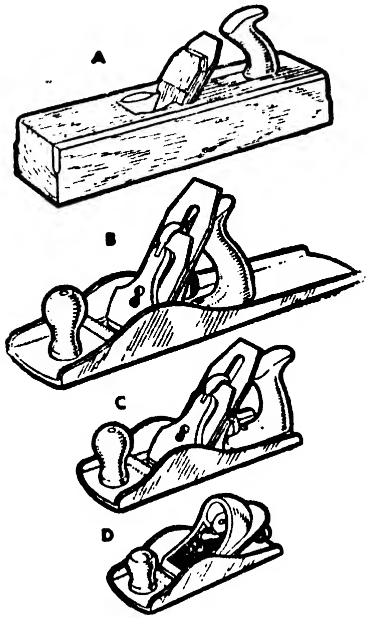


Fig. 10. Some usual types of planes. A. Wooden jack plane ; B. metal fore plane ; C. metal smoothing plane ; D. metal block plane.

satisfactory as the bowsaw owing to the liability of the blade to buckle, there being no means of stiffening it. The rule, then, is to give the blade a minimum projection consistent with a reasonable stroke.

Planes

To make a broad division there are two kinds of planes: those for carrying out such normal operations as reducing a thickness or smoothing a surface, known as bench planes; and those for such work as rebating, grooving and moulding.

Bench Planes. Although some craftsmen still use wooden planes, the majority agree that the metal plane is the superior tool. Its ease of adjustment, low position of handle (giving better control), fine mouth and suitability for end grain planing are advantages which most men recognise. Since there may be a certain amount of rough planing to be done, it is advisable to include a wooden *jack plane* in the kit (Fig. 10 A). A plane with a $2\frac{3}{8}$ in. cutter is a useful size.

Of the metal planes the Stanley or the Record types are the commonest in use. Two are needed, a *fore* or *jointing plane* and a *smoothing plane*. The choice of the former depends mainly upon the class of work usually done. The fore plane of 18 in. length is the handier all-round tool, since quite long joints can be planed with it and it is not cumbersome. On the other hand for really large work, the longer jointing plane, 22 in. or 24 in., gives greater accuracy. For the smoothing plane select the plane with $2\frac{3}{8}$ in. cutter. For small work such as trimming small mitres a *block plane* is useful. A 6 or 7 in. size is suitable; all these planes are shown in Fig. 10.

That the accurate working of a plane depends to a great extent

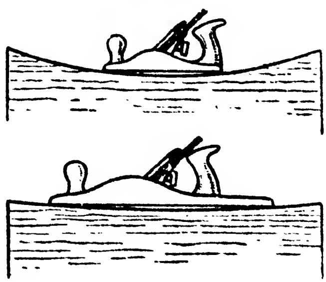


Fig. 11. Diagram (somewhat exaggerated) showing the importance of using a long plane in preference to a short one, so as to avoid hollows.

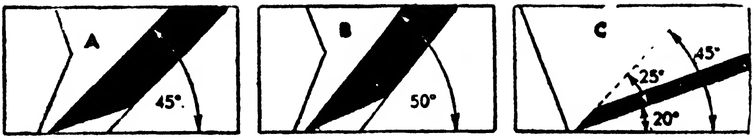


Fig. 12. Inclination of plane irons. A. Normal pitch; B. York pitch; C. single iron pitch. The normal pitch of 45 deg. gives the best all-round results.

upon its length has already been mentioned. It is clear that a long plane would not dip into a surface in the same way as a short one. This is obvious from Fig. 11 which exaggerates the extent to which two planes having the same cutter projection could plane an edge hollow. This explains why a long jointing plane makes for accuracy.

Pitch of Cutters

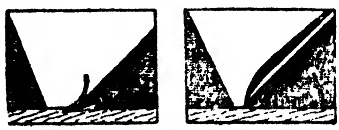
Coming now to the actual cutter, experience has shown that an angle of 45 deg. gives the best all-round results (Fig. 12 A). A lower pitch than this, whilst easing the working of the plane, makes the grain liable to tear out. On the other hand a higher pitch increases friction but reduces the tearing-out liability, owing to the action being more that of scraping. Actually, some wood planes are made with high pitch (York pitch, 50 deg., Fig. 12 B) for use with difficult grain.

Moulding planes, because they cannot be fitted with back irons, are pitched as high as 55 or even 60 deg. At the other extreme is the special low-angle plane which is invaluable for end grain. This is usually set at 20 deg., though the actual effective angle is considerably more, owing to the cutter being reversed. The exact pitch in this case depends upon the angle at which the cutter is sharpened (Fig. 12 C).

The tearing-out tendency is minimised chiefly by the fitting of a *back-iron* and by keeping the mouth as narrow as is consistent with free working. The combined effect of these is shown in Fig. 13. At A the plane has no back-iron and the mouth is wide. After the initial raising of the shaving the stiffness of the latter levers up the wood *in front* of the cutting edge, so that the latter is not really cutting. Once the shaving breaks, the cutting edge catches up the tear and begins cutting again, but only to start another cycle of similar events.

Cutting Defects

The effect on the surface is that of a series of sloping steps. It is clear that if the mouth were narrower the shaving would have to break sooner, since the split or tear could not develop so far in front of the cutting owing to the downward pressure from the mouth. This is made clear from Fig. 13 B, which also shows how the back-iron and close



A B

Fig. 13. The effect of the back or cap iron on a plane cutter. A. Plane with no back iron and wide mouth tears grain; B. how the back iron and close mouth reduce tearing of the grain.

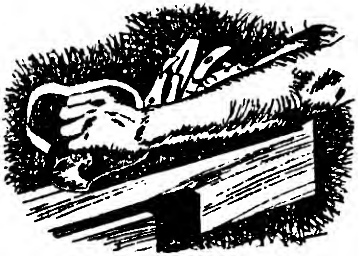


Fig. 14. Shooting or planing the edge of a board. Sometimes the fingers curl beneath the sole of the plane, acting as a fence.

mouth reduce the tearing of the grain.

Fig. 14 shows how the plane is held when dealing with an edge. Sometimes the fingers of the left hand curl beneath the sole and bear against the side of the wood, thus acting as a fence.

Precautions in Planing

This prevents the plane from wandering from side to side, a most important point because, owing to the slight curvature of the cutting edge, the shaving is thicker in the middle than at the sides. Advantage of this fact is taken when an edge is out of square. By pushing over the plane towards the high side a thicker shaving is removed where it is needed.

When starting the cut, press well down at the front of the plane, and gradually transfer the pressure to the rear as the end of the wood is reached. This prevents the ends from being dubbed over (Fig. 15A).

It is a safe plan to begin by first removing shavings from the middle of the edge. The plane when set fine cannot make an edge more than slightly hollow. When the plane ceases to remove shavings make a couple of strokes throughout the entire length, and it is generally found that the edge is straight—unless it is very long, in which case the use of the straight edge is imperative.

For end grain a special precaution is necessary owing to the wood being liable to split when the end is reached. One plan is to plane in from each end. Another way, when there is width, is to cut off the corner as at Fig. 15 B. If the wood is not wide enough for this a waste block of wood must be

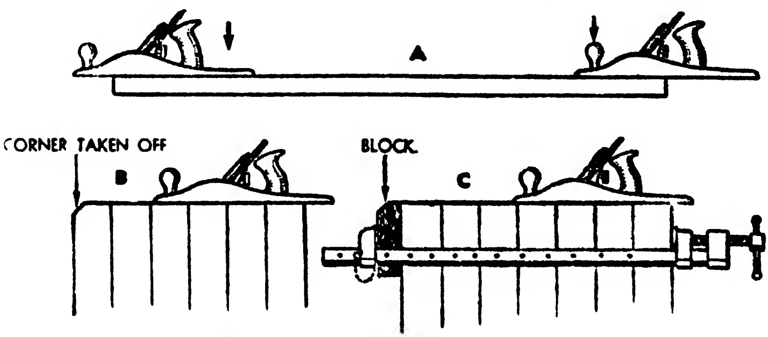


Fig. 15. Method of using a plane. A. The arrows show where to apply pressure in planing; B. how to deal with end grain by cutting off a corner to prevent splitting; C. showing a waste block cramped on the side so as to avoid damage.

Fig. 16. Planing the edges of thin wood on a shooting board. A useful method for planing end grain.

cramped on as at Fig. 15 C, the corner of this being taken off.

In all metal planes (and to a lesser extent with wood ones) lubrication is essential. The most convenient way is to have a pad of cotton wool soaked in oil and to wipe the sole on this occasionally.

Use of Shooting Board

For trimming the end grain of narrow pieces of wood, and for planing edges of thin wood, the use of the *shooting board* is desirable (Fig. 16). In the first case the wood is held up against the stop, and the plane sole is kept up against the guiding edge. In this way the end is trimmed exactly square. For planing a long edge, the latter is held so that it overhangs slightly and the plane used so that it makes the edge straight by the truth of its sole; that is, shavings are removed from the middle first, and then one or two right through.

To remove the cutter from a wooden jack plane, the top (front) must be struck smartly with the hammer to free the wedge. In the metal plane the cam of the lever cap is raised. Partly unscrew the back-iron screw and slide the back-iron along the slot until the screw-head can pass through the hole. The normal *grinding angle* of the cutter is in the region of 25 deg. That of sharpening is about 30 deg., which means that if the cutter is laid with its ground bevel flat on the stone and the hands then raised slightly, the angle will be about right.

Sharpening Process

Fig. 17 shows the process of sharpening. Some workers prefer to adopt an elliptical movement; others keep to a straight stroke. It does not matter which providing that the same bevel is maintained and the edge kept square. It is usually an advantage to hold the cutter at an angle as shown. A smoothing or trying plane cutter should be very *slightly* rounded with the corners taken off as shown at Fig. 18 A.

Fig. 17. Sharpening a plane iron on oilstone. Note the manner of holding the blade to maintain an even pressure.

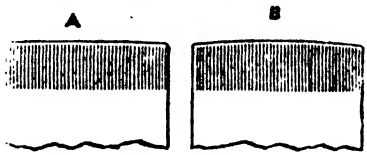


Fig. 18. Rounding the cutter edge to prevent grooves in the planed surface. A. Smoothing plane iron slightly rounded with corners taken off; B. Jack plane iron with a fuller curve.

That of the jack plane can be rounded rather more generously. (Fig. 18 B).

In order to tell when the edge is keen examine it in the light. A sharp edge cannot be seen, while a dull one shows a thin line of reflected light. It is a good plan to draw the thumb *across* the back of the cutter when the burr or wire edge can be detected. Always examine the edge by sight as well, because, although the burr is an indication of sharpness, it does not tell whether there are any gashes. Follow the sharpening by reversing the cutter *flat* on the stone and rubbing once or twice to turn the burr. The latter is removed by stropping on a piece of leather dressed with fine emery powder and oil, or by using the palm of the left hand as a strop, drawing the cutter across it first one side and then the other.

Replace the back-iron, setting it in accordance with the class of work to be done—say about $\frac{1}{16}$ in. back for the jack plane and as close as you can get it for fine smoothing. Refix the cutter and lever-cap, and sight as shown

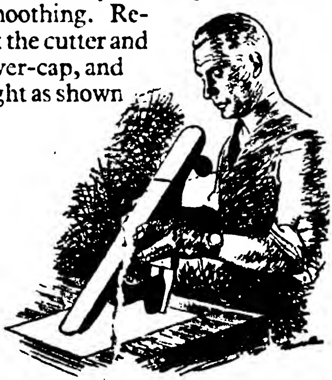


Fig. 19. Setting a plane by sighting. When viewed along the sole the cutter appears as a black line.

Fig. 20. Showing the metal rebat plane in use. The left hand holds th plane against the wood.

in Fig. 19. The cutter should appear as a thin black line tapering to nothing at each side.

Rebate planes. Several planes are included under this heading. Fig. 20 shows a metal rebate plane in use, an invaluable tool which is provided with fence, depth stop, and spur, the latter b used when working across grain (there is a neutral pos for it when working *with* grain). The important about its use is to keep the of the cutter square, and it so that the side in op is level with the side of the There are two positions cutter, but the back one variably used.

The *shoulder plane* (Fig. 21 A) is used for fine work—especially end and cross grain. Its main use is in trimming the shoulders of rails. Its cutter has the bevel uppermost. In a similar class is the *bullnose plane* (Fig. 21 B) which, apart from its use for small rebates, is an invaluable plane for a hundred-and-one small jobs.

In a somewhat different class is the *side rebate plane* shown in Fig. 21 C. Its use is in trimming the sides of grooves in w

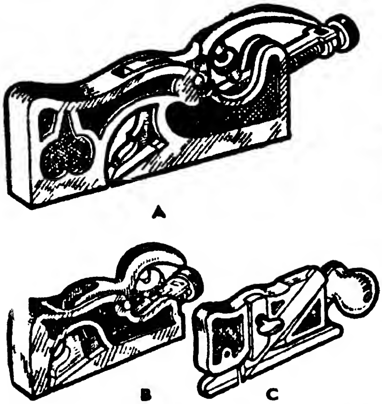


Fig. 21. Various types of metal rebate planes. A. Shoulder plane with fine adjustment for end grain ; B. bullnose plane for small rebates ; C. side rebate plane for easing grooves.

he use of the rebate plane would 'mpossible.

ough planes. A wide range anes is available for grooving from the simple, small 'd No. 040 plough which 'ork grooves of $\frac{1}{8}$ in., $\frac{3}{16}$ in. in. up to the somewhat cated Stanley No. 55 Uniplane which will not only grooves of all sizes, but al with many forms of igs. From the joiner's ... view, unless it is anticipated that many mouldings may have to be worked by hand, either the Stanley No. 45 or the Record No. 405 is an excellent proposition. Grooving, trenching, beading or sashing can be done with the tool. It can also be used as a *fillister rebate plane*, but it is not so successful for this as the proper rebate plane (Fig. 20).

As shown in Fig. 22 the plough consists of three main parts, the main stock, the sliding section, and the fence. The required 'utter being fitted, the sliding

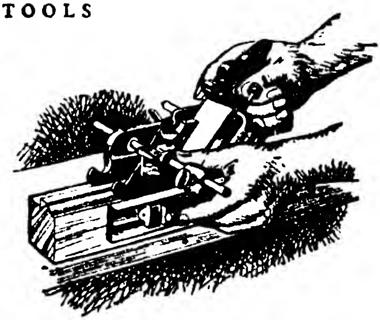


Fig. 22. Metal plough moulding sash material. It consists of three main parts.

section is slid along the arms so that it lines up with the side of the cutter. The fence follows, and finally the depth stop is set.

The usefulness of the *moulding plane* has largely passed, but there is still a demand for rounds and hollows and the smaller beading tools. It frequently happens that an odd bead is required such as on the meeting stiles of folding doors, and it is quicker to use a moulding plane than set up a machine. There are two kinds, French and English. The former is held upright in use, whilst the latter is inclined at an angle (the angle is usually marked on the front of the plane). The only advantage of the English type is that the shaving clears more easily.

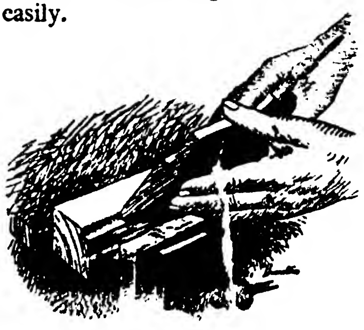


Fig. 23. Small moulding plane in use.

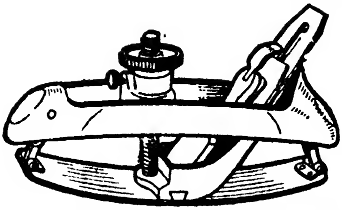


Fig. 24. Compass plane with flexible sole. This is used in shape work, and can be adjusted to suit any curve.

Moulding planes, plough planes and fillister planes should always be started at the far end of the wood. At each successive stroke the plane is drawn a little farther back until it can run right through. In this way it is not so liable to drift from the edge. The sharpening of hollows is done with small slips. Fig. 23 shows the moulding plane in use.

One other plane remains to be mentioned—the *compass plane* shown in Fig. 24. This is used in shaped work. Its sole is flexible and can be adjusted to work any desired arc of a circle. Its use and sharpening are the same as that of any bench plane, except that the grain has to be studied rather more carefully. It is desirable to work *with* the grain as far as possible.

Routers

Although scarcely a plane, the *router* may be dealt with here. Its purpose is that of making a sinking of the same depth throughout. The metal type is frequently used nowadays, and it certainly has the advantage of easy cutting, though for some work the older wooden type still has its advantages. For instance, owing to its cutter being straight and of a high pitch it will work in a much more restricted area than the metal type, which, having a cranked cutter, needs space considerably in excess of the cra (Fig. 25 A and B). Furthermc the high pitch of the woo router gives it more of a scrap action, so that it is less li to tear out the grain. I these types of router planc shown in Fig. 25.

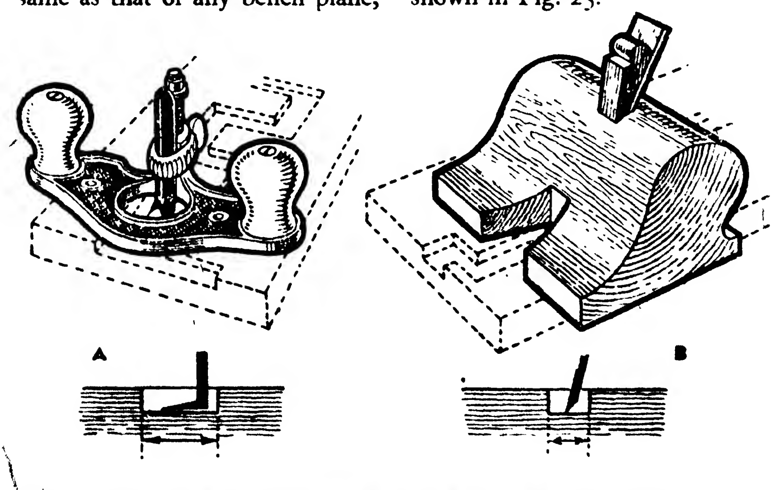


Fig. 25. Two types of router planes. A. Metal router, B. wooden router or 'old-woman's tooth.' This tool can be worked in a very restricted area

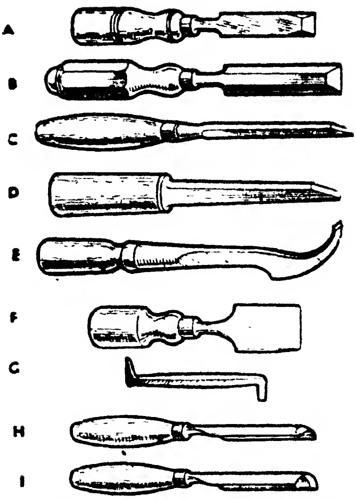


Fig. 26. Types of chisels. A. Firmer ;)evelled edge ; C. sash mortise ; ıortise ; E. swan-neck ; F. pocket ash ; G. drawer-lock ; H. firmer gouge ; I. scribing gouge.

he chief kinds of chisels are n in Fig. 26. Of these, the r is the general bench tool. sturdily built so that it used for chopping and avy work. When grind- a good plan to take off rs as shown, as this it to work in acute corners , for instance, when chopping dovetails. For fine paring the *bevelled-edge* type is desirable. Being lightly built it should never be struck with a mallet. Both kinds are available in widths ranging from a full 1/16 in. to 2 in.

For hand mortising either the *sash chisel* or the *mortise chisel* is needed. The former is the lighter tool and is more suitable for softwood. Another chisel used in mortising is the *swan neck.* It is useful chiefly in making the recess for mortise locks. The last-named invariably cuts into the tenon of the centre rail of the door, and the curved shape of the tool enables it to chop across the grain at the bottom of the mortise and so clear out the waste.

The use of the *sash-pocket* chisel is obvious from its name. It is made specially thin so as not to leave a wide joint. Both sides are sharpened, the angle being kept as low as possible. For chopping drawer lock recesses and other work in which it would be impracticable to use a long chisel the *drawer-lock* chisel (Fig. 26 G) is invaluable.

The sharpening of chisels is similar to that of plane cutters, already described. An average sharpening angle is 30 deg., grinding 25 deg. In practice, however, the mortise and firmer chisels, which need a strong edge, usually require a higher sharpening angle—about 35 deg., whilst the paring chisel can be as low as 25 deg., especially if used mostly on softwoods.

Fig. 26 H shows the *firmer gouge* used in general benchwork. It is sharpened on the outside, a rocking movement being imparted to it. A slip is used to remove the burr from the inside, this being kept flat. For such work as scribing the mouldings of sashes, etc., the *scribing gouge* (Fig. 26 I) is used. It is sharpened inside with the stone slip.

Fig. 27 shows the bevelled edge chisel in use. An important rule in all chiselling is to keep both hands behind the cutting edge so as to avoid all danger of accidents.

Spokeshaves can be obtained in either wood or metal, and the choice is a purely personal one

Fig. 27. Vertical paring with chisel. In all chiselling work both hands must be kept behind the cutting edge.

The metal type is virtually a plane with a single iron, whereas in the wooden type the cutter itself forms the rear part of the sole. This gives it an extremely low pitch which makes for easy working.

The cutter is sharpened with either the edge of the oilstone or with the slip. Metal spokeshave cutters are sharpened similarly to a plane cutter, though it is advisable to make a holder to enable it to be grasped properly.

For hollow shapes the *round-faced* iron spokeshave is needed. The *flat-faced* type is for rounded contours. The only points to watch in its use are following the grain and keeping the tool square. The latter comes only by repeated testing and correcting. Fig. 28 shows a wooden spokeshave in use. Fig. 29 shows a wooden spokeshave at A and a metal spokeshave at B.

The action of the *drawknife* (Fig. 29 C) is the reverse of the spokeshave, being drawn instead of pushed. It is used chiefly in large work for chamfering, rounding over edges, and in rapidly reducing the width of boards. It can obviously take a heavier chip than the spokeshave or plane.

Scrapers

The *scraper* is used in cleaning up hardwood, to take out marks left by the plane and to remove tears from the wood. It is also used for cleaning up veneer for which the use of the plane would be impracticable. It is of little use on softwood. The pressure would merely cause the grain of the latter to give.

Scraper planes can be obtained, but they are seldom seen in

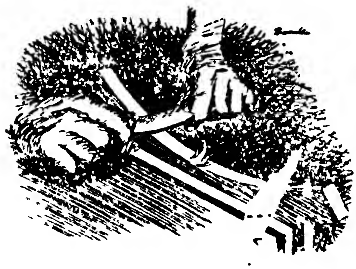


Fig. 28. Wooden spokeshave in use. Note the position of the fingers.

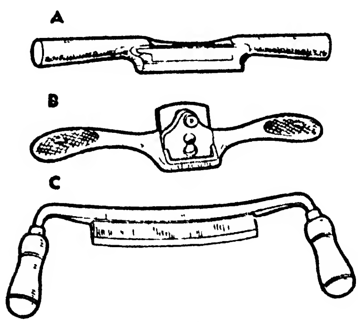


Fig. 29. A. Wooden spokeshave; B. metal spokeshave; C. drawknife.

Fig. 30. Method of using the hand scraper on hardwood panel.

woodworking shops, most men preferring the simple hand scraper. The latter consists of a plain piece of steel about 5 in. long, with the edge burred, and held as shown in Fig. 30. Properly sharpened it will remove fine shavings, not merely dust.

Fig. 31 shows the stages in sharpening the scraper. Begin by filing the two long edges perfectly straight and square. Remove the file marks by rubbing on the oilstone, using a piece of cloth to grip the scraper to prevent the hand from being injured. Rubbing the sides flat on the stone removes the rough burr.

To turn up the edge, use a tool with a rounded surface such as an outside ground gouge. First press hard on the flat surface as at D, keeping the gouge flat on the scraper.

The next step is to set the scraper up on edge, or flat as at E, and press the burred edge over firmly by an even stroke from end to end, and for each edge. This gives a double burr in section as shown at F. Treat both edges in the same way. When it becomes dull turn back the edge as shown, holding the

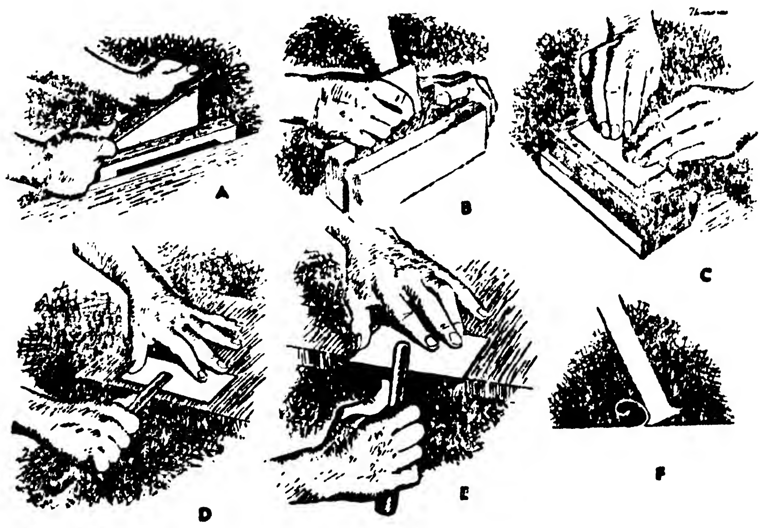


Fig. 31. Various stages in sharpening the scraper. A. Filing edge perfectly square ; B. rubbing edge on oilstone ; C. removing burr ; D. burnishing side with gouge ; E. turning edge with gouge ; F. how the scraper works.

gouge flat on the scraper and drawing it once or twice in each direction. A fresh edge can then be rubbed up as before. The tool can be sharpened several times in this way, but when rubbing fails to produce a keen edge it must be rubbed down with file and oilstone again.

Fig. 31 F shows in exaggeration how the edge is turned up and cuts the wood. Notice from Fig. 30 how the scraper leans forward at an angle—the exact angle can be found from experience. The thumbs press in the centre and this slightly bows the blade, preventing the corners from digging in.

Oilstones and Slips

Although no actual productive work is done with it, the oilstone is one of the most important items in the tool kit, and to attempt an economy by buying a cheap make will prove anything but a saving in the long run. There are two kinds, natural and artificial, the latter coming in for greater use nowadays because its cutting and wearing qualities are constant.

Best known amongst the natural stones is the *Washita* which cuts fairly quickly and gives a fine edge. *Arkansas stones* give a superfine edge, but cut slowly and are very expensive. They are ideal for finishing off edge tools. *Turkey stones* cut rapidly and give a fine edge, but, being soft, soon wear away and become out of shape. The *Charnley Forest* is not used very much nowadays, but still sells to an extent because of its low price. It gives an edge of excellent quality but unfortunately it is slow cutting.

Of the artificial stones the two best known are the *India* and the *Carborundum.* Both are available in three grades : coarse, medium, and fine. For joinery the fine stone is recommended ; for carpentry, the medium gives a keen enough edge. A size of 8 in. by 2 in. is about right.

Use a fairly thin oil. Animal or mineral oils are better than vegetable oils, the last named tending to solidify on drying. Lubricating oil is excellent. Wipe the stone after use and never use it dry.

All stones tend to become hollow in use, and although this can be minimised by sharpening narrow tools towards the edges rather than in the centre, it becomes necessary eventually to reface. This in the case of natural stones can be done by rubbing the surface on a piece of flat paving stone or marble, using silver sand and water as an abrasive. For artificial stones carborundum powder must be used, as sand is not hard enough.

Oilstone slips are needed for gouges and various moulding plane cutters, and are available in the same makes already mentioned, and in different sizes and shapes. If not exactly of the curve required a slip can usually be rubbed down on marble with sand or carborundum powder.

Boring Tools

The advantage of the *ratchet brace* (Fig. 32 A) over the simple type is so great that it is advisable to pay the slight extra cost. It can be used in rather awkward corners in which a full sweep of the brace would be impossible. The backward turn of the brace leaves the bit stationary in the wood.

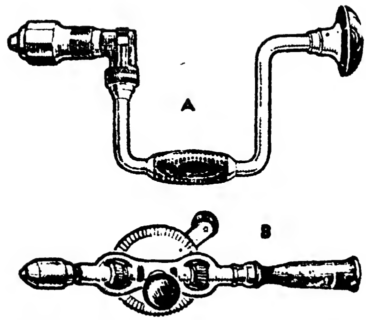


Fig. 32. Two types of boring tools. A. Ratchet brace ; B. breast drill.

The cheapest bit is the *centre bit* (Fig. 33 A). It is useful for boring comparatively shallow holes across the grain, but is not so satisfactory *with* the grain owing to a liability to drift. When the hole is to pass right through the wood the boring is made until the centre point projects at the back, and the hole then completed from that side.

The illustration shows the order of projection of the various parts : centre point, nicker, and cutter. A fine file is used for sharpening, which must be done on the inside of the nicker, keeping the outer side upright. In the case of the cutter the side farther from the wood is sharpened. The improved centre bit (Fig. 33 B) has a centre thread which draws it into the wood, so lightening the labour. This type is superseding the centre bit.

For accurate deep holes the *twist bit* is the most satisfactory. Various makes, all satisfactory, are the Russell-Jennings, Gedge and Irwin. The Gedge is at its best on end grain. The nickers are sharpened inside with a fine file, and care must be taken not to foul the thread. The *expansion bit* is handy for large holes and saves having to keep a wide range of centre bits.

For small holes such as those needed for screwing, the *shell bit* is most useful. It can be repeatedly sharpened and is not liable to split the wood. The *half-twist bit* is used for similar purposes. Its advantage is that it draws itself into the wood, but it cannot be used near the edge as it tends to split the grain. Another bit used in screwing is

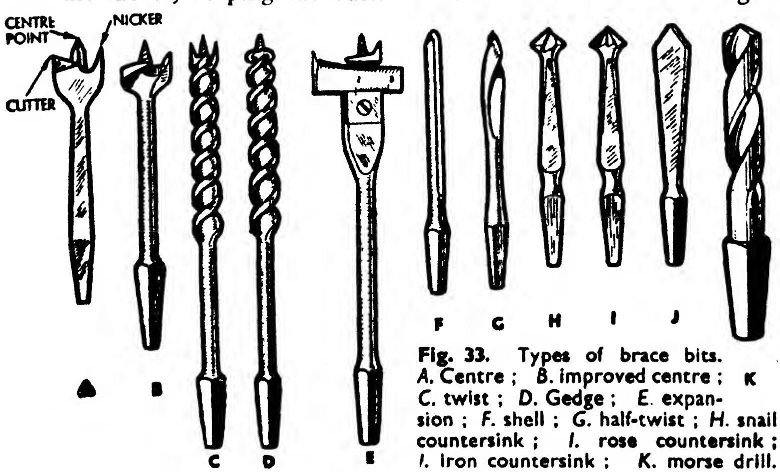


Fig. 33. Types of brace bits. A. Centre ; B. improved centre ; C. twist ; D. Gedge ; E. expansion ; F. shell ; G. half-twist ; H. snail countersink ; I. rose countersink ; J. iron countersink ; K. morse drill.

the *countersink.* The snail pattern is used for wood. The others (Fig. 33 I and J) are used for brass and iron respectively; it is occasionally necessary to enlarge holes in metal fittings. A *screw-driver bit* is handy when extra leverage is needed for big screws.

The breast drill shown at Fig. 32 B and morse drills are sometimes used by the joiner for drilling metal fittings. When holes have to be cut, an indentation should first be made with the centre punch, because the drill has no point but, rather, a short flat edge.

The morse drill shown (Fig. 33 K) has a square shank for use in the ratchet brace.

Other boring tools are the *bradawl* and *gimlet* (Fig. 34), both specially handy when screwing. The former is particularly satisfactory, in that it is not liable to split the grain. It should be used with its edge at right angles with the grain. It is sharpened with the file and finished off on the oilstone.

Bits are generally carried in an oilskin or canvas roll.

Other Tools

The *axe* is generally used in carpentry work for comparatively rough jobs, such as cutting down the width of a board, making wedges, and general trimmimg jobs. A medium weight of 3 lb. is convenient.

Glasspaper rubbers. Glasspaper should never be held in the fingers when being used. This only results in the edges being dubbed over, and would not take out inequalities in the surface. For flat surfaces the flat cork rubber is used (Fig. 35 A). This

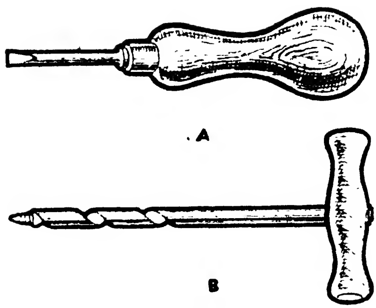


Fig. 34. A. Bradawl ; B. gimlet.

gives to any slight inequalities in the surface of the wood.

For mouldings, special wood rubbers cut to the reverse of the shape are needed (Fig. 35 B). As a fresh moulding is to be cleaned up a rubber is made, and thus a range of rubbers soon accumulates.

Marking-out and Testing Tools

The most useful, all-round *rule* is the 2 ft. four-folding type, though for measuring up *rods* should be used. One point in connection with any rule is that

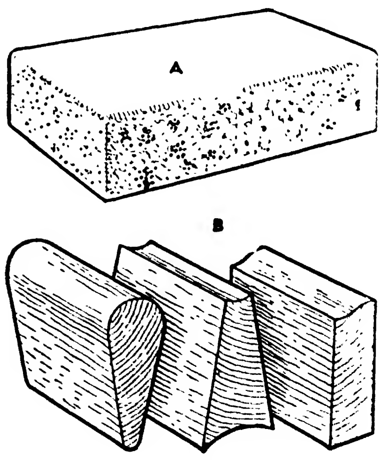


Fig. 35. A. Flat cork rubber for glass paper ; B. special pine rubbers for cleaning mouldings.

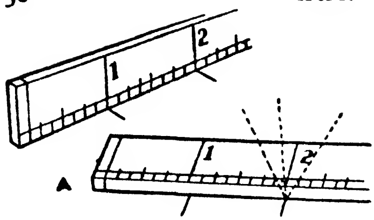


Fig. 36. Always make sure that the gradations on the rule touch the wood. A. shows how inaccuracies may creep in if this precaution is not taken.

it should be held so that the gradations actually touch the work (see Fig. 36). This eliminates any error that may creep in owing to a varying viewpoint being taken as at A.

It is desirable to have three *try-squares:* 6 in., 12 in., and 30 in. Of these, the first two can be all-metal or wood-metal, and the last all wood. This is usually made by the worker himself. When using a square for, say, marking shoulders, always keep the stock up against either the face side or face edge of the wood. This ensures that the marks will meet all round. The mitre square set at 45 deg. is useful for mitring, and the adjustable sliding bevel for marking angles. Winding strips, too, are needed at times. These may be homemade. The length is about 1 ft. They are in a dark wood and one is inlaid with a boxwood

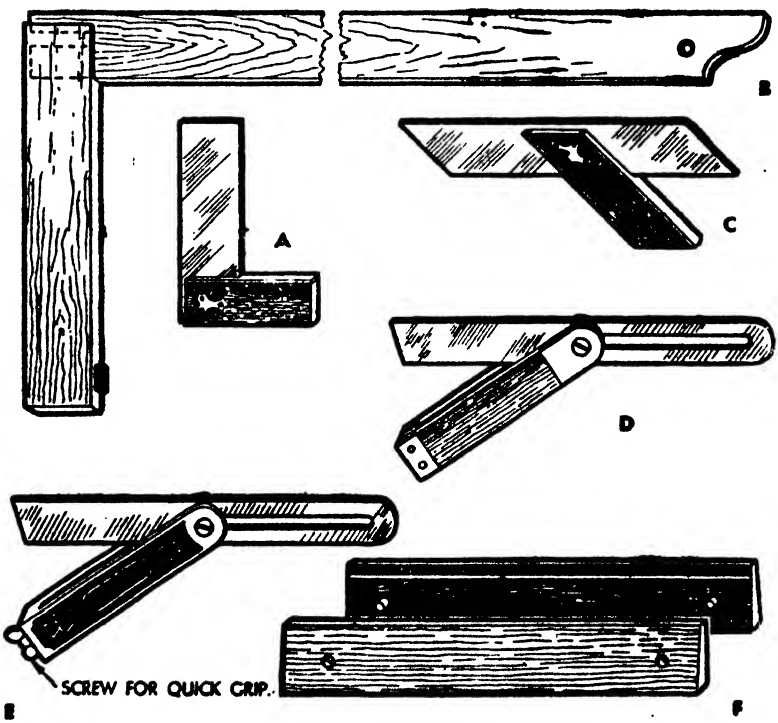


Fig. 37. Types of marking tools. A. Try square ; B. panel square ; C. mitre square ; D. metal sliding bevel ; E. all-metal sliding bevel ; F. winding strips

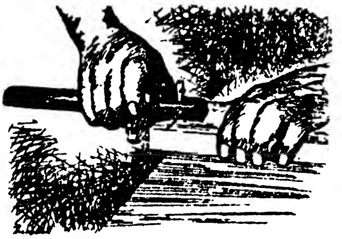


Fig. 38. Using the cutting gauge for marking across the grain. It is also used for cutting thin wood into strips.

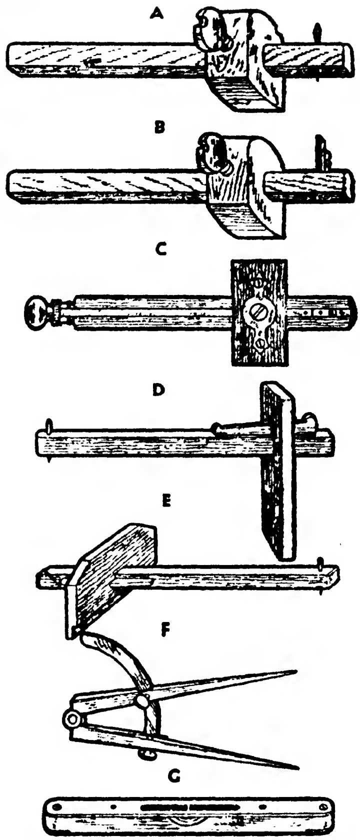


Fig. 40. Marking-out tools. A. Marking gauge; B. cutting gauge; C. mortise gauge; D. grasshopper gauge; E. panel gauge ; F. dividers ; G. spirit level.

line to enable a sight to be taken easily. (Fig. 37 F).

Gauges are important marking-out tools. The *marking gauge* is used for marking *with* the grain or for end grain. The *cutting gauge* is needed for marking *across* the grain or for cutting thin wood into strips. They are both held as shown in Fig. 38, the thumb pressing forward, the first finger bearing downwards, and the second pressing steadily inwards to prevent the gauge from drifting.

The sharpening of the cutting gauge is an important item. The bevel should be as in Fig. 39 A, and the edge should be at an angle so that it cuts as the tool is pressed forward (B). Lastly, it should be set *very* slightly out of parallel as at C (shown in exaggeration) so that the forward movement tends to draw the gauge towards the wood.

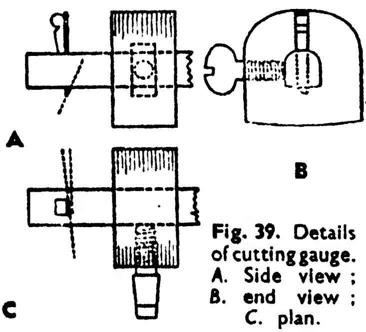


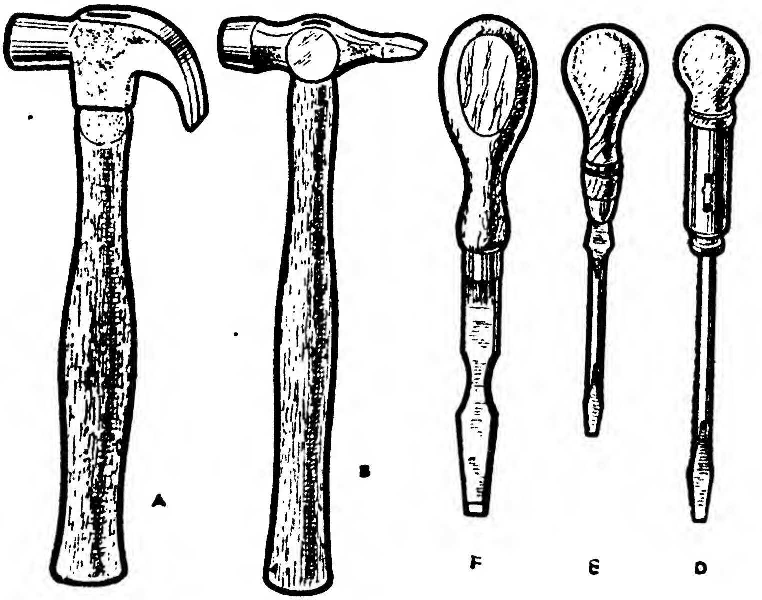
Fig. 39. Details of cutting gauge. A. Side view ; B. end view ; C. plan.

The *mortise gauge* (Fig. 40 C) is used similarly. The movable point is adjusted so that the distance between it and the fixed one equals the width of the mortise chisel being used. It should be used from the face side or edge in all cases. Both the panel and the T or grasshopper gauge are usually home-made. The former is for large work, the arm being about 2 ft. 6 in. long. The **T** gauge can be fitted with an extra long marker so that it will reach down into depressions below the general surface. In any case its long fence enables it to clear any projections on the surface of the work. (Fig. 40 D).

For stepping out measurements the *dividers* are used. The type with fine screw adjustment is the most satisfactory (Fig. 40 F). Spirit levels may be of the small type, about 9 in. long or the large size some 30 in. long. The former is handy in that it can be used for both small and large work. In the latter case it is placed on a straight edge, the edges of which are perfectly parallel.

Nailing and Screwing Tools

For carpentry the *claw hammer* is the most convenient. The claw enables nails to be withdrawn and, since the nails are invariably large, there is no need for the cross-pane for starting



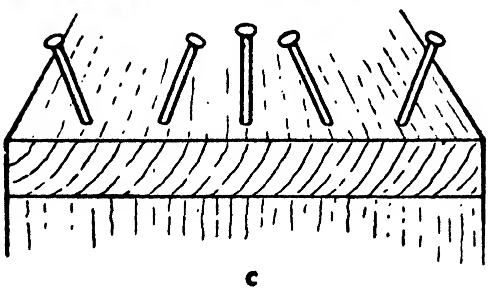


Fig. 41. Nailing and screwing tools. *A.* Claw hammer ; *B.* Warrington or cross-pane hammer ; *C.* dovetail nailing ; *D.* 'Yankee' ratchet screwdriver ; *E.* cabinet screwdriver ; *F.* London pattern screwdriver.

them. The joiner finds the Warrington pattern more convenient. (Fig. 41.)

When using the hammer for joinery cease striking when the nail is still a trifle proud of the surface and finish off with the punch. This avoids bruising the wood. When a fixing relies purely upon nails the last named should be dovetailed, that is, driven in askew in alternate directions (Fig. 41 C).

At least two punches are needed, and of these the large London pattern is handy for floor brads and other cut nails. Small pins are best driven with the round, hollow-point punch. This is not liable to slip from the nail head.

Pincers can be either the Lancashire or the Tower pattern. When pulling out a small nail place a scraper or try-square blade on the wood to avoid bruising the latter. For larger nails it is better to place a block of wood beneath the pincers as this enables a stronger pull to be obtained.

A fairly heavy *mallet* should be obtained for either joinery or carpentry, because it is used mostly for mortising, for which a heavy blow is needed. The handle should make a tapered fit in the head so that the latter cannot fly off. The mallet should always be used for handled tools, never the hammer.

For large screws the flat London pattern screwdriver (41 F) with a blade length of about 9 in. is the most satisfactory. The oval cabinet pattern (41 E) is handier for small screws, however, and a blade length of about 5 in. is recommended. For the rapid driving of screws the 'Yankee' ratchet screwdriver is handy, but it should not be used for large screws in hardwood—unless the screws have already been put in and taken out with the normal screwdriver. The downward movement of the handle causes the blade to rotate. A spring causes the blade to remain in the screw slot when the handle is raised. It can also be used as a ratchet screwdriver.

Sawing and Planing Tools

Shooting board. The use of this has already been mentioned in connection with planes, and a sketch of a small board is given in Fig. 42 A. The heart sides of the two pieces are fixed in opposite directions so that any warping tendency in the one is resisted by the other. Battens are screwed beneath with the same end in view. Note the bevelling of the under-corner of the top piece. This takes any accumulation of dust which might otherwise prevent the plane from working truly.

Mitring tools. For small mouldings the *mitre block* (Fig. 42 E) is used. An additional 90 deg. kerf is usually made to enable wood to be sawn dead square. Larger mouldings are cut on the *mitre box* (Fig. 42 D). Note that the saw kerfs stop short of the base—the sides would otherwise be cut completely through. This necessitates a waste strip being placed at the bottom. Strips of wood screwed or nailed on at the top keep the sides true.

For trimming small mitres the mitre shooting board (Fig. 42 F) is handy. It is used chiefly

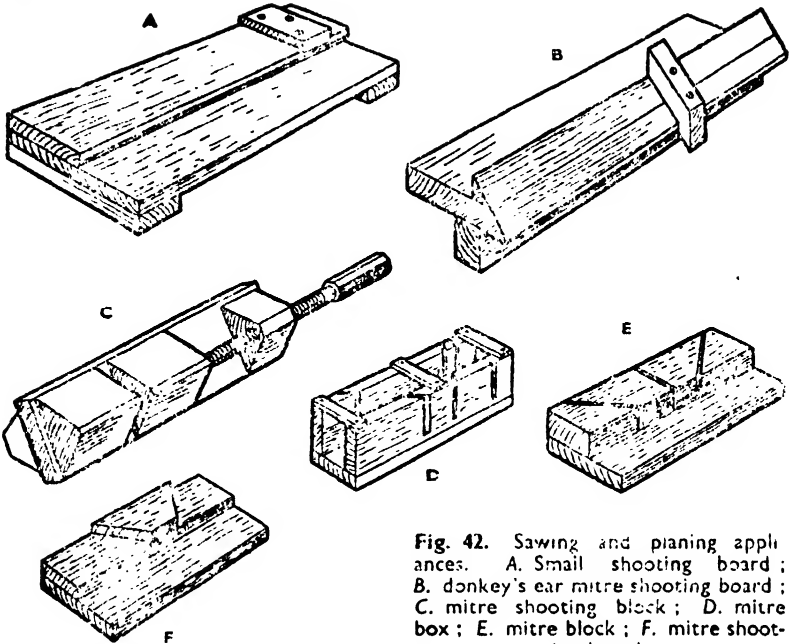


Fig. 42. Sawing and planing appliances. *A.* Small shooting board; *B.* donkey's ear mitre shooting board; *C.* mitre shooting block; *D.* mitre box; *E.* mitre block; *F.* mitre shooting board.

for inside mitres. Outside mitres are generally best trimmed on the donkey's ear pattern in Fig. 42 B. The surface of the moulding is not liable to be splintered out. Larger mouldings are dealt with on the mitre shooting block, Fig. 42 C. It is advisable to glue a piece of thin cardboard over the working faces so that these are not damaged by the plane. In some patterns one surface trims at 45 deg. and the other at 90 deg. All these appliances may be made in the workshop. Small mouldings are cut with the aid of a mitre templet.

Cramps

For the general assembling of frames such as casements, etc., the *sash cramp* is ideal (Fig. 43 A). It is capable of exerting all the pressure required without being unduly heavy or cumbersome. For heavier work the **T** sectioned cramp is used, this being of similar form but of sturdier build and with the main bar of **T** section. For work away from the shop pairs of cramp heads (Fig. 43 B) are handy. They can be fitted to a scantling of suitable width and length and are much lighter to carry about.

A useful form of cramp for smaller work and for general bench use is the **G**-cramp shown in Fig. 43 C. Some patterns have a swivel shoe which enables tapered work to be gripped. Of wooden cramps the only kind to retain much popularity is the handscrew, Fig. 43 D. This has one valuable advantage in that the pressure is not so localised as in the case of the **G**-cramp.

In use the chops are opened a trifle more than the size to be cramped (the position of the chops is easily and quickly adjusted by grasping a handle in each hand and revolving the one about the other), the centre screw tightened, and the other one then tightened up. It will be realized that after pressure has been applied, the chops should be parallel or a trifle pointing towards each other in the direction of the work they are holding. It follows then that before tightening they should point slightly in the opposite direction to allow for the movement when the outer screw is turned.

Adhesives

There are six main types of glues used in woodwork; vegetable, oil-seed residue, blood albumen, animal, casein, and synthetic resin, but only the last three are in everyday use in joinery shops. When deciding which to use, the requirements of the job have to be considered.

Animal Glue, of which 'scotch' is the most generally used, is manufactured from the hoofs, bones and hides of animals, the last producing the best quality. It is strong and durable in normal circumstances, inexpensive, and is not liable to stain the wood. It must be used hot, and is neither heat nor water-proof. It is made in cakes of about 6 in. square, and in the best quality is free from cloudiness and is so brittle that it breaks up easily when struck with the hammer.

To prepare it the cakes should be broken up in a piece of sacking to prevent flying, put into the inner container of the heater, covered with water, and allowed to stand overnight. The outer container is then half-filled with water and heated. Continual stirring with a stick will gradually bring the whole to an even consistency. The latter can be tested when the glue is really hot by raising the brush a few inches from the pot. The glue should run down in an even,

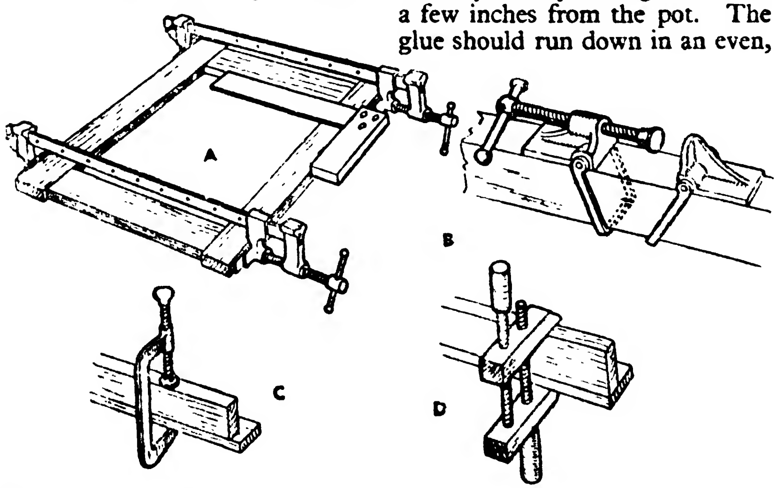


Fig. 43. Some types of cramping appliances. A. Cramping frame with sash cramps; B. pair of cramp heads; C. G-cramp; D. handscrews.

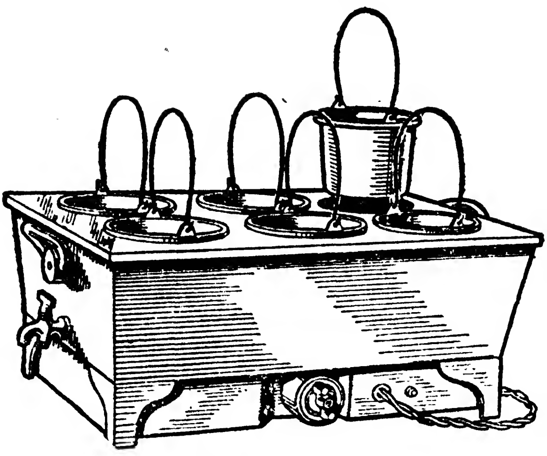


Fig. 44. Electric glue heater suitable for scotch glue.

when used on woods containing much acid, such as oak, for instance.

The preparation varies somewhat with different makes and the maker's instructions should be followed. Generally the powder is added to the water (the quantities in accordance with the instructions) and stirred until dissolved. After standing for ten minutes it is ready for use. As most caseins become rubbery after standing unused for several hours only enough for the job in hand should be prepared. One point to note is that as casein has no natural stickiness it is not generally successful to rub joints only; they should be cramped.

unbroken stream, free from lumps.

If too thick more hot water should be added; if too thin it should be heated until it thickens. Any scum should be lifted from the top before use, and only enough glue for the day's use should be prepared, as it tends to deteriorate with continual reheating. As glue must be used hot, the joints should be heated to prevent chilling, and the assembling carried out rapidly in a warm workshop. An electric glue heater, suitable for a joiner's shop is shown in Fig. 44.

Casein Glue. This is obtained mostly from skimmed milk, and is sold in powder form. It has great strength, is used cold, and is water-resistant, though not entirely waterproof. On the other hand it costs more than scotch glue, and is liable to stain most hardwoods and some softwoods. A stainless variety is available, but this has reduced water-resistance and, in any case, is not entirely free from staining

Synthetic Resin Glue is a comparatively recent introduction. There are various makes and their form varies, some being a powder, others a semi-liquid, whilst a third kind is in two parts, the glue proper and a hardener. Yet another type is in sheets something like tissue paper, and is used chiefly in plywood manufacture and veneering. Some are used cold whilst others require hot pressing.

The glue is extremely strong, is free from staining, is not subject to attack from micro-organisms, and is waterproof. Some varieties can be boiled without weakening. It is more expensive than scotch glue, and some types tend to thicken and become unusable after some three months.

For shops using a fair amount of glue, however, this is no drawback.

Preparation varies according to the type. In the two-part glue the glue is applied to one part of the joint and the hardener to the other. No setting takes place until the two are brought together. Various hardeners are available, some retarding and others accelerating the setting, so that on a job requiring considerable time in assembling a slow hardener should be used. In some kinds the glue and hardener are mixed together immediately before use.

In another type of glue the whole is in powder form and only requires mixing with water, prior to immediate use. For veneering and similar work, glues derived from phenol-formaldehyde can generally be used only under heat and pressure; whilst those from urea-formaldehyde can be used either hot or cold, the particular hardener for the purpose being selected. In some cases the glue can be extended with rye flour to reduce costs. Film glue needs hot pressing. The maker's instructions must be followed in all cases.

Nails. Fig. 45 shows the nails generally used in joinery and carpentry. The old type of cut nail (A) is sometimes used for flooring. It grips well, but leaves an unsightly head. B is the wrought nail for heavy work where strength is imperative. For general use the bright wire nail C is widely used for work where the large head is not a drawback. When a neater finish is desirable, the oval wire nail D, or the 'lost head' nail E are better, as when punched in leave only a small hole to be filled in.

Finer and smaller work is fixed with the panel pin F. Clout nails G are used mostly for fixing roofing felt, sash cords, etc. Screw nails H revolve as they are driven in and obtain a firm fixing in the wood. The glazing nail I is used for fixing panes of glass before puttying. For brickwork, the pipe nail J is useful for various fittings. In all cases where strength is imperative nails should be dove-

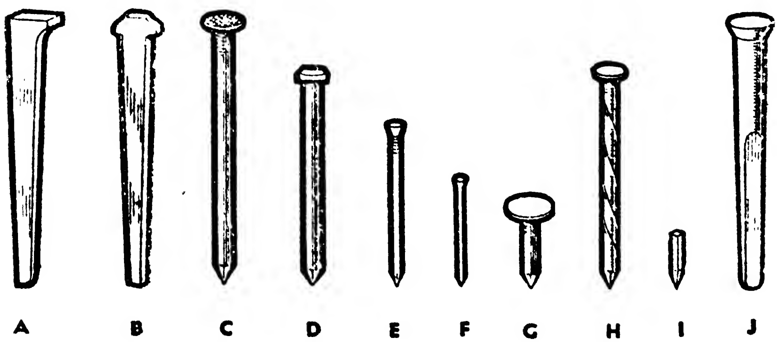


Fig. 45. Types of nails generally used in carpentry and joinery. A. Cut *B.* wrought iron; *C.* round wire; *D.* oval; *E.* lost head; *F.* panel pin; *G.* clout; *H.* screw nail; *I.* glazing brad; *J.* pipe nail.

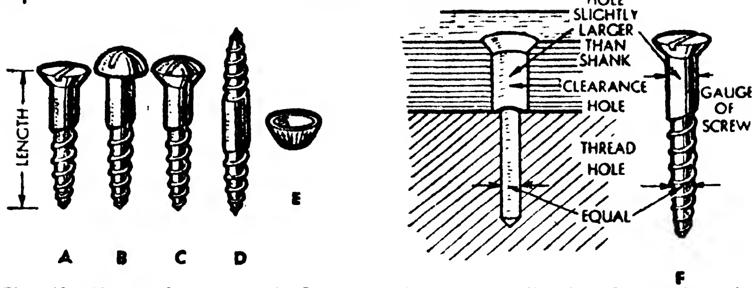


Fig. 46. Kinds of screws. *A.* Countersunk ; *B.* roundhead ; *C.* raised head ; *D.* double ended ; *E.* screw cup ; *F.* sizes of screw holes. The shank-hole should be slightly larger than the shank ; while the hole taking the thread should be the same size as the centre round portion of the shank.

tailed, that is, driven in askew in alternate directions (Fig. 41 C).

Screws. These are obtainable in three main forms and in various metals. Fig. 46 shows the kinds and makes clear where the length is taken from. The gauge is indicated by numbers from 0 upwards and is standard for all lengths. Thus a 2 in. No. 10 screw is of the same diameter as a 1 in. No. 10. A is the countersunk screw, B the round-head, and C the raised head. Screw cups E are used when a neat finish is essential and where screws may have to be frequently removed and replaced. Double-end screws D are handy when the use of ordinary screws would be impracticable.

Other Fixings. For heavy work subjected to considerable strain the fixings shown in Fig. 47 are used. The coach screw (47 A) for wood is turned in with the spanner. B and C are bolts tightened with nuts. The purpose of the handrail bolt D is obvious. Mortises are cut in the underside of the wood to receive the nuts, and holes bored for the bolt at the joining ends. The round nut is tightened with a special punch tool. For brickwork the pipe nail J in Fig. 45, or the holdfast Fig. 47 E, can be used in accordance with the purpose for which they are needed. Staples (Fig. 47 F) are useful for fixing metalwork in various positions.

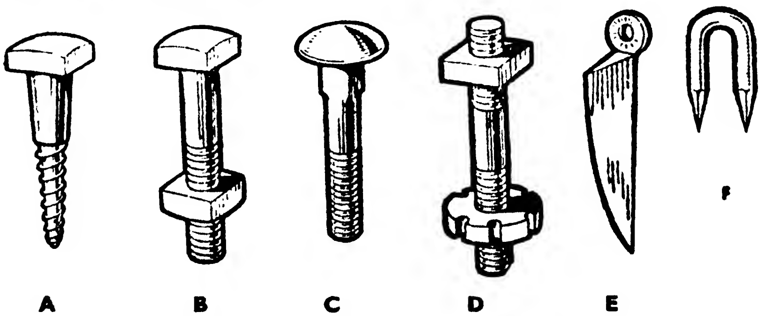


Fig. 47. Types of fixings used for work subjected to great strain. *A.* Coach screw ; *B.* bolt ; *C.* snap head bolt ; *D.* handrail bolt ; *E.* holdfast ; *F.* staple.

CHAPTER 4 : Part 1

MACHINE TOOLS

MACHINE SHOP LAYOUT. MOTIVE POWER. CIRCULAR SAWS. BAND SAWS. PLANING. MORTISING AND TENONING MACHINES. SPINDLE MOULDERS. RECESSING MACHINES. CUTTERS AND ABRASIVES. SANDERS.

WOODWORKING machinery is essential for the economic production of joinery. The improvements and the progress in machinery have made it possible to manufacture framed work cheaply and with an accuracy previously unattainable. It has evolved a technique of its own and made new methods of woodwork construction practicable.

While the actual manipulation and conditioning of the machine has become a highly specialised job, and is now the province of the wood-cutting machinist, the carpenter and joiner should become familiar with the capabilities of the machine and the fundamental principles which underlie each operation.

Machine Shop Layout

The first consideration is that of the layout of the machine shop itself, which must be well lighted and well ventilated. It should have a good floor space to give adequate means for dealing with long lengths of timber so as to avoid fouling other machines or choking the steady flow of work from machine to machine. Overcrowding often means that work which could be executed by machines has to be completed by hand methods on the bench. A typical machine shop layout is shown diagrammatically in Fig. 1.

The floor of the shop should be of the wood block type, except, of course, where the necessary foundations to the machines occur. A wood surface is less likely to convey grit to the machine than a brick, stone or concrete floor. Moreover, wood being a non-conductor of electricity, is a considerable safeguard against excessive shock to the machinist should any fault occur.

Home Office regulations in relation to the machine shop should be noted and strictly adhered to. Extracts from these regulations state :—

(1) A clear and unobstructed space shall be maintained at every woodworking machine to enable work to be carried on without unnecessary risk.

(2) The floor surrounding every woodworking machine must be maintained in a good and level condition, free from chips and loose material, and shall not be allowed to become slippery.

(3) All artificial light shall be placed or shaded to prevent direct rays impinging upon the eyes of the operator while he is using the machine.

(4) The temperature where woodworking machines are being worked shall not fall below 50 degrees (Fah.).

The motive power by means of which the woodworking plants

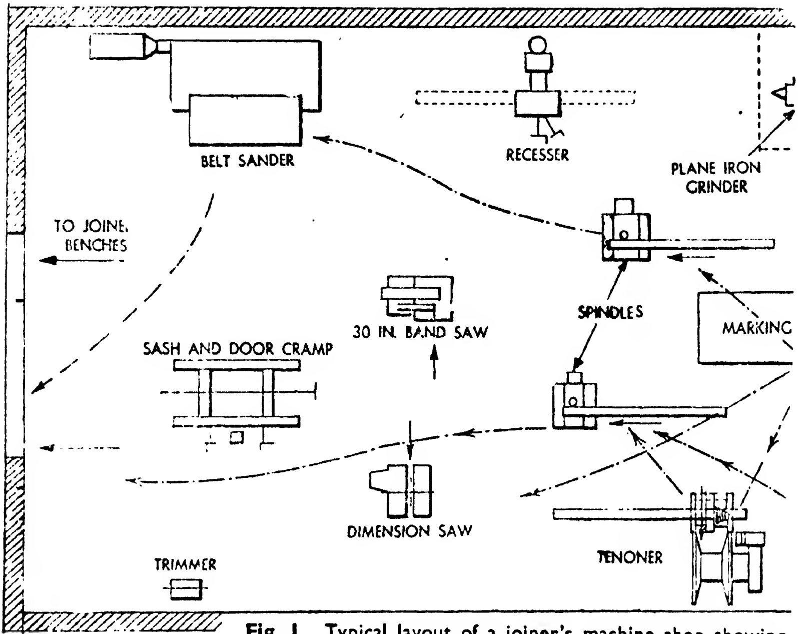
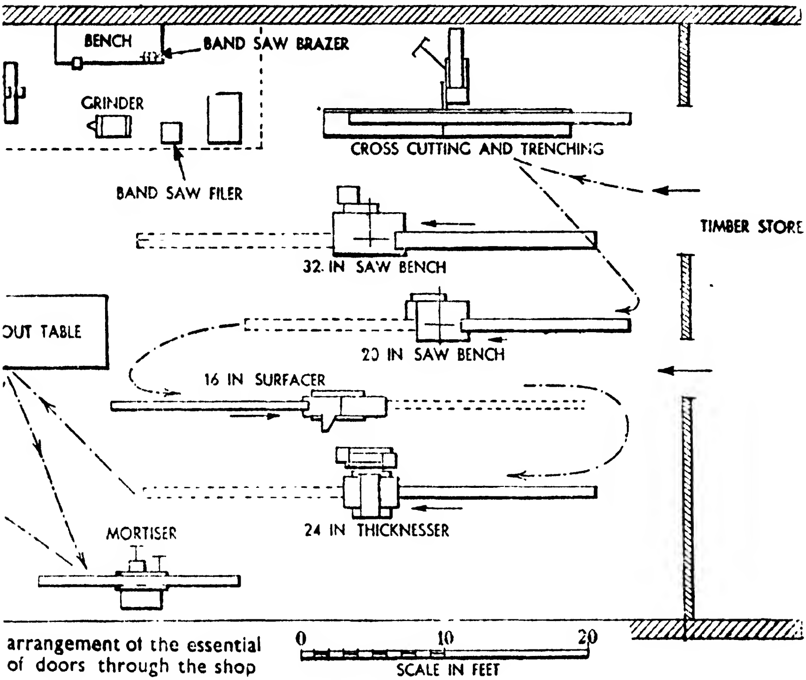


Fig. 1. Typical layout of a joiner's machine shop showing machines. Broken line with arrows shows progress of batch

may be driven may be steam, gas or electricity. Whenever any of these motive powers is used consideration should be given to the H.P. required by each machine. Although the maximum amount of power is not always required by each machine at the same time, the amount of force required to work all the machines must be provided for at the time of installation, with margin to spare for additional machines. The danger of overloading must be avoided.

The use of electricity as a motive power for each individual machine, as distinct from its use as a single power for the whole plant, has much to be said in its favour. This may be summarised as: '(1) The machine is not limited for position, nor at the angle at which it stands; it can be laid down in any convenient space; (2) it reduces the floor space taken up by casings and coverings to a minimum; (3) it lends itself to general tidiness and cleanliness; (4) the breakdown of one motor does not lead to a general stoppage of the whole plant; (5) the speeds of the different machines may be better controlled.

Many stoppages and blown fuses may be avoided if reasonable care is taken by the operator when starting up the motor. The starting up of a motor should be a gradual process. The introduction of the push button, 'start and stop,' with remote control, has largely eliminated this factor of error and, wherever possible, this fitting should



arrangement of the essential
of doors through the shop

be installed on the machine. Not only does it safeguard the motor itself, but it is a handy means of cutting off the power in the case of accidents.

Modern joinery machinery is composed of a number of units. Such machines as the tenoning machine, thicknessing machine, four-, five- or six-cutter, may have separate direct motor drives for each cutting head as well as the feed drives. Dangerous driving belts are avoided, and the operator can test each revolving head for balance, as distinct from the machine as a whole. Each motor has its own push button to start or stop each unit. Fig. 2 shows the push button starter to a circular saw.

There is a diversity of opinion among craftsmen as to whether a machine is preferable if driven by a motor coupled direct to the spindle or by multiple vee belts. Fig. 2 shows a circular saw driven by a motor coupled direct to the saw spindle, while the circular saw shown in Fig. 3 B is driven by multiple vee belts. The inset D shows a section through the multi-vee belt drive. The pulleys are vee shaped and deeper than the thickness of the belt.

When the installation of electric plant is under consideration it is advisable to inform the makers of the nature of the supply available, no matter what system is to be adopted.

If alternating current is supplied, the voltage, phase and frequency should be clearly stated. If direct current is to be used, the voltage should be

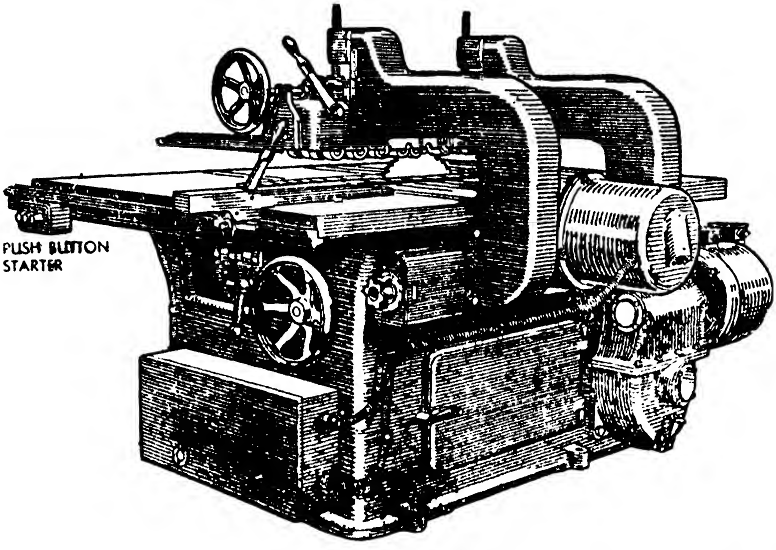


Fig. 2. Circular saw driven by motor coupled direct to saw spindle. Note the absence of loose belts or drives; also the push buttons to start and stop machine.

stated. The authorities responsible for the current should be informed as to the amount of call to be made upon the main cable in H.P. required. The H.P. required for each machine is given by the makers. Table I on the opposite page shows a fair and reliable basis of H.P. required for each machine, and the type of work which can be done by the machines.

Saws

Converting timber into small stuff is known as *breaking down.* The cutting may be done on a heavy rack saw-bench with a circular saw of 48 to 72 in. diameter, or by means of a log band saw with a ribbon saw of 6 in. and upwards in width. The actual conversion of timber requires a practical knowledge of how to saw the timber to the most economic advantage, and also a wide experience of how to hammer, level, tension, sharpen and set the saw blades.

For joinery work, the types of circular saws shown in Fig. 3 are of particular importance. A shows a roller-feed saw bench with a cutting depth of 12 in. In the hands of a capable sawyer this machine is most useful for *deeping*, that is, resawing deals into boards, and *flatting*, that is, resawing deals into scantlings. This machine is capable of dealing with most of the heavy sawing required by a joinery manufacturer.

B shows the most common type of circular-saw bench fitted with a rise and fall table and a cutting depth of 7 in. This machine is useful for ripping and all general purposes. The adjustable fence should be capable of extending well forward for ploughing and grooving purposes.

C shows a canting, rise and

Machine	Details	H.P.	Type of work done
Saw benches	26 in. rip saw ...	9	Flatting, deeping; sill sinkings; bevelling; tenoning.
„ „	32 in. „ „ ...	12	
„ „	36 in. „ „ ...	15	
Dimension saw with small rip.	18 in. „ „ ...	4	Rebating, grooving; mitring; housing; halving; wedges; angle blocks.
Surface or overhand planer	9 in. cutter length	2½	Facing; edging; rebating; tapering; moulding; fluting.
	12 16 in. „ „	4	
Panel planer or thicknesser	24 in. „ „	7½	Thicknessing; widthing; tapering; panels; veneers.
	30 in. „ „	10	
Mortise machine	Chisel only	2	Mortising; boring; sinkings.
„ „	Chain and chisel ...	4	
Tenon machine	For each revolving head, i.e. tenon or scribing or cross cut.	2	Tenoning; scribing; haunching, mitring; housing; trenching; square turning; double tenoning.
Spindle moulder	Block, french or collar	4	Most moulding; straight or circular; handrailing; string housings.
Combination, cross cut, trenching machine	—	5–6	Cross cutting, mitring; trenching; any angle, any plane.
Pendulum type cross cut...	—	4–5	Cross cutting and squaring heavy timbers.
Band saw, curvilineal ...	30 in wheels ...	3	Circular shapes; square turning domes; handrails.
	36 in. „ ...	4	
Belt sander	Belt type	4	Doors; sashes; skirtings; flooring; framings.
Recessing machine ...	—	2	Sunk mouldings; seat ends; boring.
Saw gulleting machine ...	—	1	—
Plane iron grinder ...	—	1	—
Moulding cutter grinder ...	—	1	—

Table I. Showing H.P. required for woodworking machinery and the type of work which is most suited to the various machines.

fall table dimension saw bench. This is useful for rebating, sinking, ploughing and mitring to any angle.

All types of saws demand the same consideration with regard to usage and maintenance. Blades of good quality are resistant to wear and distortion, and are capable of withstanding a high speed feed. A saw should fit the mandrel of the spindle with just enough clearance to both spindle and location pin to allow for expansion. To ensure an even grip on the saw surface, the collars which grip the saw (Fig. 4) should be sunk across their faces and lie perfectly true on the flanges.

The circumference of the saw is trued by *topping* or *stoning down* by holding a piece of fine grit stone against the teeth of the saw while it is in motion. Saw teeth may be sharpened by automatic means or by hand methods. A sawyer should retain two distinct types of blades, one for hardwoods, the other for softwoods. The setting of the teeth should also be considered for wet or dry woods. Types of teeth for various purposes are shown in Fig. 4.

The cutting edge of a saw consists of teeth and gullets. Properly shaped gullets are as important as properly shaped teeth. In ripping, the gullet has to carry away the dust and fibres cut by the tooth, and it is good practice to make the area of each saw tooth equal to the area of each gullet. Gullets should be well rounded in order to prevent the plate cracking. Teeth for softwoods require more *hook*, that is, forward rake, and more set. Teeth for hardwoods and cross

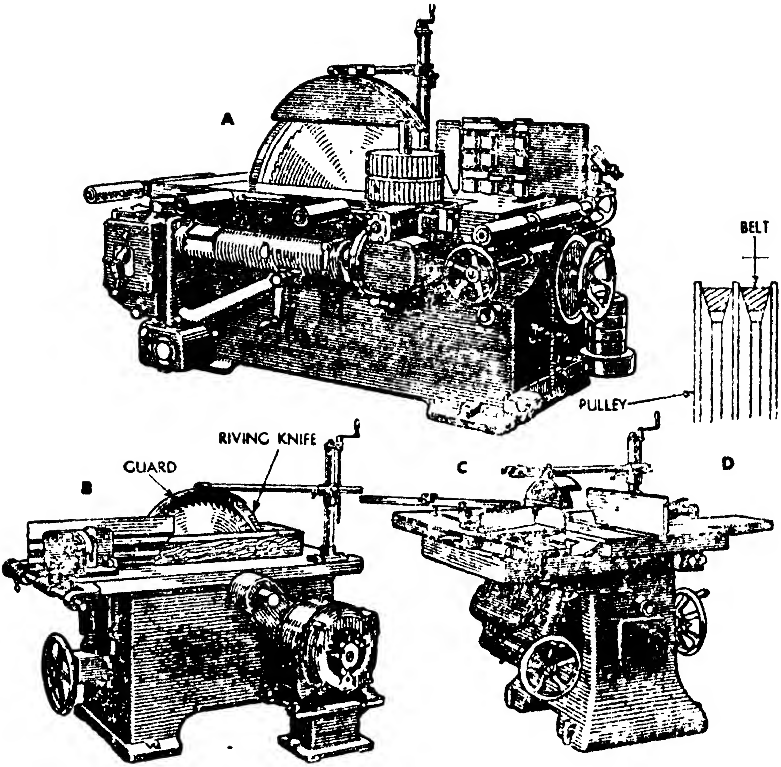


Fig. 3. Types of circular saw. *A*. 36-in. roller-feed saw bench for deep resawing ; *B*. saw bench with rise and fall table and multi-vee belt drive ; *C*. dimension saw bench with tilting spindle : *D*. section of multi-vee belt drive.

cutting need less hook and less set. Set should be on the tip of the teeth as shown in the diagram, and not on the whole tooth.

Rip saw teeth can be set by either *spring*, *hammer*, or *swage* set so that clearance is given to the saw in its passage through the timber. One gauge thicker than the saw plate is a fair allowance, with slightly more set for softwood or wet timber.

To prevent deflection, to steady the saw in the cut, and to assist in correcting the tension, the saw should be *packed* on both sides where it enters the bed of the bench. This packing should be of ' saw felt ' or teased or plaited hemp, inserted from the base of the gullets to the collar (Fig. 4).

Tensioning is a process in the manufacture of the saw whereby the rim is stiffened by hammering. This is necessary in order to counteract the centrifugal force set up by the saw when in motion.

Cross-cut saws are not packed, and they are run at a higher rim speed than the rip saw. As the operation of crosscutting is to sever the fibres, the saw-tooth should have a backward throw to gullet rather than a hook rake.

Cross-cut saws are 'spring' or hammer set.

The pendulum type of cross-cut, as shown in Fig. 5 A, is useful for heavy timbers, while the more modern machine shown at B can be adapted for trenching. Both these saws are pulled across the timber for cutting operations.

The Home Office safety precautions in respect to circular-saws must be scrupulously adhered to. They insist that the saw above the bench should be covered with a rise-and-fall guard with a sliding sheath which can be adjusted to suit the varying thicknesses of material. The saw

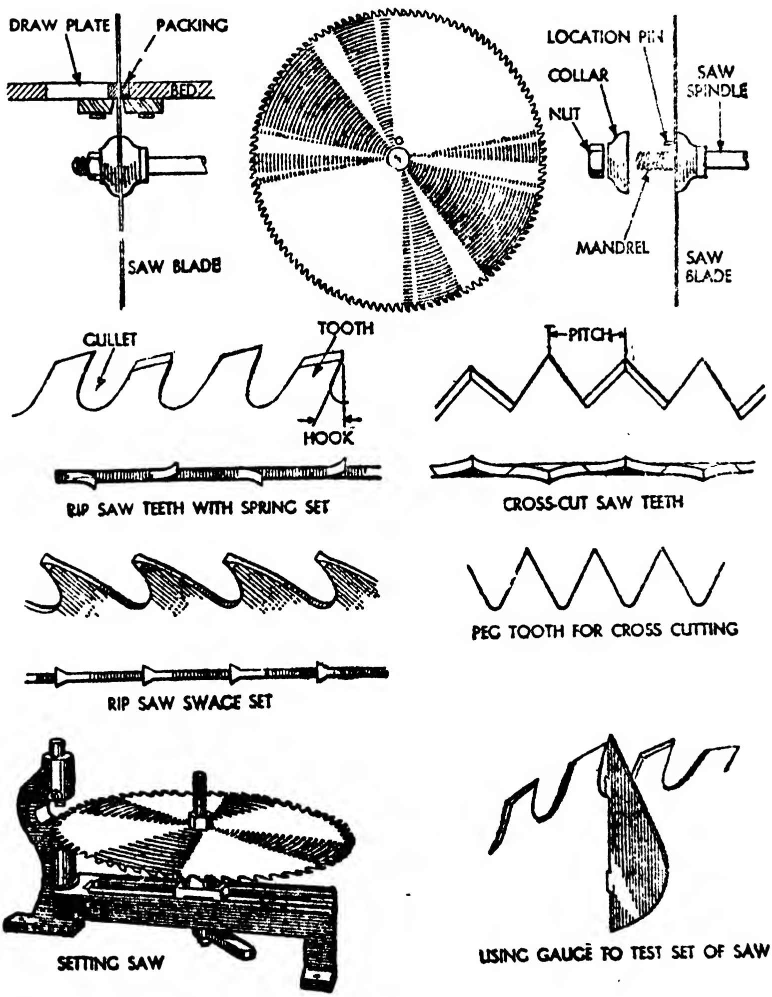


Fig. 4. Diagrams illustrating method of fitting circular saws to the spindle and also showing the shapes of teeth of circular saws, and method of setting a saw.

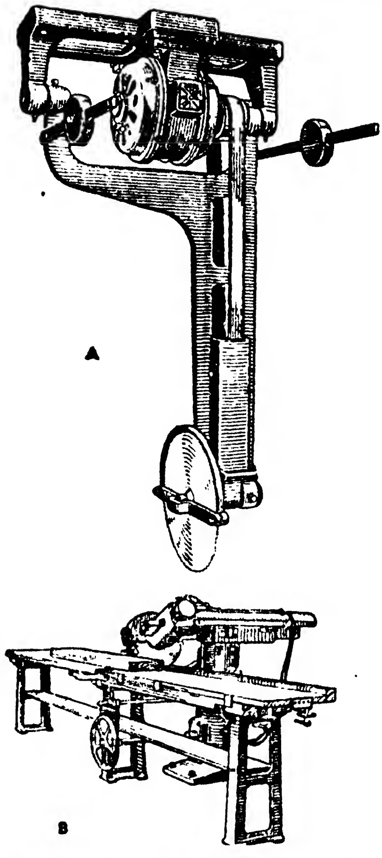


Fig. 5. Two types of cross-cut saws. A. The pendulum, in which the saw swings outwards towards the timber ; B. in this more modern type the saw is drawn across the timber.

below the bench must be encased. To prevent *back lash*, that is, the tendency of the saw kerf to close and the material be thrown back on the operator, every rip saw must be fitted with a riving knife not more than ⅝ in. away from the blade (Fig. 3 B). Push-sticks not less than 15 in. long should be used for completing the push-through of the timber.

A narrow band-saw, as shown in Fig. 6 A, is essential for joinery work. Unlike the heavy band-saw, the 'curved line' band-saw is used for more delicate and intricate work. Handrail wreaths, easings, square-turning, tracery, brackets and shaped cutting are within its scope.

Abuse of Band-saws.

This machine is abused more than any other in the mill. To avoid abuse one man should be responsible for all cutting and the upkeep of the saws. The ribbon-saws vary from ¼ in. to 2 in. in width. The materials dealt with should not lie 'dead' on the bed of the machine, but should be held so that the weight is eased. By this means the 'pull' of the saw will indicate the pressure which should be applied to the wood.

Frictional expansion of the saw should not be remedied suddenly while cutting, and the strain should be released when the work is completed. The saw should always be aligned so that it runs on the centres of the wheels which should be kept free from dust by the brush attachment supplied.

Repairing Breakages

Saw breakages can be repaired by means of an electric brazer as shown in Fig. 6 B. The saw is prepared and tapered for an overlap and is then clamped as shown, care being taken to ensure that the teeth are in alignment. Silver solder and flux are applied to the joint, and the current turned on. Great care must be taken in controlling the heat, otherwise the braze will be damaged.

Common causes of saw breakage are: overcoming inertia suddenly; badly-worn wheel bands;

improper elastic tension; gullets too sharp; improper back thrust; radius cut too small for saw; working expansion and contraction; bad brazing.

Planing Machines

Planing machines may be classed under three headings: (1) The *surfacer* or overhand; (2) the panel planer or *thicknesser;* (3) the *combination* or over and under.

The surfacer, as shown in Fig. 7 A, is used for trueing up and squaring sawn material. It is important to see that the beds of the machine are level and true with each other, both in their length and width, and that the cutters in the cutter block conform to the surface of the beds. The cutters of all planers should be of equal weight and in pairs, and should be equal throughout their length and breadth. They should not taper in width, but should be perfectly *balanced*, and should not project more than $\frac{3}{32}$ in. beyond the face of the cylinder, as shown at Fig. 7 C and E.

In using the machine the operator follows the action of the joiner by removing high corners and prominent lumps before attempting a finishing cut. This is necessary in order to obtain a true surface at the minimum cost of material.

The surfacer must conform to the Home Office regulations, which state: "Every overhand planer must be provided with a *bridge* safety guard capable of covering the full length and breadth of the cutting slot. No machine, which is not mechanically fed, shall be used for overhand planing unless fitted with a cylindrical cutter block. The machine must not be used for planing wood less than 12 in. in length unless a safety holder is used."

The panel planer or *thicknesser*, as shown in Fig. 8, is capable of dealing with timber 30 in. in width and 7 in. in depth at speeds of 25, 37 and 55 ft. per minute. The lower sketch in Fig. 8 shows the sectional feed rollers and pressure bars by means of which

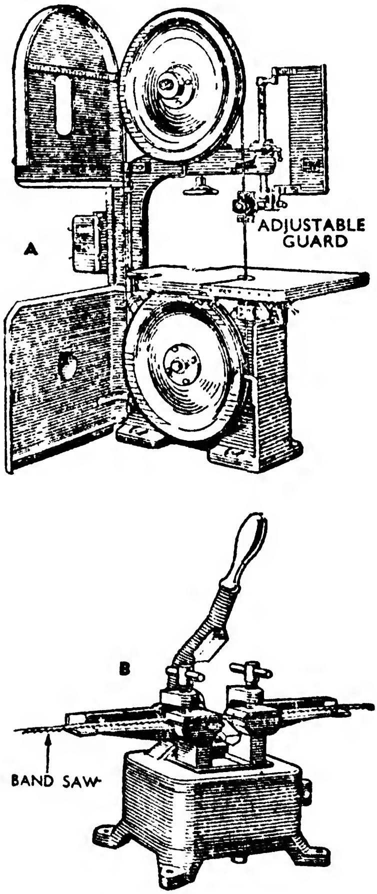


Fig. 6. A. The band-saw is an essential in joinery work. Narrow band-saw, with guards open to show mechanism; B. electric brazer for repairing saw blades.

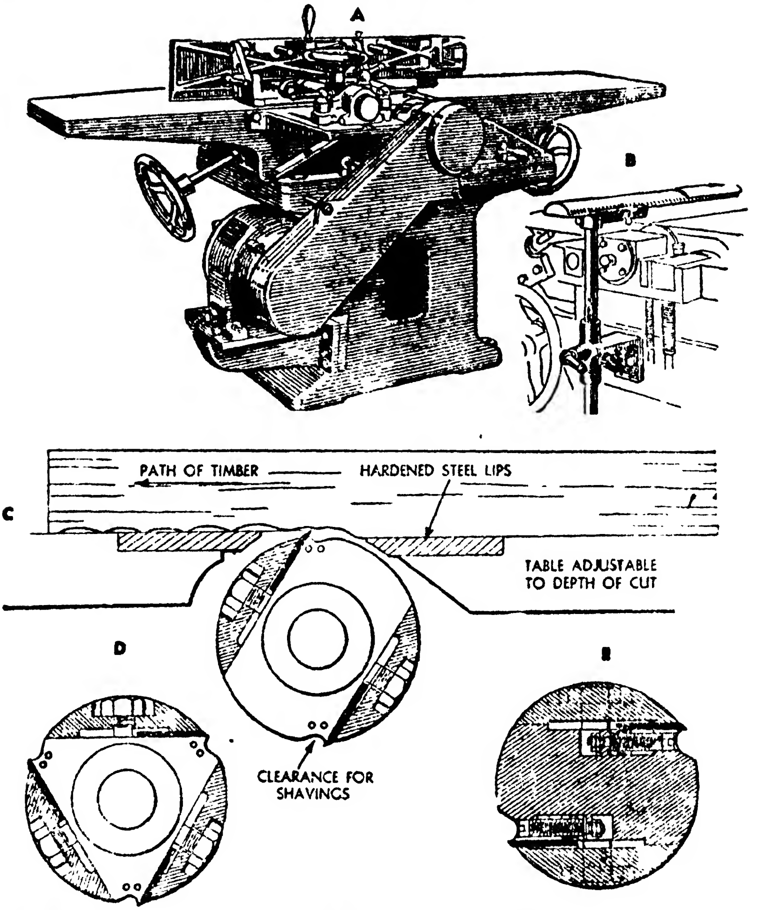


Fig. 7. Planing machine. A. General view of surfacer with self-contained drive ; B. bridge guard to cover cutters ; C. section through table fitted with safety circular block. Notice ripple marks made on timber by revolving cutters ; D. three-knife block ; E. micrometer screw knife setting arrangement.

several pieces of material can be carried through the machine without kicking back.

Cutters are frequently maintained over a given period by tracking a carborundum stick over the cutting edge in the manner shown in Fig. 9 at A.

The thicknesser obtains a parallel thickness after the face side and face edge have been over the surfacer, or it may be used for gauging thin stuff like panels.

The *combined surfacer and thicknesser* may only be accepted where shop space is limited ; its use as a process proposition under modern conditions is questionable. " Facing and edging," " thicknessing " and bringing to width are two distinct operations, therefore they cannot be performed at the same time on the same machine, and progress must necessarily be retarded.

Much use of the surfacer can be made for rebating and moulding by removing sections of the cutter block and introducing slotted cutters to suit the various requirements. Fig. 9 B shows a surfacer adapted in this manner.

Mortising Machines

The mortising machine is an important asset to the joiner. There are two main types of cutting parts: (1) the *hollow square chisel*, whereby a revolving auger within the chisel removes the core of the hole; and (2) the *toothed chain*, which consists of many cutter links forming an endless chain which scoop out the material. Both the shell of the hollow chisel and the links of the chain demand a high degree of perfection in manufacture and maintenance.

Hollow chisels leave a clean hole needing no core driver for cleaning out. The size of the chisel determines the size of the mortise, and bits up to 2 in. square may be used in a heavy machine. The chisel boring bit should be adjusted to allow enough clearance to allay any undue friction on the cutting edges of the chisel, while the clearance slot for chips should be set in the direction of the first insertion to allow for the discharge of waste.

Chains are limited in use, as the length of the mortise is controlled by the width of the chain bar or guide plus the thickness of the chain and the necessary slack.

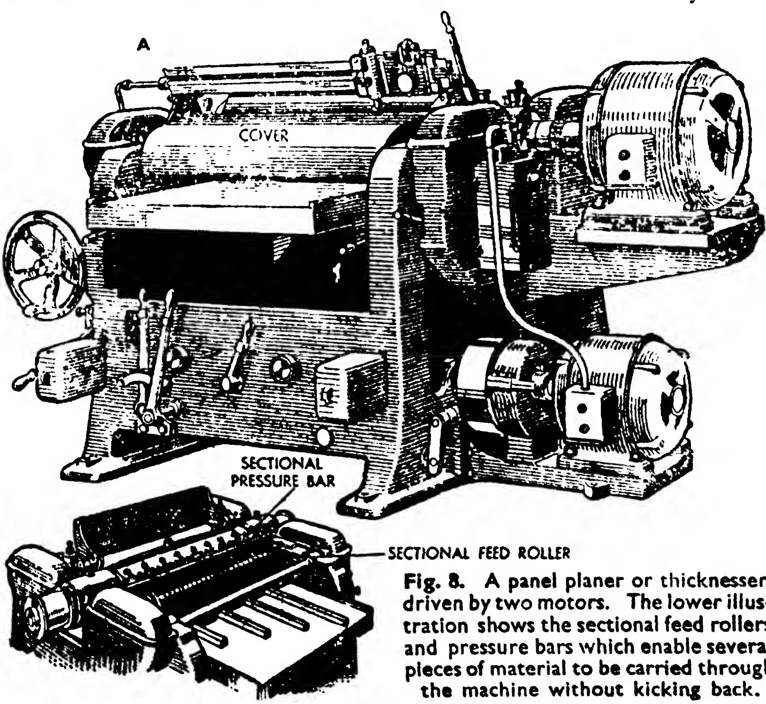


Fig. 8. A panel planer or thicknesser, driven by two motors. The lower illustration shows the sectional feed rollers and pressure bars which enable several pieces of material to be carried through the machine without kicking back.

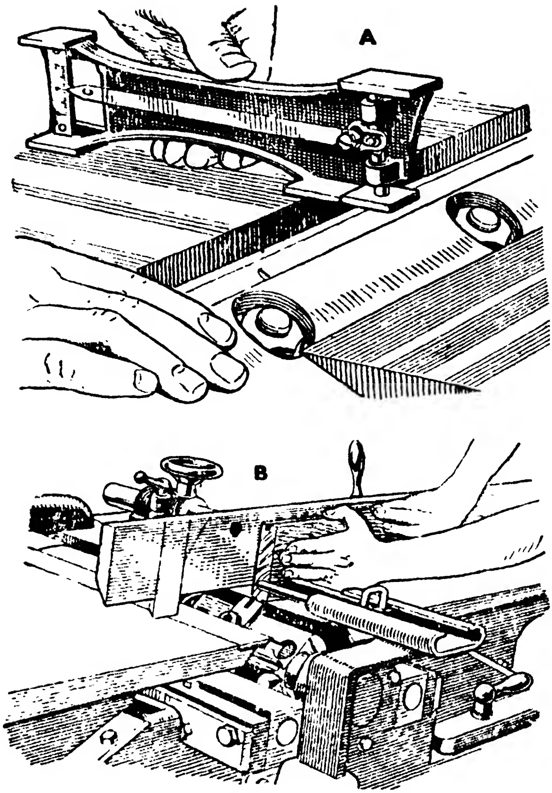


Fig. 9. A. Method of resetting the cutters of a surface planer ; B. a surfacer adapted for rebating and moulding.

Neither chain nor chisel should be traversed in the cut but lifted clear for each cut. When mortising hardwoods, it is not advisable to reach the maximum depth with one insertion ; a gradual approach will preserve the life of the tools. All chains and chisels should be immersed in an oil bath when not in use. Fig. 10 shows typical types of machines and their bits. In mortising, the face side or edge must always be placed to the fence.

Although designed for the purpose of cutting tenons for mortises, the tenoning machine lends itself to many operations, such as : mitring, housing, trenching, bracketing of sash stiles, square turning, and scribing. When used in conjunction with the mortising machine extreme accuracy between the two is essential. It is important that the exact positions of both mortise and tenon from the face of the work be maintained. This can only be done when the face sides are kept to the mortiser fence and the tenoner bed respectively. Once the mortise and tenoning machines are set, they should be locked and not moved for any apparent variations in the gaugings on the work.

Tenon cutters have a shearing action to prevent the whole of the fibres being attacked in the same section at the same time.

This shearing cut is obtained by making the cutters elliptical in shape. The cutter actually forms a section through a cylinder, the cylinder being the path the cutter makes when in motion. Fig. 11 shows a tenoning machine ; note the shaped cutters shown in the insets at A. The lancet or shoulder scribing irons should only project to give a slight cut in front, otherwise a weakened tenon will result.

Reground cutters should never be set to a previously cut tenon, but should be tested for a parallel cut. The fence of the table should be set square to the work. Note the adequate safety guards shown in the diagram, and the alternative cutter heads for trenching and grooving shown at B and C.

Spindle Moulders

In its simplest form the spindle moulder is a vertical shaft, capable of revolving at high speeds, to which various cutter heads can be fixed. The shaft is bored at the crown and screw-threaded for the purpose of receiving a shouldered sleeve to take interchangeable heads. Fig. 12 shows this machine and its various cutter heads.

A safety or cylindrical block may be used for cleaning up shaped work which is done by holding the edge of a templet to the ring fence, as in Fig. 13. Collar heads (Fig. 12) are grooved to take the cutters, and it is essential that the cutters are dead parallel, and of equal width, otherwise when tightened down they may tend

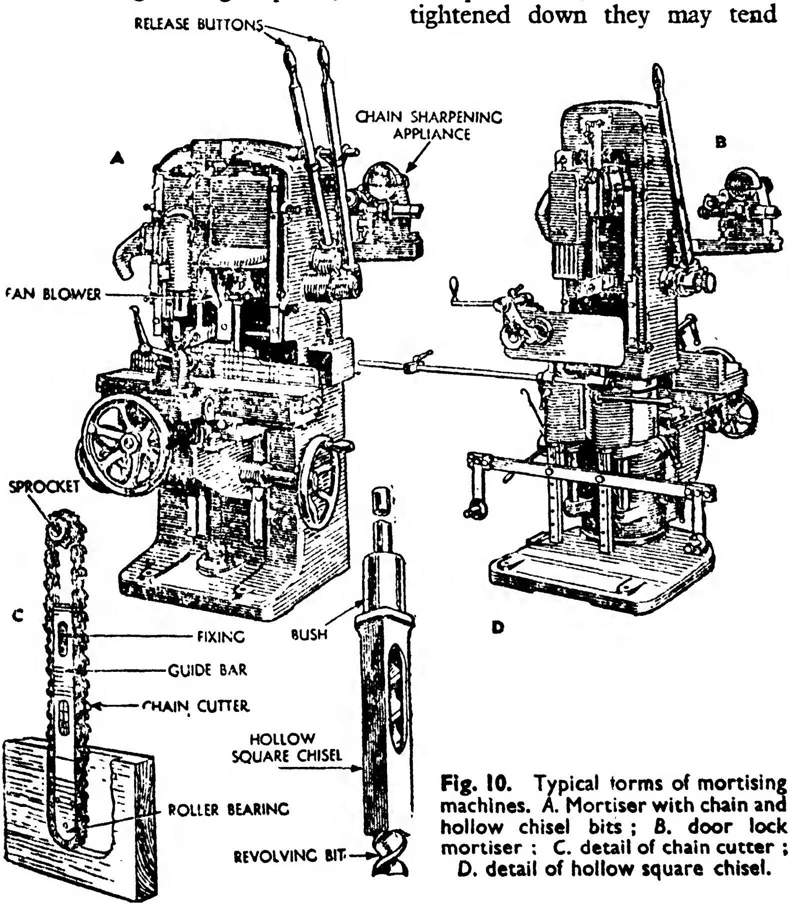


Fig. 10. Typical forms of mortising machines. *A.* Mortiser with chain and hollow chisel bits ; *B.* door lock mortiser ; *C.* detail of chain cutter ; *D.* detail of hollow square chisel.

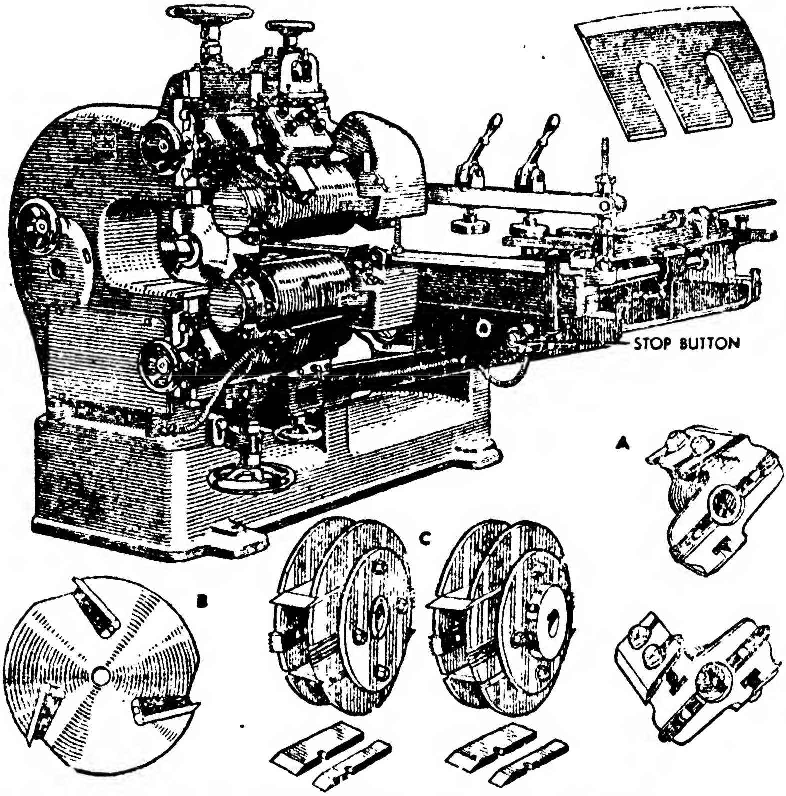


Fig. 11. Self-contained tenoning machine with motor to each head. A. Shows top and bottom blocks with elliptical cutters and scribers; B. tenoning and grooving disc; C. expanding trenching and grooving heads.

to fly out and cause accidents. A thickness of paper placed at the top and bottom of the cutters should be used to prevent this taking place. Grooving saws may be fitted to the spindle for grooves, throatings and sinkings. These are generally obtained in sets; 1 saw equals $\frac{1}{8}$ in., 2 saws $\frac{1}{4}$ in., 2 saws and 1 cutter $\frac{3}{8}$ in., 2 saws and 2 cutters $\frac{1}{2}$ in.

The *Whitehill* head (Fig. 12) may also be used; this is a circular block made to receive cutters in a slot.

The main shaft is removed when the *French* head (Fig. 12) is fitted. With this head, the cutters used are of mild steel inserted in the slot and secured by bolts tightened down to a packing piece and not on the cutter itself. The cutter does not cut in the strict sense of the term; it has more of a scraping action.

Like all woodcutting machines the spindle requires some means of guiding the material for the control of the work. Fences are provided for this purpose. When block and collar heads are in use, fences are essential, and the eccentric ring fence should be used for circular work. This is shown in Fig. 13 A. The Home Office regulations insist that every vertical moulding machine shall be provided with an efficient guard, having regard to the nature of the work being performed. For such work as cannot be performed with an efficient guard, the wood should be held in a jig or holder of some kind to reduce the risk of accident to the worker.

Several types of common guards are shown in Fig. 13, together with the methods of guiding the wood. Back cutting or back lashing is often resorted to by the machinist for the purpose of easing the finishing of the material. This should never be attempted with the block, collar or Whitehill heads, otherwise an accident would be inevitable.

Cutters on a French spindle are a true reverse profile of the required shape, but for the block, collar or Whitehill the shapes of the cutters must be obtained by development.

In a four- five- or six-cutter moulding and planing machine the true shapes of the moulding cutters have to be determined, and the cutters correctly balanced. The machine shown in Fig. 14 will prepare long lengths of archi-

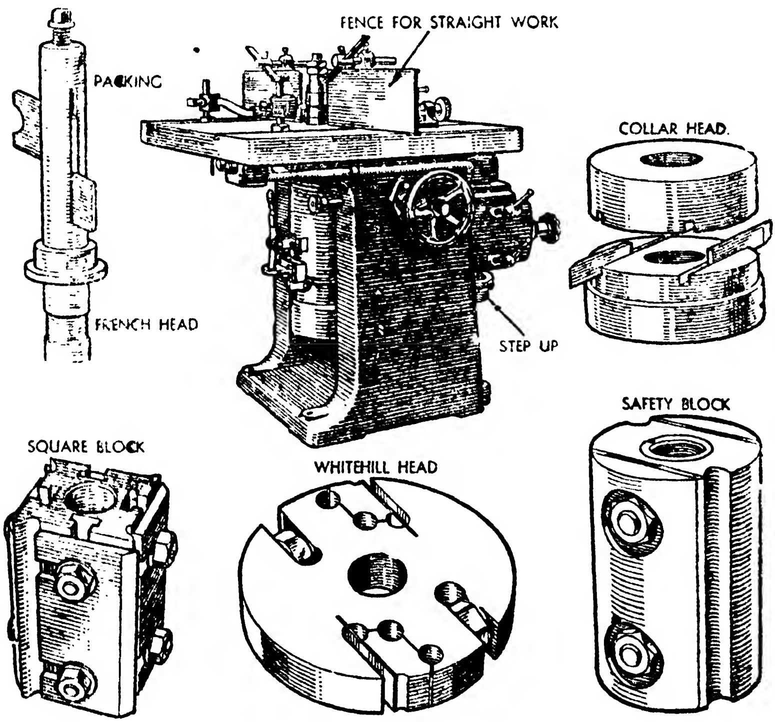


Fig. 12. Vertical spindle moulder, with fence for straight work. Various interchangeable heads for use with the moulder are also shown.

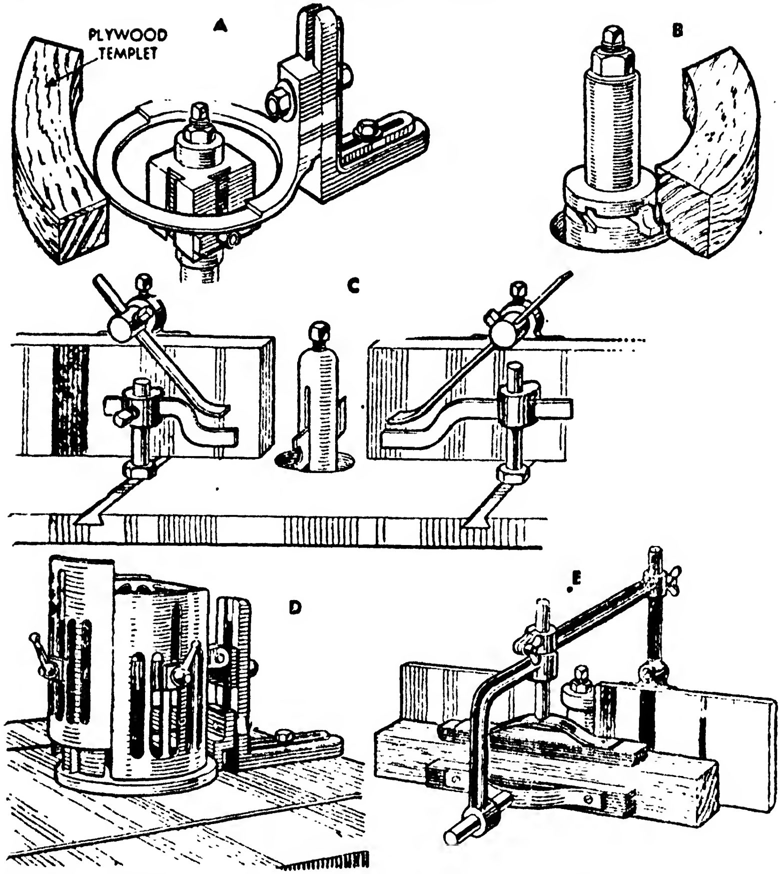


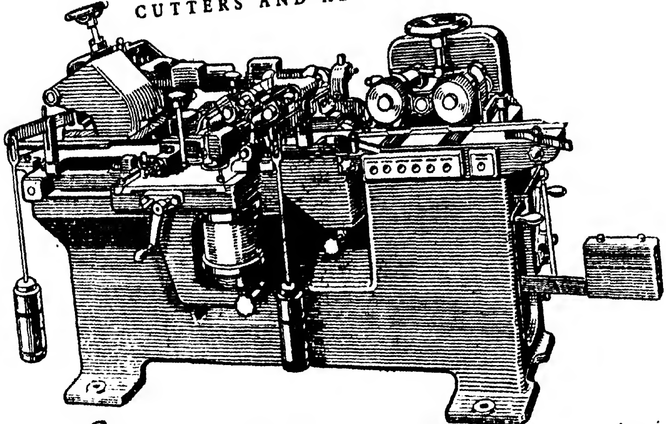
Fig. 13. Spindle moulder showing various types of fences for guiding the material. A. Use of ring fence. Plywood templet is shown held to ring. B. timber held against slotted collar. No fence—light work only ; C. spring guards to fence for use on straight work ; D. cage suitable for curved work ; E. shaw guards, a type which embodies combined springs and guards.

traves, panel mouldings and skirtings in one operation. It is usually set up by means of a templet, or a pattern moulding. Speed feeds can be controlled to suit the characteristics of the timber.

Recessing Machines

The recessing machine is also called the *elephant* spindle because of the trunk upon which the principle of the machine is built. It may be considered as an overhanging spindle moulder capable of doing a greater variety of work. The work is controlled laterally, transversely and diagonally, with a fixed or rise-and-fall table.

Stair strings, undercut mouldings, drop mouldings and all manner of recessing may be done on the machine. Fig. 15 shows the elephant recessing machine set up for housing stair strings.



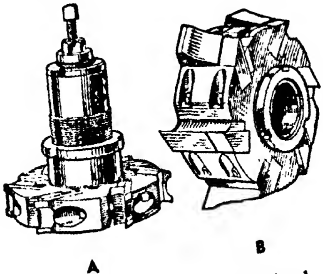


Fig. 14. General view of an electrically-driven outside moulder or four-cutter planing machine. A. and B. show types of discs for cutters

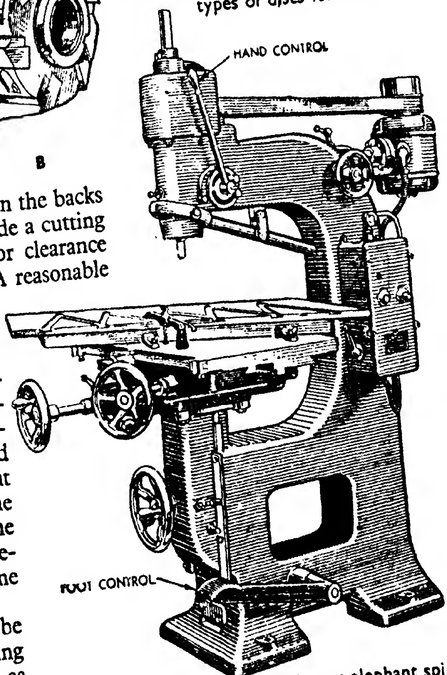


Fig. 15. Recessing or elephant spindle machine housing a stair string.

"Grinding bevels" on the backs of cutters are to provide a cutting edge, and to allow for clearance in the cutter track. A reasonable bevel for softwoods is 30 degs., and for hardwoods 35 degs. The angle is sometimes further reduced by back bevelling, but it should be remembered that the more obtuse the cutting angle is the more power is required to drive the machine.

Knives may be ground by cramping to a carriage as shown in Fig. 16 A. The lower diagram

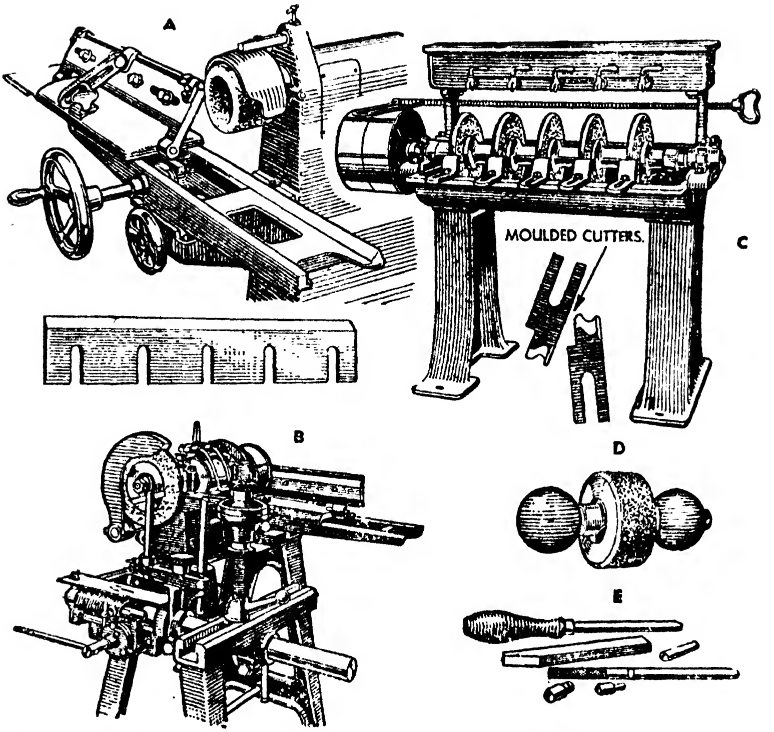


Fig. 16. Methods of grinding knives and moulding cutters. *A.* Grinding cutter blades ; *B.* combined cutter, grinder and saw sharpener ; *C.* set of grinding wheels for shaping cutters ; *D.* abrasive wheel dresser ; *E.* diamond dresser for dressing and shaping wheels. Note that all wheels should be securely guarded.

B shows a combined cutter grinder and saw sharpener. Grinding should not be unduly hurried; frequent adjustments with light settings give a more satisfactory job. Overheating should be avoided, otherwise burnt, cracked or crumbly edges will result.

Moulding, or shaped cutters are ground for profile and bevel upon wheels, as shown in Fig. 16 C. The abrasive grit should be kept open by frequent use of the dressers D and E. Dirty wheels become glazed and often cause overheating of the cutters.

The following points should be noted. Narrow wheels are more suitable than wide ones. The harder the cutter the softer the wheel. Coarse grit wheels cut faster than fine grit wheels though they do not produce the same edge. Wheels should be run true and be packed with paper or cardboard washers. All grinding wheels should be securely guarded and the operator must wear goggles at all times.

Sanders

A *sanding* machine is necessary for the mass production of joinery. For general purposes the *belt sander*, as shown in Fig. 17 A, has premier place; it is capable of dealing with built up work as well as that of a small nature. The usual practice is to sand the edges and the surfaces which lie below the face before assembling, and to complete the entire work later. The pad moves along the guide bar, and is used in conjunction with the transverse movement of the table. The table can be raised or lowered to suit skirtings, linings, panels, doors and door frames, sash and sash framings. The pad pressures should be light and consistent with the nature of the wood.

Garnet and sand papers or cloths can be purchased as belts of specified length or may be obtained in rolls. The papers are made in grades; usually garnet is FF50 mesh, FF20 mesh, and sand papers F20 mesh.

The *disc sander* is useful for small work. The fence supplied on this machine enables the work to be kept square. A *bobbin sander* is more convenient for

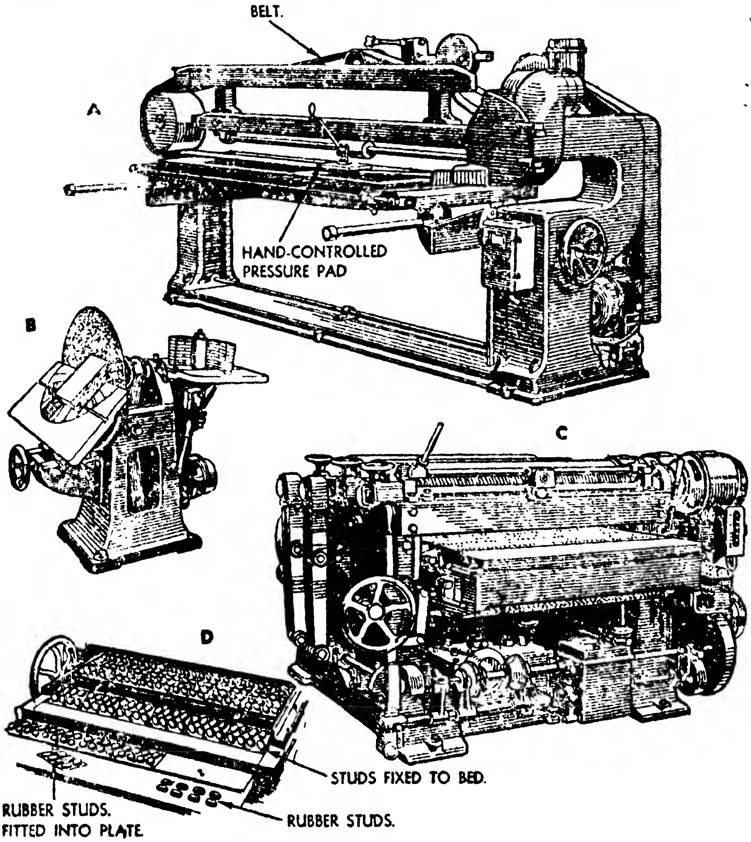


Fig. 17. Sanding machines play an important part in mass production of joinery. A. Belt sander; B. combined disc and vertical bobbin sander; C. drum sander; D. view of feed. Sanding must not be done without dust-collecting apparatus.

shaped work. Fig. 17 B shows a combined disc and bobbin sander.

When there is a demand for finished boards and matchings the *drum sander* is indispensable. The machine in Fig. 17 C reduces material to a required thickness.

Sanding must not be done without a dust-collecting apparatus. Wood flour and tiny particles of abrasive are injurious to the operator. It is essential that a respirator be worn, and a dust extractor installed at the machine.

Part 2

PORTABLE ELECTRIC TOOLS

PORTABLE ELECTRIC DRILLS, SAWS AND SCREWDRIVERS. SANDERS. TYPES OF SURFACE PLANERS. POWER SOURCES. OPERATION AND MAINTENANCE.

It is now many years since the woodworking industries first used mechanical equipment to replace long and laborious hand methods; following the introduction of machinery, the development of portable electric tools again changed production possibilities without affecting the skill of the craftsman. Only during comparatively recent years, however, have manufacturers in wood used these tools.

The speed, flexibility and ease of handling, which are the main features of electrically powered tools, have considerably helped to lighten the task of the craftsman and to increase his output far beyond that of his predecessors.

There is a wide range of portable electric tools, many of which are special units suitable for the requirements of the carpenter and joiner. These are becoming more and more popular in woodworking.

Electric drills (Fig. 1) are manufactured in capacities ranging from 3/16th in. to 1½ in. and sometimes even larger. As a general rule the capacity under which the drill is listed in a catalogue is half its maximum capacity in hardwood, the reason being that electric drills were first designed for the engineering industry, and the capacity of the tool to drill in steel continues to be the one given on the name plate. Any electric tool catalogue will, however, give the alternative capacity of the drill in hardwood.

Range of Electric Drills

Electric drills range in speed as well as capacity, as a general rule in inverse ratio; but with larger drills the torque is greater, thus enabling the tool to accomplish proportionately the same amount of work as the faster drill of smaller capacity.

The most popular drills for general woodworking are those with ½ in. capacity (i.e., 1 in. in woodworking), although where work is being carried out in thin material such as plywood a ¼ in. drill such as the Holgun is an extremely useful tool. Being a light, small, one-hand drill with a low spindle offset, holes can be drilled in awkward places where ordinary methods are useless.

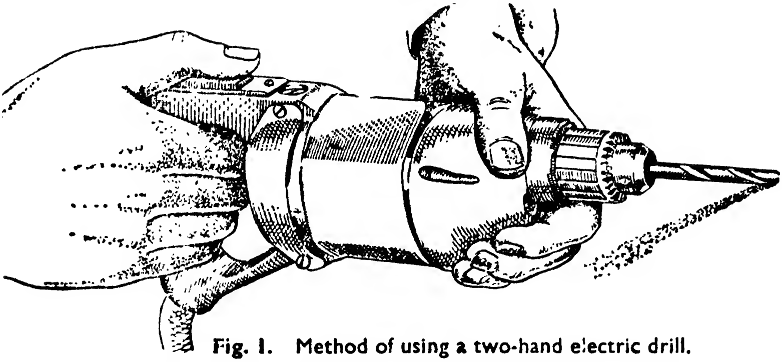


Fig. 1. Method of using a two-hand electric drill.

Most $\frac{1}{4}$ in. drills are operated by one hand, while those of $\frac{1}{2}$ in. capacity and upwards are provided with end handle, side handle and detachable pipe handle.

Every type of drill has instant release switches so that the power is cut off immediately the tool is laid down. The uses of an electric drill are so numerous that it is impossible to enumerate them here, but where a hand brace is used an electric drill will do the same job many times faster.

An ingenious addition to an electric drill is the *Holesaw*, a cup-like circular saw made in various sizes up to 4 in. in diameter, held in the electric drill by means of a mandrel fitted with a centring bit. Holesaws increase the capacity of a drill considerably. They are made in three types, the most suitable of which for woodwork is the coarse tooth (Fig. 2).

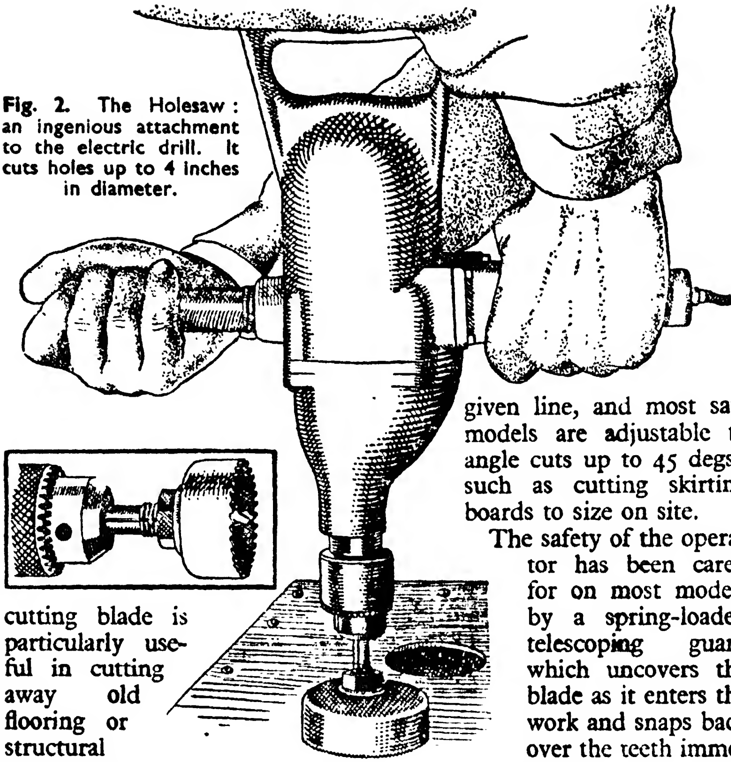
The portable electric drill can be adapted as a bench drill by the use of a bench drill stand, so that when small moveable sections of work require to be drilled they can be placed on the base of the drill stand and by means of a lever the drill is lowered into cutting position. These stands are adjustable for any reasonable thickness of wood. It might be added that the rated capacity of an electric drill is of course its guaranteed maximum, although nearly all are fitted with adjustable chucks to allow smaller sizes of drill bits and wood augers to be used.

Portable electric saws. There are several makes on the market, all of which operate in much the same way (Fig. 3). They are in effect portable circular saws sufficiently light in weight to enable operators to move freely with them from cut to cut, whether it be ripping or cross-cutting. One portable electric saw can be fitted with a variety of blades which gives it a scope far wider than can be obtained with the usual range of saws in the carpenter's and joiner's tool bag.

Special Blades and Discs

Apart from the cross-cut blade, the ripping blade, the rip and cross-cut blade, there are special blades for nail cutting, planing, metal cutting, and abrasive discs for cutting or slotting slate, marble, asbestos, tile, brick and all ceramic materials. The nail

Fig. 2. The Holesaw: an ingenious attachment to the electric drill. It cuts holes up to 4 inches in diameter.



cutting blade is particularly useful in cutting away old flooring or structural woodwork that has to be replaced. The planing blade is specially designed for making very smooth cuts, both rip and cross-cut on interior finish and trim. The metal cutting blade adapts the saw to cut non-ferrous metals in light gauges.

The variety of uses to which portable electric saws can be put makes them especially useful on outside jobs in building, although they obviously save time and effort in the shops (Fig. 4). The average portable electric saw will cut approximately 10 times as fast as a hand operated saw.

The table which supports the saw on the work is notched to enable the operator to follow a given line, and most saw models are adjustable to angle cuts up to 45 degs., such as cutting skirting boards to size on site.

The safety of the operator has been cared for on most models by a spring-loaded telescoping guard which uncovers the blade as it enters the work and snaps back over the teeth immediately the saw finishes its cut. Thus if the saw drops away when its job is finished the operator is not in danger of cutting his legs.

Electric screwdrivers. For mass screwdriving in wood the electric screwdriver (Fig. 5) has now taken precedence over all other methods, by reason of the speed with which a large number of screws can be driven home in a very short space of time. This is even more noticeable when the size and character of the screws to be driven are the same.

There are three types of clutch widely used in the construction of these tools: the positive clutch, the single adjustable and the double adjustable. The latter two are used where a predetermined tension is set for the clutch, thereby enabling the operator to drive home all the screws to the same tension. This gives a uniformity to the work difficult to obtain by the use of the hand screwdriver.

The double adjustable clutch allows a finer torsional adjustment than the single clutch, while the positive clutch is constructed with slipping dogs spring-loaded so that the clutch ceases to engage perfectly when the screw is driven right home.

Larger models of the positive clutch type can be used for nut-running and with a special stud-setting chuck for setting studs. The smaller models are more widely used in the woodworking trades.

It is essential, when making a screwed joint, that pilot holes be first made to allow for the entry of screws, and they should be deep enough to allow the shank of the screw to drop finally into this lead and large enough in diameter to permit the shank an entry without increasing the torque on the screwdriver. This will obviate all the common faults in screwdriving, such as the screw following the grain in driving into the end grain of wood, splitting with the grain, or the gaping joint instead of a tight one.

Portable electric sanders. There are two general types: the *disc sander or grinder* and the *belt sander.* Both have advantages over the other for various types of jobs and both are equally efficient in their own way.

The disc sander (Fig. 6) can be obtained in varying sizes to take discs from 5 in. in diameter to 9 in. in diameter. Most types are fitted with a flexible rubber pad on which is fixed the sanding disc. The method of use is

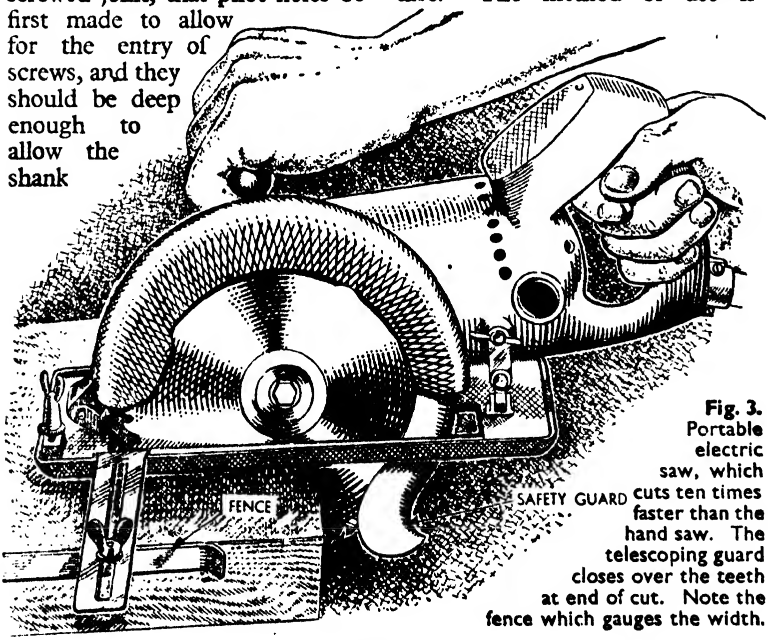


Fig. 3. Portable electric saw, which cuts ten times faster than the hand saw. The telescoping guard closes over the teeth at end of cut. Note the fence which gauges the width.

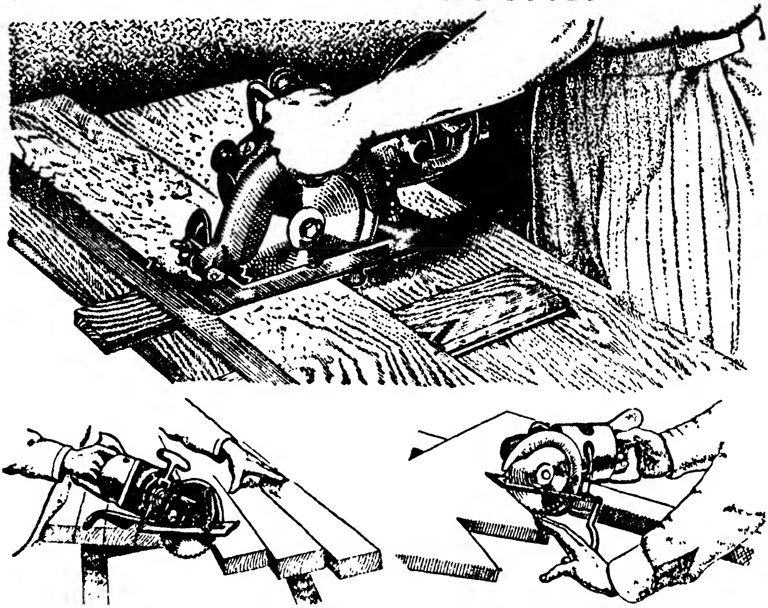


Fig. 4. Portable electric saw in operation. (*Top*) The saw used for cross-cutting ; it can be used as a hand saw. (*Below, left*) showing how quickly roof rafters can be cut. The adjustable angle fence enables jack rafters or purlins to be cut quickly and accurately. (*Below, right*) The saw in use to prepare stringers for shuttering concrete. These saws are useful for outside jobs in buildings.

extremely easy. Two handles are supplied, allowing good purchase on the machine, which is brought into action by holding the outer portion of the sanding disc against the object to be sanded.

The pressure brought to bear need not be heavy, although some of the excess pressure will be absorbed by the flexible rubber pad behind the disc. Obviously this type of sander is especially useful where curved or irregular surfaces require sanding, as it enables the operator to work smoothly across the work, sanding a larger area of curve by reason of the flexibility of the pad and disc than would be possible with a belt sander.

The latter is, however, extremely useful for rubbing down large flat surfaces. By reason of its construction a large portion of abrasive comes into contact with the surface of the work at one time, and a gentle movement to and fro with the grain of the wood produces an excellent finish.

The belt sander (Fig. 7) is constructed to hold a continuous band of abrasive material fitted over rollers one at each end of the machine. Some models have a base plate or table immediately above the portion of sanding band which is in contact with the work, thus ensuring rigidity in operation.

There are slight differences in construction with various makes of belt sanders ; such as the dust collecting bag fitted to the back end of the machine into which the loose dust is exhausted, but

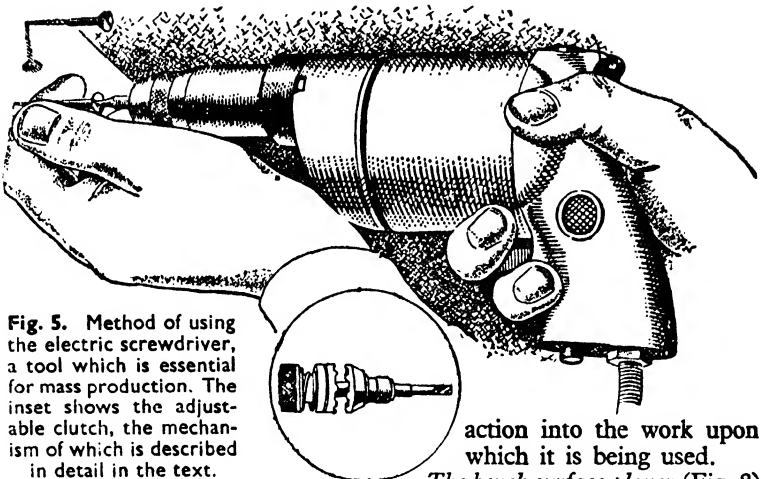


Fig. 5. Method of using the electric screwdriver, a tool which is essential for mass production. The inset shows the adjustable clutch, the mechanism of which is described in detail in the text.

in each case, however, the sanding belt is easily changed when it becomes worn.

Electric hammers are useful tools in the general building trades but are not equally applicable for woodworking operations.

They can, however, be used very successfully on heavy timber structures required for renovation of timbered houses, but are more normally used for working in brickwork, stone, or concrete.

The varying tools which can be used with the electric hammer are fitted into the nose, which has a powerful ram forcing forward the tool with a jabbing action into the work upon which it is being used.

The bench surface planer (Fig. 8) is hardly a portable tool, but by reason of their transportability the smaller models are sufficiently close in relationship to the portable electric tool to be discussed in this chapter.

They are, as the name implies, machines especially made for high speed planing, working in an inverted position from a jack or smoothing plane. Most models consist of two tables between which is a revolving cylinder of planer blades. The tables are easily adjustable, so the required thickness of shaving can be taken from the work.

The bench models are not as a rule fitted with motors and it is necessary to bring power, either by overhead shafting

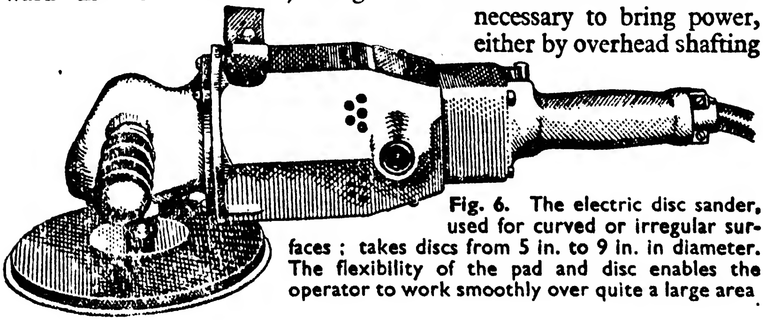


Fig. 6. The electric disc sander, used for curved or irregular surfaces ; takes discs from 5 in. to 9 in. in diameter. The flexibility of the pad and disc enables the operator to work smoothly over quite a large area.

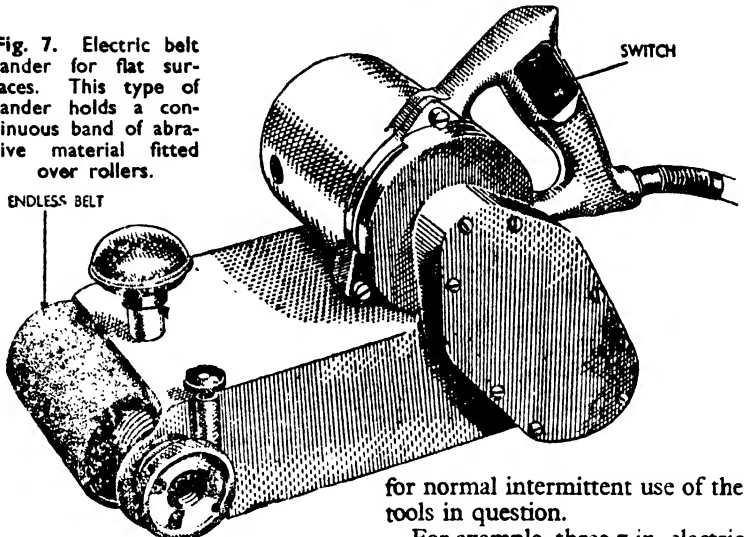


Fig. 7. Electric belt sander for flat surfaces. This type of sander holds a continuous band of abrasive material fitted over rollers.

or to fit an electric motor adjacent to the machine as a driving unit.

Most models can be arranged for rebating as well as for surface planing.

Power Sources

In the factory or workshop where electric tools are used, electrical energy is generally brought to convenient points, on or near benches where tools are to be used. These supply points usually take the form of three of four-pin sockets of the interlocking type, so that the tools are properly earthed. This is essential for the safety of the operator.

Wherever the source of supply is temporary and in the open a good watertight plug and socket must be used. The generator must of course have the capacity to supply the tools to be used, and it is generally acknowledged that a generator of approximately half the capacity of the entire load of a number of tools is sufficient for normal intermittent use of the tools in question.

For example, three 7 in. electric saws and three 7 in. heavy duty sanders comprise a load of 5,600 watts. A 3,000-watt generator would be quite large enough to supply these tools with current for all normal outside uses unless the six tools were in use at the same time, which is unlikely.

It is well known that the speed of an electric tool powered by a universal motor will drop under load. To obtain the best possible performance from the tool it is essential that the pressure produced on the tool itself should not reduce the speed to below 60 per cent. to 70 per cent. of its no-load speed, otherwise the increase in load by the additional pressure will only cause a drop in speed without increasing output.

Constant excess pressure of this nature will obviously overstrain the working parts of the tool, with the result that its efficiency is impaired, and unnecessary breakdowns occur.

A bad habit to be avoided by

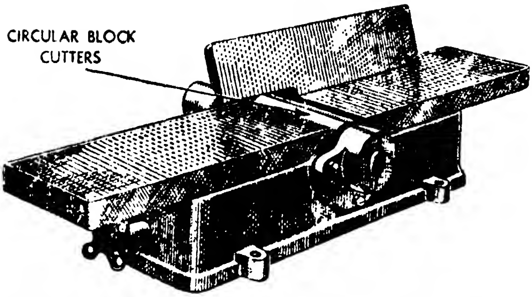


Fig. 8. Small surface planer suitable for a joiner's shop. The cutters are from 6 in. to 10 in. wide. Useful for squaring, rebating and moulding small sections of timber.

operators is that of playing with the switch. Modern switches are so convenient to use that frequently a tool is switched on and off again before it has had time to attain to its normal running speed; the switch is thus repeatedly asked to break excess current, and is bound to give trouble in the course of time.

Operators should not be allowed to leave running tools on the bench or floor. Accidents may occur to mechanics and their colleagues through this bad habit.

Another equally foolish practice is swinging or carrying an electric tool by its cable. Obviously this puts unnecessary strain on the cable clamp, and may result in loosening the earth connection or causing a short circuit.

Chuck replacements are expensive, and in nearly every case they are the result of damage by ignorant use. No chuck will withstand constant dropping on hard surfaces; the closing or opening of a chuck by means of a hammer is the quickest way to destroy the high precision of this piece of equipment. Damaged chucks should of course be replaced, as much of the advantage in using an electric drill is lost when the opening and closing of the jaws of the chuck become difficult.

It is always essential to use accessories that are in good condition. High speed drill bits, for instance, should be used with portable electric drills, and the importance of correctly sharpened drill bits is obvious.

Ventilation openings are provided in nearly all electric tools to ensure a continuous circulation of air to cool the field, the armature and the commutator. These openings, and indeed the whole motor, should be cleaned periodically, to avoid overheating which will result if they are allowed to become clogged.

Carbon brushes are designed to wear before the commutator does. Before they are completely worn out the spare brushes provided should be installed. To allow carbon brushes to wear until they become too short is false economy; this causes excess sparking and over-heating of the commutator, which may result in a scored commutator or burnt-out motor.

Greasing is only required at long intervals. A high grade gear or ball bearing grease should always be used under scrupulously clean conditions.

Most electric tools are provided with a cord protector fitted to the three-core cable, the third wire being earth conductor for the operators' safety. Any damage to the cable or connections should be rectified without the slightest delay.

CHAPTER 5

GEOMETRICAL DRAWING AND DESIGN

ESSENTIAL DRAWING INSTRUMENTS. SIMPLE GEOMETRY. METHODS OF SETTING-OUT ELLIPSES. RATIO AND PROPORTION. ENLARGING AND REDUCING FIGURES. PROJECTIONS. SECTIONS. DEVELOPMENTS. DETAILED DRAWINGS AND PLANS. LETTERING. MOULDINGS. MITRES AND INTERSECTIONS. PROPORTION, DESIGN AND ORNAMENT.

Geometrical Drawing

THE following drawing instruments are essential for accurate geometrical work: a drawing board, tee square, set squares, mathematical instruments, scales and a protractor (Fig. 1).

The size of the *drawing board* depends on the type of drawing to be undertaken; 'half imperial' is a useful size. The better quality boards have battened backs fixed to the board with slotted screws, the slots being to enable the board to swell and shrink without warping. Better quality boards also have an ebony strip inserted in one of the shorter edges of the board to enable the head of the tee square to run smoothly along the board.

The *tee square* is used for drawing horizontal lines. It consists of two parts—the head and the blade, the latter being screwed to the former at right angles. The blade (along which the lines are drawn) is best if it is bevelled and edged with hard wood.

Two *set squares* are usual, having angles of 45 deg. and 60/30 deg. respectively. They are used in conjunction with the tee square to draw perpendiculars and lines inclined at 45 deg., 60 deg. and 30 deg. to the horizontal. They can be obtained in various materials. Generally speaking, celluloid is satisfactory because of its transparency.

Good Quality Essential

It is essential that the mathematical instruments should be of good quality. They should include a pair of *compasses* with movable pen and pencil points, and with an extension arm for drawing larger circles; a pair of *dividers* for measuring, and a drawing pen for inking in the drawings. In addition, a set of spring bow compasses is useful for drawing small circles, but it is not essential as by careful adjustment the larger compasses can be used.

Scales are used for drawing objects a fraction of their true size. The usual scales are $\frac{1}{8}$ in., $\frac{1}{4}$ in., $\frac{1}{2}$ in. and 1 in. to one foot for working drawings. Larger scales are used for more accurate details.

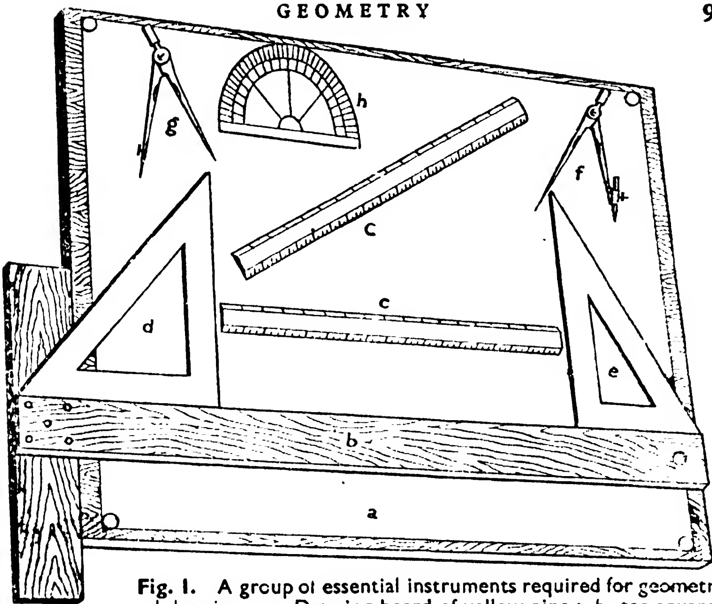


Fig. 1. A group of essential instruments required for geometrical drawing. *a*. Drawing board of yellow pine ; *b*. tee-square ; *c*. boxwood scales ; *d* and *e*. celluloid set squares ; *f*. compasses ; *g*. dividers ; *h*. protractor.

A *protractor* is used for measuring angles. It may be circular, semi-circular, or rectangular, and made of celluloid, wood or metal.

Cartridge paper is suitable for general and detailed drawings to be finished in pencil, but if the drawings are to be inked in or coloured, a better quality hand-made paper is desirable.

The pencil to be used depends upon the type of paper and the preference of the individual. Generally, a H. or HB. pencil will be found satisfactory.

Simple Geometry

To bisect a line A B (Fig. 2) with centre A and radius greater than half A B describe arcs above and below A B. With centre B and the same radius describe arcs cutting the previous arcs in C and D. Join C D., cutting A B in O. Then A O equals O B and C D is at right angles to A B.

This same method is used in bisecting the arc of a circle (see Fig. 3).

To divide a given line A B (see Fig. 4) into a number (say six) of equal parts, draw A C at any angle to A B and along A C set off six equal parts A 1, 1 2, etc. Join B 6 and through the other points draw parallels to B 6 dividing the line A B into six equal parts.

Fig. 5 shows the method of erecting a perpendicular to a line at any given point. Let A B be the line and C the given point. With centre C and any convenient radius, describe arcs on each side of C cutting A B in 1 and 2. With centres 1 and 2 and any convenient radius, describe arcs intersecting at 3. Then C 3 is the required perpendicular.

When the point through which

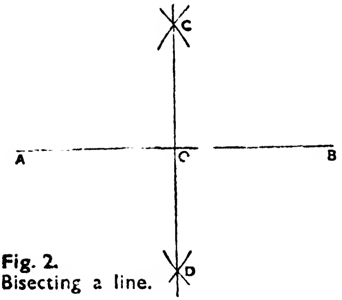


Fig. 2.
Bisecting a line.

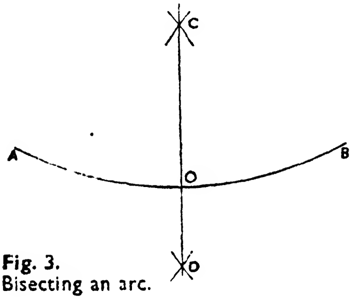
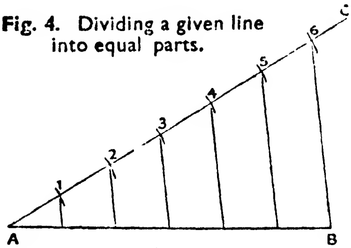


Fig. 3.
Bisecting an arc.

Fig. 4. Dividing a given line into equal parts.



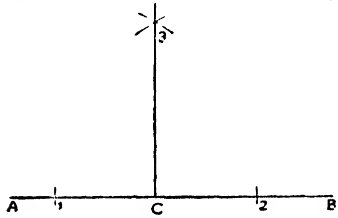


Fig. 5. Erecting a perpendicular to a line at any given point.

the perpendicular is to be drawn is outside the line, the method shown in Fig. 6 is used. Let E be the point. Join E to any point D in A B. Bisect E D in O. With centre O and radius O E, describe a semi-circle on D E cutting A B in F. Then E F will be the perpendicular.

To bisect a given angle A B C (Fig. 7), with centre B and any convenient radius, describe an arc cutting A B and B C in 1 and 2. With centres 1 and 2 and the same radius, describe arcs intersecting in D. The B D will bisect the angle A B C.

To find the centre of a given circle (Fig. 8) draw any two chords A B and C D and bisect them at right angles. Produce these two bisectors till they intersect in O which will be the centre of the circle.

To draw a tangent to a circle at any point P in the circumference join P to the centre of the circle O and produce to R. At P draw the line P Q at right angles to O P which will be the tangent at the point P, then R P will be the normal to the circle at the point P (Fig. 9).

Triangles

A knowledge of the properties of various triangles is essential to the modern craftsman if he is to become fully conversant with his craft. This is especially true where roofing is concerned, as the efficient use of the steel square depends on a knowledge of the properties of right-angled triangles.

Triangles are identical in all respects (i.e., congruent) when one of the three following statements is true :—

(*a*) When three sides of one triangle are respectively equal to the three sides of the other ;

(*b*) When two sides of one and the angle between them are equal to two sides and the included angle of the other triangle ;

(*c*) When two angles of one and the side between them are equal to two angles and the included side of the other.

The sum of the three angles of any triangle is always equal to 180 deg. and, therefore, if two angles of a triangle are known, the third angle can always be calculated.

If the three angles of one triangle are respectively equal to the three angles of another triangle, the two triangles are not necessarily congruent, and are only said to be similar, unless it can be proved that two respective sides are also equal.

Triangles are named from the comparative lengths of their sides or from the size of their angles (see Fig. 10).

An Equilateral Triangle has all its sides equal.

An Isosceles Triangle has two of its sides equal.

A Right-angled Triangle has one of its angles a right-angle (i.e., containing 90 deg.).

A Scalene Triangle has unequal sides. It may also be described as obtuse-angled or an acute-angled triangle according to the condition of its angles.

An Obtuse-angled Triangle has one of its angles an obtuse angle (containing more than 90 deg.).

An Acute-angled Triangle has all its three angles acute angles (i.e., containing less than 90 deg.).

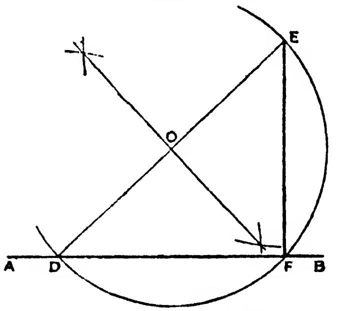


Fig. 6. Erecting a perpendicular to a point outside a line.

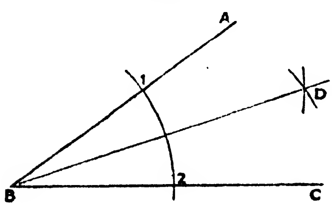


Fig. 7. Bisecting an angle.

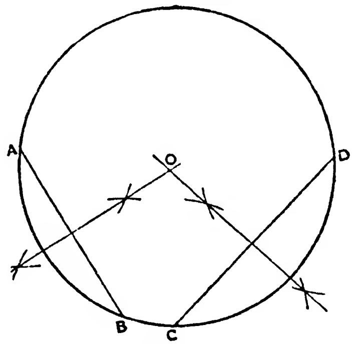


Fig. 8. Finding the centre of a circle.

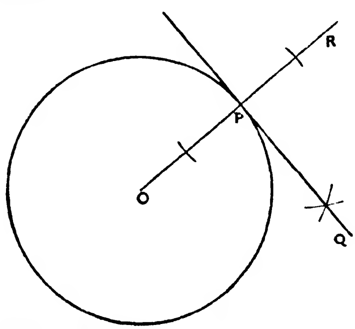


Fig. 9. Drawing a tangent to a point on the circumference of a circle.

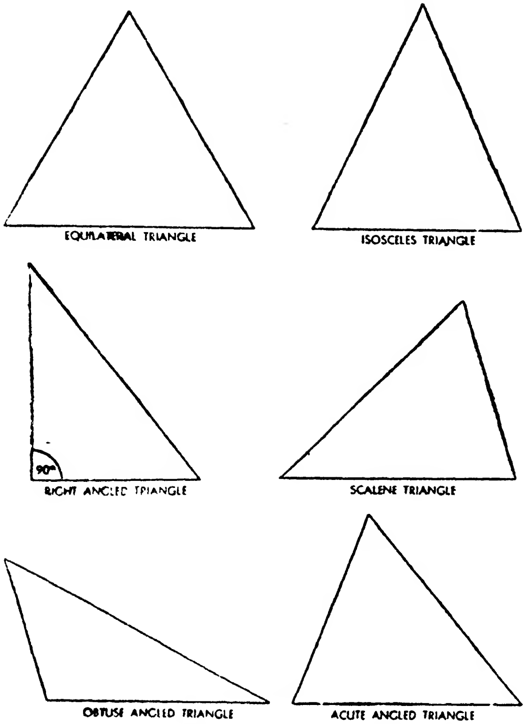


Fig. 10. Triangles are named according to the lengths of their sides or the size of their angles. Various kinds of triangles are shown above.

If a triangle be considered to be standing on one side, that side is known as the *base*. The point at which the other two sides intersect is termed the *apex* or *vertex*, and the angle there formed is the *vertical angle*. The angles at each end of the base are known as the *base angles*. The perpendicular distance from the apex to the base or the base produced is the *altitude* (Fig. 11).

Right-angled Triangles

As already stated a right-angled triangle has one of its angles a right-angle, and the side opposite to this right angle is known as the *hypotenuse* (see Fig. 10).

One of Euclid's most important theorems proved that the area of the square on the hypotenuse is equal to the sum of the areas of squares on the other two sides. Thus, if the length of longest side is 5 units and the other two sides are 4 and 3 units, the triangle must be right-angled because $4^2 + 3^2 = 5^2$ viz. $(16 + 9 = 25)$ (see Fig. 12). This principle is commonly used in setting out. If a triangle is set out with its sides in the proportion of 3 : 4 : 5 units, the angle opposite the side of length of 5 units will be a right angle.

It has also been proved that the angle in a semi-circle is a right angle. If in Fig. 13 A B is the diameter of a circle and A and B be joined to any point C on the circumference of the circle, then the angle A C B will be a right-angle no matter where the point C is placed on the circumference.

The Ellipse

An ellipse is the true shape of the section obtained by cutting a right circular cone with a plane inclined to the axis of the cone and passing through the sides of the cone; but in plane geometry it is usual to regard an ellipse as a figure traced by a point moving so that its distance from

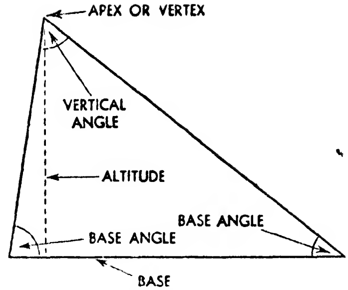


Fig. 11. It is important that the names of the parts of a triangle indicated above should be kept in mind.

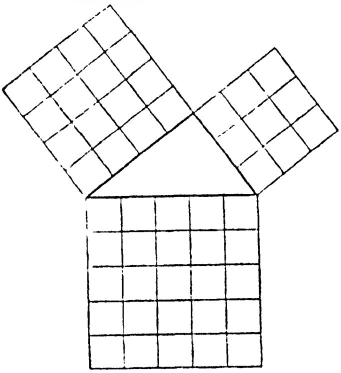


Fig. 12. Diagram illustrating the theorem of Pythagoras.

a fixed point, or focus, is less than its distance from a fixed line or directrix (Fig. 14). An ellipse being a closed figure is composed of two equal adjacent reversed curves and therefore has two *foci* and two parallel *directrices.*

From a builders' geometry point of view, it is more convenient to regard an ellipse as a curve traced by a point moving so that the sum of its distances from two fixed points, the foci, equals the length of a given line known as the major axis. The line bisecting the major axis at right angles is known as the minor axis, and the point where these two axes intersect is called the centre.

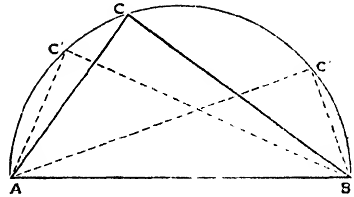


Fig. 13. The angle in a semi-circle is a right-angle, as shown in above.

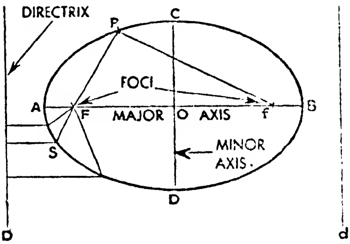


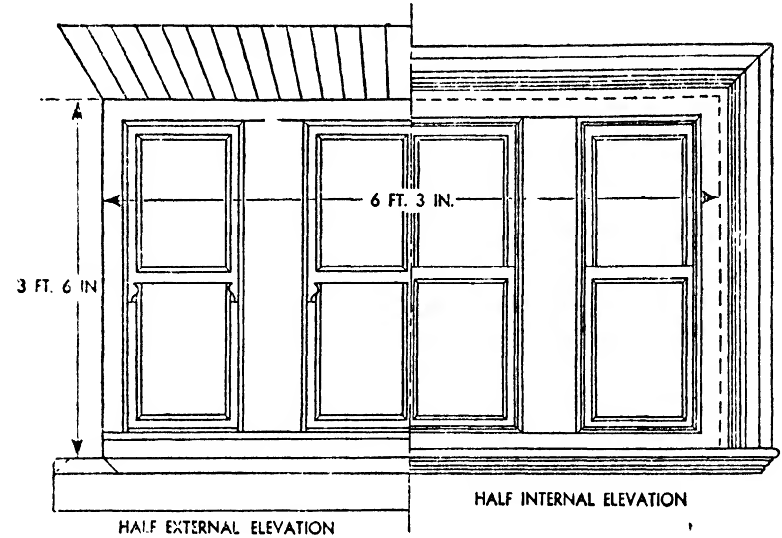
Fig. 14. The foci and directrices of an ellipse. The five methods of setting out ellipses are shown in Fig. 15.

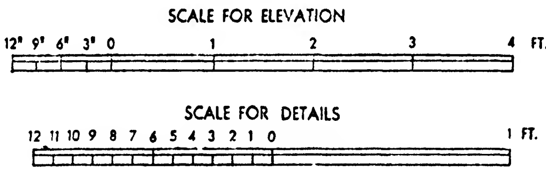
Fig. 14 shows an ellipse in which F and f are the foci and D and d the directrices. If the point F be joined to any point S on the circumference of the ellipse, the distance F S is always less than the perpendicular from S to the directrix D. A B and C D are the major and minor axes and the point O at which the two axes intersect is the centre. If any point P on the curve is joined to the two foci points F and f, then F P and f P together equal the length of the major axis A B.

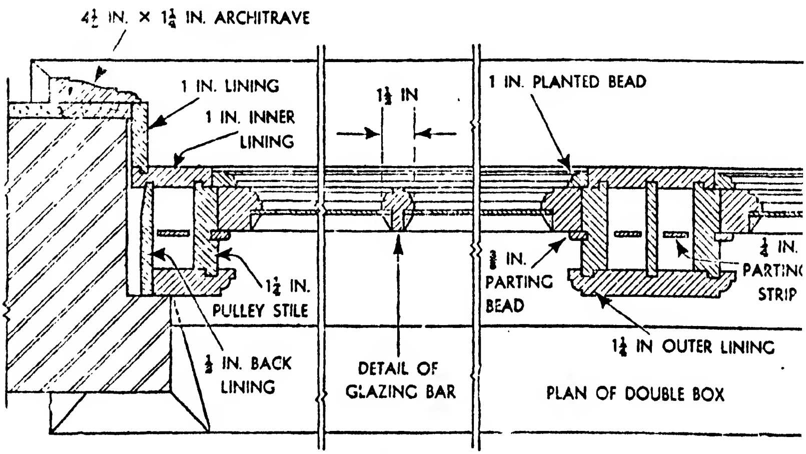
Setting-out Ellipses

There are five methods of setting out ellipses; it is necessary to know the length of each major axis.

(1) *By Intersecting Arcs* (Fig. 15). Set down the major and minor axes A B and C D inters secting at right-angles in thei-centre points O. With radius A O (equal to half the length of

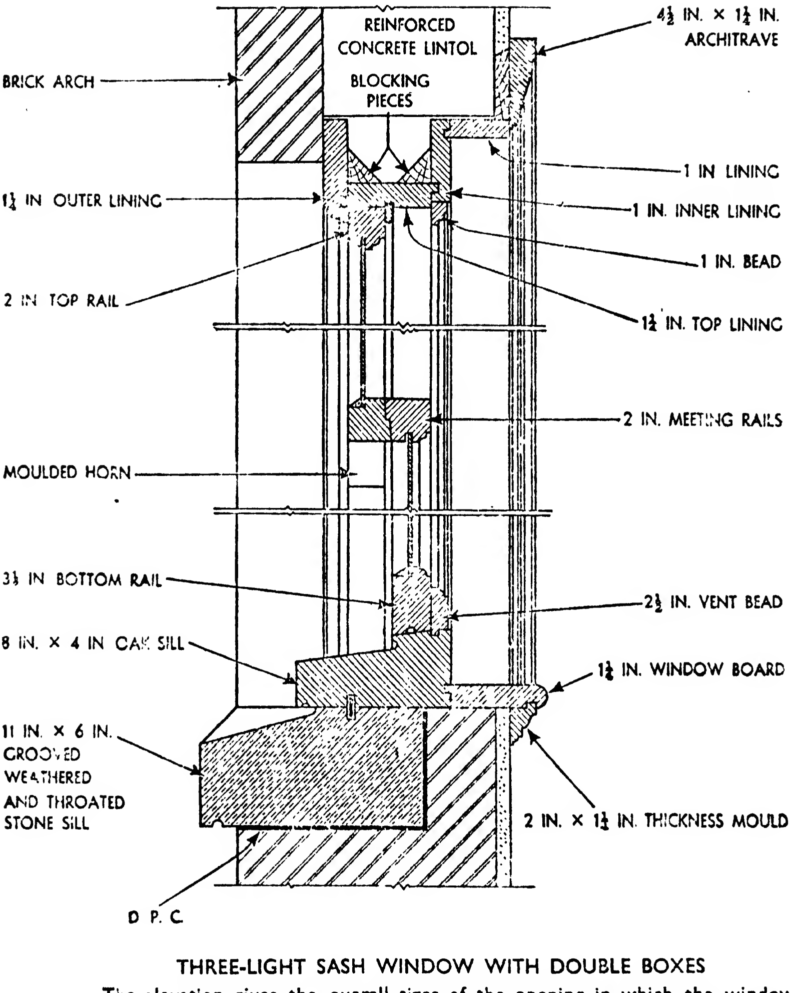

6 FT. 3 IN.
3 FT. 6 IN
HALF EXTERNAL ELEVATION
HALF INTERNAL ELEVATION


SCALE FOR ELEVATION
12" 9" 6" 3" 0 1 2 3 4 FT.
SCALE FOR DETAILS
12 11 10 9 8 7 6 5 4 3 2 1 0 1 FT.


4½ IN. × 1¼ IN. ARCHITRAVE
1 IN. LINING
1 IN. INNER LINING
1½ IN
1 IN. PLANTED BEAD
1¼ IN. PULLEY STILE
½ IN. BACK LINING
DETAIL OF GLAZING BAR
⅜ IN. PARTING BEAD
¼ IN. PARTING STRIP
1¼ IN OUTER LINING
PLAN OF DOUBLE BOX

DETAIL PLAN

DETAIL SECTION



THREE-LIGHT SASH WINDOW WITH DOUBLE BOXES

The elevation gives the overall sizes of the opening in which the window framing is set and also indicates the sizes of each sash and the type of arch and sill. Such elevations are usually drawn to a scale of either 1 in. to 1 ft. or ½ in. to 1 ft.

The detail plan and section are usually drawn full-size, and they show the plan or section of every member composing the window. The gross size of each member is figured on the drawing, $\frac{1}{16}$ in. being allowed for each surface that has to be planed. (See pages 110-111).

The details also show the jointing together of the various members and the fitting of the window in the opening. The finishing of the walls adjoining the window is also shown, including plaster, architraves and wall linings.

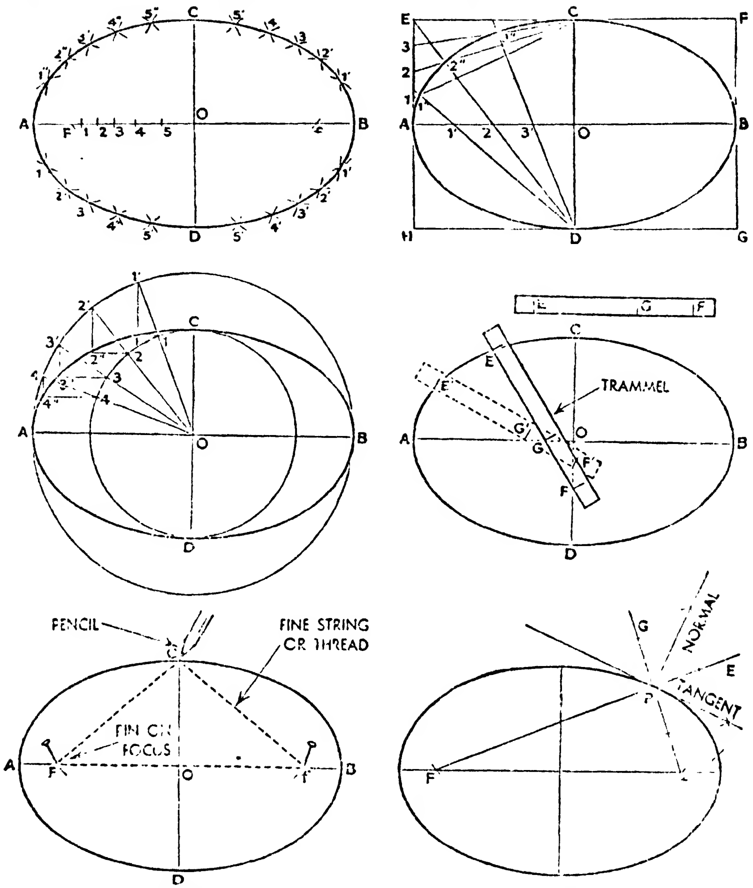


Fig. 15. Five methods of setting out ellipses. (*Top, left*) intersecting arcs: (*Top, right*) intersecting lines; (*Centre, left*) concentric circles; (*Centre, right*) the trammel method; (*Below, left*) the pin and string method; (*Below, right*) how to draw the normal and tangent at any point in an ellipse.

the major axis) and centre C, describe two arcs cutting A B on each side of C D in F and f which will give the two foci. In that part of the major axis between O and F take any points 1, 2, 3, 4 and 5. With centres F and f and radius A 1 describe arcs above and below A B. With the same centres and radius equal to B 1 describe arcs cutting the previous arcs in 1′, 1′, 1″ and 1″. These four points are then points on the curve. Other points are obtained by using radii equal to A 2 and B 2, A 3 and B 3, etc. A curve drawn through the points so obtained and the points A, C, B and D at the ends of the axes will give the required ellipse.

(2) *By Intersecting Lines* (Fig. 15). Set up the major and

minor axes as before and by drawing parallels to C D through A and B and parallels to A B through C and D, complete the rectangle E F G H. Divide A E into any number of equal parts and join each point to C. Divide A O into the same number of equal parts and join D to each point and produce till they cut the radials from C in 1″, 2″ and 3″. These points are then points in the ellipse and when joined with a curve, a quarter of the ellipse is obtained. By repeating the same construction in the other three parts of the rectangle E F G H the ellipse is completed.

(3) *By Concentric Circles* (Fig. 15). Set up the axes as before and with centre O and radii equal to O C and O A, describe concentric circles. Draw any line O 1′ cutting the inner circle in the point 1 and the outer circle in 1′. From 1′ drop a perpendicular cutting a horizontal from 1 in 1″. This point is then a point in the curve in the ellipse. By repeating this method all round the circle sufficient points can be obtained to draw in the curve of the ellipse.

(4) *Trammel Method* (Fig. 15). This method is of the greatest practical use and is often used in the workshop. Set up the axes as before. Take a straight edge and mark on it the length E F equal to A O. Also mark the distance E G equal to half the length of the minor axis, the point G lying between E and F. This completes the trammel. To set up the ellipse lay the trammel across the axes so that the point F lies on the minor axis and the point G on the major axis. The point E then marks a point on the curve. By varying the position of the trammel so that the points F and G coincide with different points in the respective axes, sufficient points can be obtained to draw the ellipse.

(5) *Pin and String Method.* (Fig. 15). Set up the axes and obtain the two foci as in Method 1. Insert a pin in the two focal points and at one end of the minor axis, and tie a piece of thread tightly round these pins. Remove the pin at the end of the axis and substitute the pencil point. Keeping the pencil vertical and the thread tightly stretched between the pencil and pins, run the pencil round in a sweep, which will describe half the ellipse. By reversing the thread to the other side of the pins the other half of the ellipse can be described.

Tangents and Normals. To draw the normal and tangent at any point P in an ellipse, join the two foci F and f to the point and produce to E and G. The bisector of the angle E P f is the tangent at the point P and the bisector of the angle E P G is the normal (Fig. 15).

Polygons

A *polygon* is a plane figure bounded by straight lines. If all the angles and sides are equal it is termed a *regular polygon* and when either the angles or sides are unequal it is termed an *irregular polygon*.

Polygons are named according to the number of their sides (Fig. 16).

To construct any regular polygon (say a pentagon) draw A B equal to the given length of side. With centre A and radius A B describe a semi-circle cutting

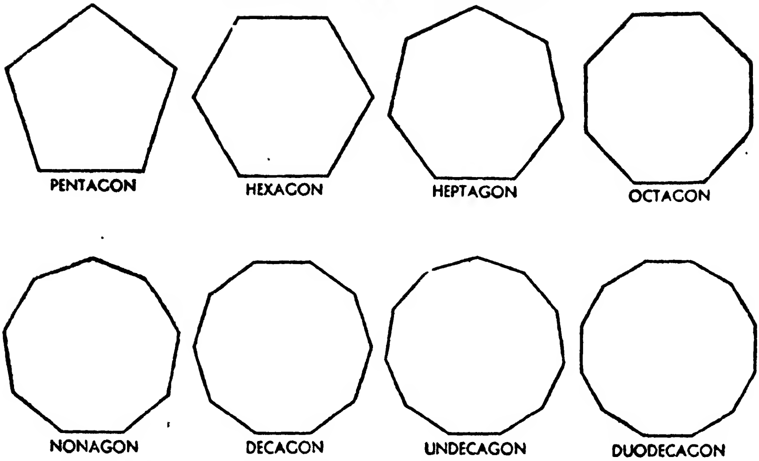


Fig. 16. Regular polygons have all their sides and angles equal. Polygons are named according to the number of their sides.

A B produced in C (Fig. 17). Divide the circumference of the semi-circle into the same number of equal parts as the polygon has sides. Number these parts 1, 2, 3, etc., commencing at C. Join A 2, which will be the second side. Bisect A B and A 2 at right angles and produce till they intersect at O. With centre O and radius O A describe a circle passing through B, A and 2. With centre 2 and radius equal to A B describe an arc cutting the circumference at D. Join 2 D (the third side) and proceed similarly until the requisite number of sides has been obtained. This construction requires very accurate draughtsmanship.

A regular hexagon is best constructed by a special method (Fig. 17). Draw A B equal to the given length of side. With centres A and B and radius equal to A B describe arcs above A B intersecting at O. With centre O and radius O A describe a circle. With centre A and radius A B step off the length of sides round the circumference of the circle and join up the points so obtained.

A regular octagon is also best constructed as follows :—Draw

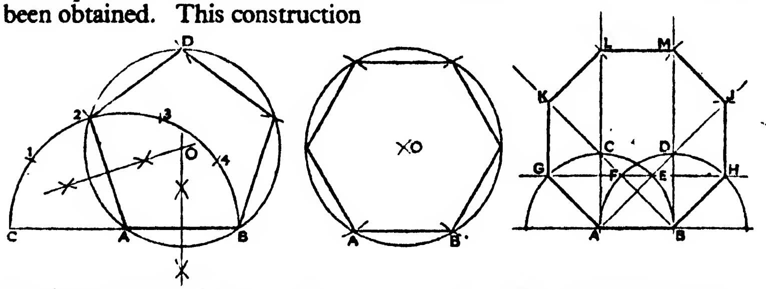


Fig. 17. (*left*) Setting-out a pentagon ; (*centre*) setting-out a regular hexagon ; (*right*) setting-out a regular octagon.

A B equal to the given length of side, and at A and B erect perpendiculars. With centres A and B and radius equal to A B describe arcs cutting the perpendiculars in C and D respectively. Join A D and B C, cutting the opposite arcs in E and F and produce. Join E F and produce in each direction to cut the arcs in G and H. Join A G and B H. With centres H and G and radius equal to A B describe arcs cutting A D and B C produced in J and K. Join G K and H J. With centres K and J and the same radius describe arcs cutting the perpendiculars from A and B in L and M respectively. Join K L, L M, and M J. Then A G K L M J H B will be the polygon (Fig. 17).

To construct irregular polygons much more information is required than in the case of regular polygons. Generally speaking the length of each side must be given and also the size of some of the angles or the lengths of diagonals.

Fig. 18 A to E show the construction of irregular polygons from differing information.

Fig. 18 D shows the construction when a point within the polygon is given and also the distance from this given point to each angle, and also the angles around the given point.

Fig. 18 E shows the construction when the length of a diagonal and the lengths of the perpendicular offsets to each angle and their spacings along the diagonal are given.

Rates and Proportion

When two numbers are compared with regard to the number of times one contains the other,

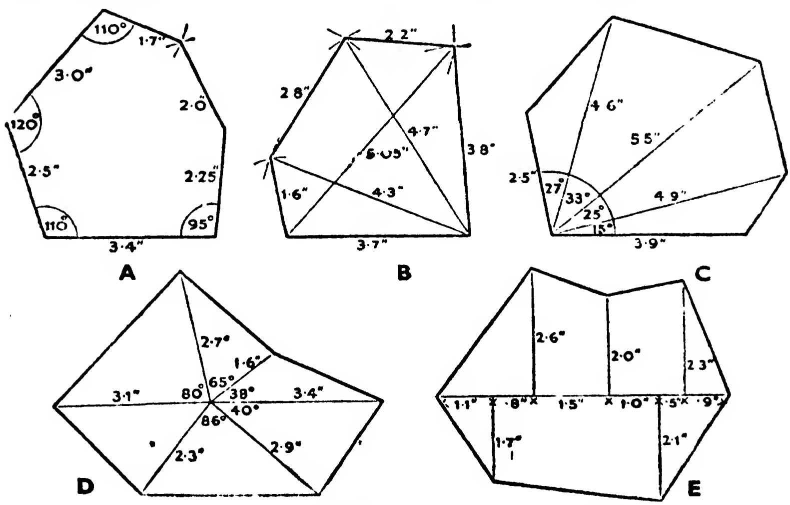


Fig. 18. How to construct irregular polygons from differing information. *A.* When the length of each side and the sizes of all adjacent angles except two are given; *B.* when the lengths of each side and diagonals are given; *C.* when lengths of two sides, lengths of each diagonal drawn from the angle between these sides, and angles between the diagonals and outer diagonals and the side are given; *D.* from a point within the polygon; *E.* by use of offsets.

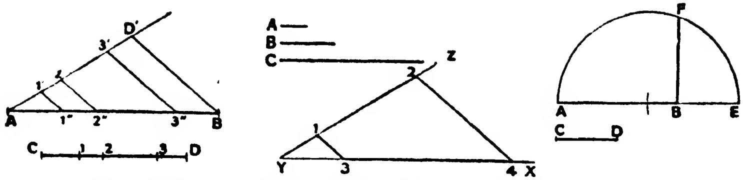


Fig. 19. (*left*) Method of dividing a given line in the same proportion as another given divided line ; (*centre*) how to find the fourth proportional line to three given lines ; (*right*) showing how to find a mean proportional to two given lines.

a ratio is formed. When two ratios are equal they are said to be a proportion. Thus 9 : 3 is a ratio and 9 : 3 :: 6 : 2 is a proportion.

In a proportion the product of the first and last terms, or *extremes*, equals the product of the middle terms, or *means*.

Geometrically, ratio and proportion problems are based on the proof by Euclid that 'If a straight line be drawn parallel to one side of a triangle, it cuts the other two sides, or those produced proportionately.'

Fig. 19 shows the method of dividing a given line A B in the same proportion as another given divided line C D. Draw any line at any convenient angle to A B and set off along this line the distances A 1′, A 2′, A 3′ and A D′ equal to C 1, C 2, C 3 and C D. Join D′ B and through 1′, 2′ and 3′ draw parallels to D′ B cutting A B in 1″, 2″, and 3″. Then A B will be divided into the same proportions as C D.

Fig. 19 also shows the method of finding the fourth proportional to three given lines A, B and C. Draw X Y and Y Z of indefinite length and at any convenient angle to each other. Along Y Z set off Y 1 equal to A and 1 2 equal to C. Along Y X set off Y 3 equal to B. Join 3 1 and through 2 draw a line parallel to 3 1 and cutting Y X in 4. Then 3 4 is the required fourth proportional.

In Fig. 19 is shown the method of finding a mean proportional to two given lines, A B and C D. Produce A B to E so that B E equals C D and on A E describe a semi-circle. At B erect a perpendicular to A E cutting the circumference in F. Then B F is the required mean proportional.

Scales

Drawings are not as a rule drawn the same size as the objects they portray, but so that the length of each portion of the object is some known ratio of its true length. Thus if the proportion was 36 : 1, the drawing would be 1/36th the size of the object, and each inch on the drawing would represent one yard on the object. Thus the drawing would be drawn to a scale of 1/36 or 1 inch to 1 yard.

Fig. 20 shows the construction of 1/60th scale to measure 5 yards. If the scale is to measure 5 yards

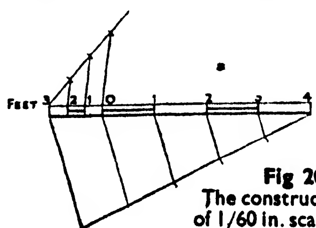


Fig 20. The construction of 1/60 in. scale to measure 5 yards.

its length must be 5/60th = 1/12th of a yard = 3 inches. Two lines are, therefore, drawn 3 inches long divided into 5 equal parts, each of which will represent 1 yard to scale. The part on the left is then sub-divided into three equal parts, each of which will represent 1 ft. The figuring of the scale is important, the zero (0) being placed between the full yards and the foot sub-divisions.

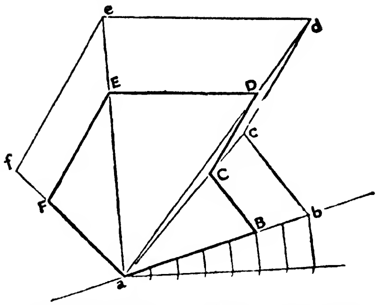


Fig. 22. Method of reducing each side of a given figure.

Enlarging and Reducing

In order to *enlarge* a given figure a b c d e f (Fig. 21) so that each side is, say, half as large again, bisect the side a b and produce to B so that b B is equal to half a b. Then a B will be half as large again as a b. Join a c, a d and a e and produce each. From B draw B C parallel to b c and from C draw C D parallel to c d. Continue thus round the figure till E F drawn parallel to e f cuts a f produced in F. Then a B C D E F will be the required enlarged figure.

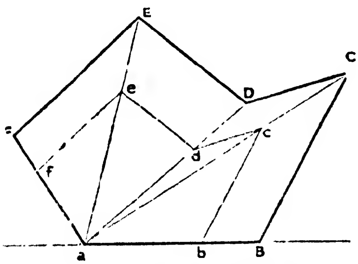
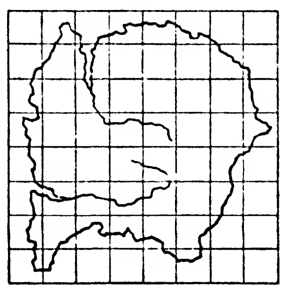


Fig. 21. Method of enlarging each side of a given figure.

To *reduce* a given figure, similar procedure is adopted, but in this case the new figure lies within the original figure. If it be required to reduce the figure a b c d e f (Fig. 22) to 5/7th its size, the side a b is divided into seven equal parts and the parallels are commenced at the fifth division from a, each parallel terminating in the radial from the point a to the respective angle.

Fig. 23 shows the method of enlarging or reducing irregular figures by squaring. In this method a square mesh is drawn over the given figure and a proportionally larger or smaller mesh drawn on which the points at which the original figure cross the mesh are plotted and the figure drawn in.

Fig. 24 shows the method of enlarging a detail by means of a proportional scale. A door A B C D is shown and it is required



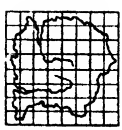


Fig. 23. How to enlarge or reduce irregular figures by means of squaring.

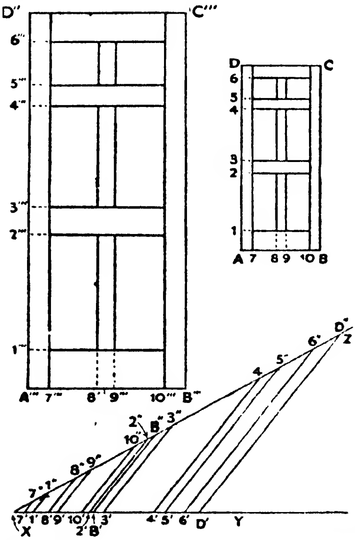


Fig. 24. It is important that the method of enlarging by proportional scale should be fully understood. This diagram clearly illustrates how a door detail is drawn to twice the given size.

accurately to draw the door twice the given size. A proportional scale is first constructed by drawing two lines X Y and X Z at any angle to each other. The distance X D' equal to A D (the height of the door) is then set off from X along X Y and the distance X D″ along X Z equal to twice X D′. Join D′ D″. Set off other distances X 1′, X 2′, X 3′, etc., along X Y (equal to the distances A 1, A 2, A 3, etc., on the original drawing) and through each point draw parallels to D′ D″ cutting X Z in 1″, 2″, 3″, etc. The door is then re-drawn using the distances on the line X Z instead of the original distances as set up on X Y.

To reduce a drawing by a proportional scale, a similar procedure is used, but in this case the given dimensions will be set along the longer line X Z and the new dimensions will be taken from the shorter line X Y.

Projections

Very often the simplest plan and elevation of a line or solid will not be sufficient to indicate its true length or form, and additional projections drawn from different points of view become necessary.

In Fig. 25 if A B represents the elevation of a line resting on the horizontal plane and inclined to the vertical plane at an angle of 30 deg., the length A B is not the true length of the line. To obtain the true length, perpendiculars are dropped from A and B below the line X Y and the line a b is drawn inclined to the X Y line at an angle of 30 deg. as shown. The line a b will then be the true length of the line A B.

If a line is inclined to both the horizontal and vertical planes the true length has to be ascertained by means of an additional projection. In Fig. 26 the line a b represents the plan of a line inclined at 45 deg. to the vertical plane. If it is also inclined to the horizontal plane at 30 deg. the elevation is obtained by erecting a perpendicular to X Y at a till it cuts the X Y line in a′. A line is drawn from this

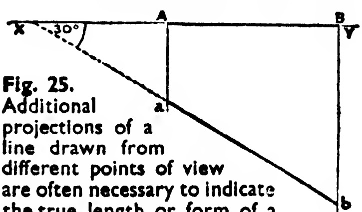


Fig. 25. Additional projections of a line drawn from different points of view are often necessary to indicate the true length or form of a line or solid. The method is shown in the above diagram.

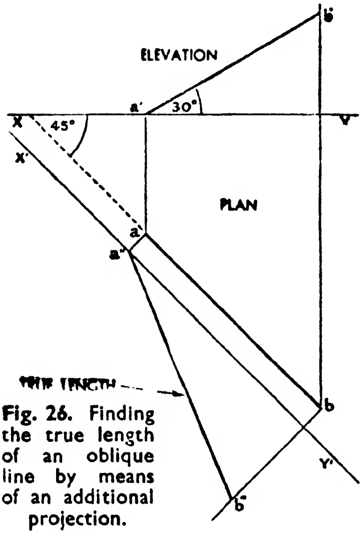


Fig. 26. Finding the true length of an oblique line by means of an additional projection.

point at 30 deg. to the X Y line cutting a perpendicular from b in b′. Then a′ b′ is then the elevation of the line. To obtain its true length draw a line X′ Y′ parallel to the plan of the line a b. At a erect a perpendicular to a b cutting X′ Y′ in a″. Erect another perpendicular at b. Above the line X′ Y′ mark the point b″ on the perpendicular from b at a height above X′ Y′ equal to the height that the point b′ is above X Y. Join a″ b″ which will be the true length of the line.

In Fig. 27 let the line b′ d′ represent the elevation of a square lying parallel with the horizontal plane and with one of its sides inclined at 30 deg. to the vertical plane. To obtain the plan drop perpendiculars from b′ and d′. At any reasonable distance below the X Y line draw the line b d inclined at 15 deg. (45 deg.—30 deg.) to the X Y line. This line is then the plan of a diagonal of the square. Bisect b d in O, and

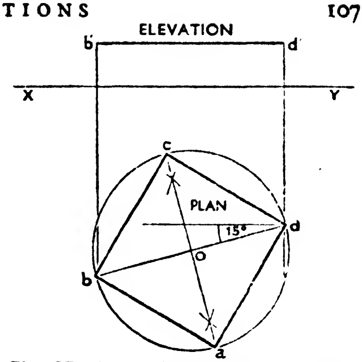


Fig. 27. Method of finding the projections of a plane.

with centre O and radius O b describe a circle. Through O draw the second diagonal at right angles to b d and cutting the circumference of the circle in a and c. Join a b, b c, c d and a d, which will give the required plan of the square.

Fig. 28 shows the method of projecting the plan and elevation of a cube standing on one edge and with one face making an angle of 30 deg. with the horizontal plane and its vertical faces parallel with the vertical plane. The elevation is first drawn by setting up the square a′ b′ c′ d′ with the side a′ b′ inclined at 30 deg. to

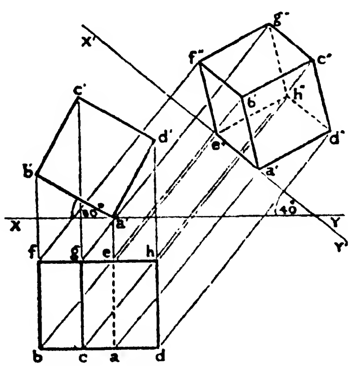


Fig. 28. Projecting the plan and elevation of a cube.

the X Y line. From a′, b′, c′ and d′ perpendiculars are dropped. Draw any line h e g f parallel to the X Y line. With centre h and radius equal to the side of the cube cut the perpendicular from d′ in d. Through d draw d a c b parallel to X Y. Join c g. The line a e should be shown dotted to indicate the edge on which the cube stands.

To obtain another view of the cube when its vertical faces are inclined at 40 deg. to the vertical plane, an additional projection is used. Draw the line X′ Y′ inclined to the X Y line at 40 deg. and project from the points a, b, c and d lines perpendicular to X′ Y′. Let the projection from a cut X′ Y′ in a″ and let the points b″, c″ and d″ be the same distance from X′ Y′ as the points b′, c′ and d′ are above X Y. Join a″ b″, b″ c″, c″ d″ and d″ a″, giving the projection of the face a′ b′ c′ d′ in the new position. Similarly, obtain the projection of the parallel face giving the figure e″ f″ g″ h″. Join e″ a″, b″ f″, c″ g″ and d″ h″ giving the full projection of the cube. Lines hidden behind other faces should be dotted as shown.

Fig. 29 shows the projections of an equilateral triangular prism,

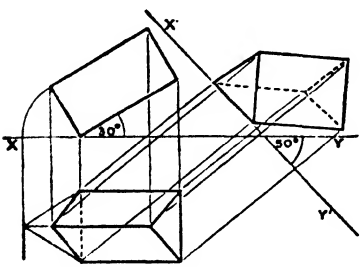


Fig. 29. Diagram showing projections of an equilateral triangular prism.

when resting on the edge of one of its triangular ends with one of its rectangular faces inclined at 30 deg. to the horizontal plane and its axis parallel to the vertical plane. An additional projection is also shown when the axis is inclined at 50 deg. to the vertical plane. The construction is similar to that described and can be easily followed from the diagram.

Sections

Frequently, plans and elevations do not supply sufficient information about a figure in which case sections are drawn. To do this the object is imagined to be cut by a plane and a drawing made of the cut object, the cut surface being indicated by *hatching*, viz., drawing equidistant parallel lines at an angle of 45 deg.

Care should be taken to distinguish between *sectional plans*, *sectional elevations* and *true shapes*. The sectional plan is the appear-

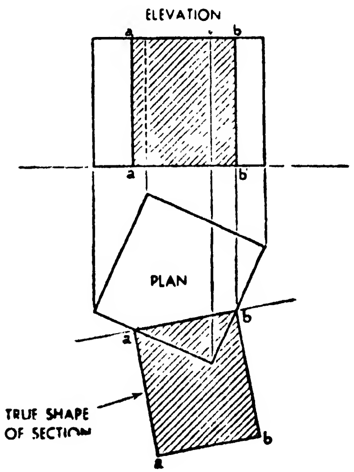


Fig. 30. Plan of cube cut by a vertical plane and method of drawing sectional elevation and true shape of section.

ance of the object from vertically above; the sectional elevation when viewed from horizontally forwards; and the true shape of the section is the appearance when viewed perpendicularly to the cutting plane.

Fig. 30 gives the plan of a cube cut by a vertical plane a b and it is required to draw the sectional elevation and the true shape of the section. First set up the full elevation ignoring the cutting plane, then project upwards from a and b cutting the elevation in a′ a′ and b′ b′. Shade in the rectangle a′ b′ b′ a′. To obtain the true shape of the section erect perpendiculars to a b at a and b and make their heights equal to the height a′ a′. Then the rectangle a b b a is the true shape of the section and is shaded in.

Fig. 31 shows the section and true shape of a triangular prism cut by a vertical plane.

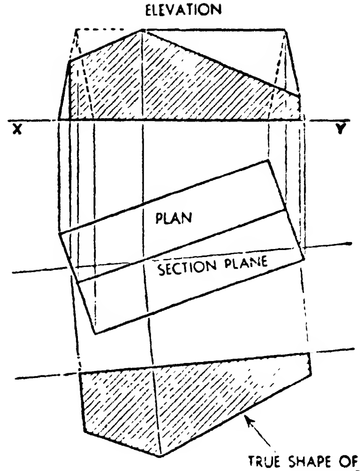


Fig. 31. Section and true shape of a triangular prism, cut by a vertical plane.

Developments

Any solid figure bounded by plane figures can be developed by simple construction, and consists of drawing each face of the figure adjacent so that if the resulting figure was folded up, it would form the surfaces of the solid figure. An example of this frequently met with is the wrapper from an 'Oxo' cube; if the fixing tabs are cut off, the remaining figure is a perfect development of a cube.

Fig. 32 shows the development of a cube, which consists of six adjacent squares so arranged that

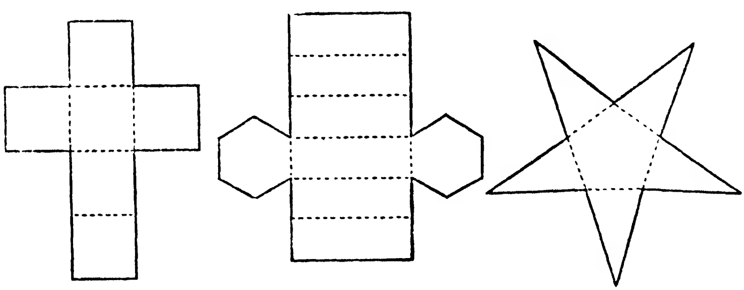


Fig. 32. (*left*) Development of a cube surface, consisting of six adjacent squares arranged so that they may be folded up to form the figure. **Fig. 33.** (*centre*) Development of the surfaces of a hexagonal prism. **Fig. 34.** (*right*) Development of the surfaces of a pentagonal pyramid.

they could be folded up to form the figure.

All polygonal prisms are similarly constructed and consist of two polygons and the same number of rectangles as the polygons have sides. Fig. 33 shows the development of a hexagonal prism.

Other figures are similarly treated. Pyramids are developed by drawing the base figure and on each side of this figure is constructed a triangle equal to the side triangle of the pyramid. Fig. 34 shows the development of a pentagonal pyramid.

Design and Decoration

CARPENTRY and joinery are generally set out from detailed drawings, which are drawings to a larger scale than the working drawing for the complete work. The scale of these detailed drawings depends to a large extent on the type of work under construction, but generally includes sections of the various members drawn 'full-size.' It is essential, therefore, that the craftsman should have sufficient knowledge of drawing to enable him to interpret the intended work.

Detailed Drawings

In this volume several examples of detailed drawings of various types of work will be found, and these should be studied. They consist of general elevations, plans and sections on which are figured the exact overall sizes of the construction and the general layout of the work. Other drawings consist of full-size sections of various members, both in plan and section.

Fig. 35 shows the detailed drawing of an external panelled door suitable for a small public building. The general drawing (plan, section and elevation) will be seen to show the exact overall size of the door and frame, the thickness of the wall in which it is to be set, the size of the reveals and the type of arch or lintel carrying the wall overhead.

On the drawing are indicated the sectional sizes of the various members and the lengths and widths of the panels. These panel sizes are sight sizes and allowance must be made when cutting the panels for the increased size necessary for rebating into the stiles and rails. The remainder of the drawing consists of full-size details of the various members.

Down the left-hand side is a section through the door and frame and along the bottom a full-size plan of the door and frame. These full-size details are broken across the panels as it would be uneconomical to draw a full-size section through a seven-foot door.

The lengths of the panels are ascertained from the general drawing as stated above.

The section of each member is figured on and named. The dimensions figured on are not the finished size of the member but the size from which the member is worked, 1/16th of an inch being allowed for each surface that has been planed. Thus the frame figured 4 in. by 4 in. on the drawing would only

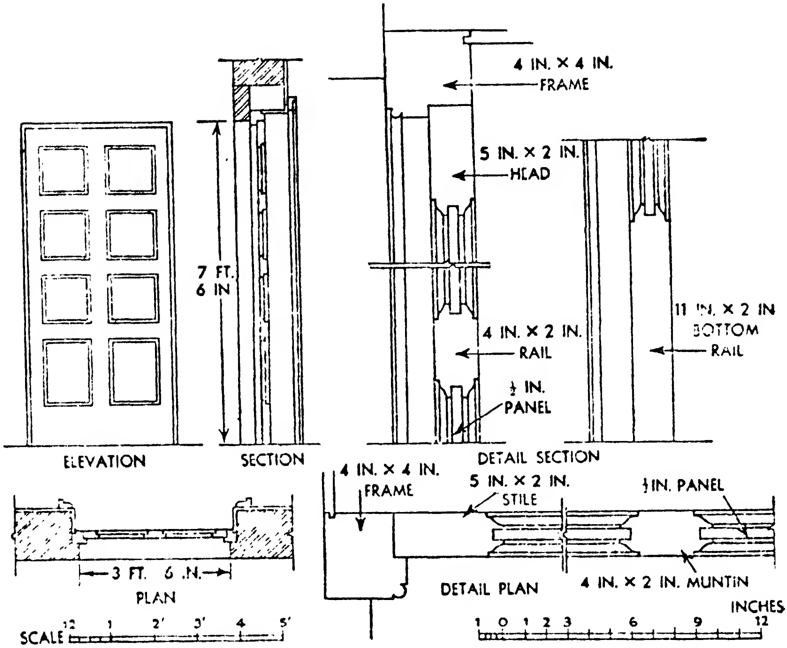


Fig. 35. Detailed drawing of an external panelled door suitable for a small public building, showing plan, sections and elevation.

measure $3\frac{7}{8}$ in. by $3\frac{3}{8}$ in. on the full-size detail.

Detailed drawings are generally arranged as stated above, but no hard and fast rule can be laid down, as in the case of detailing large works such as panelling to a room, including doors, the general drawings would have to be done on one sheet and the details on a second sheet, or the drawing would become unwieldy and difficult to handle in the shop. In any case the scale to which the general drawing is drawn should be stated on the plan and also whether or not the details are ' full-size ' as in some cases details may be done ' half full-size ' or to any large scale.

As the use of lettering on drawings is to assist in the understanding of a drawing, its chief characteristic should be clarity, so that it can be easily read and understood. This does not mean that the lettering should lack style, but that legibility should be the primary consideration.

The heading of the drawing should be especially clear, so that it can be seen at a glance to which job the drawing refers and which detail of that job it delineates. The lettering for these headings should not be less than half an inch in height and should be placed consistently either at the top or the bottom of the drawing.

The other lettering may be quite small as long as it is clear and easily read.

Throughout a drawing the lettering should be in the same

ABCDEFGHIJK
LMNOPQRSTU
VWXYZ
1234567890

Fig. 36. Example of a clear and legible upright lettering, suitable for using on plans and similar drawings. This lettering can be rapidly done with practice.

style, and with this end in view everyone should develop a style of his own. Fig. 36 shows the alphabet and figures of a type which can be rapidly done, is easily read and has some style, both when used as a heading or much smaller general lettering.

Whether vertical or inclined lettering is used depends on the preference of the individual. In the case of inclined lettering (Fig. 37), every letter should be inclined at the same angle.

Mouldings

The mouldings in use at the present day are in general based upon those used by the Greeks and Romans. The Greek mouldings are formed of conic sections (the ellipse, parabola and hyperbola); whereas the Romans always made use of the arcs of circles.

ABCDEFGHIJK
LMNOPQRSTU
VWXYZ
1234567890

Fig. 37. Example of sloping lettering (italic) of a similar character to the upright lettering shown above. This style of lettering is equally suitable for plans.

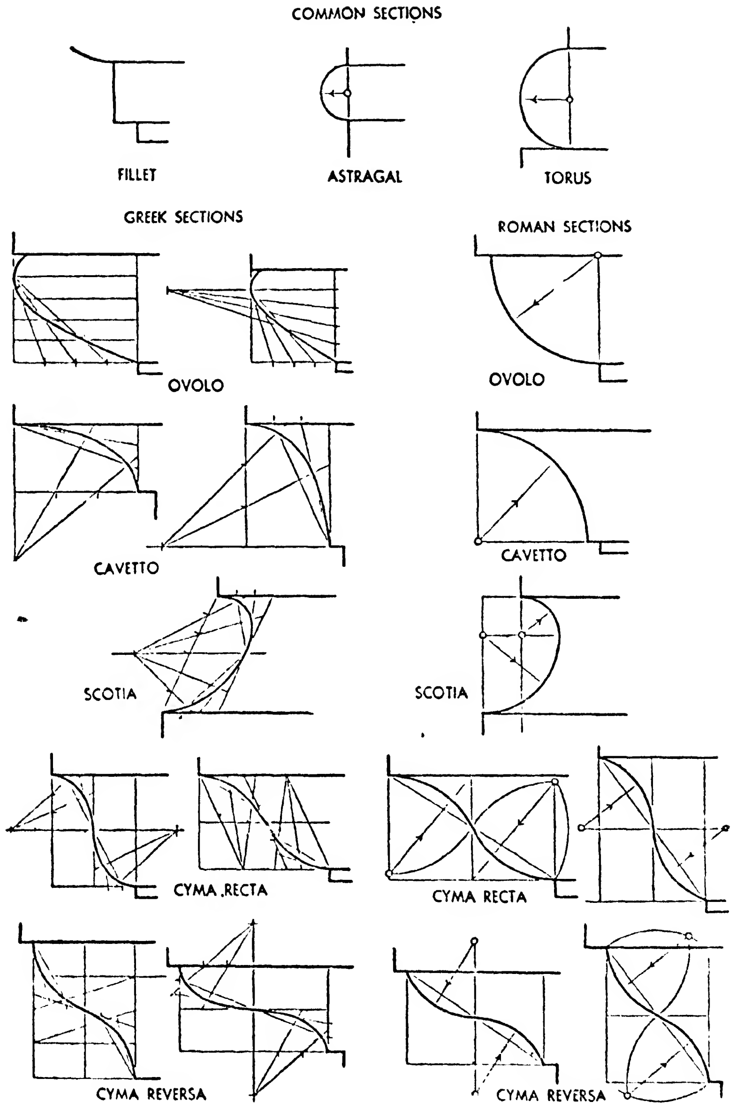


Fig. 38. The various mouldings in use to-day are all based on those used by the Greeks and Romans. Greek mouldings are formed of conic sections (the ellipse, parabola and hyperbola). The Romans used the arcs of circles. The outlines of these fundamental mouldings and the method of obtaining their sections are illustrated above. The various mouldings were generally used in combination.

Both Greeks and Romans used the same eight fundamental mouldings which are the Fillet, Astragal, Torus, Ovolo, Cavetto, Scotia, Cyma Recta and Cyma Reversa. The Fillet, Astragal and Torus are common to Greeks and Romans both in type and outline, whereas the remainder are common in type only.

Fig. 38 shows the outlines of these mouldings and the methods of obtaining their sections. These mouldings were generally used in combination.

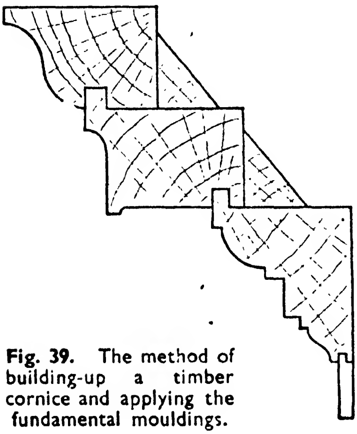


Fig. 39. The method of building-up a timber cornice and applying the fundamental mouldings.

Fig. 39 shows the construction of a timber cornice and the application of the fundamental mouldings thereto.

Mitres and Intersections

When two members in the same plane meet at right angles a 45 deg. mitre is obtained. The mitre is obtained by cutting each arm at 45 deg. inwards from the outer angle of the mitre (Fig. 40). The true shape of the member is enlarged in width along the mitre face, but the depth remains the same. The true shape is obtained as shown by drawing the plan of the mitre, and from this an elevation is projected showing the sectional elevation a b c d of the arm at right angles to the picture plane. From suitable points 1, 2, 3, 4, etc., on the moulding perpendiculars are dropped to the plan line of the mitre and from the points of intersection 1′, 2′, 3′, 4′, etc., perpendiculars are erected to the mitre line X Y. The points 1″, 2″, 3″, 4″, etc., and the points a″, b″, c″ and d″ are then marked on these perpendiculars so that their heights above a line drawn parallel to the mitre line X Y equals the height of the respective points above a b on the elevation. By joining up the points so obtained the true shape of the section of the mitre is obtained.

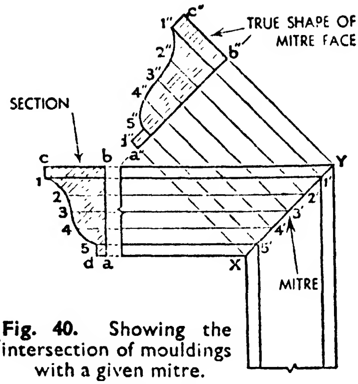


Fig. 40. Showing the intersection of mouldings with a given mitre.

Where the two members do not meet at 90 deg. but at some other angle, the angle between the mitre line produced and each arm will equal half the angle between the two arms of the member. Fig. 41 shows the plan of two members meeting at 120 deg. and the resultant mitre. The true shape of the mitre section is obtained as with a 45 deg. mitre.

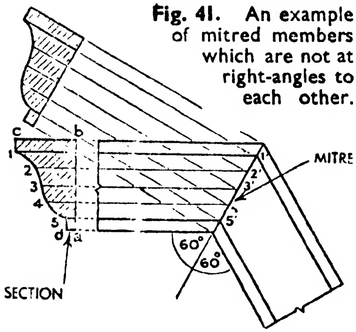


Fig. 41. An example of mitred members which are not at right-angles to each other.

When the two members mitred together are not of the same width, the mouldings have to be developed from one arm to the other, so that their true sections will permit of an accurate mitred joint. The plan of the mitre is drawn as shown on Fig. 42 and the section of one member a b c 1 2 3 4 5 d is drawn on the plan of the arm. The intermediate points 1, 2, 3, 4 and 5 are then projected on to the mitre line and cutting same at 1′, 2′, 3′, etc., and projectors are then run along the other arm from these points. A line a″ b″ is then drawn at right angles to this member and the points c″, 1″, 2″, 3″, 4″, 5″ and d″ are each made the same distance from this line as the respective points are from a b on the other arm. The new section is then drawn. The true shape of the mitre section is obtained as before.

Proportion and Design

The best way to obtain an eye for good proportion is to study good examples of existing work. By proportion is meant the overall dimensions and shape of an item in regard to its surrounds, and one should guard against being led away into considering that an item that is well made is necessarily of good proportion. Panes of windows and panels are of good proportion when the height of the pane or panel is equal to the diagonal of the square on the width; and doors, panelling and windows built up on these lines always tend to be of better proportion than if built up of units of different proportion, but this does not mean that these are sure to give good results.

Design should be considered as being based on proportion, as items require to have good proportion and be well designed to be really successful, and in neither case will the lack of one be made up for the greatest care with the other. Design should be consistent throughout all the different items of a job, and should be considered right down to the smallest moulding, so that everything is in keeping.

Ornament should be used with restraint, as too much ornament is liable to mask good proportion and design, with a result that the work becomes restless and conflicting. Ornament is also very expensive and, therefore, is best from all points of view when made use of sparingly.

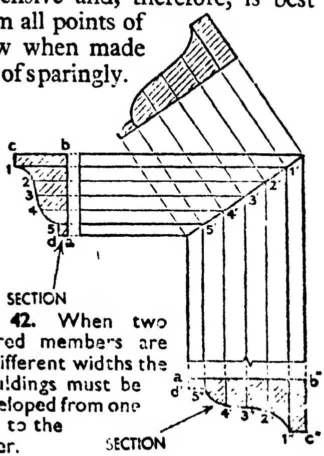


Fig. 42. When two mitred members are of different widths the mouldings must be developed from one arm to the other.

CHAPTER 6

JOINT CONSTRUCTION: JOINERY

PRINCIPLES AND PROPORTIONS. TYPES OF JOINTS. GLUED JOINTS. MACHINE-MADE JOINTS. EXTERNAL ANGLES. PLYWOOD, LAMINBOARD AND BLOCKBOARD. CARCASE WORK. MITRING. GENERAL PRINCIPLES OF TENONING. INTERNAL WORK. OBLIQUE TENONS. SUB-FRAMES. MOULDED GLAZING BARS. SASHES. DOORS.

Good joinery is entirely dependent upon well-made joints. Thus a clear conception of the principles which govern their design and construction is of utmost importance in order that the most suitable joint can be selected for any particular purpose or condition.

The type or form of any well-made joint is determined by the purpose of the members to be connected, the nature of the material, and the method of preparing the joint.

Purpose of the Joint

The purpose of a joint may be to increase the size of a member in width or length, to connect members together at an angle, to form a required shape, or to provide a framework to hold other portions of joinery. A joint should be so made that it will enable the joinery to retain its shape, and so arranged that any movement will not expose an open joint or weaken the work.

There are some joints which are suitable for many purposes, and which are equally applicable to both carpentry and joinery, but even these must be adjusted to conform with the particular nature of the work which is being done.

Joinery rarely supports great weights as does carpentry; and, apart from the movable units of joinery, external stress can be completely ignored in designing joints. A more important factor in their design is the appearance of the finished work. End grain and all fixings must be hidden from sight as much as possible.

Due to its fibrous structure, wood will readily split and shear in the direction of the grain. It will also swell and shrink across the grain with changes in its moisture content. Because of these peculiarities, the grain of all members should be parallel to their length, and all fixed members should be as small as possible in width and thickness.

The manner of making a joint also influences its design. Hand-made joints should be as simple as possible. A simple joint is more likely to be better made than a complicated joint. With joints made by machinery this does not apply, as the machine is capable of greater precision, and, when once set up, is able to reproduce many similar joints to a predetermined pattern.

Sometimes the size or position

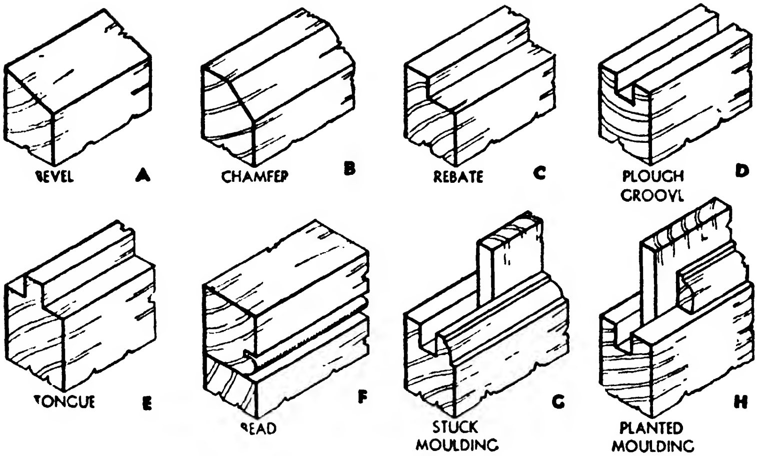


Fig. 1. Terms used in joinery joints. A stuck moulding is cut from the solid wood ; a planted moulding is a separate member pinned to the frame.

of a piece of joinery affects its construction; joints may have to be prepared in the workshop and assembled on the site, in which case special provision must be made in the type of joint used.

Before the various types of joints are dealt with in detail, consider Fig. 1, which illustrates a few general terms used in connection with joinery joints. A and B show the difference between a bevel and a chamfer. The former consists of a sloping edge whereas the latter is the corner or arris planed off, usually at an angle of 45 deg. A rebate C is a rectangular section cut away from one edge, while a plough groove D is cut out from the centre of the edge. A tongue E is the corresponding member made to fit the groove. A bead F is used to make a joint inconspicuous by masking it with a shadow. A stuck moulding G is a member cut out of the solid wood, while a planted moulding H is a separate member which must be secured to the main frame.

Widening joints are used to increase the width of the material in the same plane. For general purposes they may be grouped into three main classes: (1) glued joints as made by hand methods; (2) glued joints as prepared with the aid of machinery; and (3) dry joints which allow each individual member to shrink and swell independently.

Fig. 2 shows the most common methods of making glued joints by hand. The simplest form of joint possible is the butt, as shown at A. This must be carefully made, and the glued edges should be rubbed together to squeeze out air and surplus glue. As the usual manner of preparing a rubbed joint is to plane the edges until light cannot be seen through the joint, accuracy and practice are required, because light will pass through an aperture of less than one hundredth

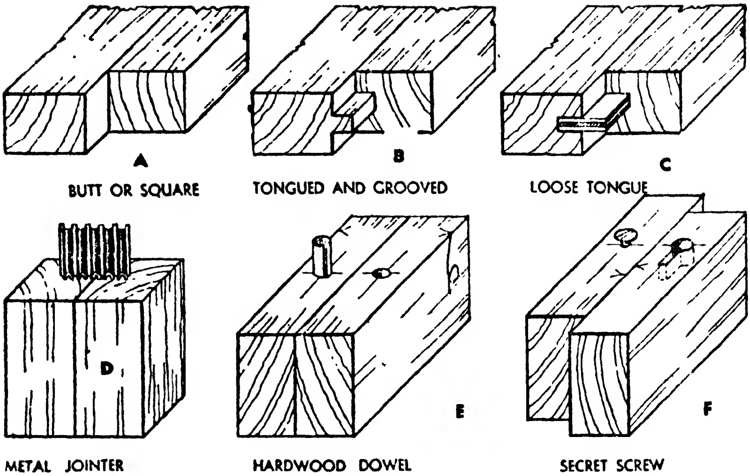


Fig. 2. Glued-edge joints for increasing the width of surfaces, as made by hand methods. Note the vee cut in the length of the hardwood dowel to allow air and glue to escape. The simplest form of joint possible is shown at A.

of an inch. A glued joint is more suitable for boards up to 1 in. thickness.

For thicker boards, or for joints where their position renders them liable to fracture, a tongue, cut from the solid wood as at B or made in a separate piece as at C should be used. The grain of loose tongues should be across the joint to give the maximum strength. Such tongues are liable to damage during manufacture; hence, cross tongues, which have the grain in a diagonal direction across their faces, are used. Strips of plywood provide a more economical and convenient material for these tongues. Loose tongues are often referred to as feathers.

Long lengths of wood are held while being jointed by dogs or cleats until the glue is set.

A cheap method of jointing thin boards is by means of corrugated metal fasteners, sometimes known as wiggles. These may be driven either in the end grain, as shown at D, or across the face of the work.

Dowelled joints, as shown at E, consist of short lengths of cylindrical hardwood inserted across the joint. A vee groove or a saw kerf should be made in the length of the dowel to allow for the air to escape, which would otherwise tend to burst the sides of the material when the dowel is driven in.

An alternative method of strengthening a butt joint is by means of slotted screws, as shown at F. Stout screws are partially inserted in one edge, and slots to receive the heads and shanks of the screws are cut into the opposite board. The board containing the slots is then dropped over the screws and tapped at the end to drive the slots over the screw heads. After this preliminary fitting, in which the screw heads cut into the sides of the slots, the screws are given a half turn so as to ensure a good fit when the joint is finally glued.

With the aid of machinery more elaborate joints are possible, the object being to increase the area of glued surface, as shown in Fig. 3. A shows a common type of glued tongued and grooved joint. When thicker wood is used, a double tongue, as at B and C, gives a more satisfactory job. The dovetailed joint at D is prepared and glued on machines specially made for the purpose. Narrow boards can be conveniently jointed to form any width. The plough grooves for the double tongues shown at E may be cut on the spindle or fourcutter. F illustrates the method employed in jointing large sheets of laminboard. Because of the size of the boards, hardwood dowels spaced at 9 in. to 12 in. centres are used as well as a tongue.

A board 9 in. wide may shrink nearly a quarter of an inch during the ordinary process of manufacture. Therefore, where wide surfaces are essential, adequate provision must be made to allow for the reduction in size; at the same time the surface must be held securely to prevent distortion by twisting.

Fig. 4 shows the need for this precaution. At A is shown a solid board fixed at both ends with the resultant splitting and tendency to loosen the fixings. Warping and cupping may be overcome by selecting choice material, by arranging the boards with their heart sides alternatively outwards and inwards, and also by using rift sawn stuff as indicated at B and C respectively.

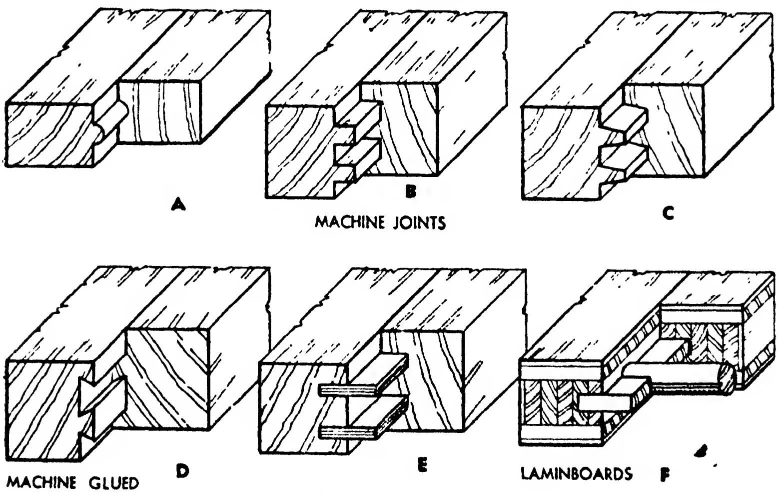


Fig. 3. Glued joints for increasing the width of surfaces, as made with the aid of machinery. A. Tongued and grooved joint; B. double tongues; C. splayed double tongues to ensure a tight fit; D. dovetailed joint made in one operation on a continuous-feed glue jointer machine; E. double feathers; F. tongued and dowelled joint between sheets of laminboard. A loose tongue is fitted with dowels at a distance apart of from 9 in. to 12 in.

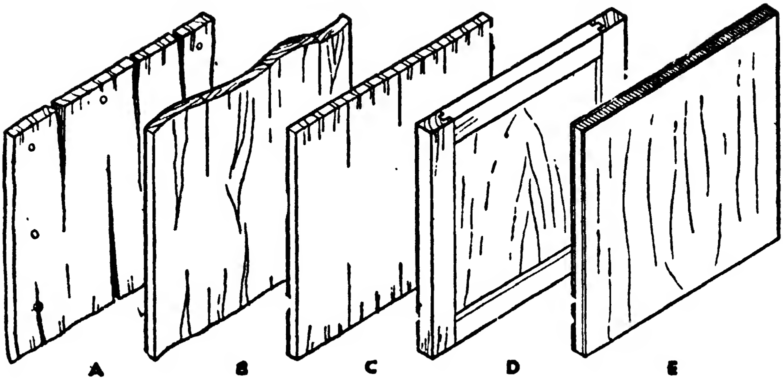


Fig. 4. Showing the need for making adequate provision against distortion. *A.* Solid board will split and warp. This warping may be minimised by gluing narrow boards together with heart sides in alternative directions as at *B*, or by using selected rift sawn boards as at *C*. A better method is to form a frame or enclose the large surface as at *D*, or to use laminboard as at *E*.

A better method is to frame or enclose the large surface as at D or to use laminboard as at E.

Where solid wood must be used, as in the case of a facia board or wide counter top, the treatment may be as shown in Fig. 5. These fixings are designed to hold the boards yet allow them to swell and shrink without warping. A shows a cleat with screws inserted through slots to the back of the board. Slotted plates with round headed screws, as at B, allow smoother movement than the ordinary countersunk screw.

Another way is to cut dovetailed keys, tapered as at C, into the back of the board. The keys should be about 18 in. apart and placed in alternate directions along the board. For boards seen on both sides, or where they are exposed to alternative wet and dry conditions, metal rods, as at D, should be inserted through the centre of the boards to maintain a good surface.

For internal work, hardwood buttons (E and F) form a secure fixing and afford a satisfactory means of preventing the boards being disfigured by shrinkage.

Where boards are required to cover a large area, dry joints are used to distribute the shrinkage over a number of joints. For this reason narrow boards should be used. In Fig. 6 A and B are shown the usual types of tongued and grooved matching used on cheap work. A better means of masking shrinkage is to use ornamental boards similar to C. These may be used both internally or externally, and may be fixed in a vertical or horizontal position.

Joints between large sheets of veneered laminboard may be as at D and E. No attempt is made to conceal the joints; in fact, they are often emphasised to form part of the general decorative scheme.

A housing joint is where one member is fitted into a trench cut into the other. In its simplest form it is used to connect boards together at right angles, as shown in Fig. 7 A. Variations such as

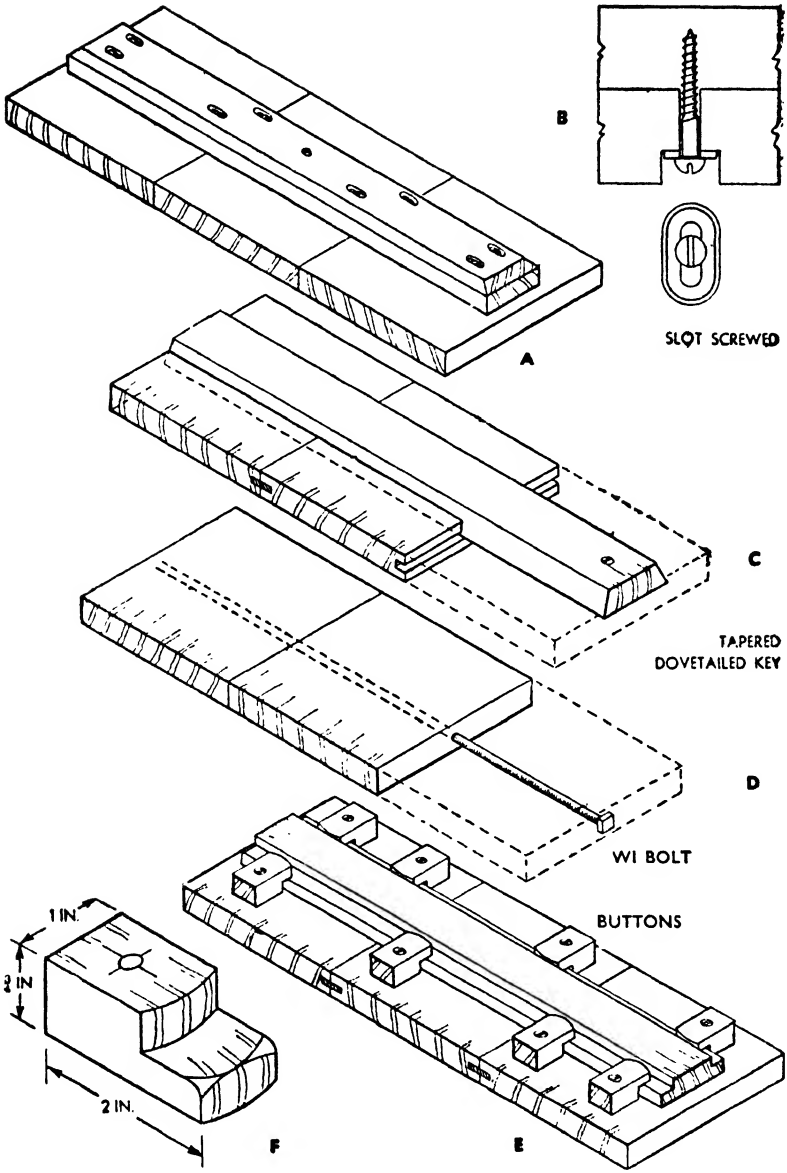


Fig. 5. Joints to prevent warping in wide surfaces. The fixings shown hold the surface, yet allow the material to swell and shrink. *A.* Cleat slot screwed to board; *B.* detail of screw with plan to show slotted washer; *C.* tapered dovetailed key housed in board; *D.* wrought-iron bolt through centre of material; *E.* board fixed with buttons to bearer; *F.* detail of wooden button.

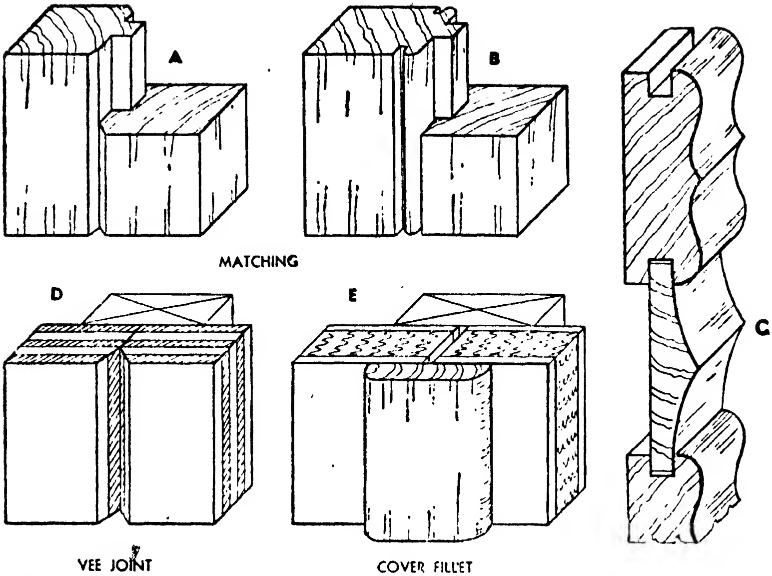


Fig. 6. Dry joints for increasing width of surface. *A.* Tongued and grooved vee matching; *B.* tongued and grooved beaded matching; *C.* moulded boards tongued and grooved together; *D.* vee joint between large sheets of laminboard; *E.* butt joint in laminboard masked with cover fillet.

a shouldered housing B and a dovetailed housing C depend upon the particular nature of the work and the thickness of the stuff.

An application of the shouldered housing is the joint between the jamb and the head of a door casing, as shown at D and E. Sometimes a member is housed to hide a joint from view, or, as at F, to make a weatherproof joint between the front edge of a projecting transom with a window jamb.

Types of angle joints to connect the edges of boards or sections of framing together which do not lie in the same plane, are shown at Fig. 8. There are three basic angle joints, the butt A, the mitre B and the rebate C. These joints have many variations, according to the nature of the work, the direction of the grain in relation to the joints, the position of the joint (whether for an internal or external angle), and the method of fixing.

Fixing may consist of gluing the members together, nailing or screwing.

A mitre is used where an unbroken surface is required. It is a difficult joint to fix, and the edge tends to curl away from the joint unless well made. Tongued and grooved, or rebated joints are more satisfactory. The joint line can be successfully masked by a bead, as at F and L, or by making the joint in a line with the fillet of the moulding as at G.

External angles are strengthened by means of glued blocks. These are in the form of triangular blocks cut from 2 in by 2 in.

softwood about 3 in. long and spaced about 12 in. apart. Glue blocks should be made perfectly square on their faces and should be carefully rubbed into position to obtain the maximum holding power. The application of glued blocks to joinery is given in Fig. 9.

The greater use of reliable plywood and the various types of laminboard and blockboard has been largely responsible for a new technique in joinery construction. The need to make ample provision against swelling and shrinking has been eliminated. Larger surfaces can be covered with lighter fixings, and numerous choice woods can be used with charming effect.

Consequently, joints are fairly simple, as the sheets can be merely butted together on a much lighter framework. For external angles in built-up boards (Fig. 10) the mitre is not satisfactory, as the outer veneer is liable to split during manufacture, and tends to become unsightly. To overcome this disadvantage, hardwood strips are fitted at the corner, or metal angle strips are used as shown in the diagrams. Sometimes a facing veneer is carried over the corner

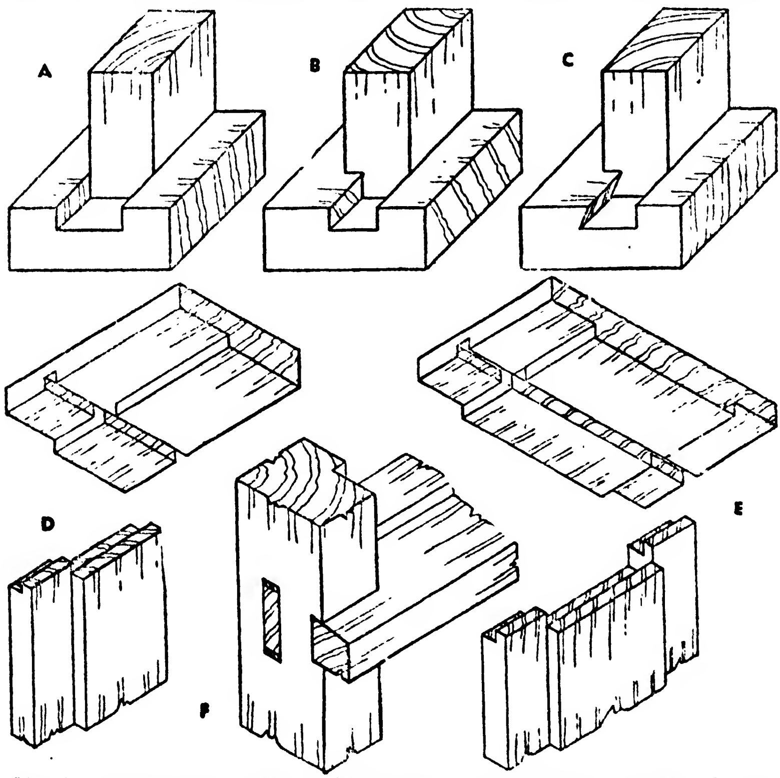


Fig. 7. Housing joints. A. Simple housing ; B. shouldered housing ; C. dovetailed housing ; D. and E. show the application of a shouldered housing to door casing ; F. projecting portion of transom housed into window jamb, a means by which a joint may be made weather-proof.

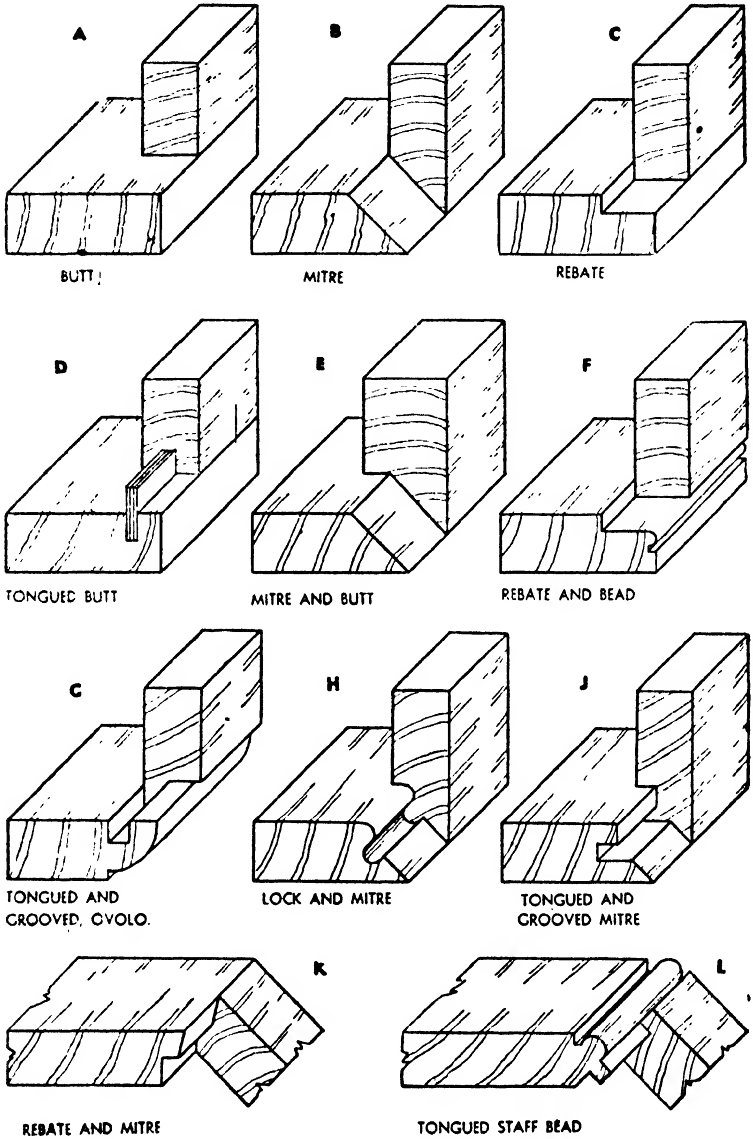


Fig. 8. Angle joints common to both directions of grain are : *A.* The butt, the simplest type of joint ; *B.* the mitre, for hiding end grain ; and *C.* the rebate, which gives definite fixing. Variations of these three basic joints are : *D.* Tongued butt ; *E.* mitre and butt ; *F.* rebate and bead. The bead is to mask the joint. *G.* tongued and grooved ovolo moulded ; *H.* lock and mitre ; *J.* tongued and grooved mitre ; *K.* obtuse-angle rebate and mitre ; *L.* tongued staff bead.

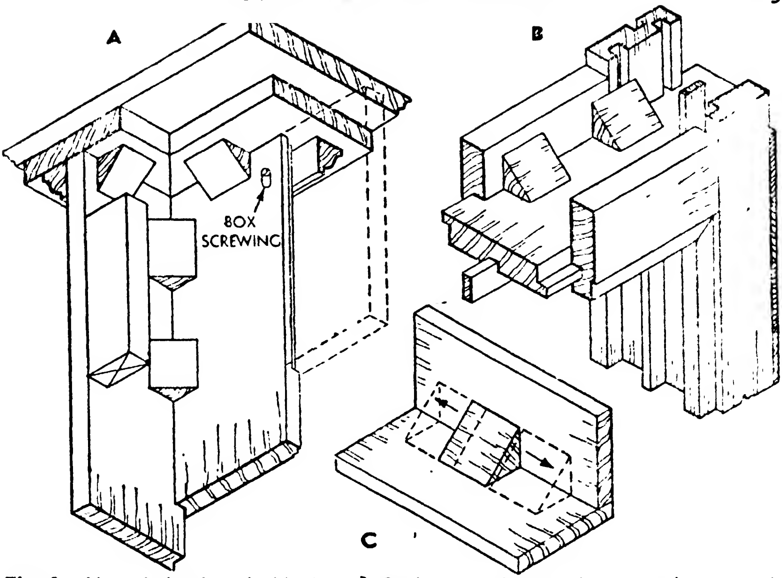


Fig. 9. Use of glued angle blocks. A. Back view of a wooden mantelpiece with blocks to give added rigidity. The method of inserting screws is known as box or pocket screwing ; B. head of a boxed frame with angle blocks to hold the linings firm. Angle blocks are glued and rubbed into position with a movement which is indicated by the arrows shown at C.

strip, but however carefully it is done, any slight movement of the angle will show the line of the joint on the face.

The strongest type of angle joint across the grain is the dovetail, of which there are three main types : (1) common dovetail, (2) lap dovetail, and (3) secret dovetail.

The angle or inclination of a dovetail should not be too acute, otherwise there is a danger of the sharp corners breaking off. A satisfactory angle is about 80 deg., and this inclination may be determined by setting out 6 or 7 units of equal length and marking 1 unit at right angles, as shown in Fig. 11 A. The proportions of the pins to the sockets of the dovetails vary from 1 in 3 or 4 for general carcase work up to 1 in 6 in the case of lighter work.

The common dovetail B shows portions of end grain on both sides. Where this is considered undesirable, as in a drawer front, the lap dovetail C is used. In this joint the end grain of one piece is hidden by the lap of the wood over the face. Where it is necessary to hide the end grain on both faces, a secret dovetail F is used. This gives the appearance of a mitred joint, but because of the expense in its preparation it is only used for good quality work in hardwood.

Where several boards are to be jointed together in carcase work, a through dovetail may be used as at D. For lighter work a mitre may be used and fastened by inserting thin veneers in saw kerfs cut to form the shape of a dovetail, as shown at E.

Dovetails may be cut on a

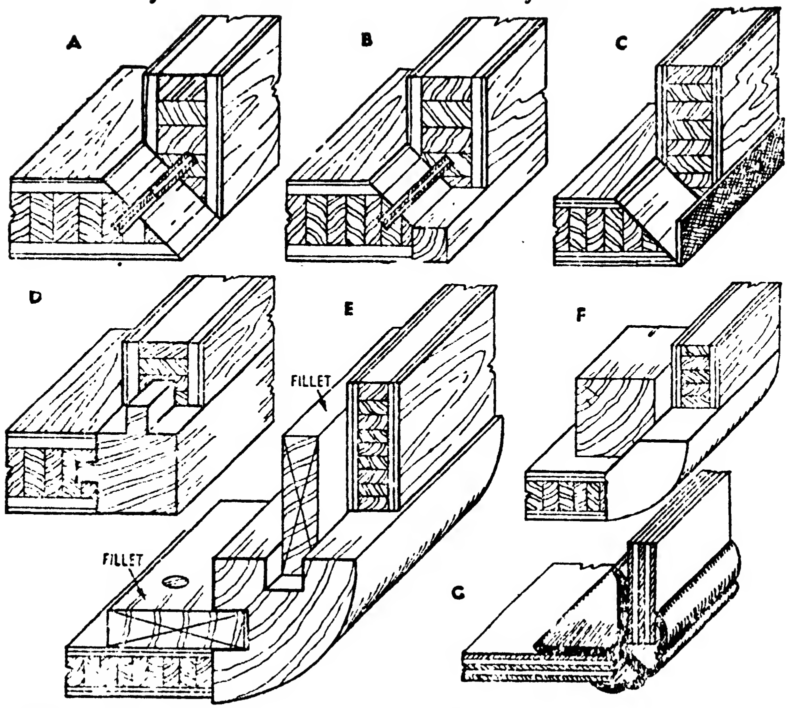


Fig. 10. Angle joints to laminboards. *A.* Mitred joint with a loose tongue. In this the outer veneer tends to split and become unsightly. A better method is to fix a hardwood strip at the corner as at *B*, or a metal strip as at *C*. Solid wood should always be tongued to laminboard, as at *D*. *E.* a stouter corner piece for larger work; the fillets are screwed to the backs of the boards, and are tongued to the corner piece. *F.* a quadrant corner with glued blocks, which is more suitable for smaller work. *G.* metal corner clip which holds the boards together.

machine specially designed for the purpose, or on a spindle moulding machine by means of a jig attachment. Fig. 12 A shows the shape of the dovetails when cut by the latter method. For cheaper work, corner locking by means of a combed joint may be used, as shown at C. This joint relies entirely upon the tightness of the toothing for strength.

Fig. 13 shows the special attachments for both dovetailing and corner locking on the spindle moulding machine.

Where moulded members intersect at an angle, special attention must be given to the joint. The crudest method is to stop the moulding before it reaches the joint, as in Fig. 14 A. This stop moulding, as the finish is called, may be formed by gradually offering the material up to the cutter of the spindle moulder, or it may be finished by trimming with hand tools.

Sometimes the moulding is continued round the joint by cutting a mason's mitre, as at B, but this method is unsuitable for machine-made joinery. Furthermore, the line of the moulding is broken at the joint, and the

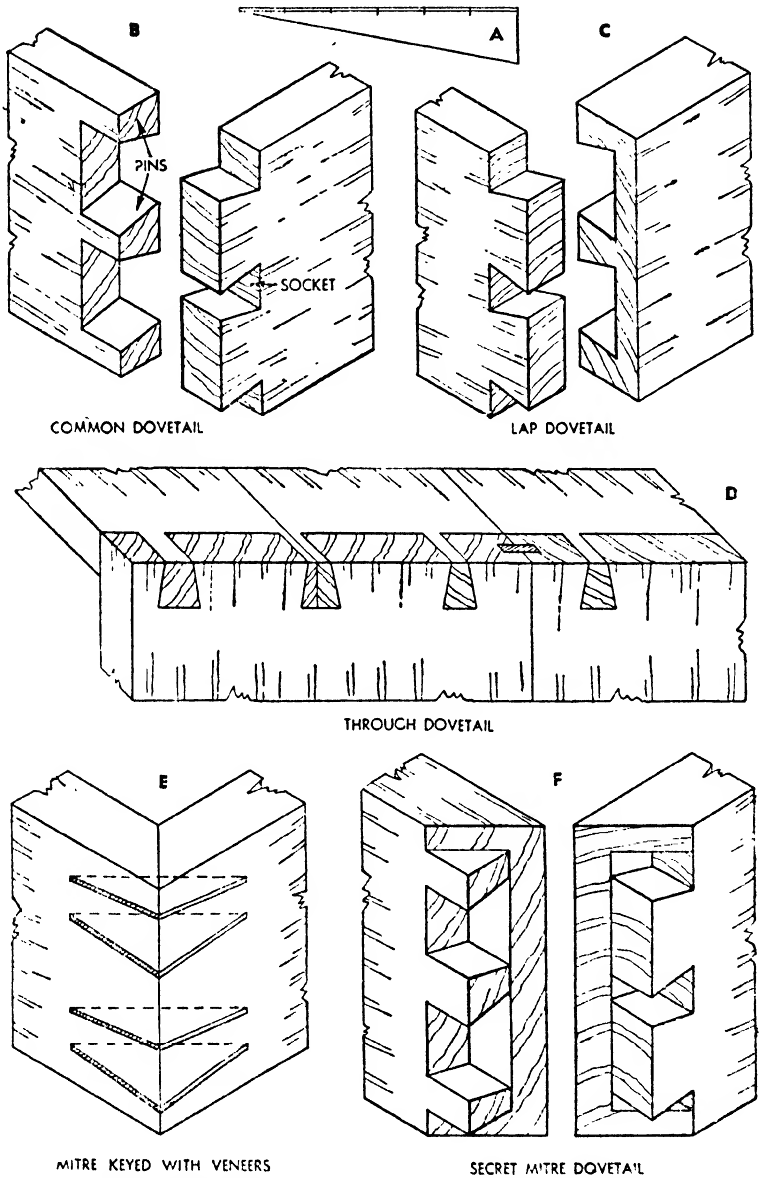


Fig. 11. Dovetailed joints for joints at an angle across the grain. *A.* Method of setting-out the slope of a dovetail ; a proportion of 1 in 6 or 7 gives a satisfactory angle ; *B.* common dovetail showing pins and sockets. *C.* is a lap dovetail. *D.* through or box dovetail. Note the overlap of the butt joints. For small work a mitre keyed with veneers (*E*) is often used. *F.* secret mitre dovetail

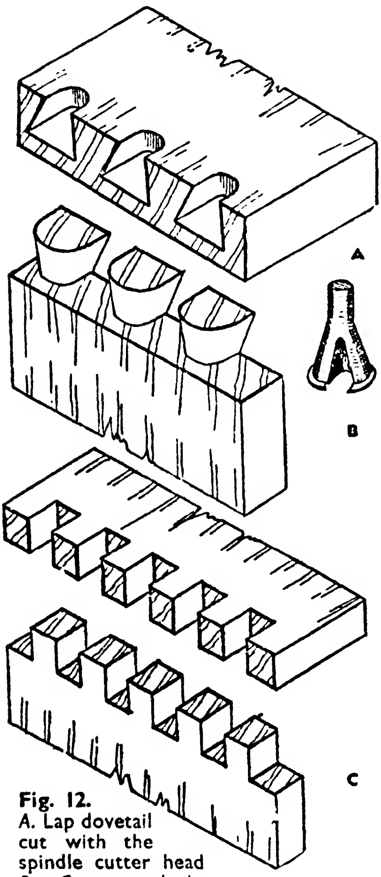


Fig. 12. A. Lap dovetail cut with the spindle cutter head B; C. corner locking for cheap work.

unequal shrinkage of the jointed members makes it rather unsightly. A better method is to mitre the mouldings together as at C, or better still to scribe the mouldings, that is, to fit one member to the other as at D.

At an external angle the members should be mitred together, but for all internal angles it is better to scribe the moulded members together. When fitting such members as the skirting board shown at E by hand methods on the building site, the moulded portion is first cut as a mitre. This is to give the profile required, so that it may be accurately cut with a coping saw or gouge to the desired shape.

For moulded framing members, the scribing can be formed on the tenoning machine at the same time as the tenons are cut. Even in the shop, the mitre has to be cut by hand methods, and it is not as satisfactory as the scribed joint, as the mitre is liable to gape when the wood shrinks.

On the other hand, the scribed joint can be fitted under pressure, and shrinkage does not expose an open joint. The shrinkage is only equal to the shrinkage of one member, and that does not present itself squarely to the eye, but the sprung mitre advertises its deformity.

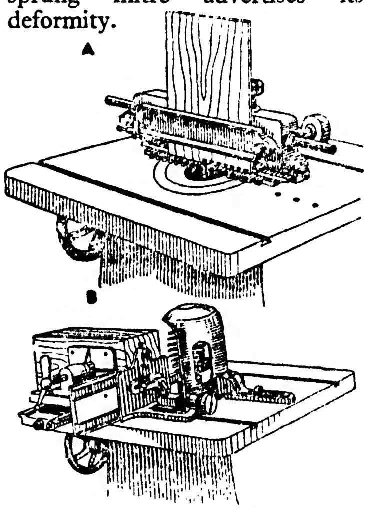


Fig. 13. A. Dovetail attachment fitted to a spindle moulding machine. Note how the jig enables both the dovetails and sockets to be cut in one operation. B. corner locking attachment for use on the spindle. By this means many joints can be cut together.

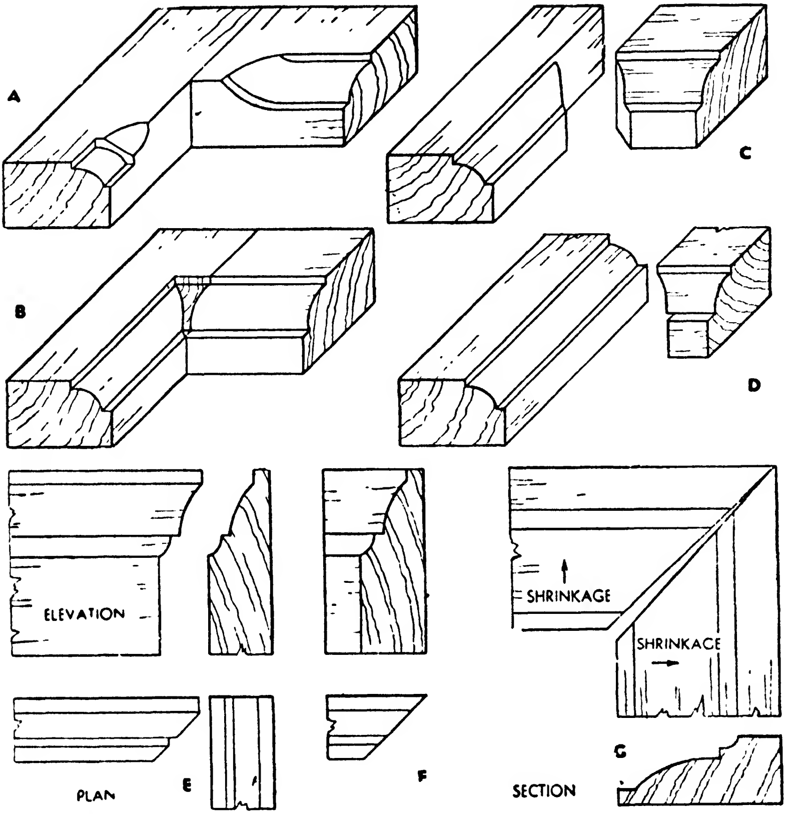


Fig. 14. Scribing and mitring. In mitring, mouldings are butted together, while in scribing one moulding is cut to the profile of the other. *A*. Types of stop mouldings ; *B*. mason's mitre ; *C*. true mitre ; *D*. scribing joint ; *E*. shows a detail of a scribed skirting board. The scribing line is marked out by mitring the moulded portion as at *F* ; *G*. mitres expose an open joint when wood shrinks.

The mitre can be applied to all mouldings, but the scribed joint is not practicable when the moulding is undercut or runs to a feather edge. Such mouldings cannot be machine scribed and therefore should be avoided or adjusted to a more practical design.

The assemblage or combination of members jointed together to form an item of joinery is known as framed joinery. Considering the nature of the material, the most obvious means of making a frame is to cut a tongue called a tenon on one end of one piece to fit into a slot called a mortise cut in the centre of the other.

A mortise and tenon is the principal framing joint, and is used in all kinds of woodwork construction. Fig. 15 shows the joint in detail with the names of the various parts clearly indicated. Note that a haunched tenon is to allow the tenon to be wedged as

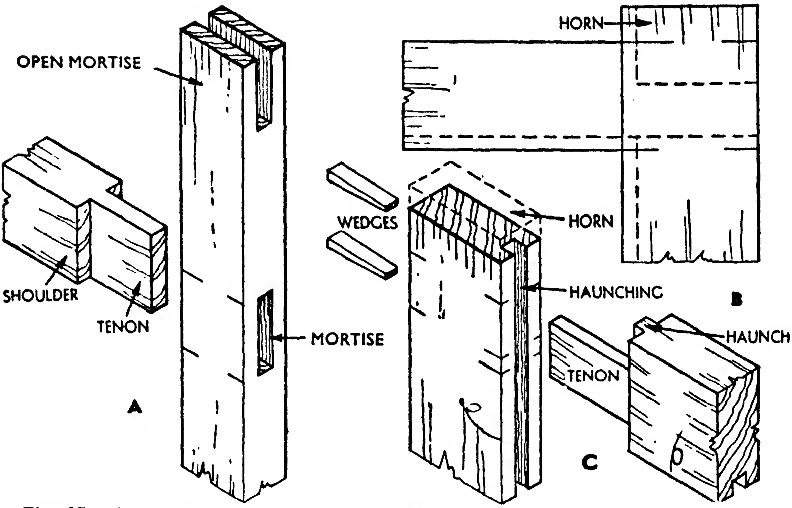


Fig. 15. A mortise and tenon joint is the principal framing joint. The diagram shows the names of the various parts. An open mortise and a haunched tenon are also shown. The haunch is to allow the tenon to be wedged and to prevent the rail from twisting. The haunching is the groove on the mortised member to receive the haunch. The horn is left on a haunched mortise and tenon joint to protect the work, and to give added strength during wedging.

well as to prevent the tenoned member from warping.

While no definite proportions can be laid down as final and binding for all cases met with in practice, there are certain guiding principles which should be closely followed. These are :—

(1) The thickness of the tenon should be one-third the thickness of the stuff mortised. This is to give the same strength to the tenon as the sides of the mortise, and is applicable even when the mortised member is of larger size than the tenoned piece. To facilitate production, the mortise is made to the nearest size of the tool available, and often is made nearer to one face than the other to simplify fitting the shoulders of the tenon.

(2) The width of a tenon should not exceed five times its thickness. This particularly applies to tenons which are held by wedges. As a rule, a tenon should not be wider than four inches unless held by pins or other similar fixing.

Where two members are connected together by a mortise and tenon joint at a corner, a portion of the tenon is cut away to enable the wedges to hold. The joint is known as a haunched tenon, and has a short portion of tenon, called a haunch, left on near the root of the tenon to prevent the member twisting (Fig. 15 B and C).

(3) The width of a haunched tenon should be equal to half the width of the member tenoned. If more than half were given to a haunched tenon the fibres on the member containing the mortise would be inclined to shear when the wedges were driven in, as in Fig. 16 A. Wide tenons are objectionable because of their

liability to shrink from the sides of the mortise, loosen the wedges, and distort the joint. Wide thin tenons also tend to buckle and burst the sides of the mortise.

Where a wide member has to be tenoned, the tenon should be divided into two parts by a haunch. The rule for wide tenons is :—(4) The total width of the tenons should equal half the width of the rail.

Mortise and tenon joints should be carefully marked out and executed in a methodical manner. With hand-made joints, the faulty cutting of tenons and shoulders must be avoided at all costs, as badly made joints affect the entire work. Some of the most common defects in a mortise and tenon joint are shown at C, D and E.

The undercutting of shoulders should not be tolerated because when the face of the work is cleaned off an open joint is exposed. Inaccurate mortising may cause the joint to wind. A twisted joint is a source of trouble; attempts at straining the joint during cramping and wedging are rarely effective, and it is a risky procedure.

In machine work, care should be taken to ensure that the face of each member is held square and firm against the fence of the machine. The trial piece should fit through the mortise and the tenon should be flat and not

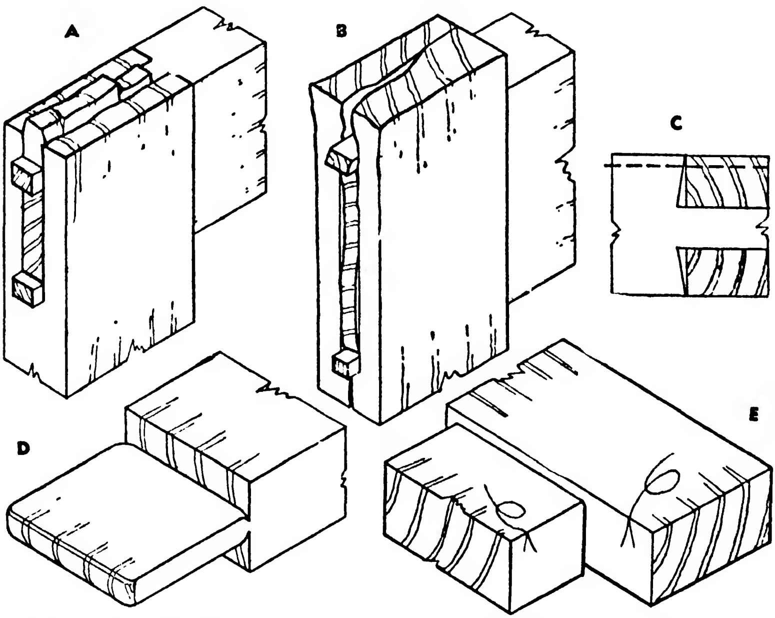


Fig. 16. Possible defects and faults in mortise and tenon joint. The wood may shear, due to insufficient material above the mortise hole, as shown at A. Ill-fitting tenons, if too wide, tend to buckle and burst the mortise, as at B. C. shows the evil of undercutting shoulders in an effort to obtain a good fit on the face. When the face is cleaned off the joint is exposed. Too deep cutting at the shoulders, as at D, may result in broken tenons. Bad marking out means more cleaning off and a thinner frame. E. shows what must be avoided.

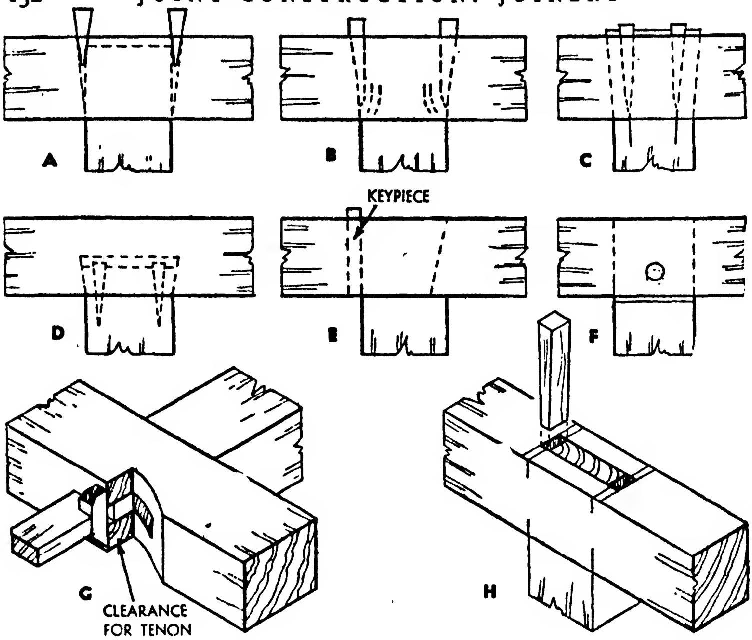


Fig. 17. Methods of fixing tenons. *A.* Stumpy wedges tend to force the tenon outwards. Wedges should always grip the tenon close to the shoulders, as at *B.* At *C* the wedges are inserted in the tenon itself. Foxwedging (*D*) consists of wedges inserted in the mortise with the tenon hammered up. A dovetailed tenon with a key-piece is shown at *E.* *F.* tenon prepared for draw-bore pinning. At *G* the tenon is keyed outside the mortise. *H.* the proper shape of a wedge and the method of marking out for wedge room.

rounded; care should also be taken that the scribing cutters do not score the line of the shoulders too deep. In both hand and machine operations the mortise is cut before the tenon.

There are various methods of securing a tenon in its mortise, and a few ways are shown in Fig. 17. The most usual method is by means of wedges driven in the outside edge of the mortise to give a dovetailed form. The object of wedging a tenon is to keep the shoulders up, and to provide a secure fixing which will not loosen when shrinkage takes place. To be effective, the wedges should be only slightly tapered and should not be made with a sharp point; the proper shape of a wedge is shown at H.

A common fault is to cut the wedges with too much taper, as at A. These hold at the end of the tenon, and in addition to forcing the joint apart when they are driven in, they are responsible for an open joint when the mortised member shrinks. Wedges should be made and inserted so that they grip the tenon at the root, as at B.

Sometimes the wedges are inserted in the tenon itself, as at C. This is not a good method, for unless the material is of sound straight-grained stuff, the wedges may tend to split the rail. A similar form of fixing is foxwedging, as at D. This is a secret fixing and is used when the end grain of the tenon must not show through the mortised member. The wedges are inserted in the mortise with their ends in saw kerfs in the tenon. The tenon is made shorter than the depth of the mortise hole to allow the ends of the wedges to burr over without fouling the joint when the rail is driven in.

In large framing a dovetailed tenon, as at E, may be used with a key piece or folding wedges to secure the joint. The purpose of the key is to fill the space required by the dovetail to enable it to be fitted in the mortise.

Where cramps cannot be conveniently used to pull the joint together, the tenon may be drawbored and pinned, as at F. A hole to suit the size of the pin is bored through the sides of the mortise, the tenon fitted into position, and the centre of the hole is marked on the tenon with the point of the bit. The tenon is then withdrawn from the mortise and a hole bored through the tenon nearer to the shoulder. When the joint is finally fitted together, the action of the pin in being driven through the holes is to pull or draw the shoulders of the tenon close to the mortised member.

A keyed tenon G acts in a similar manner, except that the key is fitted outside the mortised member. This joint is used for detachable members or where the appearance of the joint is of secondary importance. When inserting pins or keys their position with relation to the grain of the material must be carefully considered. To avoid the material shearing along the grain a pin should be placed nearer to the shoulder of the tenon, and where more than one pin is used in the same tenon, they should be staggered to avoid the possibility of a split or shake loosening the joint. Similarly, a keyed joint should have sufficient material on the tenon to resist any tendency to shear, with clearance behind the key to allow the joint to be drawn close.

Joints for internal work are

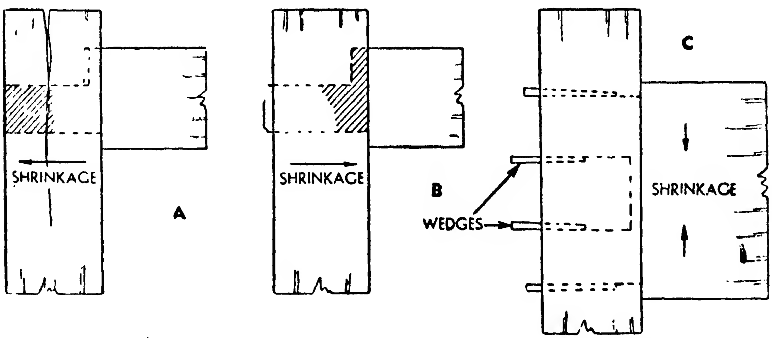


Fig. 18. Gluing and wedging tenons. How not to glue a mortise and tenon joint is shown at A. The shaded portion at B is the proper place to apply glue. The shrinkage can then move as shown by the arrow, and the joint is not affected. C. proper wedging counteracts shrinkage by subjecting a wide rail to compression.

glued together, while the joints for external work are treated with lead paint or other suitable preservative. Gluing a mortise and tenon does not mean merely smearing the surfaces with glue; there is a right way and a wrong way of gluing a joint, as shown in Fig. 18. If the end of the tenon is dipped in the glue, as shown in shaded portion at A, or the whole of the surface coated, the joint will tend to gape and the stuff split when the material starts to shrink.

A better way is to coat the shoulders of the tenon and the haunch with glue, as shown by the shaded portion at B. If the ends of the tenon and the outside of the mortise are kept free of glue the shrinkage of the mortised member will be from the outside, and the shoulders will remain intact.

In wedging up a divided tenon, the inside wedges should be partially inserted first, and then the outside wedges driven in to subject the tenoned member to compression, as shown at C. By this means the danger of shakes occurring due to shrinkage may be avoided.

Fig. 19 clearly illustrates several variations of the tenon joint. A single haunched tenon, suitable for the outside rail of a frame, is shown at A. Sometimes the haunch is bevelled as at C, in which case it is known as a table haunch. An unequal shouldered tenon is shown at B. This is necessary where a rebate or moulding is stuck on one edge of the mortised member. Where the tenoned member is thinner than the mortised piece, as in the case of rails to tables, skylights and ledged doors, a barefaced tenon is used to keep the mortise in the centre of the stile. This type of tenon is made with one shoulder, as at D.

For wide rails a pair of single tenons (E and G) is used. To give the maximum strength to the mortised member, the tenons should be as wide apart as possible, while to maintain strength on the tenoned member at its weakest point, a haunch is used to connect the tenons together. At G is shown a wide rail at the end of a stile. Note how the lower tenon is raised to allow for wedging at the end of the mortised member. The set-back on the lines of the tenon, shown at H, is necessary because of a plough groove in the frame to receive a panel.

Where the material used for the framing is very thick, or where a mortise lock is to be fitted which would foul the joint, double or twin tenons are used, as at F. The thickness of each tenon should be one-sixth the thickness of the mortised member.

Oblique Tenons

Oblique tenons are necessary where a tenoned member is connected to a mortised member at an angle. Such occasions arise in spandrel framings, roof lights, and stair strings. The peculiar shape of an oblique tenon is due to the fibrous nature of the material. It is not expedient to undercut mortise holes, either by hand methods or by the machine, nor is it practicable to have short grained portions of tenon which are liable to snap off. In the tenon shown at K allowances are made for these important facts.

A box tenon, as would be used

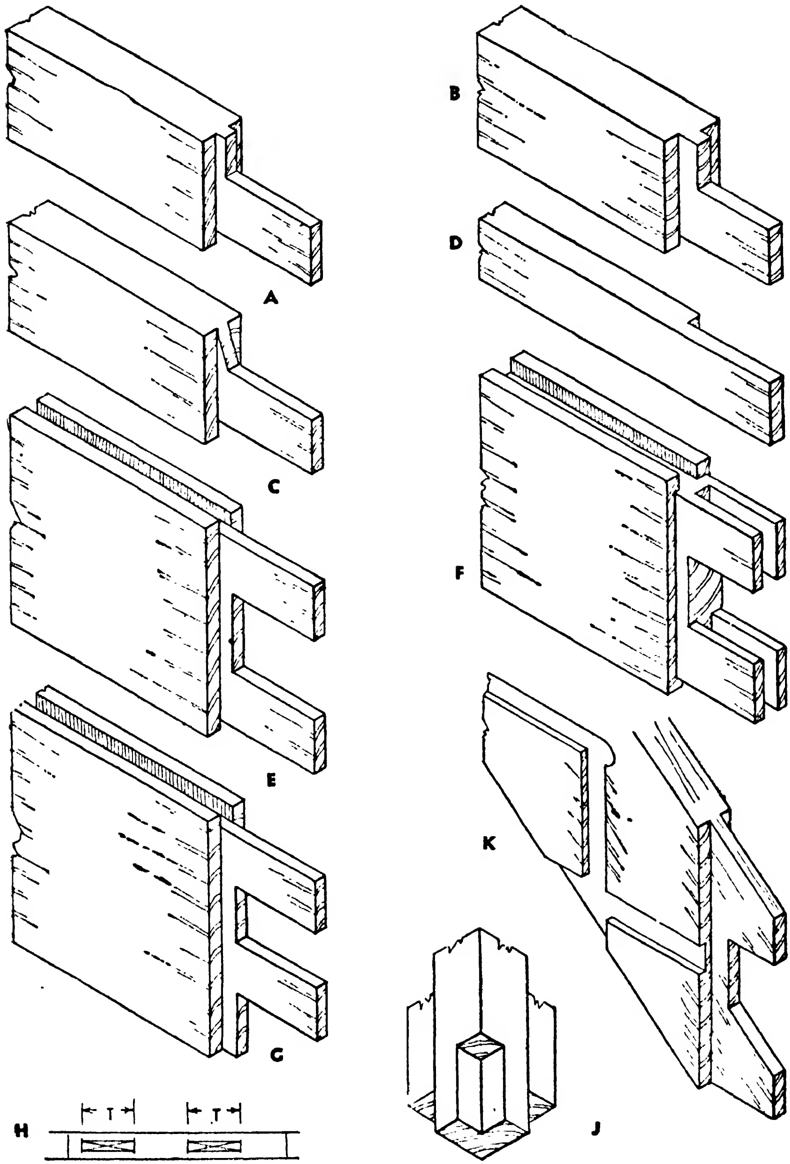


Fig. 19. Types of tenons. *A.* Single haunched tenon ; *B.* tenon with unequal shoulders ; *C.* table haunch ; *D.* barefaced tenon ; *E.* pair of single tenons suitable for a middle rail ; *F.* pair of double or twin tenons ; *G.* pair of single tenons suitable for a bottom rail. The marking out for this tenon is shown at *H* ; *J.* box tenon for use in bay windows or lantern lights ; *K.* oblique tenon.

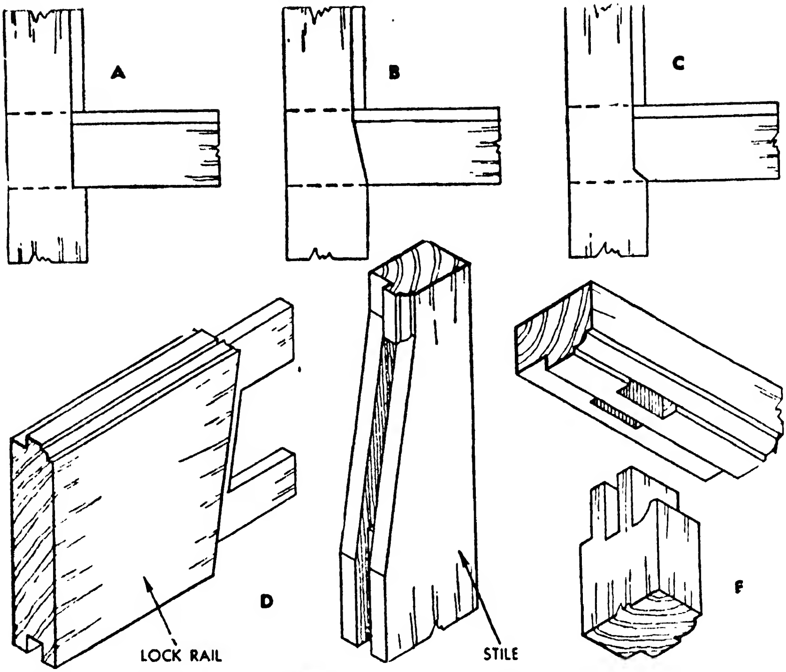


Fig. 20. Use of splayed shoulders on tenons to allow for change of width on face of mortised member. The joint shown at *A* is not a good method, because of the harsh line across the grain. *B* and *C* give a far better appearance, and the material can be held more securely. *D*. pair of single tenons to a diminished stile ; in this case the shoulder has more splay because the stile is reduced in width above the rail. *E*. use of double tenons on the face of wide material.

on the angle post in a bay window or lantern light, is shown at J. Sometimes this type of tenon is dovetailed to give additional holding to the mortised members.

Fig. 20 shows further variations of the mortise and tenon joint as applied to joinery. A splayed shouldered tenon is necessary where the portion of stile above or below the tenoned rail is reduced in width, rebated or moulded. If the arrangement were as at A the shrinkage of the rail would spoil the appearance of the work. B and D show how an improved appearance is possible by bevelling the shoulder to avoid abrupt change of grain. An alternative method is given at C, where the difference in length of the shoulder is mitred to the stile.

To lessen the production costs in the cheaper type of framing, especially in internal doors, a dowelled joint, as in Fig. 21 A, is used instead of a mortise and tenon. In this joint, the dowels are inserted in holes bored in the stile and rail. The minimum size of dowels should be at least $\frac{5}{8}$ in. by $4\frac{5}{8}$ in. ; they should be spaced in the adjacent members at not less than $2\frac{1}{4}$ in. centres. In joints of this kind a continuous machine scribe or a tongue should always be employed at the shoulders.

The preparation of a mortise and tenon to a moulded frame is shown at B. This diagram is included to show how the tenon is kept back from the inside edge of the frame to allow for the moulding to be mitred.

Where thick material is jointed together there is always the danger of the shoulders opening due to the large amount of end grain at the joint. As end grain cannot be glued satisfactorily, tongues should be inserted on each side of the tenon to hold the faces of the joint. In the example given at C the grooves for the panels are utilised for the tongues.

In first-class joinery a bolder appearance to the finishings is often desirable with larger sections of material; consequently, greater care must be taken to prevent any damage by shrinkage. One

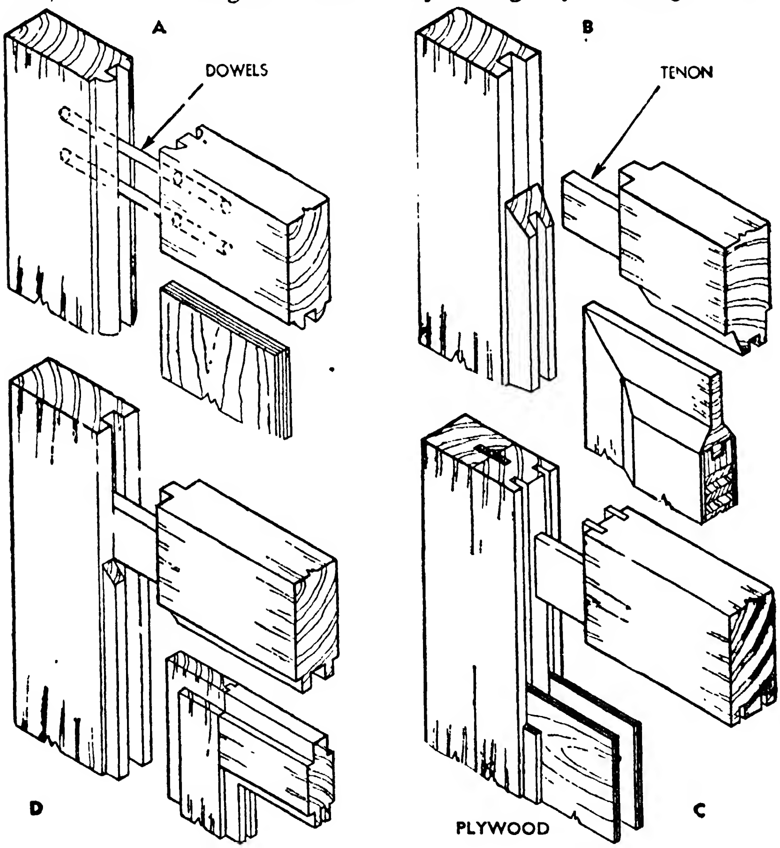


Fig. 21. Further framing joints used in joinery. A dowelled joint with the shoulders machine scribed to the stile is shown at *A*. *B*. haunched tenon with the moulding mitred. Note how the raised panel is built-up and veneered. With thick material tongues should be inserted on both sides of the tenon to hold the joint together, as at *C*. *D*. use of a sub-frame which allows for movement of the material without disturbing the joinery as a whole.

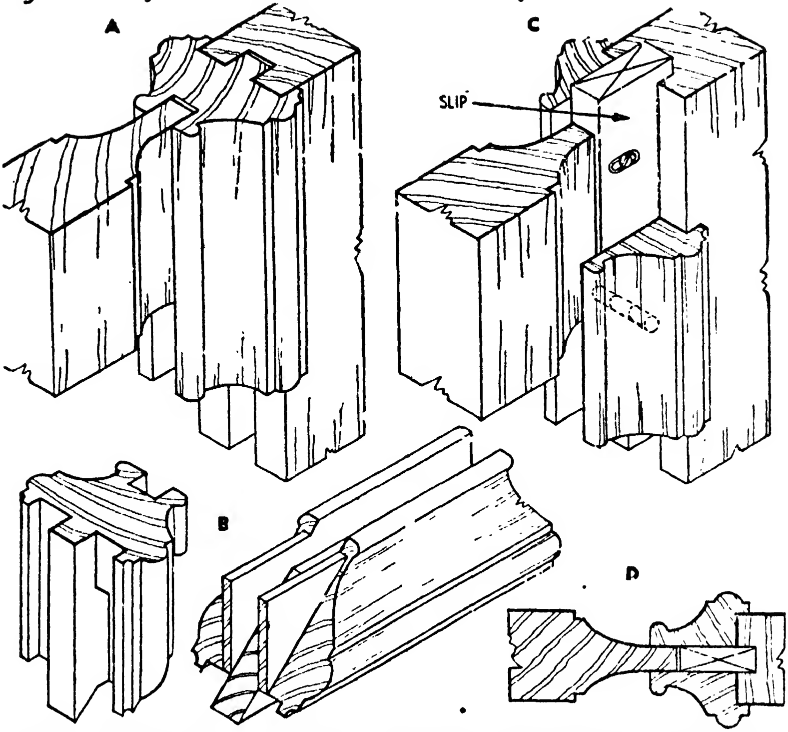


Fig. 22. Bolection moulding joints. *A.* framed moulding tongued to the framing ; *B.* method of jointing the angles by a mitre and double tongues. *C* and *D.* show a more economical method of achieving the same effect. A softwood strip called a shrinkage fillet is framed up and the moulding is fixed later.

method of doing this is to form a sub-frame within the main frame. D shows a sub-frame, to carry the glazing, tongued into the frame of the door.

Where panels are surrounded on both faces by a raised member called a bolection moulding, the treatment may be in a similar manner. Fig. 22 A shows a bolection moulding treated as a separate sub-frame and tongued to the main frame. The angle joints between the sub-frame may be mitred, tongued and screwed, or mitred and mortised and tenoned together as shown at B.

A more economical method of preparing the work to give the same effect is to use a panel fillet or shrinkage slip, as shown at C and D. With this method, the main frame can be fitted together with the shrinkage slip inserted, and the work can be cleaned off after gluing; at the same time, the panels and bolection mouldings can be prepared and polished as a separate job, then the whole may be put together.

It is important to remember in dealing with hardwoods that all mouldings should be bodied up for polishing before they are fixed, otherwise a polisher is unable to get a clean finish at the corners.

Fig 23 illustrates some of the principal joints used in sash

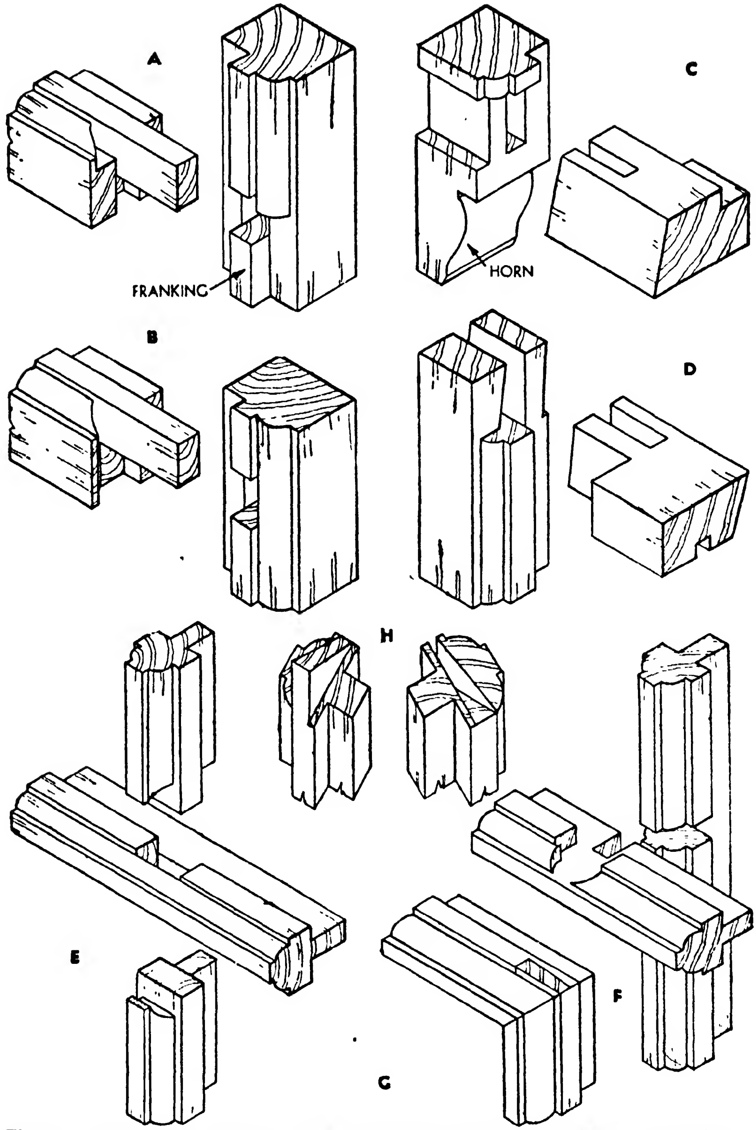


Fig. 23. Sash joints. A joint to stock sash stuff has a franking left on the stile to serve the purpose of a haunch. At *A* is shown a hand-made joint, and at *B* a machine-scribed joint. C and *D*. sash joints for vertical sliding sashes. Note how the extra width of the rails is housed into the stiles. *E*. machine-joint between glazing bars. The vertical members are stub-tenoned and scribed. An alternative joint is shown at *F*, where the bars are halved and scribed. *G*. angle joint between glazing bars ; these are mitred and dovetailed together as shown at *H*.

construction. At A is shown a haunched tenon on ovolo moulded sash stuff. Because of the slenderness of the material, a haunch is formed on the mortised stile instead of on the tenoned rail. The method of leaving this projecting portion on the stile is known as franking. B shows the same joint as made by machinery. In this case the scribing of the shoulder to the moulding on the stile is cut through the full length.

C and D illustrate the joints at the meeting rails of sliding sashes. The ornamental horn shown at C is left on the stile to give the additional strength necessary to support the weight carried by the rail of the upper sash. An alternative method is to dovetail the members together, as shown at D, which is normally used for the lower sash.

Joints between moulded glazing bars may be mortised and tenoned together or they may be halved, as shown at E and F respectively. In both cases the ovolo mouldings should be scribed at their intersections in preference to mitring. Angles may be mitred and nailed together, or they may be mitred and dovetailed as shown at G and H. With very thin glazing bars the angles should be strengthened by inserting metal angle plates in the rebates.

When doors or sashes are hinged at one edge, the opposite edge must be splayed to an angle to allow a reasonably close joint to be made. When the hinged frame is wide and thin, the bevel is hardly noticeable, but when the door or sash is thick and narrow the bevel is more pronounced, and must be taken into account in setting out. Every point on the hinged member revolves about a centre pivot which is the knuckle of the hinge.

As a curved rebate is not always possible the shutting joint is set out to a straight surface tangential to the greatest radius on the framing. This tangent is determined as shown in Fig. 24 A. Draw a line from the centre of the pivot (P) to the opposite corner of the hinged member on its shutting face, point (d). A line drawn perpendicular to this will give the required bevel for the edge.

To allow a hinged door or sash to open outwards over a reveal, hinges of the parliament type are used which have their pivots well outside the framing. The position of the pivots increases the bevel at the shutting edge, as at B.

Double Rebate Bevels

At D is shown the method of setting out the bevels for a double rebate. Although two bevels of a different inclination are shown in the diagram, the rebates are usually made parallel with each other and to the greater angle. For hinged frames which are fairly thick, the rebate on the shutting jamb should be splayed as well as the shutting edge.

Shutting joints to swing doors with floor springs are invariably curved, as at C. The jamb is hollowed to receive the rounded edge of the hanging stile and the curve on the stile is of a greater radius than that on the jamb to give clearance to prevent the corners of the door rubbing on the edges of the jamb.

When sashes or doors are hinged in pairs, the meeting stiles

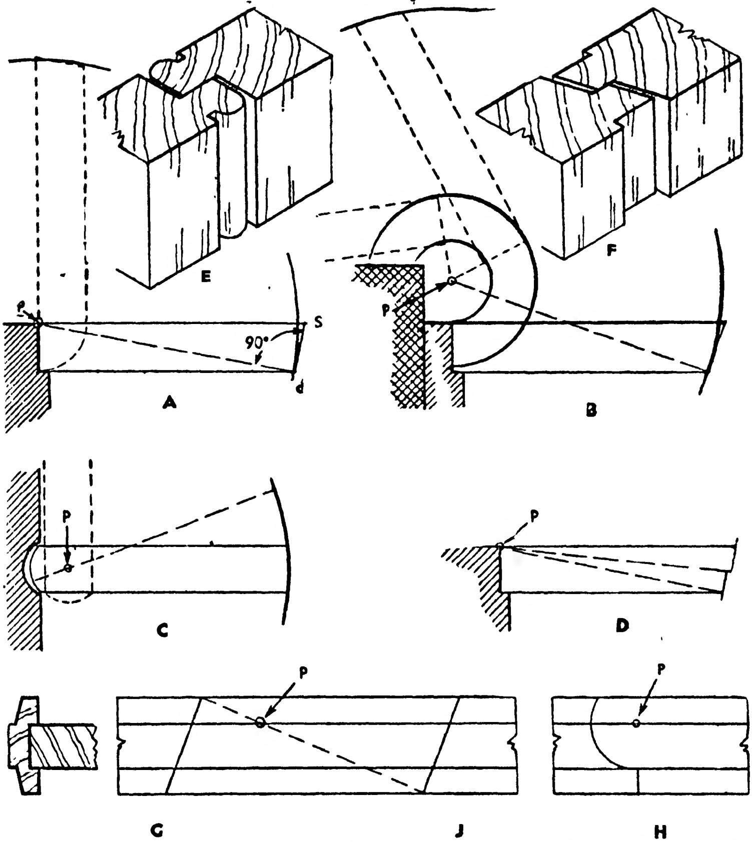


Fig. 24. Shutting joints to doors or sashes. A. Method of determining the correct angle. A line Pd, drawn from the pivot to the outside of the shutting edge, is first set up ; then a line square to this gives the angle required as at sd. *B.* how the angle increases if the pivot is moved outwards ; C. curved edges for a swing door ; *D.* double rebate on the shutting edge. *E* and *F.* details of the meeting edges to doors ; and *G, H* and *J* bevels for a hinged door with projecting capping.

are rebated, as at E and F, with a moulded edge or bead to mask the joint.

When cappings or protruding mouldings are attached to a hinged frame it is necessary to set out the plan full size to obtain the correct shutting bevels at both the hinged edge and the shutting edge. G shows how a straight cut is determined to give adequate clearance and allow the frame to open. A better and less unwieldy joint is that given at H, where a circular cut is formed to give the necessary clearance to the hinged side. Any radius not less than the thickness of the door may be used. This joint is explained more fully in the chapter on Setting-out Rods (page 270).

Lengthening joints are not often required in joinery, because of the ease in which a butt joint can be

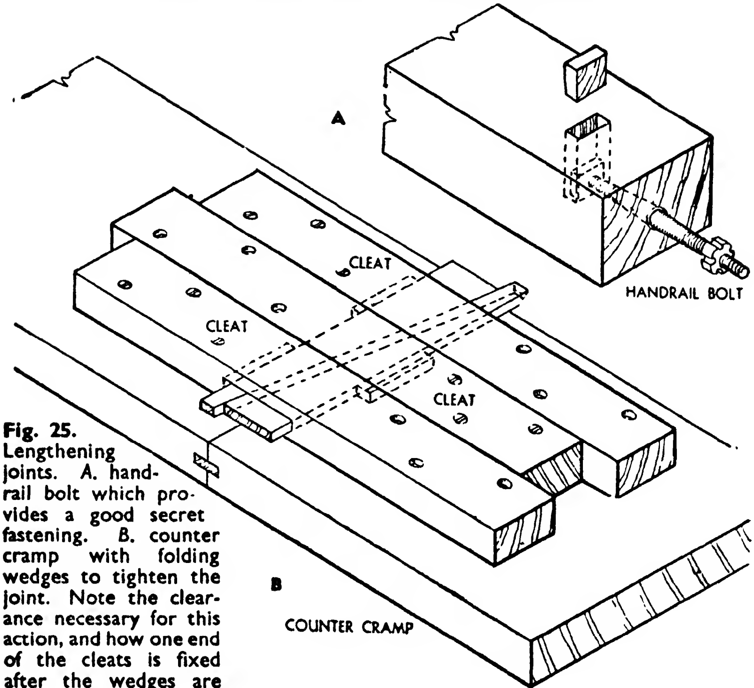


Fig. 25. Lengthening joints. A. handrail bolt which provides a good secret fastening. B. counter cramp with folding wedges to tighten the joint. Note the clearance necessary for this action, and how one end of the cleats is fixed after the wedges are driven in.

covered with some decorative member. In good work, exposed joints in end grain should be avoided because the movement of each piece tends to exaggerate the unevenness of the surface adjacent to the joint.

For thick members, hammer-headed keys or handrail bolts may be used, as fully described in the chapter on Curved work. The handrail bolt in Fig. 25 A is an exceptionally good and convenient type of lengthening joint.

Wide boards may be connected together by means of a counter cramp. This consists of three cleats screwed to the back of the joint; to pull it together folding wedges are so arranged that when they are driven in they drive the cleats in opposite directions. In fixing the cleats, the two outside cleats are screwed to one side of the joint and the centre cleat is screwed to the other side with enough clearance to allow the folding wedges to insert a direct pressure on the joint, as shown in Fig. 25 B. When the wedges are driven in and the joint pulled together, screws are inserted in the opposite ends of the cleat to secure the joint.

The practical application of the joints described in this chapter is shown throughout the rest of the book. Many adaptations are necessary to suit the particular purpose of the work, but it is well to remember that, although drawings are supplied for the joinery, it is the craftsman's job to decide upon the various details.

CHAPTER 7

FRAME AND JOINT CONSTRUCTION: CARPENTRY

MECHANICAL PRINCIPLES. STRESS. SAFE LOADS. MOMENTS AND REACTIONS. BEAM STRENGTHS. TRIANGLE OF FORCES. FRAMING AND BRACING. POSTS AND TOWERS. TYPES OF JOINTS. CONNECTORS. LAMINATED MEMBERS. FASTENINGS.

THE structural use of timber calls for an understanding of its mechanical properties and of how it can be most economically used in supporting loads. Joint and framing methods are the practical applications of mechanical principles. Structural mechanics is a big subject, but the carpenter should learn the elementary principles. Knowledge of these principles will enable him to avoid costly mistakes and will help to solve awkward problems.

Compression and Tension

Stress. First, the beam, which is perhaps the most widely used structural member in carpentry. The lintel, binder, bressummer, and floor joists are all beams. A beam is a structural member supported at both ends (usually horizontal), and carrying a load over a space or opening. When a beam is loaded it bends or deflects. The deflection may be so slight that it is not noticeable, but if it is excessive a plaster ceiling might be cracked as a result.

Consider Fig. 1 A and 1 B. It is clear that when the beam bends under load the top surface is shortened and the bottom lengthened. This effect is accompanied by stress in the timber fibres. Stress is an internal force, usually measured in lbs. per square inch. The stress at and near the top of the beam is called *compression* because the fibres are compressed, while the stress at and near the bottom of the beam is called *tension* because the fibres are pulled or stretched. There is a third stress called *shear* which tends to part fibres by sliding one portion in one direction and another in the opposite direction, as shown in Fig. 1 C and D. Shear stress occurs vertically in a beam where the load tends to push the material downwards while the supports push it upwards. This is vertical shear as in Fig. 1 C, but horizontal shear also occurs, as shown in Fig. 1 D, where, if the beam is considered as a number of layers, it is obvious that the layers will slide over one another if the beam bends as shown.

The compression is greatest at the top and the tension greatest at the bottom of a beam. These stresses decrease as they near the centre line, and this line is called the *neutral axis*. In a built-up lattice girder or roof principal a considerable proportion of the

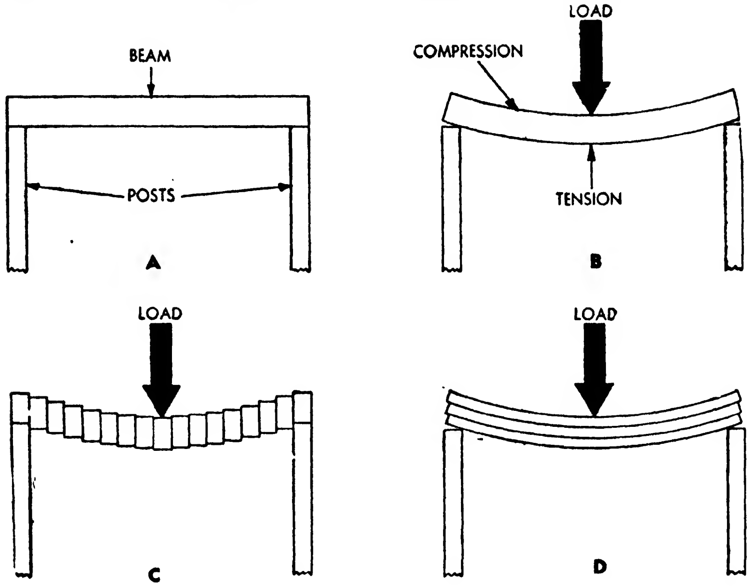


Fig. 1. Stress in beams. *A.* Unloaded beam ; *B.* compression and tension in loaded beam ; *C.* vertical shear ; *D.* horizontal shear.

material is placed at the top and bottom to meet these respective stresses.

Other definitions. The supports at the ends of a beam supply upward thrusts, the sum of which equals the load. The supporting forces are called *reactions*. *Elasticity* is the property which enables a structural member to return to its original shape and length after the load is removed. *Strain* is an alteration of length and shape: mathematically it is the increase of length when a load is applied divided by the original length. Strain is thus an effect of stress. An increasing load may be applied to material until it reaches the *elastic limit,* which is the maximum stress at which the material will recover its original length when the load is removed. If stress be continuously increased beyond the elastic limit the fibres will ultimately fail; the load producing this is called the *ultimate strength* or breaking load. A *safe load* must be within the elastic limit and it must allow for emergency loads and concealed weaknesses. It is obtained by dividing the breaking load by a *factor of safety.* The more a material varies in strength the greater must be the factor of safety.

Safe loads on timber. The softwood structural timbers have an ultimate strength of about 10,000 lbs. per square inch in tension and about 7,000 lbs. per sq. in. in compression. Under the L.C.C. by-laws timber is divided into two qualities: non-graded timber in which a maximum extreme fibre stress of 800 lbs. per sq. in. is allowed; and superior grade timber in which the maximum extreme fibre stress is 1,200 lbs. per sq. in. The factor of safety thus allowed is about 8. In other words, the maximum safe load is one-eighth the breaking load.

Mild steel, which is a more consistent and reliable material, is used with a factor of safety of only 4. It should be remembered that decay, concealed weaknesses and extra loads which cannot be foreseen, may reduce the theoretical factor of safety, so that timber used with an assumed factor of safety of 8 may have an actual working factor of safety of a much lower value.

Moments and reactions. Force is that which causes or tends to cause movement and to counteract movement. For any structure to be sound it must be in a state of equilibrium, and every force must be balanced so that the structure is able to carry its predetermined load, plus an extra load as a factor of safety.

The *moment of a force* is its turning effect about a point. It is measured by the product of the force and the perpendicular distance from the axis of rotation. The moment of a force may be considered as being clockwise, or positive, and anti-clockwise or negative, according to the direction of rotation. For a beam to be in equilibrium the sum of the moments tending to cause rotation in the one direction must be balanced by those tending to cause rotation in the opposite direction.

For example, Fig. 2 A shows a beam or lever supported at the fulcrum F and balanced by two weights W_a and W_b. The moment of the force W_a about the fulcrum F is $W_a \times L_1$, and the moment

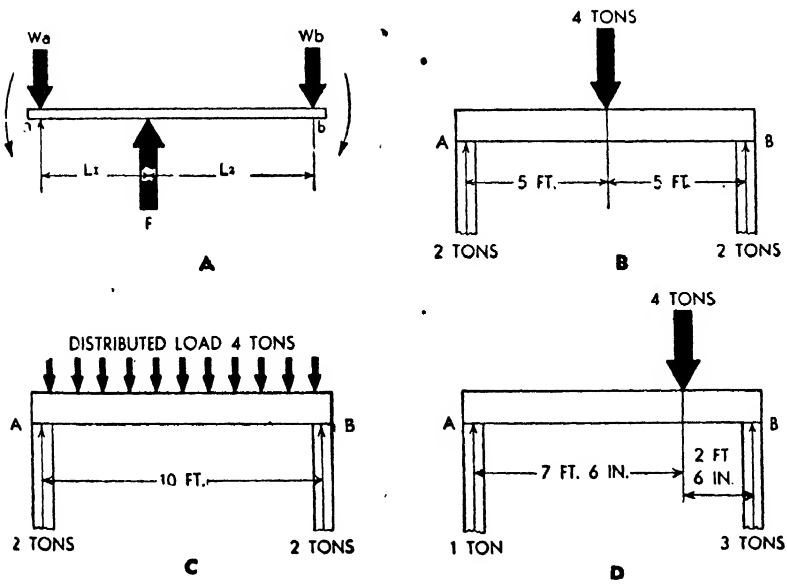


Fig. 2. An understanding of the moments and reactions of beams is essential in all structural work. *A.* Balanced lever ; *B.* concentrated load in centre of beam ; *C.* distributed load on beam ; *D.* concentrated load not in centre of beam.

of the force W_b about F is $W_b \times L_2$. Each force tends to produce rotation of the lever about point F. W_a tends to rotate in an anti-clockwise direction and W_b in a clockwise direction. If L_1 were 2 ft.; L_2, 4 ft.; W_a, 100 lbs.; and W_b, 50 lbs, the moments would be:—

$W_a \times L_1 = 100 \times 2 = 200$ ft. lbs. negative.

$W_b \times L_2 = 50 \times 4 = 200$ ft. lbs. positive.

Thus the moments cancel one another and the beam is in equilibrium.

Law of Stability

Notice that the moment expressed as a product of weight and distance is in foot-pounds (ft. lbs.). The unit ft.-ton can also be used. This law of balance or stability governs all structures.

Beams. An important application of the law of stability is seen in the load carried by a beam and the division of this load between the points of support. Beams can be loaded in a variety of ways. If a load is concentrated in the centre (Fig. 2 B) it is fairly obvious that the reactions at the points of support will be equal and, neglecting the weight of the beam, will each be equal to half the applied load. In the example in Fig. 2 B:

positive moment about A=
$4 \text{ tons} \times 5 \text{ ft.} = 20 \text{ ft. tons}$;

negative moment about A=
reaction $B \times 10 \text{ ft.} = 20 \text{ ft.tons}$.

$$\text{reaction B} \frac{20 \text{ ft. tons}}{10 \text{ ft.}} = 2 \text{ tons};$$

Reaction A must also=2 tons.

The term reaction has already been defined. The description *moment of reaction* follows from the definition. The reaction at the point of support is equal to the load on that point of support. The moments found in the above are moments of reaction, and as they tend to bend the beam they are called "bending moments."

In Fig. 2 C the load is evenly distributed on the beam, as with a floor supported on a bressummer. Here again the total of this load is obviously equally divided between the two points of support, as in Fig. 2 B. In practice the reactions in both cases may be found simply by dividing the load by 2.

Fig. 2 D is complicated by the fact that the concentrated load is not centrally placed and it is fairly obvious that the load on support B will be greater than the load on support A. Calculating by taking the moments of reaction:

positive moment about A=
$4 \text{ tons} \times 7\tfrac{1}{2} \text{ ft.} = 30 \text{ ft. tons}$;

negative moment about A=
$B \text{ tons} \times 10 \text{ ft.}$,

$$\text{so } B = \frac{30 \text{ ft. tons}}{10 \text{ ft.}} = 3 \text{ tons}.$$

The reaction at A must equal the load, 4 tons, — the reaction at B (4 tons − 3 tons) = 1 ton.

This is obviously a useful calculation to the carpenter. For example, if A and B are dead shores, the beam is a needle and the load is the shored up wall, the calculation gives the loads on the shores. Shores cannot always be placed at equal distances from the load.

If there are a number of concentrated loads at various points they may be dealt with separately.

Strength of beams. The portion of a beam that is subjected to the greatest stress is the point where the greatest amount of bending takes place, and it is important to discover the amount of the greatest tendency to bend and the position on the beam where it occurs. This maximum amount of bending is called the *maximum bending moment* (written as B.M.).

In Fig. 2 B the bending will be the greatest in the centre of the beam and will be the moment of the force A about the centre—

$\therefore$ 2 tons $\times$ 5 ft. = 10 ft. tons. Max. B.M.

In Fig. 2 C the greatest B.M. occurs at the centre of the beam. Taking moments about the right-hand side from the centre (B), 2 tons $\times$ 5 ft. gives an anti-clockwise moment which is partly balanced by the load upon the beam between B and the centre acting through its own centre of gravity and having a clockwise moment of 2 tons $\times$ $2\frac{1}{2}$ ft., therefore the max. B.M. =

(2 tons $\times$ 5 ft.) − (2 tons $\times$ $2\frac{1}{2}$ ft.) = 5 ft. tons

In Fig. 2 D the max. B.M. is under the load of 4 tons. Taking moments about the right-hand side (B) and checking by moments about the left-hand side the max. B.M. is :—

(B) $2\frac{1}{2}$ ft. $\times$ 3 tons $= 7\frac{1}{2}$ tons ft.
(A) $7\frac{1}{2}$ ft. $\times$ 1 ton $= 7\frac{1}{2}$ tons ft.

For the stresses of a beam to be in equilibrium, the max. B.M. must be exactly balanced by the internal resistance of the beam. This internal resistance of the fibres exerts what is called a *moment of resistance*, and is denoted by the letters M.R.

For a given span, the dimensions and shape of the cross section, and the safe stress for the material, determine the strength of the beam. The dimensions and shape give the *section modulus* Z, while the safe stress is usually denoted by the letter f. For a beam rectangular in section Z is $\frac{bd^2}{6}$, where b is the breadth of the beam and d is the depth.

The relation between the bending moment, the moment of resistance, and the section modulus is :—

$$\text{B.M.} = \text{M.R.} = fZ.$$

For a rectangular beam $Z = \frac{bd^2}{6}$, so that M.R. $= f\,\frac{bd^2}{6}$.

The units are important and should not be mixed.

W is the load in lbs.
L is the span, from centre to centre of bearings, in inches.
f is the safe working stress in lbs. per sq. inch.
b is the breadth of the beam in inches.
d is the depth of the beam in inches.

Suppose it were necessary to find the size of a freely supported beam of redwood with an effective span of 12 ft. to carry a load of 6 cwt. in the centre.

First, consider the external forces and find the max. B.M. Using the standard formula of B.M. $= \frac{WL}{4}$ this is equal to

$$\frac{6 \times 112 \times 12 \times 12}{4} = 24{,}192 \text{ lb. in.}$$

Next, consider the internal forces, f can be taken as the safe stress of 1,000 lb. per sq. inch.

The equation becomes

$$B.M. = M.R.$$

$$\frac{WL}{4} = \frac{bd^2}{6} f \quad \therefore \ 24{,}192 \text{ lbs. in.} = Z \times 1{,}000.$$

$$Z = \frac{24{,}192}{1{,}000} = 24.192$$

The required beam would have to be such a size and shape that its modulus is not less than 24.192. From this it should be clear that $\frac{bd^2}{6} = 24.\ 192$. bd_2 then equals 145.152.

Assume the breadth of the beam to be 3 in., then $d^2 = 48.288$. 7×7 would give 49, so that the beam should be 3 in. by 7 in. to carry safely the load of 6 cwt.

The triangle of forces. There are many joints in structures which are kept in equilibrium by three forces acting at a point. As a simple example, the case of a jib spar fixed in an inclined position and secured by a wire or rope back guy. The frame diagram in Fig. 3 A is a diagram of the structure. A weight of 80 lbs. is suspended from the jib.

A little consideration will show that this weight compresses the jib and pulls the back guy, so the jib is in compression and the back guy in tension. The rope by which the weight is suspended is also obviously in tension. The tension in C A is 80 lbs., and the compression in A B and the tension in B C may be found by the triangle of forces.

If three forces acting at a point are in equilibrium, a triangle with sides parallel to the directions of the forces indicates the propor-

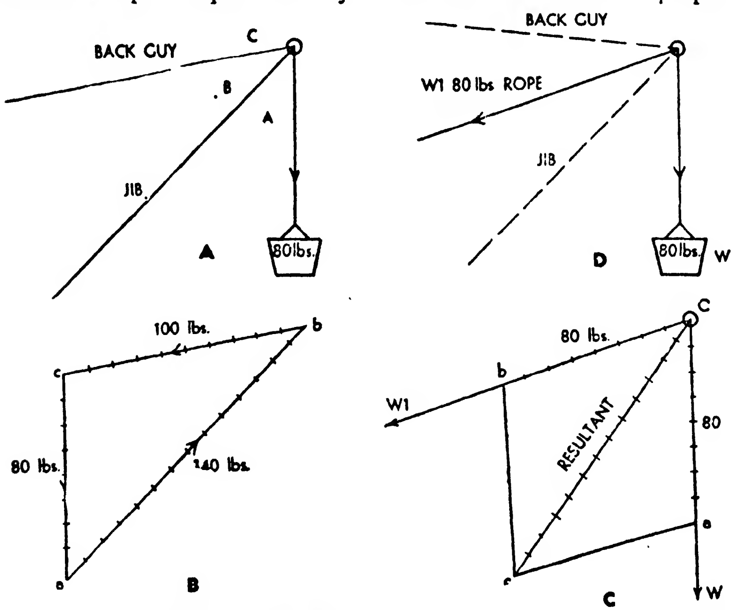


Fig. 3. Force diagrams. A. Frame diagram of a jib crane ; B. force diagram (triangle of forces) : stresses in a jib crane ; C. force diagram : parallelogram of forces ; D. frame diagram showing the structure of a jib crane.

tions of the forces by the lengths of the sides. The directions in which the forces act at the point are also indicated by the direction shown in following a circuit of the triangle.

Referring to Fig. 3 B; if a vertical line c a is drawn, and with a scale rule 80 units are marked off to represent 80 lbs. (any convenient scale may be selected; one-tenth of an inch to represent 1 lb., for example). this line represents the 80 lbs. tension stress obviously caused by the suspended weight on the rope C A. Now complete the triangle by drawing c b parallel to C B and a b parallel to A B (notice the method of notation). The forces in A B and B C can now be measured off a b and b c with the scale rule, on the same scale as used for setting out a c, and their directions noted. A B acts towards the point and B C acts away from the point. The accuracy of the result depends upon the care with which the triangle of forces and the magnitude of the scale are set out—the larger the better. An approximate result is a b = 140 lbs. and c b = 100 lbs.

Parallelogram of forces. If two forces acting at a point are represented in magnitude and direction by two lines (o a and o b in Fig. 3 C), and if the parallelogram o a c b be completed by drawing a c parallel to o b and b c parallel to o a, then the resultant of the two forces is represented in magnitude and direction by the diagonal drawn from o to c.

The *resultant* of two forces (or of more than two) is the single force which, acting alone, would produce the same effect as the two or more forces acting together.

The *equilibrant* of a number of forces produces equilibrium when acting in combination with those forces. The equilibrant is equal and opposite to the resultant.

Referring to Fig. 3 D, the frame diagram illustrates the structure of a jib crane with a weight-lifting rope running over a pulley. With a weight of 80 lbs. suspended from the rope a pull of 80 lbs. must be exerted on the other end of the rope to hold it at rest (ignoring friction and the weight of the rope). Thus two forces of equal magnitude but different direction acting on the point O (the position of the pulley at the end of the jib) are given. Find the resultant of the two forces.

The parallelogram is completed, as shown in 3 C, setting out o a and o b to any convenient scale so that 80 units of measurement represent 80 lbs. The diagonal is drawn from o to c and this gives the direction of the resultant. If this diagonal is measured on the same scale the magnitude is thus given.

In this case the two forces are replaced by one. Referring to the frame diagram in Fig. 3 D, this could be re-drawn, allowing the resultant to replace W and W_1, so that there are three forces, from the data of which could be drawn a triangle of forces and the tension on the back guy and the compression on the jib found.

Resolution of a force. The process of finding a resultant force from two given forces can be reversed. In Fig. 4 is shown a rafter exerting a diagonal thrust on a wall and obviously tending to

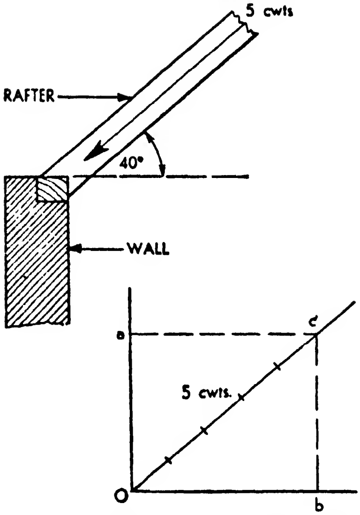


Fig. 4. Resolution of forces. Diagram illustrates the horizontal and vertical stresses on a wall due to the diagonal thrust of the rafter.

push the wall outwards. In practice it is often useful to find the horizontal outward thrust and the vertical downward thrust. In the diagram in Fig. 4 the direction of two sides of a parallelogram and the magnitude and direction of the diagonal are given. Set out the diagonal O c to scale, complete the parallelogram and measure the magnitude of the vertical and horizontal forces. It will be found that the vertical thrust down the wall a O =360 lbs. and the horizontal outward thrust b O=430 lbs. If a tie beam were used to take this horizontal thrust the tension in the tie beam due to the thrust would be 430 lbs.

Framing. In Fig. 5 A a diagram is given which shows how an unframed structure may collapse owing to the outward thrust of the pitched roof. This thrust tends to strain the fastenings at ridge and wall plate. If the wall or posts move outwards it is quite obvious that failure of the fastenings must occur.

The next diagram in Fig. 5 B illustrates the use of a horizontal tie to take the outward thrust of the roof. The thrust will produce tension stress in the tie, but the load on the walls will be vertical. The roof rafters are indicated as being in compression, but this is complicated in practice by the positions of purlins and by wind pressure, so that most rafters are subject to bending stresses.

It should be clear that a triangular system of construction will closely approach the ideal of placing all structural members either in compression or tension and so avoid, to a large extent, outward or inward thrusts and bending stresses. Fig. 5 C and D illustrate two common roof trusses.

Triangular Framing

An ideal system of triangular framing is illustrated in the elevation of a bridge frame in Fig. 6 A. The members are either in direct compression or tension, as indicated, though this will only apply if the loads are applied at the intersections or nodal points, as they are called.

Bracing. This system of triangular construction has the effect of bracing together the essential structural members. Fig. 6 B shows how the fastening of a roof truss to the supporting beam or post may be strained by side thrust due to heavy wind pressure. This may cause collapse of the structure. Fig. 6 C shows how such failure may be avoided by placing a brace or tie running from the roof truss to the post.

The final diagram in Fig. 6 D illustrates the use of *cross-bracing* between roof trusses with the object of avoiding failure of the roof by the trusses swinging over on their bearings, which may occur through wind pressure. Such cross-bracing is commonly placed down the centre of a roof, and sometimes a double set is used.

Studded partitions and framed walls for huts offer other examples of the value of cross or diagonal bracing. Fig. 7 A illustrates how a simple studded partition or hut wall tends to fold up, and Fig. 7 B shows how cross-bracing keeps the studding rigid. In a small hut this cross-bracing may consist merely of two light boards nailed at the crossings of the studs, though the studs are usually notched to receive the braces.

The diagram of a framed wall for a large hut (Fig. 7 C) illustrates the simplest type of bracing, which consists of diagonal members meeting alternately at top and bottom of the framing. Notice how these braces stiffen the corners and that the use of a horizontal corner tie from wall plate to wall plate, combined with the wall bracing, makes the whole wall structure rigid.

It should be observed, also, that this bracing takes comparatively little material in proportion to its value in strengthening the structure. The skilful carpenter keeps in mind this aim of using the material in a scientific manner, achieving strength with economy.

The elevation of a porch in Fig. 7 D illustrates one of the many uses of corner brackets on an interior angle for making a rigid connection between a horizontal

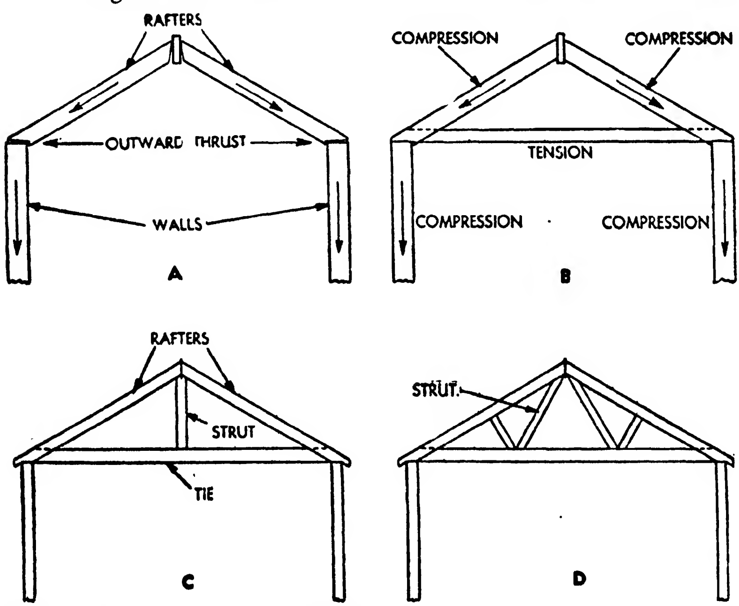


Fig. 5. Method of triangular construction of roofs. *A.* Failure due to outward thrust ; *B.* use of tie to take outward thrust ; *C* and *D.* common roof trusses.

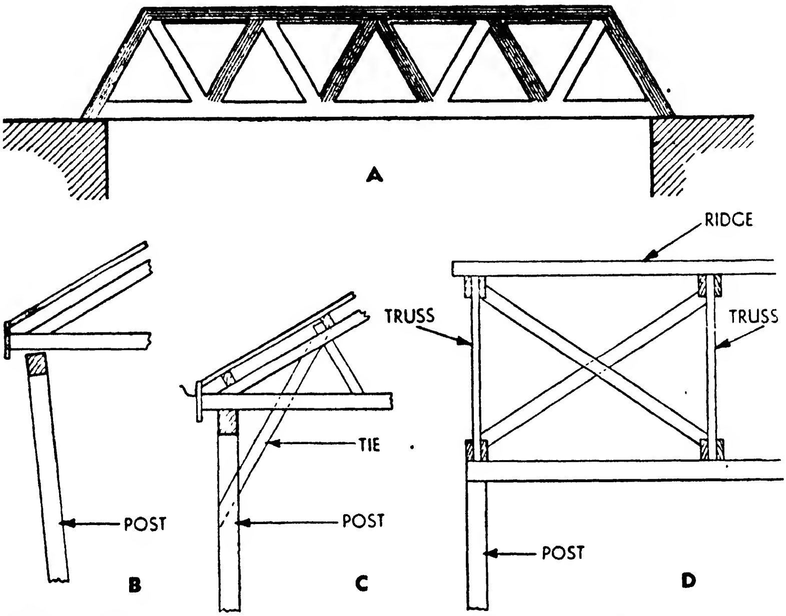


Fig. 6. Ideal system of triangular framing in bridge construction. *A*. Bridge frame. Struts (shaded) are in compression ; ties (white) are in tension *B*. failure of fastenings due to side thrust ; *C*. how failure may be avoided by use of brace or tie ; *D*. wind braces : longitudinal cross-section of bracing to roof.

member and a vertical member.

Composite framing. It is sometimes convenient to use timber and steel in combination. Timber is used for the members in compression and *steel rods* or bars for the members in tension. The advantages of this arrangement are obvious from a study of Figs. 8 A and 8 B. The *composite roof truss* shown in Fig. 8 A is a common type for light spans. The framing of the girder is very simple, the rods being in the form of long bolts.

Cantilevers. A projecting beam with one end unsupported and the other fixed is called a cantilever. Fig. 9 A illustrates a familiar type of cantilever—a length of timber built into a wall at one end and projecting to support a door canopy or other light load. The carpenter should study the nature of the stresses in the cantilever. The load naturally tends to bend down the cantilever at the unsupported end, so that the unsupported end tends to move downwards and the fixed end upwards.

A little consideration will show that the fibres at the top are in tension and those at the bottom in compression—the reverse of the stress positions in an ordinary beam. At the fixed end the cantilever must be constrained so that it cannot move. This is very important, as any weakness in the fixing will cause the cantilever to move downwards at the unsupported end. It should be noticed that at a the cantilever presses downwards on the support and at b it presses upwards.

In Fig. 9B a cross-section through a portion of a building illustrates a projecting balcony. A cantilever is formed by running the floor joists through the outside wall and allowing them to project the required distance. The load on the cantilever causes downward pressure on the outside wall at a and upward pressure on the inside wall at b. It is important that the weight of brickwork at b is sufficient to " tail down " the end of the cantilever.

It should be noticed, however, that as the joists also act as simple beams the load on the floor will also tend to counteract the load on the cantilever.

The bracket illustrated in Fig. 9C might be described as an attempt to convert the cantilever into a simple beam by providing the horizontal member with support at the end. One end is built into the wall and the other is supported by the diagonal member which transfers its load to the projecting corbel. The frame obviously depends for stability on the security with which the one end of the beam is built into the wall. This should be anchored into the wall by fixing a metal cross bar to it.

Posts and Towers. A very short post of comparatively large sectional dimensions, centrally and vertically loaded, will not fail until the load reaches the ultimate compressive stress of the particular kind of timber. But a fairly

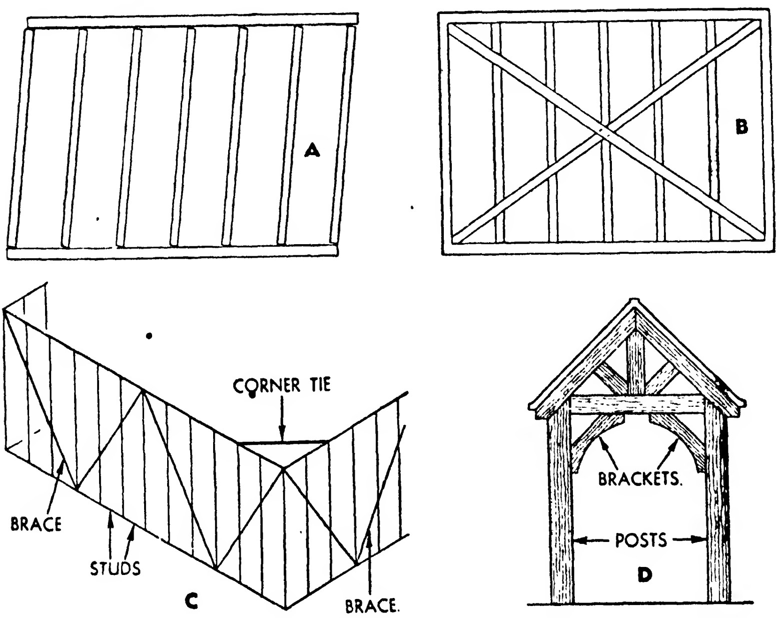


Fig. 7. Value of struts and braces for studded partitions and framed walls. *A.* Failure of simple studding ; *B.* cross-bracing keeps studding rigid ; *C.* framed wall showing braces and corner ties ; *D.* corner brackets to porch, to give rigidity.

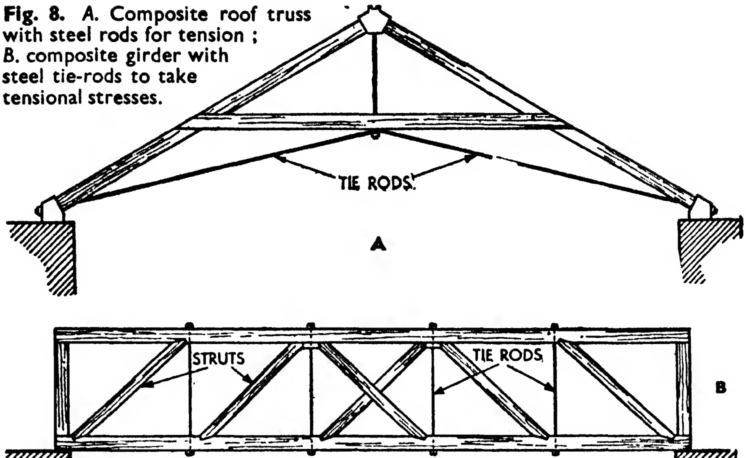


Fig. 8. A. Composite roof truss with steel rods for tension ; B. composite girder with steel tie-rods to take tensional stresses.

long post will often fail by bending (with consequent compression and tension) at a load much less than the ultimate compressive strength of the timber fibres.

In Fig. 10 A a rather long post of rectangular cross-section is shown bending under load. The inside curve is shortened by compression and the outside lengthened by tension. With a post of square section the direction of bending would be decided by

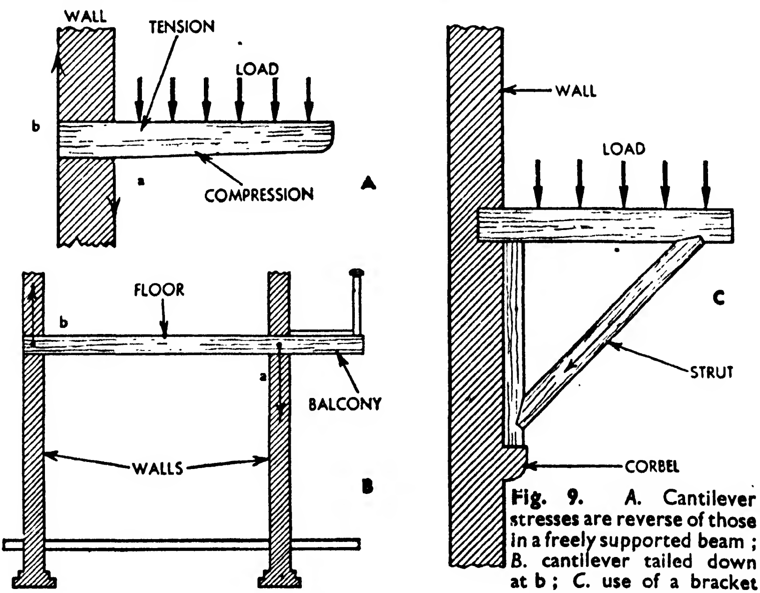


Fig. 9. A. Cantilever stresses are reverse of those in a freely supported beam ; B. cantilever tailed down at b ; C. use of a bracket to support the load.

some accidental factor such as slight eccentricity of the load or slight weakness on one side of the post.

For these reasons it is impracticable to use very long posts. A given load may be supported at a height by four comparatively light posts separated by a short distance, but braced by light boards or timbers, as in Fig. 10 B, using a smaller bulk of timber than would be necessary if one solid post were employed. This timber tower takes the vertical and downward (compressive) load on the four posts, which are prevented from buckling by being interconnected by horizontal and diagonal braces. Such a tower is often used to support a water tank or a crane staging.

Joints. In joining together two pieces of timber the kind of stress to which the joint will be subjected in use and the approximate loads on the timber members must be considered. Some joints are excellent in compression but poor in tension, and vice versa.

The timbers must not be unduly weakened by cutting out material. Accurate marking out and cutting are very important, so that the joint is a good fit and stresses are uniformly distributed and transmitted from one part of the joint to another. Particular consideration should be given to a joint which may be subject to considerable shear stress, as the cutting out of material to form certain joints greatly weakens their resistance to shear stress.

Lengthening joints. The simplest way of lengthening timber is to lap two pieces and fasten the lap with nails, screws or bolts. As the full length is not in line it is obvious that this method is not suitable for some jobs, and where the joint is visible it is unsightly.

Fished joints, as illustrated in Fig. 11 A and 11 B, consist of butting the ends of the timbers together and securing cover plates of wood or steel to them with nails or bolts. If the joint is in tension it is wise

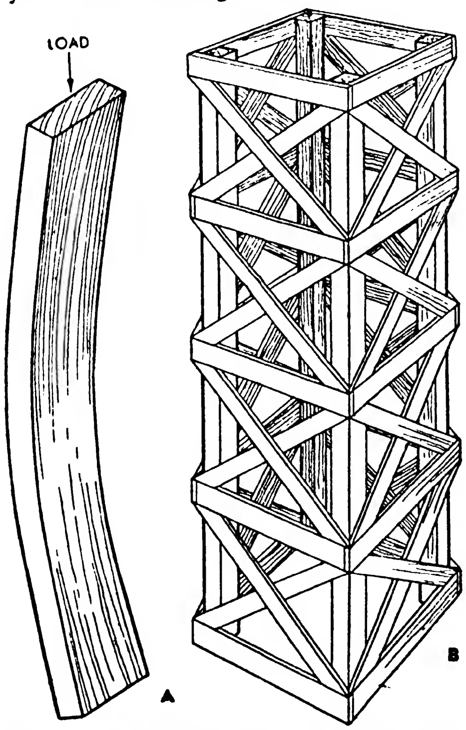


Fig. 10. Strengthening posts by means of a tower. A. Long posts tend to buckle under load; B. four posts braced to prevent buckling. Note that all four sides are well braced.

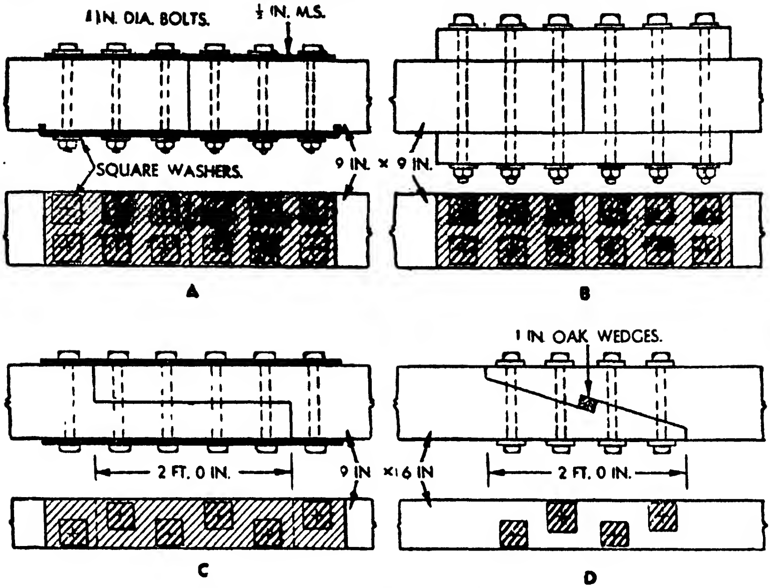


Fig. 11. Methods of lengthening joints. *A.* Fished joint with metal plate (the bottom plate is shown turned into timber to resist tensional stress); *B.* fished joint with wooden plates. This is more cumbersome than *A.* *C.* scarfed joint with metal plates ; *D.* scarfed joint wedged together.

to have the ends of the plates turned into grooves in the timber. The effective tensile strength of fish plates should equal the effective strength of the timber section in the joint.

The number and size of bolts must be sufficient to prevent failure either of bolts or timber through shear stress. It should be noticed that a fished joint does not reduce the length of the timbers, but the *fish plates* increase the thickness. While the joint is a strong one it is not very neat.

Scarfed joints (Fig. 11 C and D) consist of cutting the timbers to form an internal lap which is bolted or nailed together. The use of mild steel fish-plates adds to the strength of the fastening. The length of the scarf is usually taken at about three times the depth of the timber employed.

Timber connectors. Before describing other joints attention should be given to timber connectors, which are used to give increased strength with economy of material and labour.

The connectors fit either into grooves in the contacting faces of the timber members to be joined, or bite into such members with toothed edges. The bolt serves the purpose of holding the timbers together. The load is taken by the metal connector and is spread over the surface area of the timbers involved.

The timbers are temporarily nailed or clamped together while the bolt holes are drilled. They are then prised apart for insertion of the connectors. Typical applications of timber connectors are shown in various forms in Fig. 12.

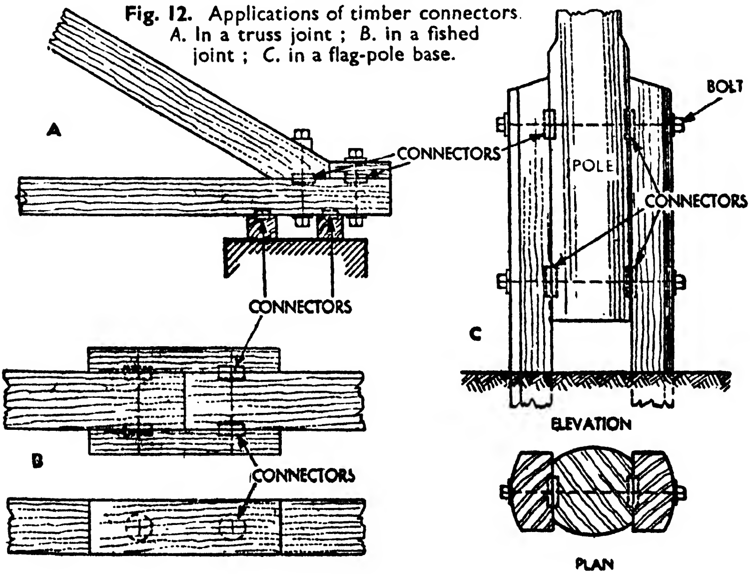
Halved joints. A halved joint is a junction between two timbers which are similarly cut, so that when fitted together the surfaces are flush. Fig. 13 illustrates typical examples. Two timbers crossing at right angles are shown at A; a plain halved corner is shown at B; a bevelled halved corner at C; a bevelled halved junction at D; and a dovetailed halved junction at E. Well-seasoned timber should be used for dovetails, as shrinkage tends to open the joint and destroy its value in tension.

Mortise and tenon joints. The cut end, called the *tenon*, of one timber is fitted into a slot or hole, called the *mortise*, of the other timber, and the joint may be secured by wedging or pinning, or keying.

In Fig. 14 four types are illustrated. The ordinary mortised, tenoned and wedged joint (A) has many applications in framing and has reasonable strength both in compression and tension, but for a joint in tension the *dovetailed tenon* B secured by a wedge is preferable. The *splay-housed tenon* C has a housed bearing and is suitable where the horizontal tenoned member carries a load. The *pinned tenon* D is an alternative to the wedged tenon: it is a compression joint—in tension the pin may shear through. The pin may be of hardwood or a nail.

The *stub tenon* (Fig. 15 A), also known as a stump, is used to secure a stud or post to a plate or sill. The *foxtail tenon* shown in Fig. 15 B is useful where a new timber is joined to an old one, the back being inaccessible. A mortise of dovetail section is sunk in the one timber and the tenon of the other timber has two saw cuts into which thin wedges are introduced. The tenon is then forced home into the mortise, the

Fig. 12. Applications of timber connectors. *A.* In a truss joint; *B.* in a fished joint; *C.* in a flag-pole base.



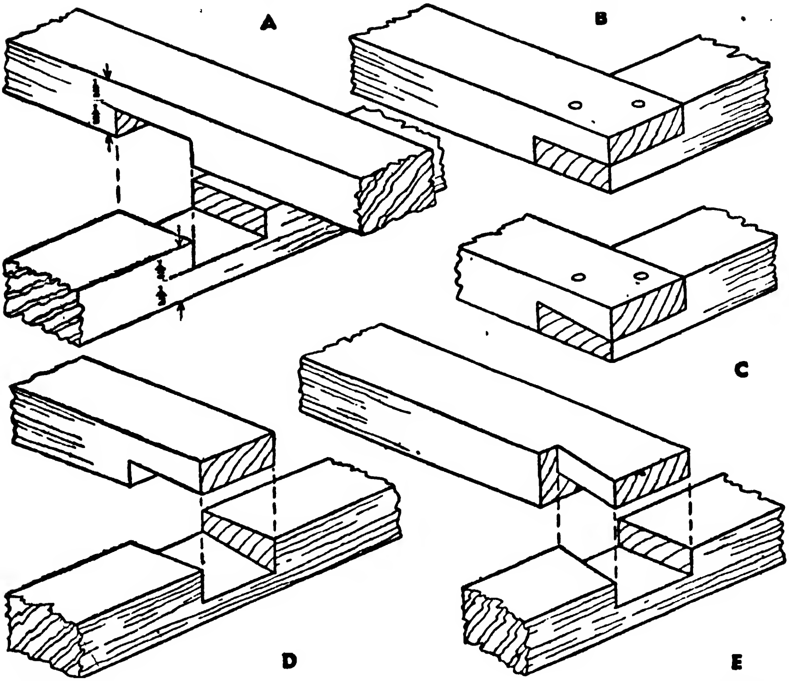


Fig. 13. Types of halved joints. *A.* Cross halving ; *B.* half lap ; *C.* bevelled halving ; *D.* bevelled tee halving ; *E.* dovetail halving.

wedges expanding it to fit the dovetail section. The *bridle joint*, shown in Fig. 15 C, is a special type of mortise and tenon. It gives good bearing to the end of a post but has no strength in tension. It is used in king and queen post truss construction.

The *housed joint*, one form of which is shown in Fig. 15 D, consists of a sinking in one timber into which the end or some other portion of the second timber is fitted. Another form of housed joint is shown in Fig. 16 D, where the end of a joist is shown housed into a plate.

Notching may be considered as the opposite to housing. In Fig. 16 C the end of a joist is shown notched to a plate. *Cogging*, shown in Fig. 16 E, gives complete security from horizontal movement. These three joints are now not often used as bearing joints for joist ends. It is more usual to place the joist on the wall plate and skew-nail it to secure it. This is sufficient, as such joints are subject to very little lateral thrust, and the weakening of the timber by cutting is avoided. Notching joist ends obviously weakens their resistance to shear stress.

The *chase mortise*, shown in Fig. 16 A and B, enables ceiling joists to be fixed to timber binders. An ordinary mortise is formed on the side of one binder to receive one end of the ceiling joist and a chase mortise is formed on the side of the other binder so that the ceiling joist can be swung into the mortise at that end. A fillet may be fixed to the side of the binder to save cutting into it.

Joints in trimmers. Where floors are trimmed round staircase wells and hearths, floor timbers of equal depth must be framed together, the joist ends bearing into the sides of trimmer joists, as in Fig. 17 A. The *tusk tenon* is the best joint for this purpose, as it provides a good bearing area and security against horizontal movement. It will be seen that the wedge holds it against tension. In much modern building the housed joint (Fig. 17 C) is considered sufficient, further security being given by nailing. In some cases the housed joint is dovetailed on one side. The patent metal joist hanger, also shown (Fig. 17 D) is a new method of securing floor joists to trimmers. It hangs on the trimmer and provides a seating for the joist end. Small holes are provided for nailing into both timbers. For heavy timbers this is better than the housed bearing, which is obviously weak in shear.

Laminated members. Where a timber member of large sectional dimensions is required it may be inconvenient or costly to provide this in one solid piece. Timbers of smaller section may be built up to provide one member of the required strength. Typical examples are illustrated in Fig. 18. A *laminated beam* (Fig. 18 A) is shown consisting of three thicknesses. Thus a 9 in.×9 in. section may be built up of three

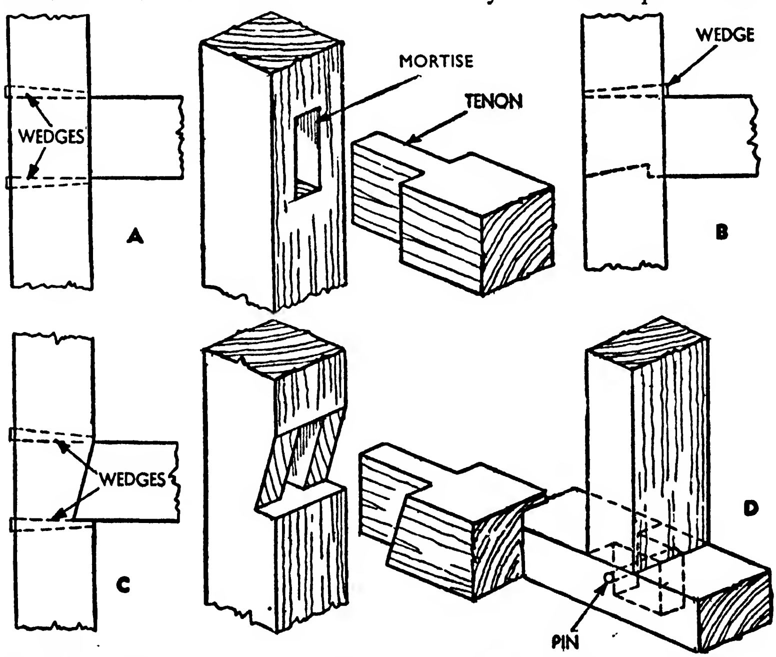


Fig. 14. Types of mortise and tenon joints. *A.* Tenon wedged ; *B.* dovetailed tenon ; *C.* splay-housed tenon ; *D.* pinned tenon.

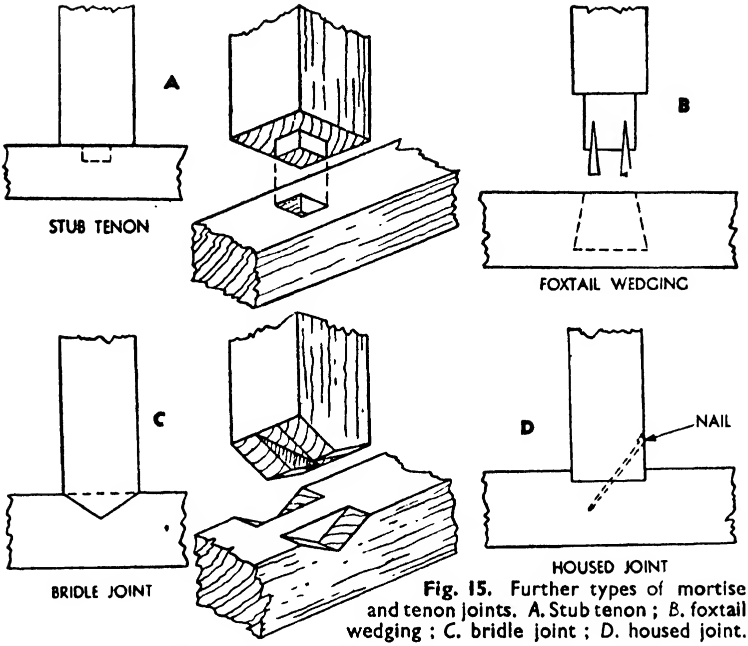


Fig. 15. Further types of mortise and tenon joints. A. Stub tenon ; B. foxtail wedging ; C. bridle joint ; D. housed joint.

9 in. × 3 in. timbers. The timber should be in full lengths if possible but shorter lengths may be used provided that the joints are lapped. A similar laminated construction is illustrated for a post (B), and the use of hoop iron to bind the timbers together is shown.

Where a wall must be supported on a beam, it is necessary to make the beam of suitable width. Two narrow beams are packed between with small pieces of timber, as in Fig. 18 D. Thus two 9 in. × 3 in. timbers may be packed out to give an overall thickness of 9 in., so providing a suitable beam for a 9 in. or 11 in. wall.

Curved members may be constructed by using laminations of small section. Fig. 18 C shows a *curved laminated rib* of a Belfast truss or bow string girder at the point where the rib joins the tie beam. This rib consists of two $1\frac{1}{2}$ in. × $1\frac{1}{2}$ in. lengths nailed on each side of the lattice members. Notice the joint between rib and tie beam, and also the laminated construction at the end of the tie beam.

Fastenings. Bolts, screws, coach screws, nails, pins, screw-nails, metal straps and metal connectors are used for fastening carpentry joints. Consideration should be given to the approximate stress which the fastenings must bear. The simplest type of joint consists of placing the timbers in contact (butting or lapping) and fastening them together. Such joints are largely used in temporary and rough carpentry. In temporary work *iron dogs* are used. Modern screw-nails, which can be driven in with a hammer but have the holding power of a screw, are recommended where high resistance to tension is required. Wrought iron plates are sometimes used to make joints in such work as trestles.

Metal Fastenings

Nails are suitable where no great stress is placed on the fastening. The French wire nail is largely used, and carpenters use mainly 4 in. and 6 in. nails. In old methods of carpentry a nail or other metal fastening was never used if a joint could be made which would make the metal fastening unnecessary. This was in the days when nails were costly and carpenter's time cheap, but to-day the position is reversed. Despite this, a metal fastening should only be used to increase the strength of a joint, or where it will be at least as strong as a framed joint.

Straps are used to take tension and shear stresses in important joints. Some examples are illustrated in Fig. 19. The stirrup A and three-way strap B are those used in a king-post truss. Notice the use of *gibs and cotters* (C) for tightening the stirrup strap. An illustration is also given of a heel strap E at the foot of a principal rafter—this is used in conjunction with a bridle joint. Alternatively a bolt may be used for connecting the timbers, as in Fig. 19 D.

In large carpentry constructions

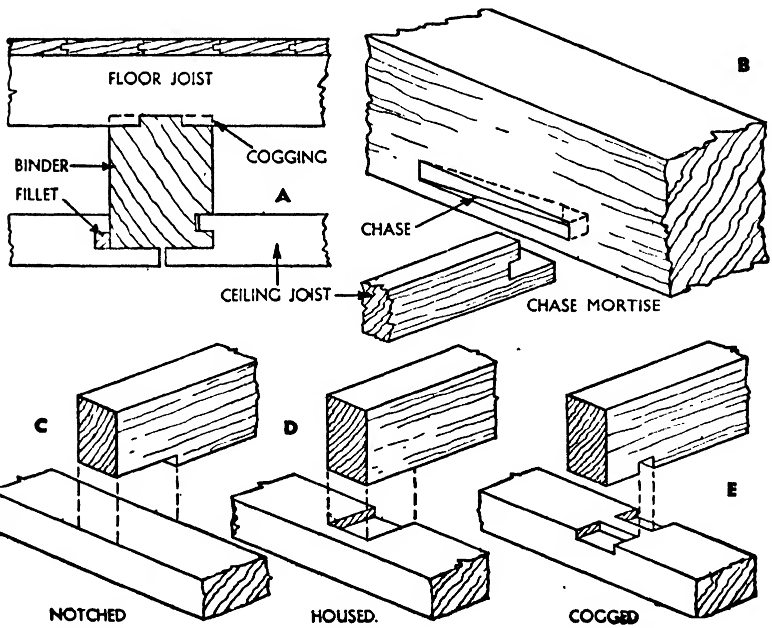


Fig. 16. Each form of mortise and joint is designed to solve some special function. A. Chase mortise : method of fixing ceiling joists to beams already in position ; B. view of chase mortise ; C. notched joint ; D. housed joint ; E. cogged joint.

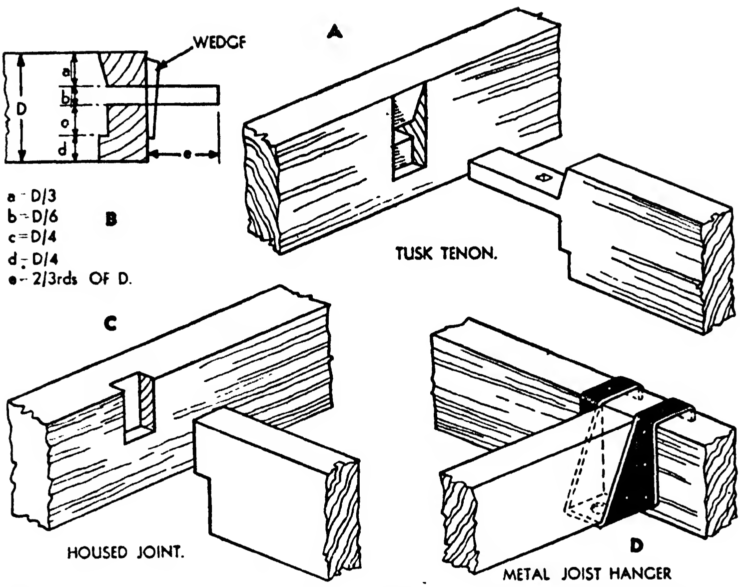


Fig. 17. *A, C, D*, types of joints to floor trimming. *B*. Proportions of a tusk tenon.

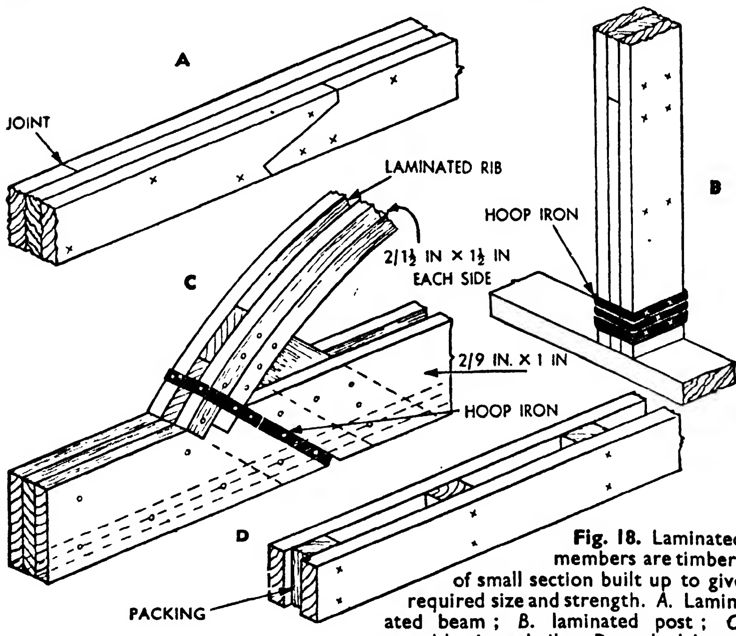


Fig. 18. Laminated members are timbers of small section built up to give required size and strength. *A*. Laminated beam; *B*. laminated post; *C*. curved laminated rib; *D*. packed beam.

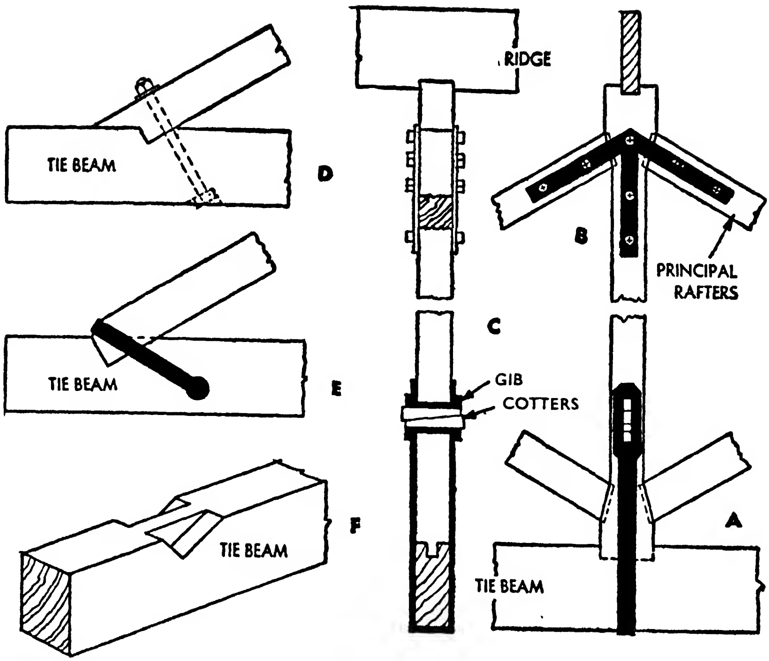


Fig. 19. Metal straps are valuable for strengthening joints. A. Stirrup strap to king-post ; B. three-way strap ; C. gib and cotters to tighten joint ; D. bolt to hold principal rafter ; E. heel strap ; F. tie-beam prepared for bridle joint.

most of the work is put together with fished joints, bolts being used with large square washers and metal plates to secure the joint. Timber connectors, as previously described, greatly simplify such construction.

Modern Developments

Two modern developments in carpentry which are altering the practice of the craft are: first, the timber connector and bolt, which give good stress distribution in the joint; and second, the increasing use of the *sandwich* system of framing, which consists of making joints by sandwiching the ends of single structural members between double members and securing the lapped joint with nails, bolts or timber connectors.

This method enables large timber structures to be built on the lines of steel framing. By the methods employed in the sandwich system the ends of the timbers are cut to shape and holes are drilled for bolts. The bolts and connectors are standard productions of known strength. In the traditional system much labour is involved in cutting the joints and much material is wasted, owing to the fact that to give adequate joint strength large timbers must be used and these have to be cut down beyond the joints, as in the case of king-posts.

CHAPTER 8

WALL PANELLING AND DOORS

SLOTTED BATTENS. USE OF PLYWOOD. PANEL DESIGNS. VENEERS. MUNTINS. VARIOUS FINISHES. EXTERNAL AND INTERNAL DOORS. FLUSH AND SEMI-FLUSH DOORS. LOCKS AND BUTTS.

Wall Panelling

IN working on wall panelling and doors, as in the other branches of his trade, the joiner must know his material and its vagaries, otherwise trouble is bound to accrue. Provision has to be made for swelling and shrinkage, especially in large panels and on deep mouldings, for unless the timber is thoroughly dry and seasoned, splitting and cracking are bound to occur.

Slotted Battens

The slotted batten is very essential, and if intelligently used will prevent a lot of trouble. Reference to Fig. 1 A shows how to apply this. One end of the batten is fixed in the ordinary way, but the remainder of the screw holes are slotted so that any movement in the timber can take place. This method can be used for attaching the under framing to counter tops and large panels.

As an alternative to the wood batten a small angle iron can be used as in Fig. 1 B and slotted in a similar manner, but the iron work should be well painted before it is screwed to the panel.

Another fixing method is the ordinary wood turn-button as in Fig. 1 C. This is very useful for holding glue-jointed landings or table tops; here again, metal plates can be used, as in Fig. 1 D, but they are much more expensive.

Use of Plywood

If plywood is used instead of solid timber the question of shrinkage and swelling is almost negligible, but twisting and warping are equally important and provision should always be made for counteracting these defects.

If plywood panels are to be veneered, they should have a cheap counter veneer on the opposite face, in order to maintain the balance. The only exception to this applies to imported plywood, which is veneered during manufacture. The explanation for the need of veneers on both sides is that the moisture in the adhesive has an opportunity to dry out simultaneously through the veneer and plywood, and so maintain the equilibrium of the panel.

When plywood panels are polished, the opposite face should have a similar application of either paint or size to maintain the balance. This is very important.

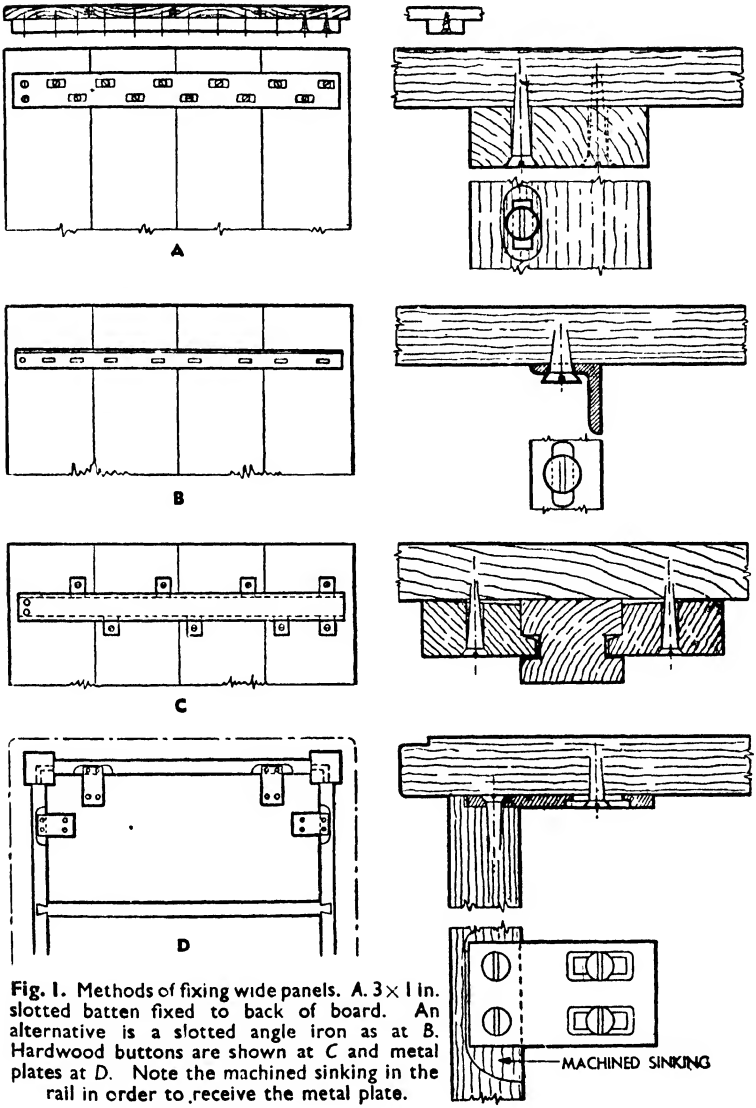
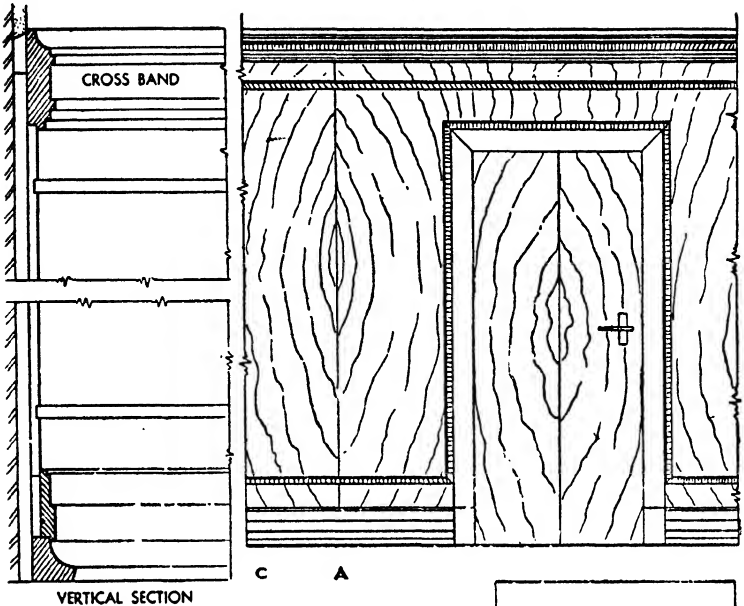


Fig. 1. Methods of fixing wide panels. *A.* 3 × 1 in. slotted batten fixed to back of board. An alternative is a slotted angle iron as at *B.* Hardwood buttons are shown at *C* and metal plates at *D.* Note the machined sinking in the rail in order to receive the metal plate.

The introduction of flush doors and panelling has brought with it many fresh problems which are being gradually mastered, both by trial and error, and by scientific investigation, but whether plywood will ever supplant the solid wood is very doubtful; and it remains to be seen how some of the ornate work that has recently



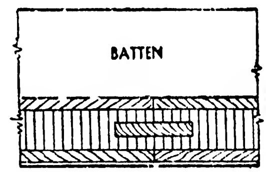


Fig. 2. Laminboard panelling. *A.* Portion of the elevation of panelling with a solid cornice and skirting ; *B.* horizontal section through a joint ; *C.* vertical section through the panelling. The plain surface is broken by cross bands of different coloured veneers.

made its appearance in plywood and veneer will stand the test of time as the solid oak panelling of the Middle Ages has done. However, public demand and supply will have to be met and the joiner must be prepared to grapple with the various problems as they arise.

The modern trend is for solid mouldings with plywood veneered surfaces. A typical section of this type is given in Fig. 2. The actual panels are laminboards and can be from $\frac{3}{8}$ in. and upwards. The mouldings are all applied on the site. This class of work has opened a new field to the designer and to the veneer layer. By a judicious selection of veneers some beautiful effects can be obtained. but restraint must be practised, otherwise the effect may prove disastrous.

With regard to the actual making up of the panels and the selection of the veneers, the setter-out must plan his joints not only to suit the available size of the plywood sheets, but also to suit the width of the actual veneers. These have to be opened out and matched very carefully. Other governing factors are the size of the veneer press, and the size of the panels that can be transported and taken on to the site.

When these questions have been settled, the plywood can be jointed to the required size, the face cleaned off and the work taken to the veneer press. The joints must be cleaned off flush, otherwise ridges will show as soon as the panels are polished. Fig. 2 B shows a typical joint which is well battened on the back to prevent racking during transport. These battens can be removed just before the panels are fixed.

Another typical panelling section is shown in Fig. 3. In this example the panels are framed together and conform to the more orthodox type of panelling. The definition of the word 'panel' is simply 'a piece of wood whose edges are inserted in a frame' or 'to form with panels.'

The modern fashion for producing horizontal lines is shown in Fig. 4. All the panels are prepared in the shop and then applied direct to the wall battens. In this example there is more work for the fixer than for the shop joiner.

Fig. 5 is another example of modern panelling, suitable for a board room or office. The actual panels are covered with leather and are held in position with small rosettes or pateræ at the angles, as shown in Fig. 6. The joiner simply has to make a number of small wood frames covered with ply, which are then covered with a layer of felt and the leather skin applied by the upholsterer. The skirting and cornice are machined and go to the polisher direct.

The panels shown in Fig. 7 are of solid oak, and the framing can be mitred at the mouldings or, to be authentic, the mason's mitre can be used. This scheme is worthy of investigation and is actually the prototype of all forms of modern wall panelling.

If the design is correct, the panels should not be more than

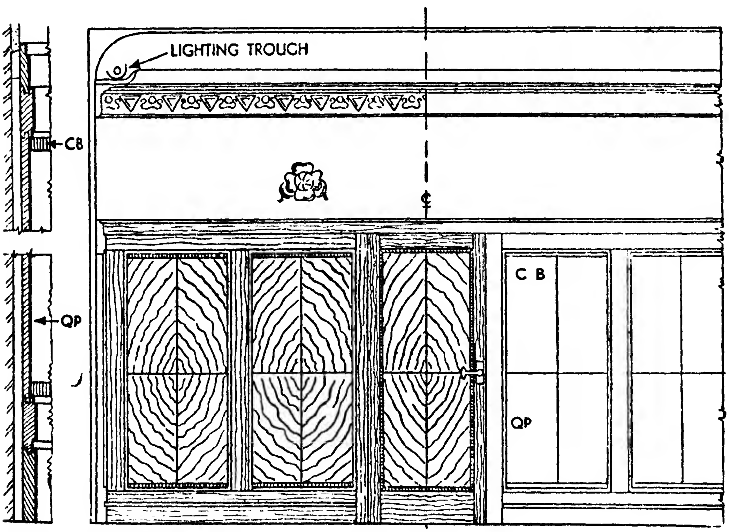


Fig. 3. Portion of panelling with plywood panels framed together. The panels (QP) are covered with quartered veneer and inlaid with cross bandings (CB). The larger detail on left shows how the members are fixed together.

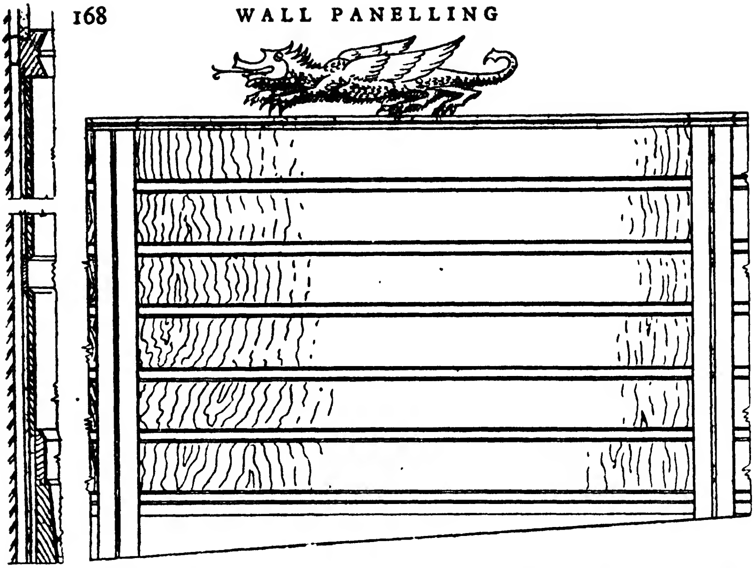


Fig. 4. Details of auditorium panelling. The solid members, such as cornice and skirting, are of sycamore, while the veneered plywood panels are fixed direct to wall battens. The panels, which are first prepared in the shop, are arranged to form a series of horizontal sinkings along the wall surface.

12 in. wide, in one width and about ½ in. thick. If the panels have to be jointed the grain must be matched and the joint kept in the centre of the panel. If the panelling is not more than 8 ft. 0 in. high it is possible to select long boards and cut them into short lengths as required. By keeping the butt of the plank at the bottom and numbering the panels, the finished effect will be perfectly natural.

The panels are held in the framing in grooves or in rebates with loose fillets at the back as shown in Fig. 8 A. In either case, the panels should be polished before being framed up. This obviates any unsightly white lines at the edges should the panels shrink. Panels should not be glued to the frame as this prevents movement and causes splitting.

When the panels are polished, and before the framing is assembled, the back of the panels should be painted, especially round the muntins. This will prevent any moisture from entering at the edges. If the framing is grooved, the grooves must be of the right width, making allowance for both paint and polish, otherwise the joiner will waste time easing the backs of the panels before he can commence gluing up.

Cutting the panels to the correct size is an important feature. It is better to have these slightly under size rather than over size. If the panels are cut too long they will prevent the shoulders on the muntins from fitting properly, and if they are cut too wide, it means that all the individual panels must be reduced in width or that the mortises in the rails will need easing and the piece of framing will finish wider than is necessary; then the fixer will have to reduce the margin at the stiles.

This points to the necessity for the closest supervision in marking out and machining, and to the need of using properly seasoned timber before commencing operations. When softwood panels are used the shrinkage is great, and ample allowance must be made, otherwise it will involve jointing pieces on the edge, a very expensive job, and will delay production.

Fig. 7 also shows a typical set of details. All the joints are mortised and tenoned together with dowels or trenails to keep the shoulders of the muntins tight to the rails. The deal rail at the top can be glued on before cutting the tenons at the ends.

It will be obvious that if the framing is to be square when finished, the rails must all be the same length over the shoulders. The same remarks apply to the muntins.

The stub tenons of the muntins

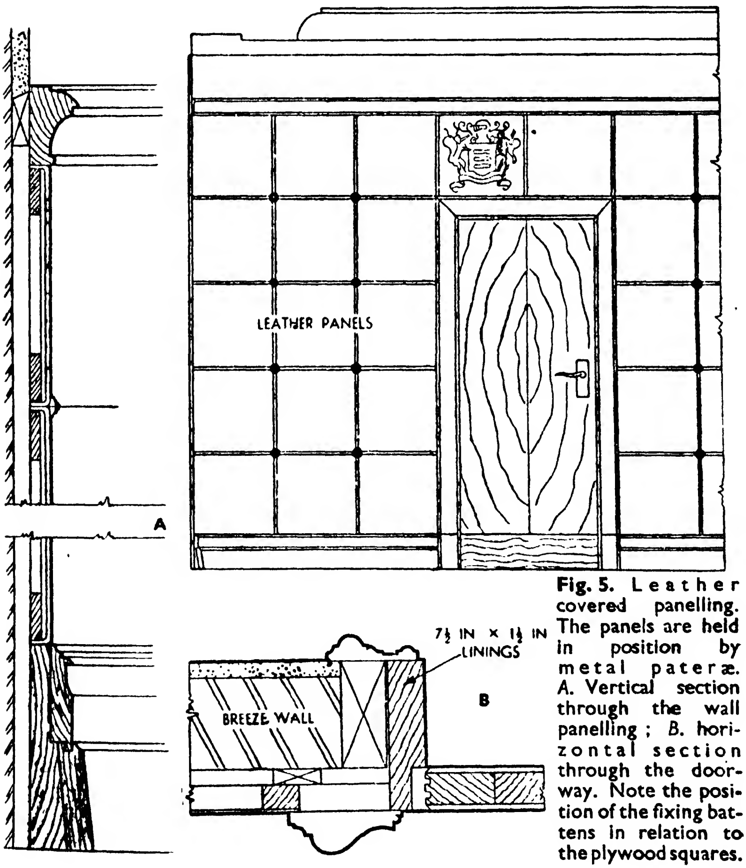


Fig. 5. Leather covered panelling. The panels are held in position by metal pateræ. A. Vertical section through the wall panelling; *B.* horizontal section through the doorway. Note the position of the fixing battens in relation to the plywood squares.

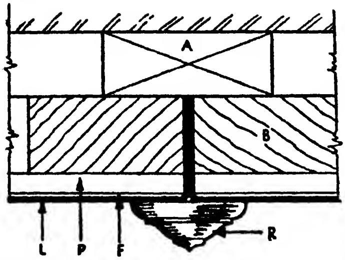


Fig. 6. Detail to show how panels are fixed to wall. A deal frame (*B*) is secured to the wall battens (*A*), while the plywood squares (*P*) are first covered with felt (*F*) and then leather facing (*L*). The squares are held by rosettes (*R*) screwed into the battens.

must not foul each other where these go into the middle rails, otherwise the shoulders will not fit. Where trenails are not used, the tenons are screwed from the back.

Provided that the machining is accurate, it should be a simple job to assemble the framing on the bench in sections, using the bottom rail and middle rail with muntins as one section, and the top rail and middle rail as another. The two sections can then be assembled by means of the middle row of muntins and then the end stiles driven on. A long cramp can be used to test the framing joints and, if satisfactory, the framing can be knocked apart, the panels fitted in and the whole piece of framing glued together.

After gluing up is finished, allow at least twelve hours to elapse before cleaning off the shoulders. This will allow the moisture to dry out, and the wood to become 'set.'

The rails are moulded on the solid and the machinist can run these out as shown in Fig. 7 B. The joiner has then to carry on the moulding and return it in itself until it intersects with a similar mould on the muntin edge (Fig. 7 C). In the case of the bevel on the top edge of the rail, this has to be finished as shown in Fig. 7 D and 8 B.

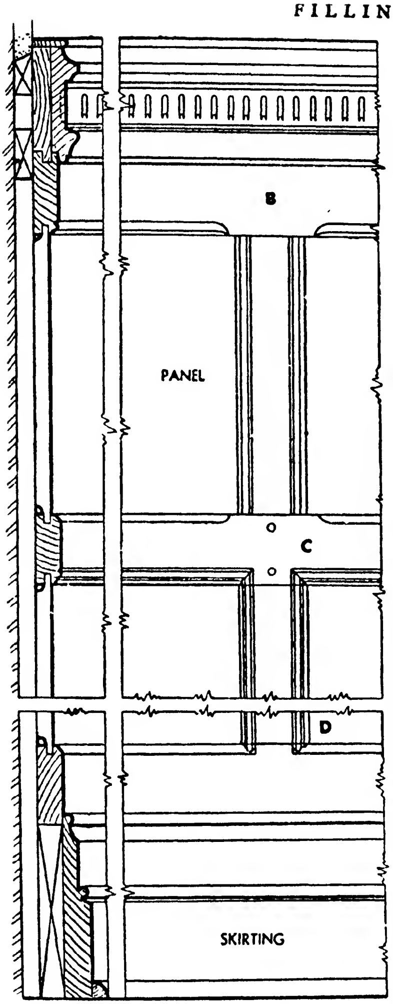
If it is decided to mitre the mouldings, this must be done as in Fig. 8 C, E and F. Here again, the joiner has an interesting job to perform by cutting away the moulding and fitting the muntin until the shoulder and mouldings fit. The lower end of the muntin can be scribed to fit over the bevel of the rail, and this operation can be performed on the tenoning machine when the tenon is cut.

With regard to the trenails, these may be either dummies, sunk into the face of the framing about a ¼ in. and left projecting about the same amount, or driven right through (Fig. 8 D), in which case there is no need to screw the tenon on the back.

Veneered Plywood

On account of cost it may be necessary to use veneered plywood panels instead of solid oak, in which case a good wide veneer is selected and laid in the usual manner. There should be no difficulty about length, so that for normal height panelling, i.e., not over seven feet high, the vertical panels can all be cut from one leaf as in the case of solid panels. The panels should be numbered on the back, so that the joiner when assembling will get them in their proper sequence.

The great disadvantage in using veneered plywood, especially oak, is that should there be any moisture in the walls when the panelling is fixed, it will gradually penetrate through the panels and



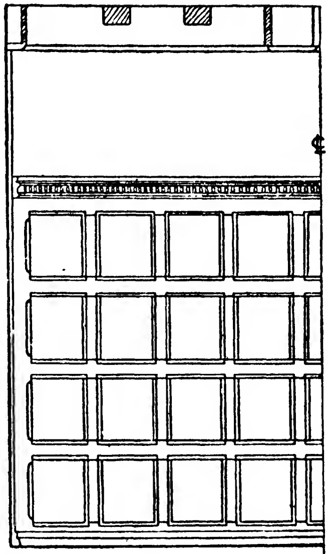


Fig. 7. Details of traditional method of forming wall panelling. Series of small rectangular panels cut from the solid wood are framed together, as at *A*. The section shows the construction, and illustrates how the panels are mulletted on the back to allow a flat surface on the face. The elevation at *B* shows how the moulding is 'run out' at the shoulders by the machine. This is then finished by hand, as shown at *C* and *D*, so as to form a mason's mitre.

cause the glue to turn black. As veneers are thin, usually about forty leaves to the inch, black stains soon become apparent and are impossible to remove. Bleaching may eradicate the marks temporarily, but it generally involves entirely new panels.

The finish of panelling is a matter of taste and suitability. For hard wear, such as in public buildings, a full polish is desirable. Oak is much better if wax polished, especially when veneers are used. Walnut and mahogany take a full polish very well. Teak can be treated similarly, but after polishing can with advantage be dulled down with pumice or whitening.

"Filling in" is essential with a full polish, otherwise the polish will sink in the grain and ruin the appearance. Veneered work is rather prone to show cracks in time if full polished, therefore a rubber of polish and then wax

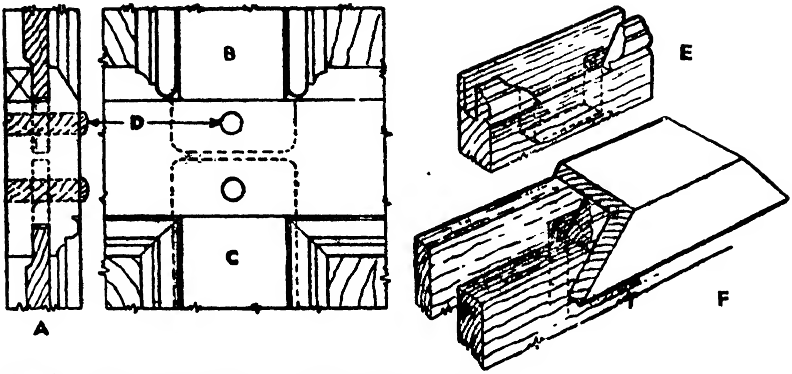


Fig. 8. *A.* Vertical section through a rail in orthodox panelling. Stub tenons on the muntins should have ample clearance, and should be secured with dowels or trenails (D). *B.* moulded muntin scribed over a chamfered rail ; *C.* moulded members mitred together. A view of the mitred rail is given at *E* and the method of cutting the joint with the aid of a mitre templet at *F.*

polished is preferable. Cellulose is also inclined to show minute cracks in the surface, especially on veneered work. Lacquered work has proved successful on some timbers, but has to be used with discretion.

If protection from the weather is required, the grain of the wood should be filled in with a good hard filler, and then two or three coats of copal or matt varnish applied. Oiling by itself is not much protection and only provides a surface for dirt. Hot tallow, well burnished, has been used with great success in many cases.

Painted panelling is often used, especially in hot climates. Here again the usual precautions must be taken against shrinkage. The panels should be painted before being fitted to their frames, and if hardwood is used, a good filler is necessary to prevent the paint from sinking in. Unless timber is well protected, either with paint or polish, it will absorb moisture quite readily, even after seasoning. Plenty of ventilation will prevent trouble in more ways than one, and with adequate protection, should prevent dry rot and attack from beetles.

External Doors

There are a great many varieties of external doors available for all purposes. The type of door for each particular purpose should be studied with care, and not simply selected from a catalogue because the design seems pleasing to the eye. Imported doors of cheap manufacture should be avoided if at all possible. The panels are chiefly plywood, generally not more than 6 m/m thick, and are not suitable for external use. The joints in the framings are mostly dowelled instead of mortised and tenoned. This type of construction may be suitable where the timber is in its natural environment, but not in this country, where all the extremes of weather occur in twenty-four hours.

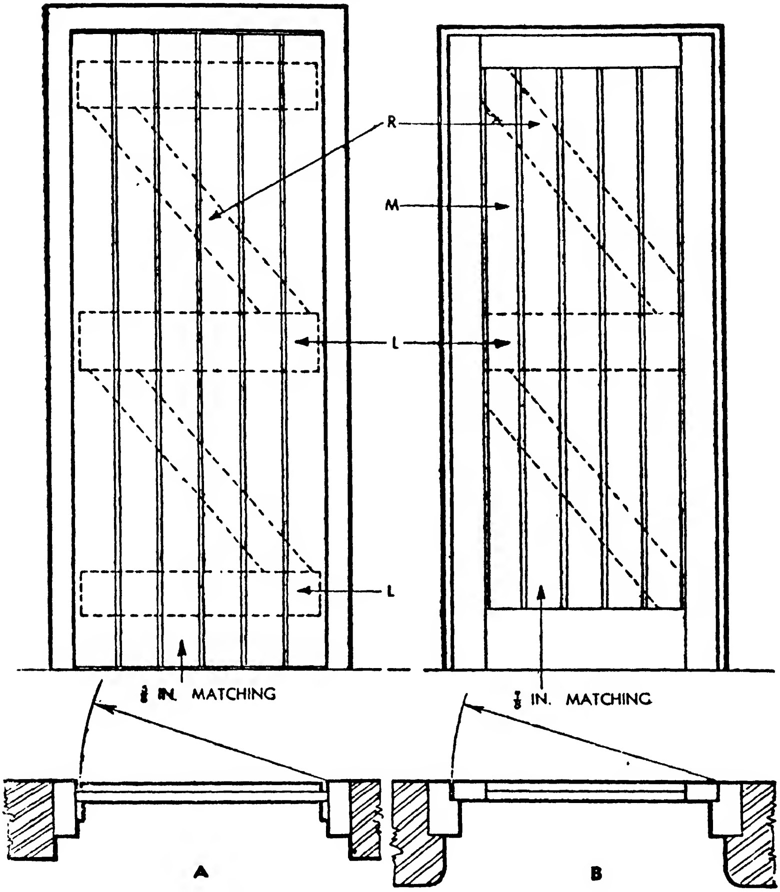


Fig. 9. A. Ledged and braced door formed of ⅞-in. matching nailed to 6 in. by 1 in. ledges (*L*) and 4 in. by 1 in. braces (*R*). The plan shows a 6 in. by 2 in. door frame, with 2 in. by ½ in. door stops. B. 2 in. framed and ledged and braced door. In this case the door is framed and "filled in" with ⅞ in. matching (*M*).

The cheapest form is the ledged and braced door (Fig. 9 A). This type consists of a number of tongued, grooved and veed boards held together by means of ledges with diagonal braces to prevent the whole door from dropping out of shape. Assembling doors of this type calls for no particular skill and can quite easily be carried out by a good apprentice who has only reached his second or third year.

The boards are all cut to the correct length on the fine saw. Butt jointing of the matching in length is permissible providing the joint is made on the middle ledge and no two adjacent boards contain joints. After the boards are assembled on a jig, the ledges are nailed across, the pointed ends of the nails being clenched over the face of the matching, making sure that the clenched ends are punched below the surface so that the holes can be puttied up before painting the door. The braces are then cut in and nailed in the same way as the ledges. The braces must be fixed in the right direction. The heel of the brace should always be on the same edge as the hanging side, and the top pointing towards the closing edge; this prevents the door from dropping by reason of its own weight.

The angle of the brace should not be less than 45 deg., otherwise it will lose its effectiveness. The ends of the braces may also with advantage be cut into the ledges, to give a better seating, but cost must be the deciding factor in this case. The same applies to screwing the ends of the ledges in lieu of nailing; if cost allows it, the screws can be sunk below the surface and pellets inserted.

Priming Coats

Before the matching is assembled, the edges of the braces, and the tongues and grooves, should be given a coat of dark priming to prevent unsightly white lines showing when the matching shrinks. The joints should also be left apart the thickness of a piece of zinc, to allow for any swelling. This type of door is only suitable for very light work and preferably of a temporary nature. Cross garnets or tee hinges (Fig. 24) are generally used for hinging with Norfolk latches or rim locks for fastening purposes.

Fig. 9 B shows a framed ledged and braced door, which is a more serviceable type. The joints in the framing are mortised and tenoned, the centre ledge having a barefaced tenon to allow the boarding to pass. The bottom rail can also be replaced by a ledge treated in the same manner providing a cheaper door is required. The matching is tongued into the framing and the ends of the boards are machined to fit into grooves in the top and bottom rails. This entails a little more work, but shows a saving in maintenance spread over a period of use.

Solid Framed Doors

A solid framed door with a bead at the junction of the panel and the stile to break the joint is shown in Fig. 10 A. This bead is very important, as it allows for a certain amount of movement in the width of the panel; at the same time it neglects the joint between the end grain of the panel and the rails

The type of door shown in Fig. 10 B is suitable for most positions and can be used as a fire-resisting door as specified by the London County Council. If necessary, the panels can be built up in widths of four to five inches with a similar type of bead to each joint. This has the advantage of reducing swelling and shrinking, but, of course, entails more work. Before the introduction of the loose beads and tongues it was the practice to work these in the solid on the edge of the panel, a difficult matter across the end grain of the panel as the quirk of the bead has to be finished by hand.

When doors are used in very exposed positions, such as on

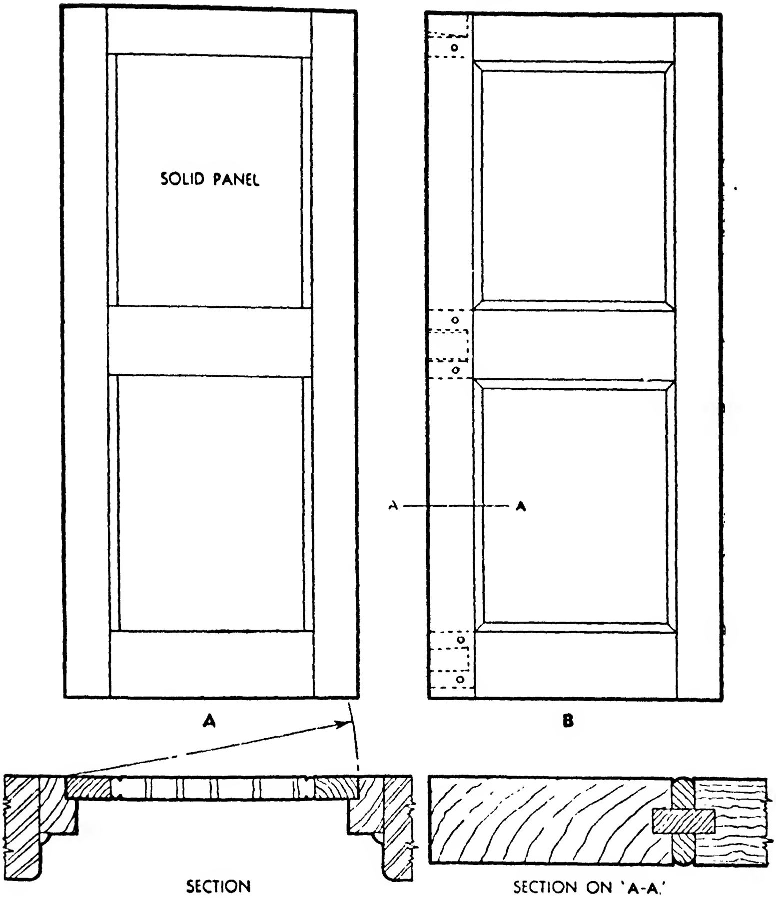


Fig. 10. A. Solid bead and butt door, composed of 5 in. by 2 in. stiles, 5 in. by 2 in. top rail, 8 in. by 2 in. middle rail, 9 in. by 2 in. bottom rail, with a 2 in. solid panel. B. 2 in. solid bead and flush door, with a section on line A-A.

lift shafts and power houses on top of a building, the tenons should be pegged close to the shoulder. This helps to keep the framing tight and prevents rain from driving in at the shoulders.

Before the introduction of waterproof glue it was the practice to use paint instead of glue for outside framings, as glue will perish in time, owing to the action of the atmosphere. Doors which have to stand up to extreme heat and cold should always be of hardwood and preferably in teak. The natural oil in the teak resists the climate and, providing the doors are maintained in a good condition, will last indefinitely. Good strong hinges, such as bronze, steel washered, are necessary, and a door spring, or overhead check spring should be

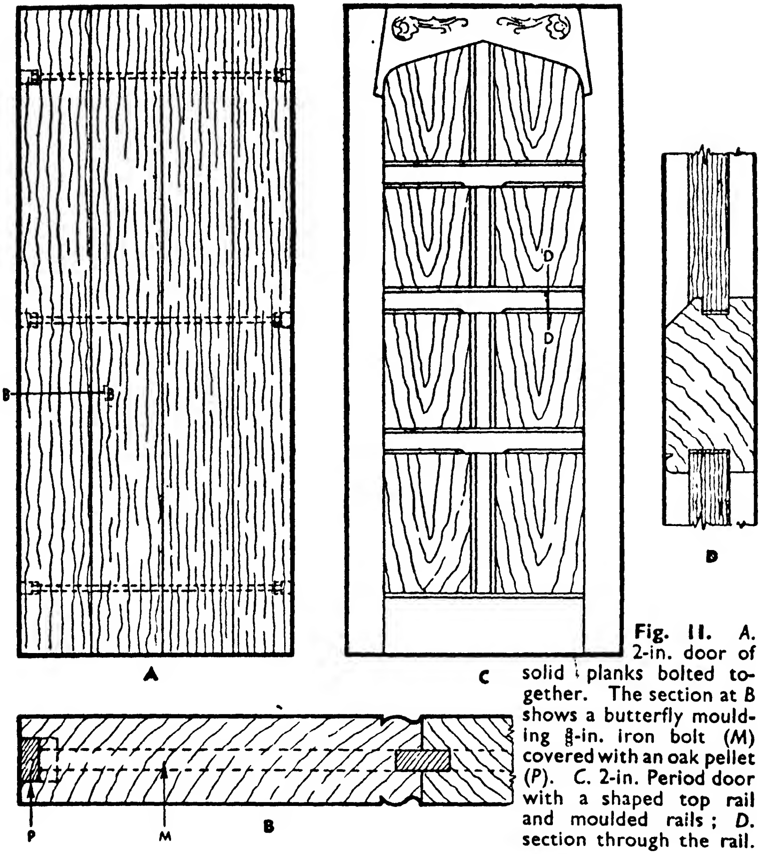


Fig. 11. A. 2-in. door of solid planks bolted together. The section at B shows a butterfly moulding $\frac{5}{8}$-in. iron bolt (M) covered with an oak pellet (P). C. 2-in. Period door with a shaped top rail and moulded rails; D. section through the rail.

fitted, to prevent the door from slamming in a high wind.

When mortise locks are fitted, the middle rail should have double tenons. The lock will then fit between the tenons and not weaken the door. The haunchings to the bottom rail should always be kept well up in order to conserve strength and also, if it is necessary to shorten the door, to allow for cutting without weakening the tenons.

Weather moulds are a great help in keeping out the rain. These should have a drip on the underside, the top edge being tongued into the face of the bottom rail. A good bedding of white lead should be used and the mould screwed into position, not nailed.

A further variation on a solid flush door is obtained by the introduction of muntins in the top and bottom panels. This produces what is known as a four-panel, bead flush, solid door. This particular type of door is, if properly made and maintained, one of the most serviceable doors ever devised. The introduction of the muntins reduces the width of the panels to serviceable dimensions.

The prototype of the flush door is shown in Fig. 11 A, and many examples of this door may be seen, dating back to the Middle Ages. The joints can be moulded, or left square, and the head of the door cut to Gothic or Tudor outlines, as in Fig. 12 B. Hinges, locks and furniture can be fixed in any position, except adjacent to the steel bolts. The panels should be left to dry in the joiner's shop as long as possible.

Iron work should be well painted before insertion, and it is advisable to leave out the pellets on the edges for at least one winter and summer after the doors are in position. The panels will shrink in the summer and swell in the winter during this period, but a box spanner will easily adjust the joints when the material is more stable.

The finished product is naturally heavy and not to everyone's taste, but if the panels are cut properly, i.e., wainscot or quartered, the grain in the panels will be shown to the best effect.

Fig. 11 C shows a period door typical of our old country houses, one that is still in great demand. For external use the panels should be solid and the top edges of the rails bevelled on the outside in order to throw the rain away from the bottom of the panels. The panels should be scribed over the bevel of the rail if at all possible, as shown at D. The spandrel of the top rail can be carved, or the panels themselves can be linenfold as in Fig. 12 A. This class of work is naturally very expensive.

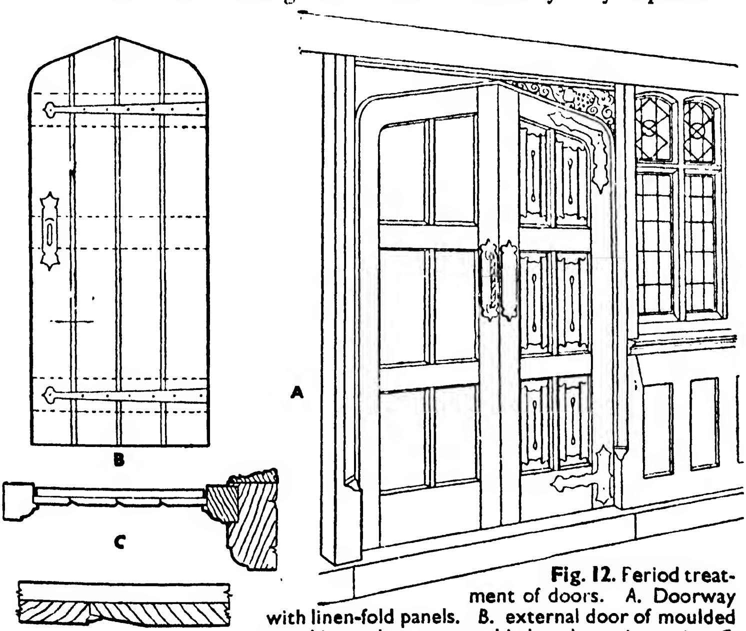


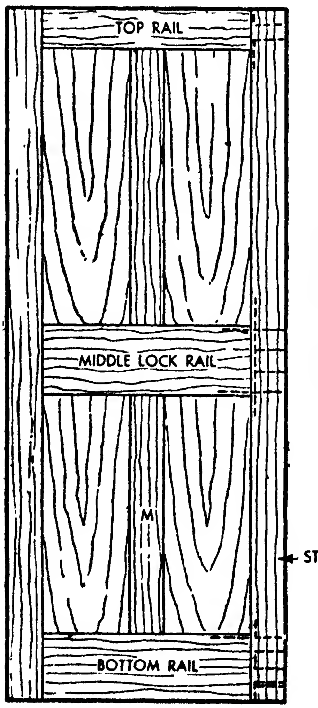
Fig. 12. Period treatment of doors. A. Doorway with linen-fold panels. B. external door of moulded matching ; these are moulded as shown in section C.

Internal Doors

INTERNAL doors have suffered more than any other joinery item in the way of mass-production, especially the flush door and stock four-panelled imported doors. The timber and workmanship in these doors leave much to be desired.

Fig. 13 shows an ordinary four-panel square-framed door; from this has evolved the ovolo moulded, the bolection moulded, the raised panel, and all the other variations now in vogue. With careful machining it is unnecessary to fit up simple doors before commencing the gluing-up operation. The same remarks apply to doors as to panelling. The panels must be correct to size and mulletted properly, i.e., gauged to thickness; the muntins and rails should be to the correct length, and the tenons should fit the mortises cleanly and accurately. A shoulder plane is necessary when fitting up hardwood doors, but on softwood, this should not be used.

When gluing up doors, or any kind of framing not held in position, the bearers on the bench must not be twisted otherwise the framing will not be true. Many large shops now have metal cramping machines which save an enormous amount of time.



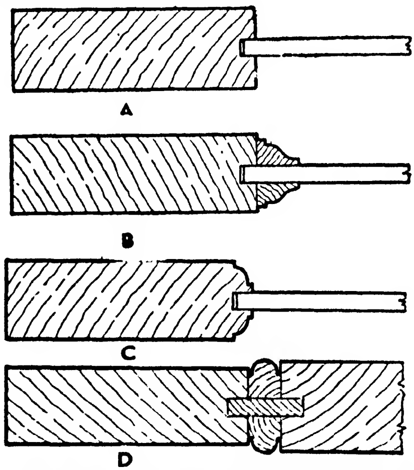
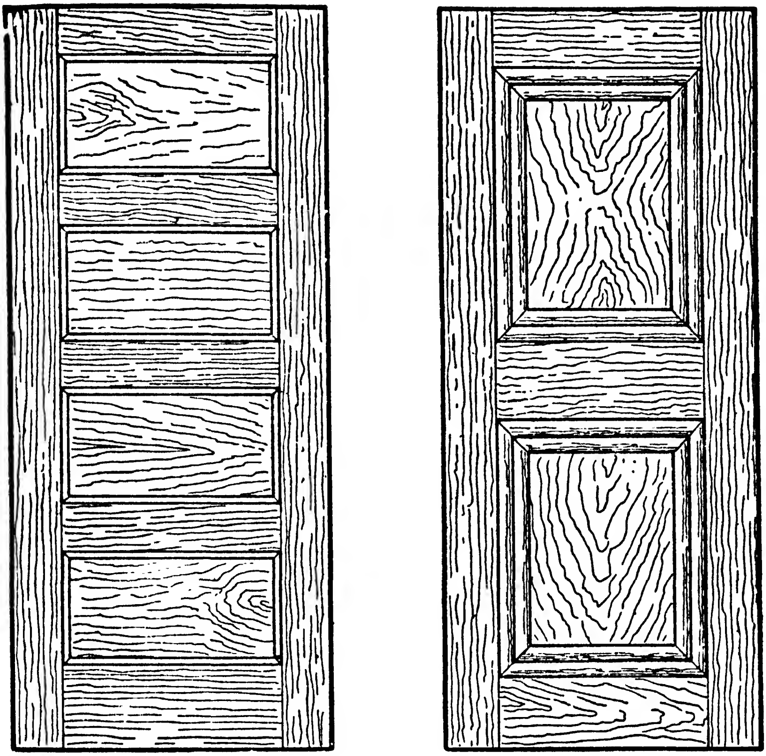


Fig. 13. Ordinary four-panelled door with alternative methods of panel treatment. The stiles are from 5 in. to 4 in. wide, the top rail is of the same size as stile. Middle or lock rail is twice width of stile, bottom rail is twice width of stile, plus 1 in. in good work, muntins (*M*) width of stile, less ½ in. Panels are from ⅜ in. to ⅝ in. thick. *A*. Section through a 5 in. by 1½ in. stile. 6 m/m plywood or ⅜ in. solid wood square framed panel; *B*. slip moulded and square framed panel; *C*. ovolo moulded and scribed frame; *D*. beaded and solid panel.



A B

Fig. 14. Internal doors are described by the number and position of the panels A. Door with horizontal panels whose grain runs across the width of the door. B. two-panelled moulded door. This door can be moulded as shown in Fig. 15.

In good-class joinery, it is the practice to knock doors together and leave them on the wedge for as long as possible. This applies to any framed joinery, especially if the mouldings are worked in the solid. The mitres can be cut as described for Fig. 8, but not fitted tightly, as the final fitting can be carried out prior to gluing up. By taking these precautions, the finished product will bear close inspection and also give satisfaction to the craftsman. Nothing looks more unsightly than a joint between framing or mitres that are tight on the heel and off at the toe.

Reverting to Fig. 13, the side sketches show the various types of mouldings that can be used to improve the appearance of the door. Small slip moulds nailed in are certainly more pleasing than the ovolo mould, which has the advantage, however, of being worked on the solid, and makes a good scribing section. Any attenuated mould, or one shallow in contour, does not scribe very effectively, as the feather edge of the mould tends to break away.

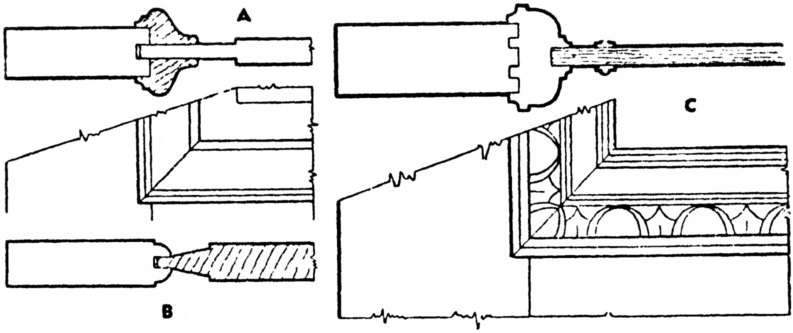


Fig. 15. Further types of panel finishes. A. Bolection moulding round a fielded panel ; B. ovolo-moulded stile with a raised panel ; C. double bolection moulding round a panel with a planted fillet. This type of panel is suitable for carving.

A type of door which is easy to manufacture, and can be moulded similar to Fig. 13, is shown in Fig. 14 A. The panels should have the grain in the horizontal direction if the finish is stain or polish. Fig. 14 B is of a two-panel door that can be moulded as shown in Figs. 15 A and B. The bolection moulding and fielded panel make an excellent combination and call for first-class workmanship. When fixing the mouldings these must not be fastened through the panel, unless one side is slot-screwed to allow movement of the panel. The other side will then naturally have to be nailed to the framing. The mouldings can also be mitred together and screwed at the corners before the mouldings are dropped in.

It is obvious that the fielding on the panel will need cleaning up before the door is glued up, and in the case of the raised panel the mitres on the panel must intersect with those of the moulding. Reference to Fig. 15 C shows a double bolection mould which is suitable for carving, such as the egg and dart, or acanthus leaf.

Before any of the mouldings are four-cuttered (if sufficient quantity) the thickness of the door should be carefully checked, otherwise the small tongues and grooves will need easing with the side rebate plane and this should be avoided if at all possible. Most hardwoods shrink about one sixteenth to the inch during seasoning, so that a 2-in. door will normally finish about $1\frac{7}{8}$ in., and this should be borne in mind when setting up for mortising and tenoning. If the material is twisted, the finished thickness will be less ; it is no use using a twisted stile and expecting a door to be out of wind : the joiner can do a certain amount of easing on the tenons in order to overcome any small twist in the stile, but not very much.

Where it is undesirable to show end grain of the wedges and tenons, they should be cut back about $\frac{1}{4}$ in. and a small diamond inserted, or, if the job warrants the additional expense—as Fig. 15 C certainly does—then fox-tail wedging should be used as shown in Fig. 16 A. The panels and moulds are assembled first, then fitted to the stiles and rails; the whole door is then dry-fitted together and note taken of any shoulders that require easing. After these adjustments are made, the door can be glued up. Fox-wedging calls for great skill, as once the wedges are inserted, and the cramps tightened up, it should be impossible to get the door apart.

Fig. 17 shows a typical door and surrounds in the Georgian style. This actual example was taken from Clifford's Inn and set up in the South Kensington Museum. Fig. 18 gives a typical build up of this beautiful work, with a Wren detail on the opposite side of door opening.

Yellow pine was the favourite timber used, although many examples can be seen in oak. Owing to the wide surfaces used, every provision must be made for movement as the shrinkage is naturally more pronounced where the timber has been cut away to give the required contour. If possible, a heavily moulded architrave should be built up in sections so that the members are somewhere near equal in thickness, to reduce excessive shrinkage.

Fig. 19 gives more modern examples of joinery and shows how to frame up both double and single swing door frames and surrounds. When striking the radius, keep the centre for the heel of the door half the thickness of the door away from the inside face of the frame, but the hollow in the frame should be slightly sharper so that when the door is moving to right angles the heel will not grind in the frame. (See pages 140, 141.)

The meeting stiles also need to be slightly rounded, but not very much. For single-action floor springs a rebated frame is suitable, although some manufacturers are now making a special spring which can be used in the same position as a double spring, but acting one way only.

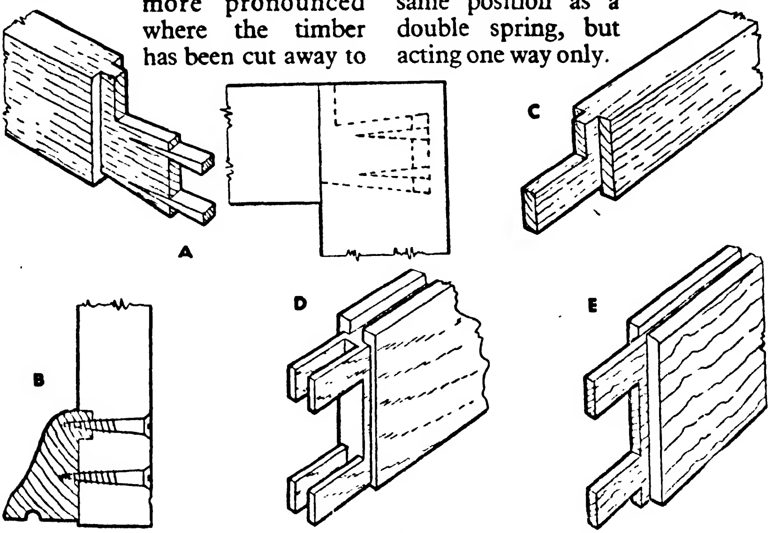


Fig. 16. A. Method of fox-wedging a tenon suitable for a hardwood door; B. section of a 3 in. by 2 in. weather moulding; C. haunched tenon to a top rail; D. double tenons to a middle or lock rail; E. haunched tenons to a bottom rail

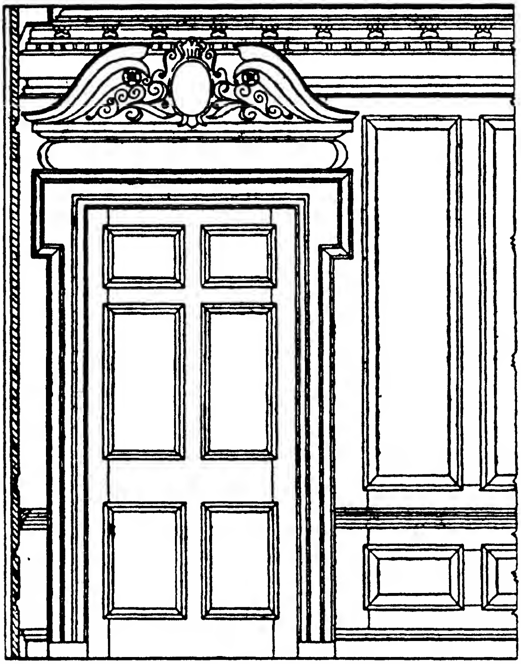


Fig. 17. Further example of Period work: a typical Georgian six-panelled door with ornamental overdoor in panelled room, now in South Kensington Museum.

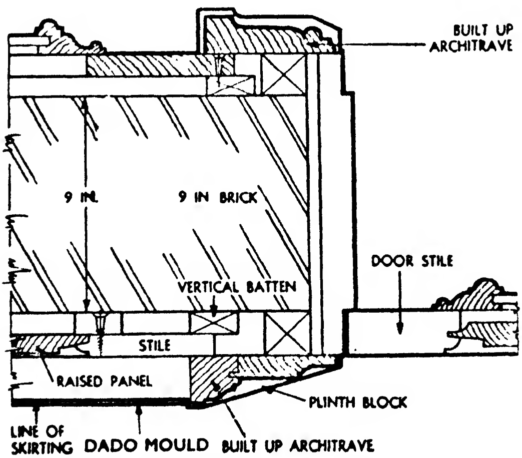


Fig. 18. Section of doorway opening to the door which is shown in Fig. 17. Note how the joints of the stiles of the wall panelling are covered with architraves.

For fastening doors with open joints, clutch locks are better than the usual mortise lock; flush bolts top and bottom also make effective fastenings. When pairs of doors need locking, full or half rebated locks can be used, or the bevelled rebated lock if a specially strong fastening is required. The hook joint (Fig. 19 C) is specially designed to keep out driving rain, but requires cockspur fastenings and espagnolette bolts. The glass in glazed doors should be bedded in wash-leather, velvet or mastic to prevent breakage through inequalities in the rebates or movement in the door itself.

Flush doors have become very popular since the production of plywood in large quantities. What was once exclusively used in hospitals has now become available to anyone. The cheaper form of flush door consists of two sheets of plywood glued to an open framework with a cover fillet on the closing edge. When mass-produced, every part can be machined and the assembly carried out by unskilled labour. The rails are often dowelled at the joint, or a stub tenon used, with a corrugated-iron dog across the shoulder. Fig. 20 A shows a skeleton-framed door answering to the above description. The great drawback is that the panels are inclined to drum when the door is slammed. Fig. 20 B shows how this can be partly overcome by the introduction of slats, which prevent the plywood from sinking and give rigidity to the frame.

Fig. 21 A is a better example. The stiles are laminated together to prevent twisting, for which flush doors are notorious. The wood filling gives more weight and strength. Edging fillets are used on both edges and, if required, on top and bottom edges. The top and bottom rails are mortised and tenoned into the stiles. The wood slats can be square-edged or tongued and grooved together, with their ends stub-tenoned into grooves in the cross rails. By using narrow slats, shrinkage is effectively reduced, and wastage practically eliminated. After the framing and slats have been assembled, both surfaces should be sanded, to remove any inequalities and so give a flat surface for the plywood, which should be glued to the framing under pressure by means of an hydraulic press.

There are many types of presses now available and it is the amount and nature of the work which

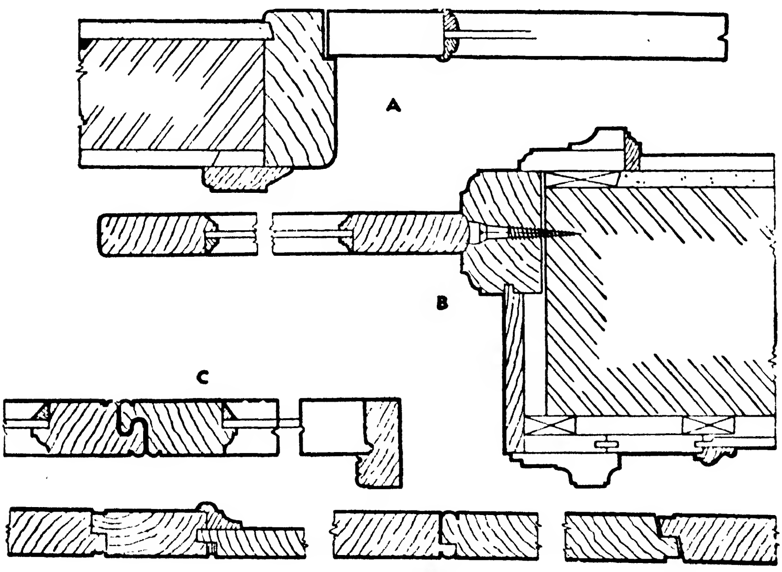


Fig. 19. Types of closing joints to doors. *A.* Single-action swing door with a rebated door jamb ; *B.* plan of a double-action swing door with frame and surrounds : *C.* hook joint to casements ; *D.* a full rebate; and *E.* a half-rebate. Rebates are sometimes bevelled as shown at *F.*

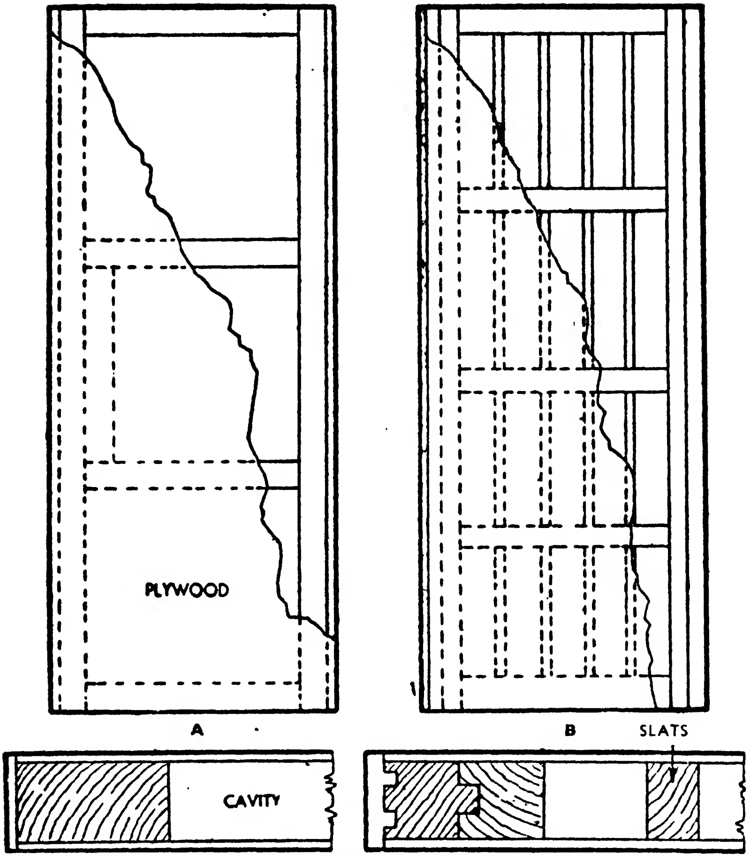


Fig. 20. Flush surface doors. A. Cheap type of flush door, which has a skeleton frame faced with sheets of plywood. At B slats are used to give greater rigidity and to prevent the plywood sinking. In both examples, edging fillets are used in order to hide the end grain of the plywood.

determine the type and size of the press. When the plywood is securely fastened to the framework, the edges of the door have to be machined to receive the edging fillets. These are tongued into the edge and held in position by adhesive, or sometimes by screws, the heads of which are pelletted up.

The edging fillets should be slightly thicker than the framing and plywood together, so that any inequalities in thickness can be adjusted when cleaning off the edging fillets. The door is now ready to go to the sanding machine for the final cleaning off.

Regarding the timber used in flush doors, Western red cedar is the most stable ; it is easy to work and is free from defects. If this timber is carefully dried to a moisture content of 12 per cent. there is little to go wrong.

With reference to the plywood

facing, 6 m/m is most generally used, although any thickness from 3/16th in. upwards is equally suitable. The plywood should be purchased in most suitable sizes to avoid wastage and should be kept dry until wanted. Imported plywood can be obtained in many different grades and kinds of wood, such as gaboon, birch, alder and hoop pine.

Fig. 21 B shows a typical door suitable for hospital work. The circular observation panel should be at the average eye level of from 4 ft. 9 in. to 5 ft. 0 in., with a tendency to the lower size rather than the higher. The filling of the door can be of compressed cork, or other suitable sound preventing material.

Fig. 22 A shows how an ordinary four-panel door can be converted into quite a good semi-flush door by means of a single panel of plywood. The edges of the plywood are nailed and glued in the usual manner with a few brads

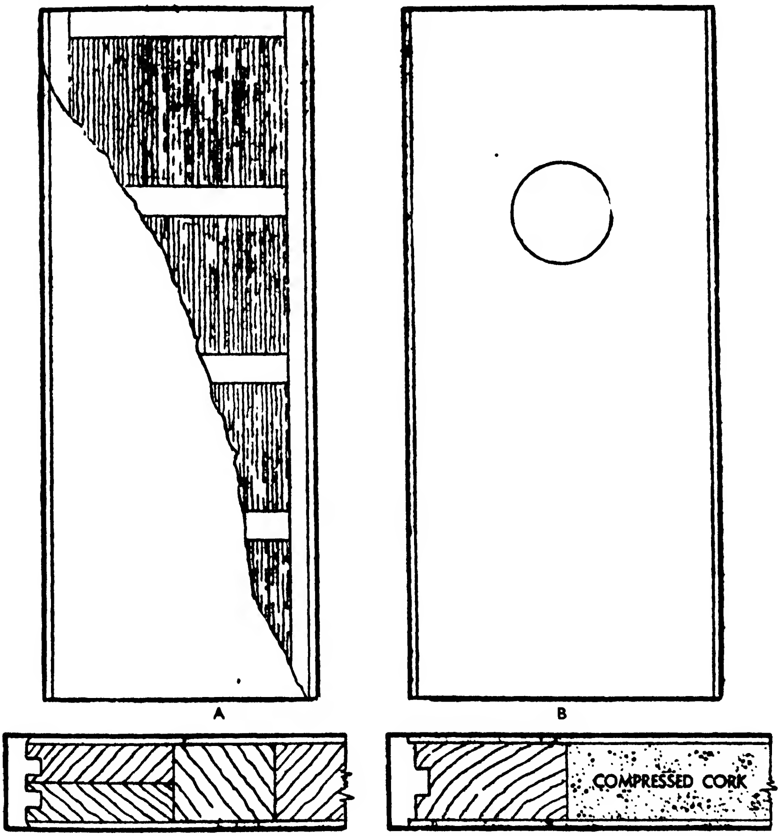


Fig. 21. A. Flush door with a solid filling. The core is laminated to prevent the door from warping and twisting. B. flush door suitable for hospital. A circular observation panel is fitted at a height of from 4 ft. 9 in. to 5 ft., with a tendency to the low size rather than the higher. The filling is of compressed cork.

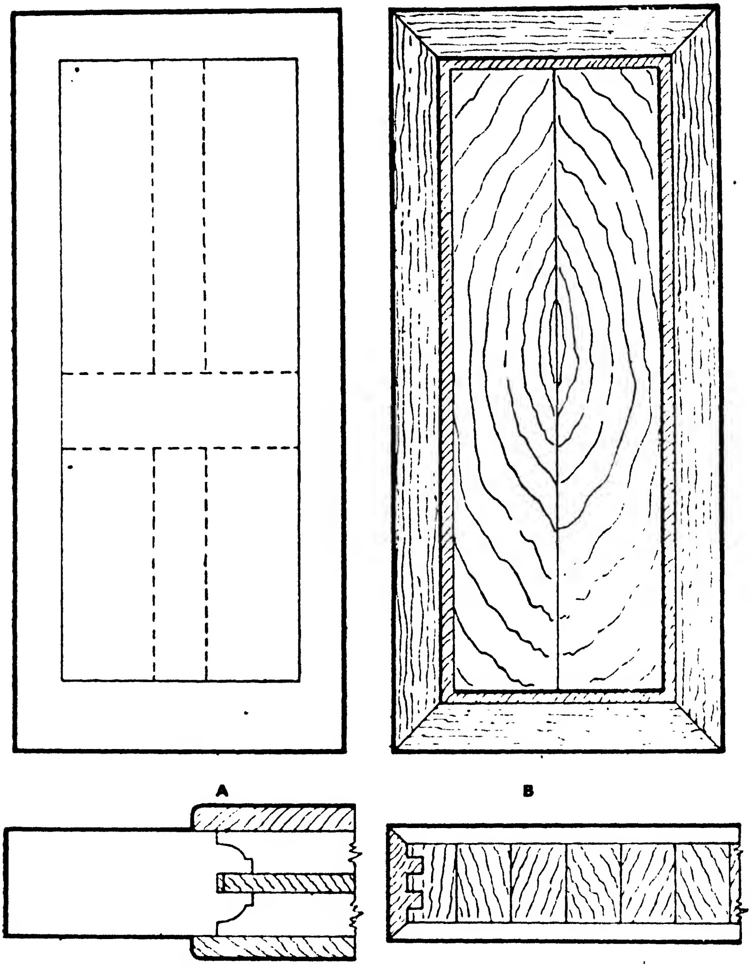


Fig. 22. *A*. Method of converting an ordinary four-panelled door into semi-flush door by fixing plywood panels over face ; *B*. laminboard covered with veneer.

to hold the panel against the muntins and rails. This is quite an easy job and can be accomplished by an intelligent apprentice.

A more ornate type of flush door is shown in Fig. 22 B. Construction can be as previously described, or a piece of solid laminated blockboard can be used. The veneered ply panel should be made up by the veneer-layer before the panel is pressed to the core. The edging fillets are mitred as shown.

A modern application is the use of sponge rubber to the door stop (Fig. 23 A). In a large building, especially one with long corridors and many doors, this type of door stop is very effective in reducing the noise from closing doors. Fig. 23 B shows how to seal effectively the joint between door and frame in the case of gastight rooms.

How to provide a door and frame giving protection against X-rays from an unscreened machine sometimes used in hospitals is given in Fig. 23 C.

A door for cold storage purposes is usually over 4 in. thick and is very heavy (Fig. 23 D). It is made by firms specialising in this class of work. It is essential that all the rebates should fit, and the use of felt will help considerably. The door can be hung in the frame and the whole unit built in. Special hinges are necessary in order that the bevel on the edges of the door easily clears when the door is being opened. Good dry timber is essential and every care has to be taken in the manufacturing stage to ensure that the door is out of winding and correct to size. This is an example where it is better to make the frame to suit the door, than the other way round.

Generally, the manufacture of the doors described requires certain conditions, and these can be summarised as follows:—

That the core frames are glued up true and out of winding; that the timber and plywood are of the correct moisture content; that the edging pieces are not cleaned off until the adhesive is thoroughly set; that the door when finished should be protected either with paint or polish before delivery to the site; that the tops and bottoms of the doors should be painted; and that the doors should be effectively protected during transit.

By arrangement with the building contractor, the doors can be mortised for locks and recessed for butts before delivery, but success of this arrangement depends

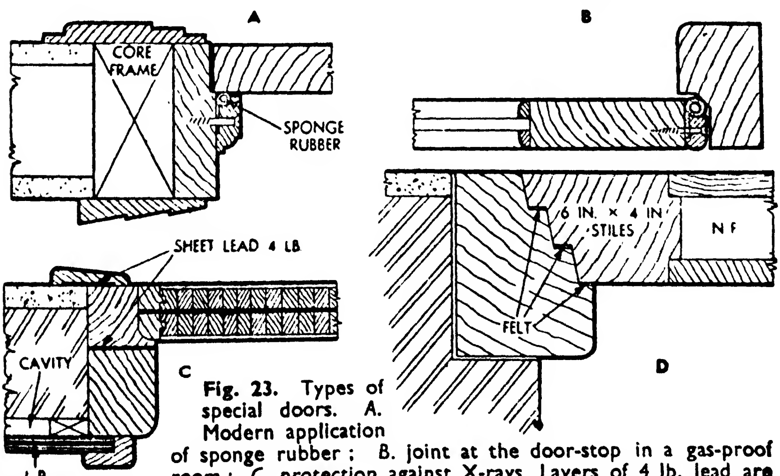


Fig. 23. Types of special doors. *A.* Modern application of sponge rubber; *B.* joint at the door-stop in a gas-proof room; *C.* protection against X-rays. Layers of 4 lb. lead are inserted in the points shown. 12 m/m lead core plywood (LP) is used to line the walls of the room. *D.* refrigerator door with insulating core filling (*NF*).

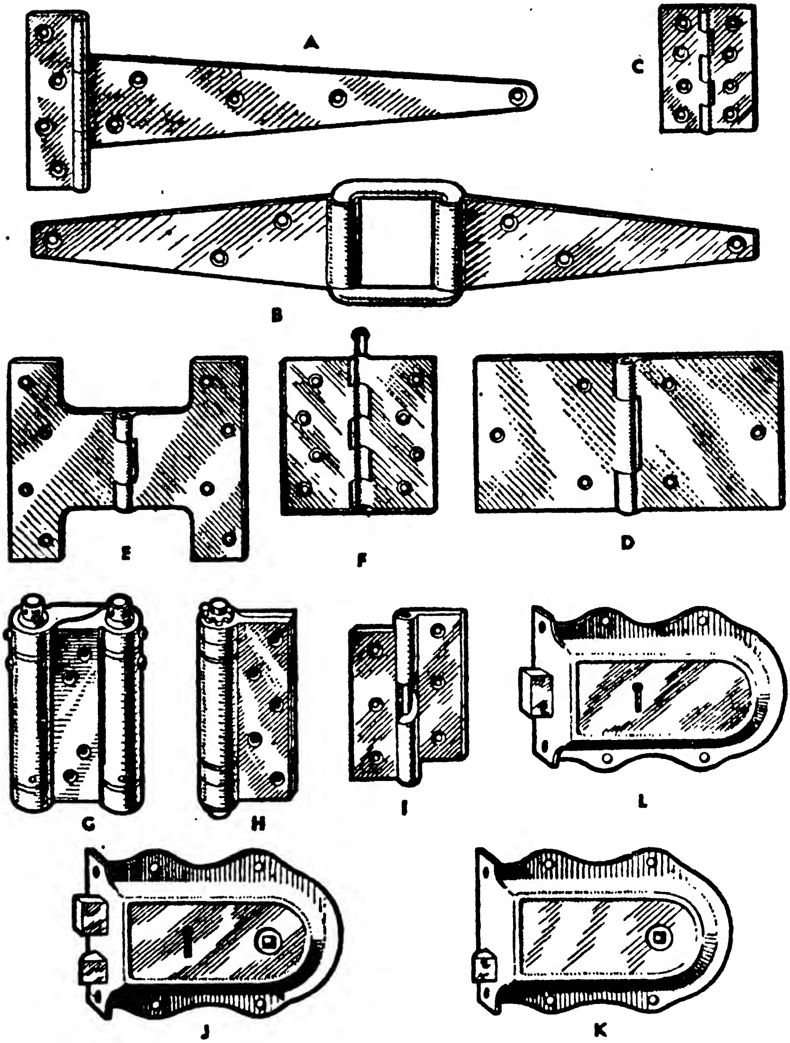


Fig. 24. Types of door furniture. *A.* Cross garnet or tee hinge ; *B.* strap hinge ; *C.* butt hinge ; *D.* back flap hinge ; *E.* parliament hinge ; *F.* butt hinge with a detachable pin ; *G.* helical spring hinge for double-action doors ; *H.* single-action door spring ; *I.* skew or rising butt hinge ; *J.* rim lock, with latch and lock ; *K.* rim latch, without lock ; *L.* dead lock (lock but no latch).

upon the doors being manufactured to give the correct clearance, and the door frames being fixed plumb and parallel.

Fig. 24 shows types of hinges. Where a large quantity of doors of similar design is required, such as in a hotel, the doors can be hinged to the linings and braced before delivery, but it is absolutely essential that brick or core frames are fixed in situ first.

CHAPTER 9

WINDOWS AND SKYLIGHTS

SELECTION OF TIMBER. DRIPS. WATER BARS. TYPES OF WINDOWS. GLAZING BARS. STAYS AND FASTENERS. CASEMENT CONSTRUCTION. SASH DOORS. DOUBLE-HUNG SASHES. SKYLIGHTS. LANTERN LIGHTS. PIVOT-HUNG SASHES. BORROWED LIGHTS.

EXTERNAL joinery is wholly or partly exposed to the elements. It must therefore be designed, prepared, assembled and protected in such a manner as to render it capable of resisting the action of the weather. All joints at opening members must be made watertight, and provision must be made for the swelling and shrinking of the material due to changes in humidity.

Use of Softwood

Domestic joinery is generally made from softwood. European redwood is largely used because of its reasonable initial cost, high weathering properties, and good finishing qualities. It is particularly suitable for painting.

The durability of redwood is judged by the compactness or density of the wood structure. Fig. 1 A shows the cross section of a piece of redwood in which the sapwood, heartwood and growth rings are distinctly visible. Timber of this species whose growth rings are wide apart should be avoided. The widely spaced rings indicate a quickly grown tree, the timber of which is inferior in strength and resistance to weather to that of a slow grown tree, whose growth rings are fairly close.

Sapwood, as shown in Fig. 1 A, is more absorbent than heartwood, and if placed in an exposed position will take up moisture more readily than the heartwood portion. This tendency to absorb moisture results in excessive shrinkage when dry and excessive swelling when the atmosphere is wet. To give a lasting and satisfactory service, this unstable condition must be avoided in all work.

It is essential that the softwood timber used for external joinery should be of heartwood, with growth rings not more than 18 and not less than 8 to the inch. It should be free from large knots likely to cause weakness in the structure, and small dead knots which tend to form defects in the surface. Unsightly work is often caused by the timber shrinking back and leaving the knot protruding over the face of the work.

Cutting out Sapwood

When a particular piece of "stuff" which contains a certain proportion of sapwood has to be used, the sapwood portion should be arranged so that it gets the most protection possible. The

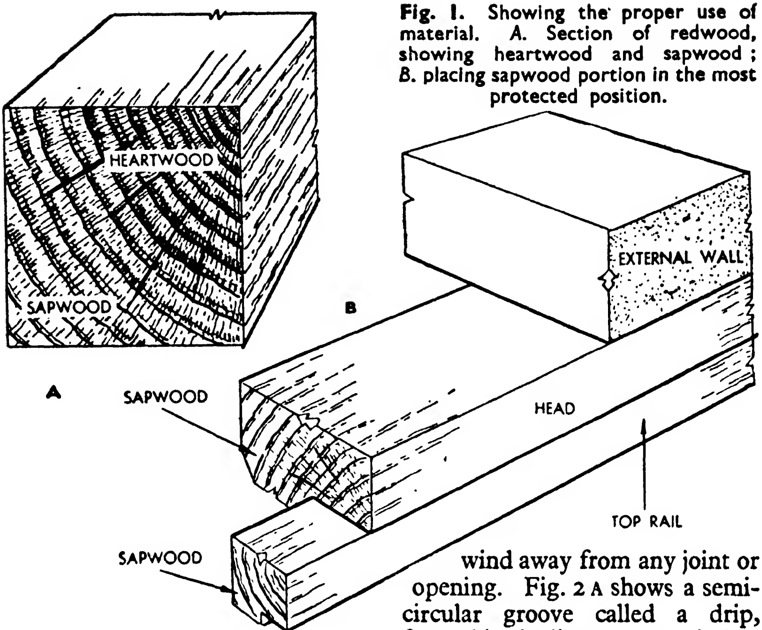


Fig. 1. Showing the proper use of material. A. Section of redwood, showing heartwood and sapwood; B. placing sapwood portion in the most protected position.

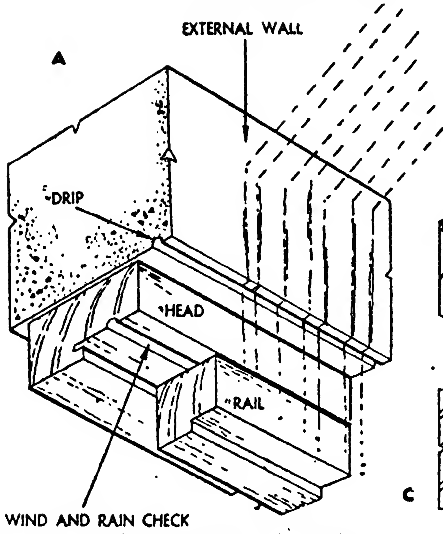
best results from indifferent timber can only be obtained by taking extra care in cutting-out and marking-out.

Fig. 1 B shows an example of how the selection and protection of doubtful timber can be arranged. The sapwood portion of the top rail is protected by the head of the frame, while the sapwood portion on the head is in turn protected by the brickwork or concrete of the external wall. Both layers of sapwood are placed on the inside of the window. With the selection of good material, careful design will ensure that each particular member has the necessary protection.

Any projection that may be provided in the external construction of the building, or in fact any joinery unit, should be arranged to deflect the rain and wind away from any joint or opening. Fig. 2 A shows a semicircular groove called a drip, formed in the lintel over a window opening, to throw off the drips or drops of rain which otherwise would tend to run down the face and underneath the lintel.

Similar protection may be given by a lead cloak or other flexible damp proof cover fixed to the head of the window. This can be fixed to the head with copper or zinc nails, as shown in Fig. 2 B. Protection can also be afforded by means of overhanging eaves, canopies, or by the joinery being fixed in a recess as shown in Fig. 2 C. This latter method gives a greater protective cover to a larger proportion of the timber.

Very often the provision of suitable drips and flashings to protect the joinery is not practicable in the design or construction of the building. Other ways have then to be adopted and this calls for special preparation in the



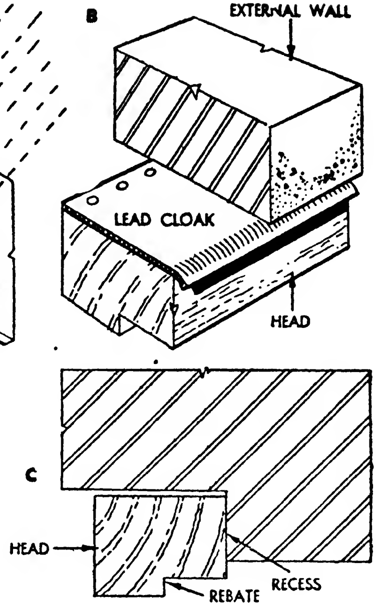


Fig. 2. A. Use of drips and checks to make windows weather-proof; B. lead cloak turned down over window head to form drip; C. protection of window head by means of a recess.

arrangement of the members or in the method of fixing the windows.

Fig. 3 shows an instance where the exclusion of the weather relies upon the joinery alone. Drips or overhanging projections are not available, and a lead flashing is not provided. To cover the joint between the head and the wall is a quadrant moulding bedded in a mastic composition. This mastic allows for any slight movement taking place without injury to its waterproof seal. A moulded weather board, tongued to the head, protects the joint between the head of the frame and the top rail of the sash underneath.

Weatherboards should be solid in section and shaped to avoid acting as a catchment or ledge for water. They should be solidly tongued to their respective members and provided with a groove for drip. Any planted mouldings or weatherboards fixed as separate members must be well painted with a red or white lead paint before fixing. The portion to be covered by them should also be treated. Teak or similar

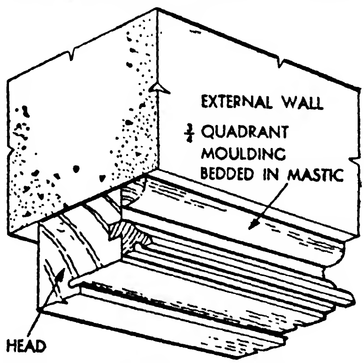


Fig. 3. An example of exclusion of weather depending upon joinery alone. The small quadrant is bedded in mastic to allow for movement and the moulded weather board in lead paint.

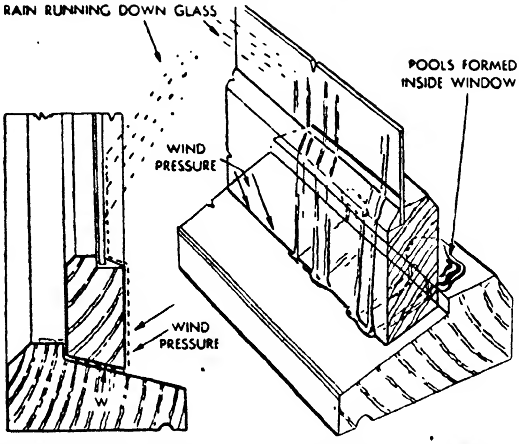


Fig. 4. Section and sketch of a window-sill. Creeping water started by capillary attraction at the sill (W) is forced by wind pressure, acting on the outside of the window, into the interior.

hardwoods are specially suitable for small external mouldings.

Rain flowing down the face of a window has a tendency to creep under the lower edge. As the joint between the opening window and its frame is usually about $\frac{1}{16}$ in., capillary attraction induces the moisture to collect under the edge of the rail and to creep along the joints. It only requires a slight wind to force the water up inside the window as shown in the section and sketch of Fig. 4.

This can be avoided by a groove in the lower edge of the sash rail, as a drip or wind and rain check; by providing an additional groove, called a throating; and by bevelling or 'weathering' the sill to throw the water off the wall or sill underneath. These are clearly shown in the section and sketch (Fig. 5). The provision of check grooves and throatings reduces the wind pressure and stops capillary attraction through the joint between rail and sill.

Besides protection to the junction between the rail and sill, the joint between the wood sill and the wall underneath must be sheltered. To prevent the rain running back and percolating to the inside of the building the wood sill is usually mounted on a sill of stone, tile or other impervious building material, while the joint between the two is such as will form an effective bar to water penetration.

A *water bar* is a length of metal bedded in stiff lead paint or mastic, and tongued into both the wood sill and the stone sill so as to form an effective barrier against the passage of moisture. Fig. 5 shows a water bar in position. The bar should be of non-corrosive metal such as bronze, copper or galvanised iron. Lead cloaks and flashing can also be used under the wooden sills to act as 'weather bars.'

As the exclusion of water is of such a nature as to warrant special care and treatment, and as the foregoing has applied to windows opening outwards, it can readily be assumed that windows which open inwards present an even greater problem for the joiner to make weathertight. Because of the difficulty of obtaining a reasonably weathertight job, windows which open inwards are not used to the same extent as those which open outwards.

Types of windows in ordinary use can be classified as :—

(1) *Casement*, with sashes either fixed, or to open. Opening casements can be hinged at the side, top or bottom, to open inwards or outwards. Casements to open inwards are difficult to make watertight, and cause obstruction to the curtain furnishings. Hence casements are generally made to open outwards.

(2) *Sliding*, with sashes to slide horizontally or vertically. The latter are specified as *double-hung*.

(3) *Pivot-hung*, with sashes hinged on centre pivots.

Timber for windows is usually rebated, grooved and moulded in long lengths by a four-cutter or similar machine. After machining, the material is referred to as *sash stuff* or *frame stuff*. ' Stuff' is the joiner's term for any converted timber.

The sizes of the sections are smaller than the named sizes :—e.g., 2 in. by 2 in. sash stuff is actually between $1\frac{13}{16}$ in. and $1\frac{7}{8}$ in. square, while 3 in. by 4 in. frame stuff is approximately $2\frac{3}{4}$ in. by $3\frac{3}{4}$ in. in section. This difference of sizes is due to the loss of material in machining, together with certain shrinkage from the original sawn sizes. Therefore, the term *nominal* or the abbreviation *EX* infers that the finished section is prepared or machined out of the size stated.

For a small *single light* window, the frame may be constructed from material of rectangular section, and the rebates and mouldings formed by separate members called *stops*, which are either moulded, beaded or plain in section. Stops which are separate members are known as *planted stops*.

Fig. 6 shows the elevation and section of a simple single-light window suitable for a larder. The glazing portion at the top may be fitted with a gauze panel.

If the window is made by hand

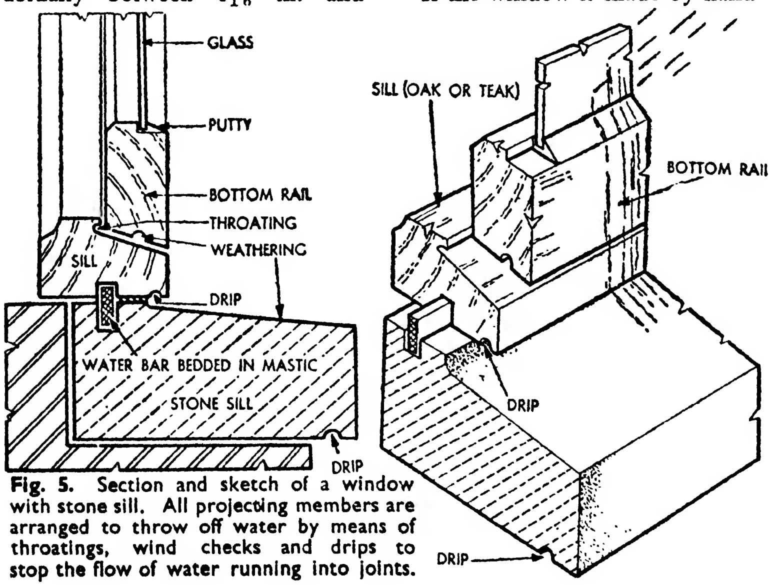


Fig. 5. Section and sketch of a window with stone sill. All projecting members are arranged to throw off water by means of throatings, wind checks and drips to stop the flow of water running into joints.

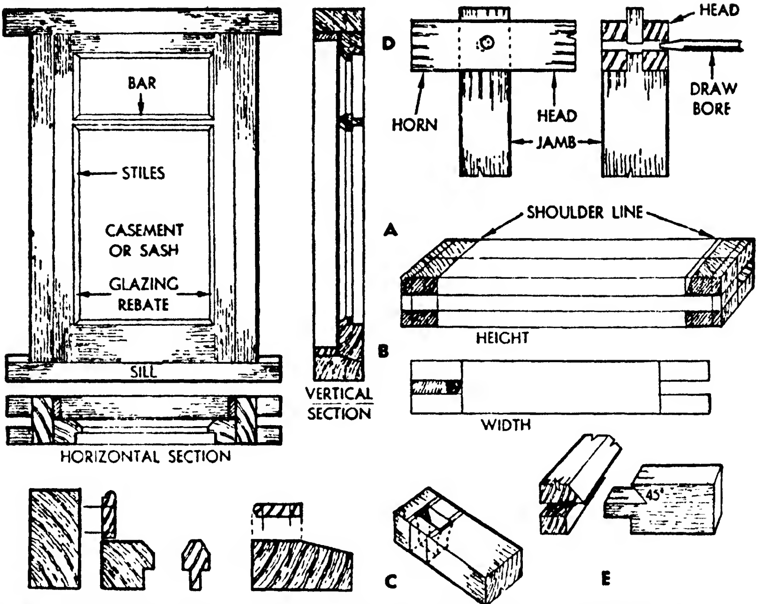


Fig. 6. Elevation and section of a single-light casement window with details of marking-out the material. *A.* Marking-out a pair of jambs. Note the shoulder lines and the set-back for bevel on sill ; *B.* slot mortise in the head and sill, a hole being bored to start the mortise ; *C.* sketch to show allowance for wedging where required ; *D.* elevation and section of joint with draw-bore pin; *E.* feather edge on a shoulder which is difficult to scribe.

methods, construction may be simplified by slot mortising the head and sill to the jambs. The tenons are pinned at the top and bottom to the head and the sill respectively. The frame is constructed from 4 in. by 2 in. section and has a planted stop, while the sash, light or casement is moulded and rebated from 2 in. by 2 in. solid wood.

The frame consists of two vertical members called *jambs*, with a top member called a *head*, and a lower member called a *sill*. The vertical members on the sash are known as *stiles*, the top member a *top rail* and the bottom member a *bottom rail*. A sash is divided into panes of glass by *sash bars* or *glazing bars*.

Measurements for the frame are taken overall (O/A), that is, from the outside edges of the jambs, and from the top of the head to the bottom of the sill. Dimensions should be made to suit brick sizes wherever possible.

The two jambs are set out as a pair, and from the overall size are deducted the thicknesses of head and sill with an additional allowance or *set-back* at the sill end for bevel or weathering (Fig. 6 A).

Head and sill are also marked-out as a pair, the thickness of the jambs being deducted from the overall width of the frame for the mortises, as shown in Fig. 6 B. The same gauging is used for the mortises and tenons.

If the joints are to be slot-mortised, the head and sill are sawn as shown in Fig. 6 B, a hole slightly smaller than the width of the tenon is bored as shown, and the waste wood cut out with a chisel.

When the head and sill are mortised as at 6 C, an allowance is made on the mortise holes for the insertion of wedges. The cutting of a mortise is started from the wedging side and finished off from the face side.

If the frame is to be *draw-bored*, holes are bored in the head and sill before the frame is assembled. When the frame is assembled, the positions of the holes are transferred to the tenons, the frame taken apart, and then holes bored in the tenons $\frac{1}{16}$ in. nearer the back edge of the shoulders as indicated in Fig. 6 D.

The object of draw-boring is to provide a means of pulling up and holding the joint; as the two holes are offset, a pointed pin will pull the joint together.

Nail Fixing

Additional fixing can be obtained by nailing, using 5 in. wire nails through the outside of the head and sill into the tenons. Care must be taken not to place a nail in any position likely to be cut when the window is fixed.

The stops are scribed and mitred round the inside of the frame, glued, and fixed with oval brads or panel pins, care being taken to ensure an even margin on the rebate thus formed. The stops may be fixed after the sash has been hung to the frame; if the sash is twisted the stops can be adjusted to suit.

The sash is marked-out in a similar manner to the frame, care being taken to arrange such members as stiles and rails to face each other in pairs.

Fig. 7 shows the joints usually used when a sash is made by hand methods. The mouldings can be either scribed or mitred at their intersections according to their shape and size. Where the section of a moulding has an angle of less than 45 deg. (Fig. 6 E) it is not easily scribed by hand and should be mitred. If scribed, it is liable to damage in cleaning up.

The remainder of the joints shown in Fig. 7 are scribed joints. With the aid of machinery the scribing can be cut the full width of the shoulder to give a

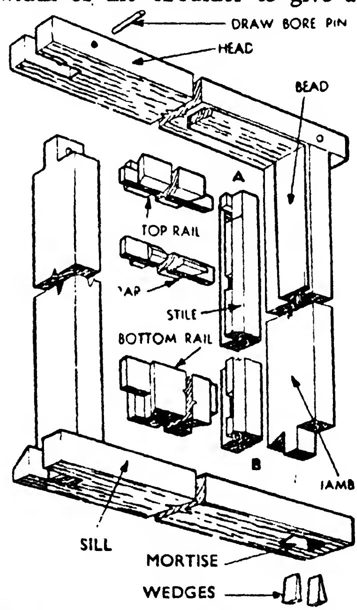


Fig. 7. Isometric view of separate members in single-light casement. Joints to the frame on the left are slot mortised, and those on the right mortised and wedged. A. Hand-made sash joint; B. machine-made joint.

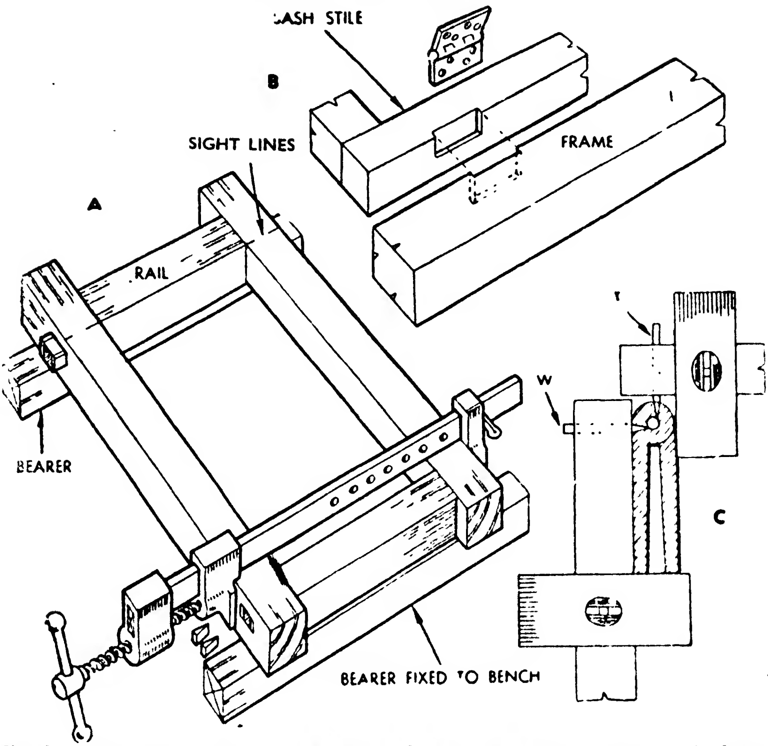


Fig. 8. Cramping a sash. *A.* Bearers are fixed to the bench at each end of sash to ensure a true flat surface. In wedging, the outer wedges are driven in first to keep sight lines clear at the joint. *B.* sash and frame housed to receive butts ; *C.* setting marking gauges for the hinge housings. The pin of gauge *T* is set $\frac{1}{32}$ in. from centre of rivet, and pin of gauge *W* is set $\frac{1}{16}$ in. from rivet.

simpler and slightly stronger joint than the hand made joint. All joints to the sash should be glued with waterproof glue, and the sash cramped and squared with a squaring rod before the wedges are driven in.

It is important to make sure that the rail is fitting at the sight lines before commencing to wedge. The outer wedges should be partly driven in first to ensure a tight joint at this point as shown in Fig. 8 A.

After cleaning up, the sash is fitted to the frame with an allowance of $\frac{1}{16}$ in. all round the sash. This is to allow for movement of the sash in wet weather and also for painting. Should the sash be a fixed-light, then it is fitted with a reasonably tight joint. The edges and the rebates of the frame should be painted before a fixed light is fastened in the frame.

Butt hinges are usually used for hanging sashes to frames. After the sash has been fitted to the frame, the positions of the butts are marked on both the stile of the sash and the jamb of the frame. Two gauges are required for marking-out the housing for the hinges. Depth of housing is obtained by setting a marking gauge to within $\frac{1}{32}$ in. of the centre of the butt (Fig. 8 c). When this distance is transferred to the stile and jamb it will leave $\frac{1}{16}$ in. for the joint.

The amount the butt is housed in the back of the sash depends on the position of the sash in relation to the jamb. For a window whose sash is flush with the outside of the jamb, a gauge is set from the centre of the knuckle as shown in Fig. 8 c. These gaugings are used for both sash and frame.

In large joinery works cramping is done on a machine which has shoes along each side that can be adjusted to allow the whole of

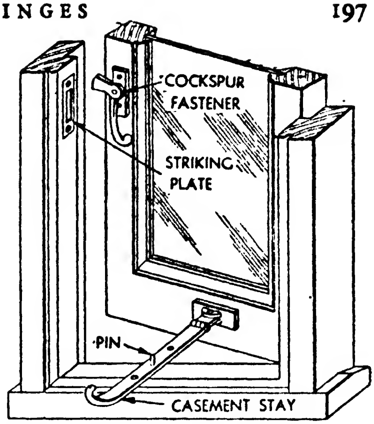


Fig. 9. Fasteners for a casement which opens outwards, showing fittings.

the sash or frame to be cramped.

Housings for the butts are also

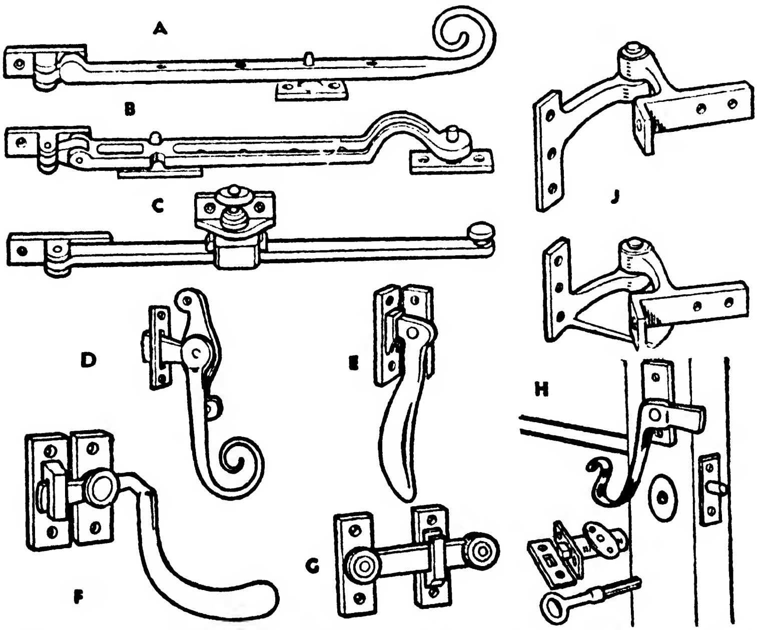


Fig. 10. Types of casement fittings. A. Casement stay, single pin, outward opening type ; B. double-locking stay for outward opening ; C. friction stay for inward opening casement, with end plate fixed to the sash, and the centre plate fixed to the frame ; D. and E. cockspur casement fasteners for sashes to open outwards ; F. and G. fasteners for sashes to open inwards ; H. fastener in position with locking arrangement, details of which are shown in inset. J. casement hinges, to allow windows to be cleaned from inside.

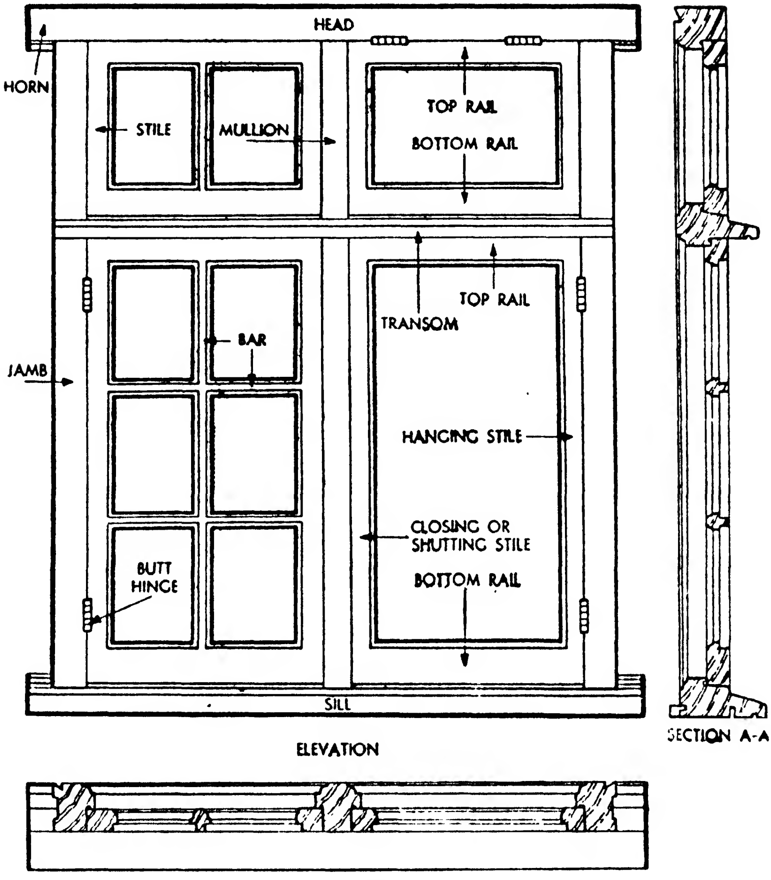


Fig. 11. External elevation with vertical and horizontal sections of a four-light casement window. The left-hand side shows arrangement of glazing bars.

cut by machine, leaving the joiner to fit the sash and fix the screws.

Fastenings to casements are usually of the cockspur or stay type as shown in Fig. 9. Note the striking plate can only be fixed one way in the type shown, as there is a bevel inside the plate mortise which assists in pulling the sash tight to the stop.

Several types of stays and fasteners suitable for inside or outside opening sashes are shown in Fig. 10. Locks or bolts are sometimes fitted to casements. The mortise bolt shown in Fig. 19 is a good type of bolt because the key can be taken out when necessary.

The casement shown in Fig. 11 is known as a *four-light* casement. The frame is mortised and tenoned throughout, and has an upright centre member called a *mullion*, and is divided horizontally by a member called a *transom*, the section of which follows the line of the sill. Upper sashes are termed *fanlights;* their construction is exactly the same as the casement sash.

The names of window members such as head, sill, jambs, mullion and transom, remain unaltered for all window frames, but each may have its own singular specification. For example, for the window shown in Fig. 11 the specification would ask for jambs and head to be ex. 3 in. by 4 in. solid moulded, rebated, throated, and keyed for plaster, as shown more clearly by the section in Fig. 12. Mullion, ex. 3 in. by 4 in. twice solid moulded, rebated and throated. Transom, ex. 3 in. by 6 in. twice moulded, rebated, double sunk and weathered, throated and grooved for drip. Sill, ex. 3 in. by 7 in. solid moulded, double sunk and weathered, throated, grooved for water bar and drip. It would also state which sashes are to open, how the fanlights are hung and the type of fastening.

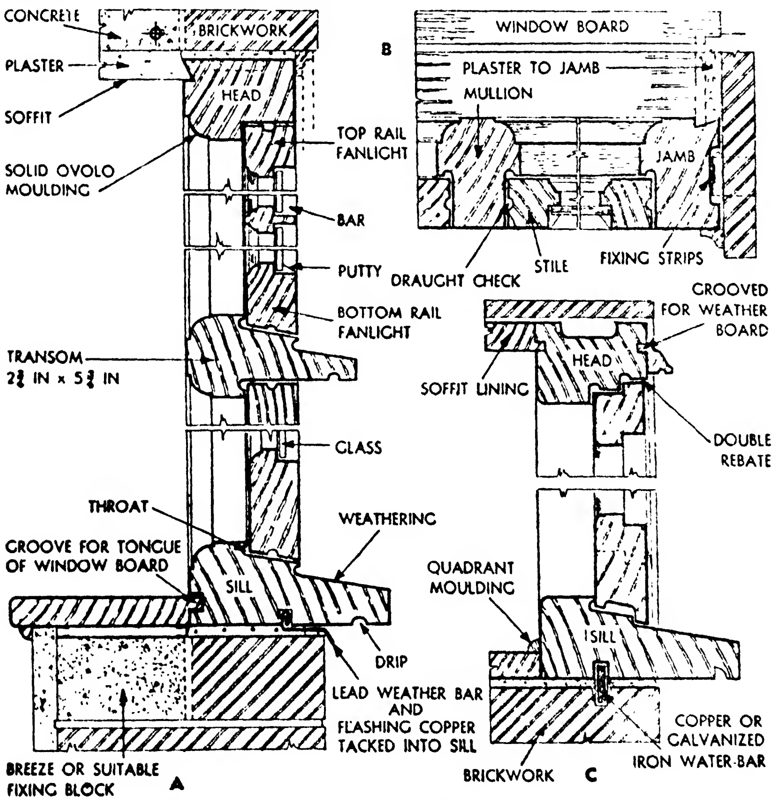


Fig. 12. Details of ovolo moulded four-light casement window. A. Vertical section showing head, transom and sill ; B. horizontal section showing mullion and jamb ; C. alternative vertical section with different details of head and sill.

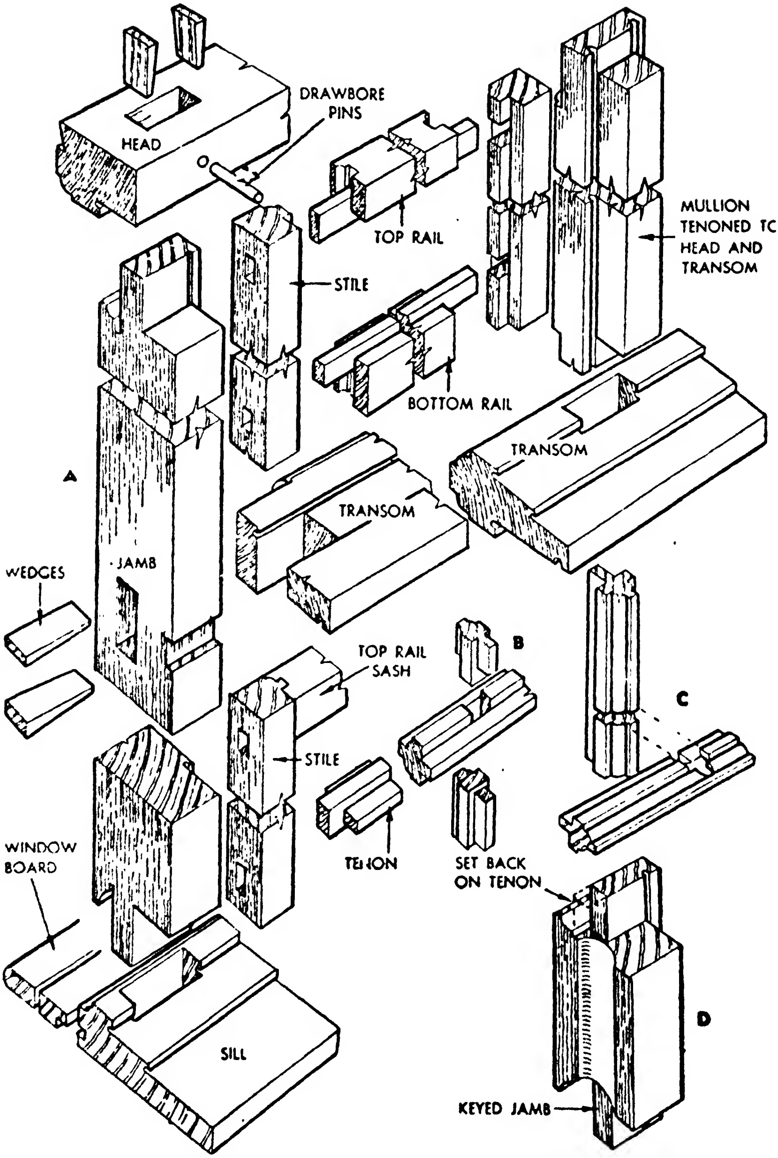


Fig. 13. Pictorial views of joints in a four-light casement window. *A.* Transom shown housed into jamb ; *B.* joint of sash bars mortised and scribed ; *C.* joint of sash bars halved and scribed. Note the jamb tenoned to head and sill ; mullion tenoned to head and transom ; and also how the mouldings are scribed throughout ; *D.* detail of the window jamb which is grooved for mortar key, which requires the set back on the tenon.

The detailed construction of a four-light window is shown in Fig. 13, where all the joints can be readily seen. It should be noted that the transom is housed into the jamb to prevent rain entering at this point.

All joints are scribed, and the frame and sash are assembled in a manner similar to that previously described. Sash bars may be mortised and scribed, or halved and scribed or mitred. Bars in sashes and fanlights are arranged to hold the stiles or rails of a sash; therefore sashes which are hung at the sides should have the horizontal or lay bars continuous, while the vertical bars are tenoned into them. Fanlights or sashes hung at the top or bottom should have the vertical bars continuous and the horizontal bars cut. This strengthens the sash in places where it is subject to most stress.

Width of tenons in sashes should be from one-half to five-eighths the width of the rail, while the thickness should be one-third the thickness of the sash or ½ in., whichever is the less. Usually tenons to sashes are made ½ in. thick as this is the amount of the square on the sash. This arrangement simplifies marking-out and reduces operations in machining.

Bay casements can also be arranged in any desired shape to any plan. Square, semi-circular, segmental and "cant" bays of 30 deg., 60 deg. and 45 deg. of regular formation are most used.

Construction, while closely following the lines of the casement, differs in certain respects. The main difference is in the section of the mullions, as shown in the plan of the segmental bay, Fig. 14 A, and the *cant bay* plans at Fig. 14 B and C. The mullions must be

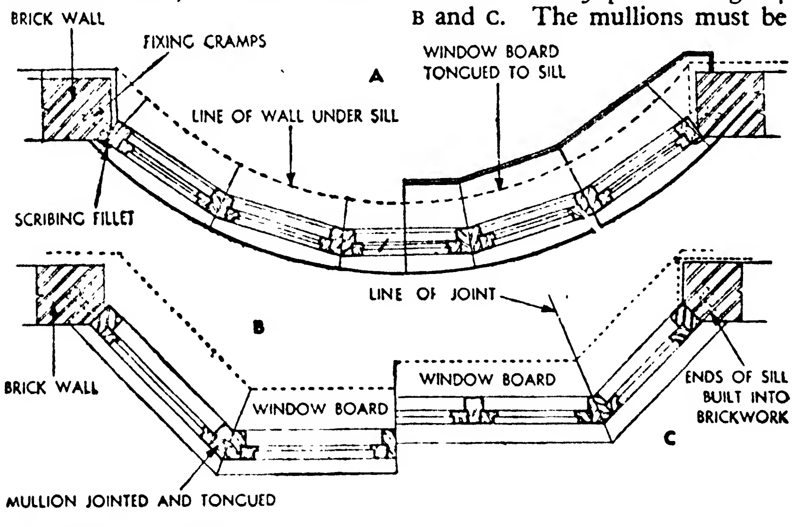
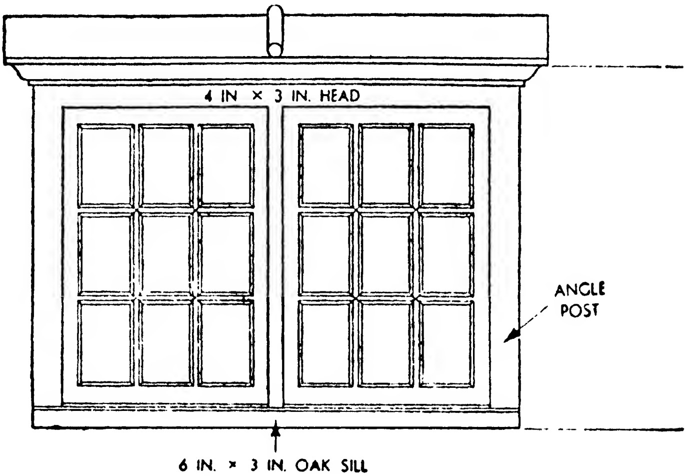


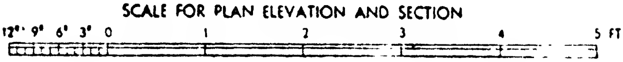
Fig. 14. Bay Windows. *A.* Plan of five-light segmental bay window, in which the joint lines of sill and head radiate to a common centre; *B.* half-plan of four-light "cant" bay. The cant is 45 deg. and the mullion is mitred, tongued and grooved; *C.* half plan of five-light cant bay.

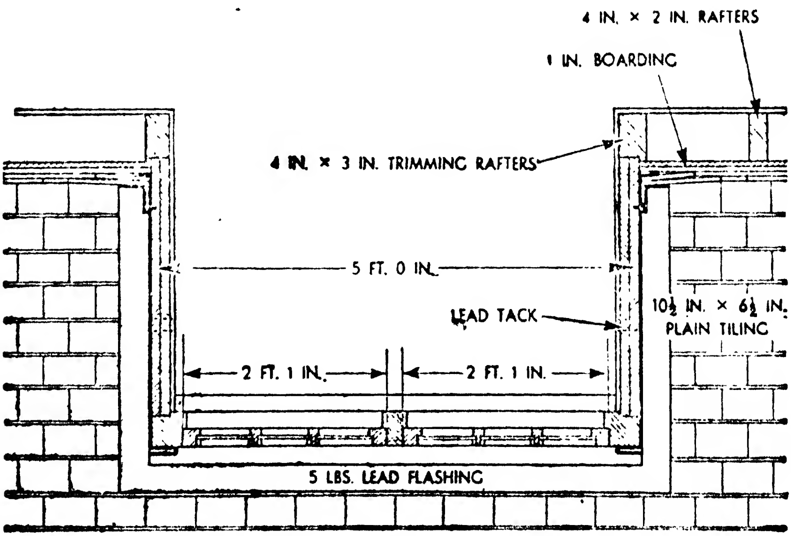
Windows to rooms within the roof space of a building may take the form of a dormer as shown. This detail drawing shows the type of working drawing which is supplied by the architect. Note how the window itself follows the method of construction which is described in the text.



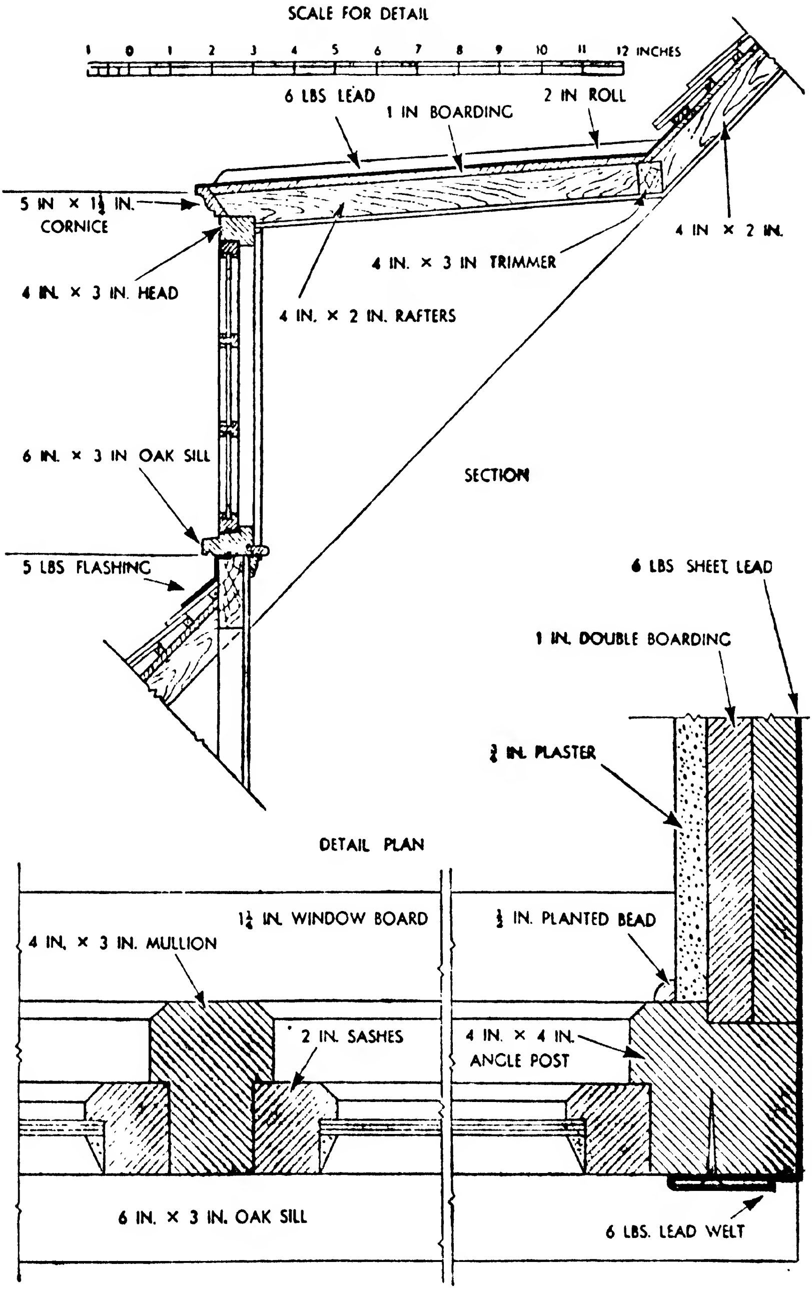
ELEVATION

SCALE FOR PLAN ELEVATION AND SECTION





PLAN


SCALE FOR DETAIL
1 0 1 2 3 4 5 6 7 8 9 10 11 12 INCHES
6 LBS LEAD
1 IN BOARDING
2 IN ROLL
5 IN × 1½ IN. CORNICE
4 IN × 2 IN.
4 IN. × 3 IN TRIMMER
4 IN. × 3 IN. HEAD
4 IN. × 2 IN. RAFTERS
6 IN. × 3 IN OAK SILL
SECTION
5 LBS FLASHING
6 LBS SHEET LEAD
1 IN. DOUBLE BOARDING
¾ IN. PLASTER
DETAIL PLAN
1¼ IN. WINDOW BOARD
½ IN. PLANTED BEAD
4 IN. × 3 IN. MULLION
2 IN. SASHES
4 IN. × 4 IN. ANGLE POST
6 IN. × 3 IN. OAK SILL
6 LBS. LEAD WELT

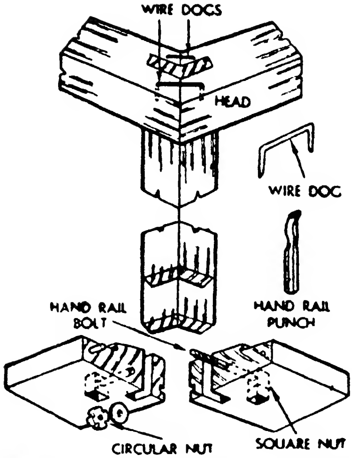


Fig. 15. Joints between the head mullion and sill in a bay window. The head is slot-mortised and is held together by wire dogs. The mullion is tenoned into the sill. The sill is mitred and held by handrail bolt.

shaped to the internal and external faces of the head as well as being arranged to receive the casement sashes.

While it is usual to machine the mullion from one piece of wood, it can be formed of two members bevelled and tongued together to form the required section. As the formation of the bays is in separate ' breaks,' each corner mullion forms in effect a jamb to its adjacent sashes, and where a transom is used, it is cut and tenoned into the corner mullions as shown in Fig. 13 A and the overhanging portions are mitred together.

The construction of the head and sill joints is shown in Fig. 15. Both are mitred together with slot mortises for the mullions. Fixing at the head is simple owing to the smaller sections, and the joint can be nailed, dogged, or draw-bore pinned together. The sill must have more adequate fixing because of its position and larger section.

The sill may be halved and mitred or tenoned and mitred, but the usual practice is to mitre the ends and bolt them together with a double-headed handrail bolt as shown in Fig. 15. Tongues or dowels should be used to prevent the sills twisting. Wire nails are used to fasten the mullions to the head and sill or hardwood pins inserted through the tenons.

Windows with fanlights are preferably arranged with transoms as previously described, but a cheaper method can be adopted by omitting the transom and rebating the sash and fanlight together. This is known as the split transom type, but the name is a misnomer and would be better described as a *split rail* casement.

The sash and fanlight are framed up complete, and after cleaning up, the stiles are cut through to form a separate sash and fanlight, with the meeting rails rebated together. As these windows are used in casements of more than one light, the adjoining sash is framed up to match the split rail fanlight sash.

In these windows it is usual to open the fanlight of one light and the complete sash of the next light. The method of construction and the manner of indicating which sashes are to open is shown in Fig. 16.

In the casements dealt with, the construction follows orthodox practice, but special types of *weather-proof* windows of patent construction are made. In these the normal practice of keeping a fairly tight joint of $\frac{1}{16}$ in. between the sash and frame, is countered by making special provision for any ingress of rain to be effectively trapped and led away. The larger air spaces between the sash and frame also help to dry the remaining moisture.

Where wall space is limited, a window frame and door frame may be formed in one unit called a *combined frame*. The construction of the frame and even the sections of the members are similar to a casement window with a transom.

Standard doors may be used, either half or fully glazed, while the complete frame may be of single or double light construction as shown in Fig. 17 A and B. Sections of door jambs vary according to the manner of fixing the door and the arrangement of the adjacent sashes. Where the section makes provision for a side light, it is shaped as a mullion, except that one rebate is stopped at the sill.

In Fig. 17 C and D show half elevations of alternative forms for a frame using purpose-made casement doors to open outwards, side or *wing* lights, and fanlights. At C the door only has glazing bars; these are of $1\frac{1}{4}$ in. by 2 in. section, and are placed horizontally; they serve to tie the 2 in. by 3 in. stiles together. Fully glazed doors without bars should have at least 2 in. by 4 in. stiles, and should be glazed preferably with $\frac{3}{16}$ in to $\frac{1}{4}$ in. plate glass.

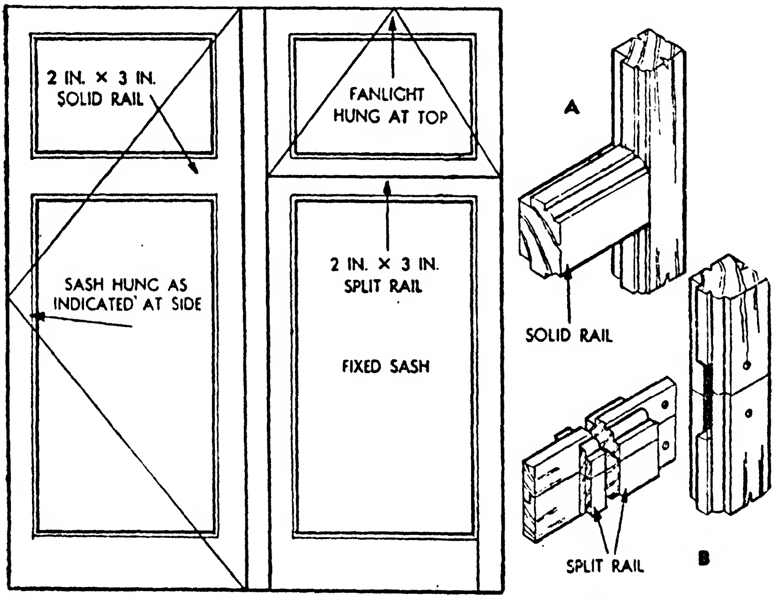


Fig. 16. Elevation of a pair of sashes, one of which is arranged to form a fanlight with a split-rail. The diagonals indicate which sashes are to open. A. 2 in. by 2 in. standard section of 'sash stuff,' with a 3 by 2 solid sash rail; B. split-rail sash and fanlight. After the sash is glued up and cleaned off the stile is cut through in order to form two sashes.

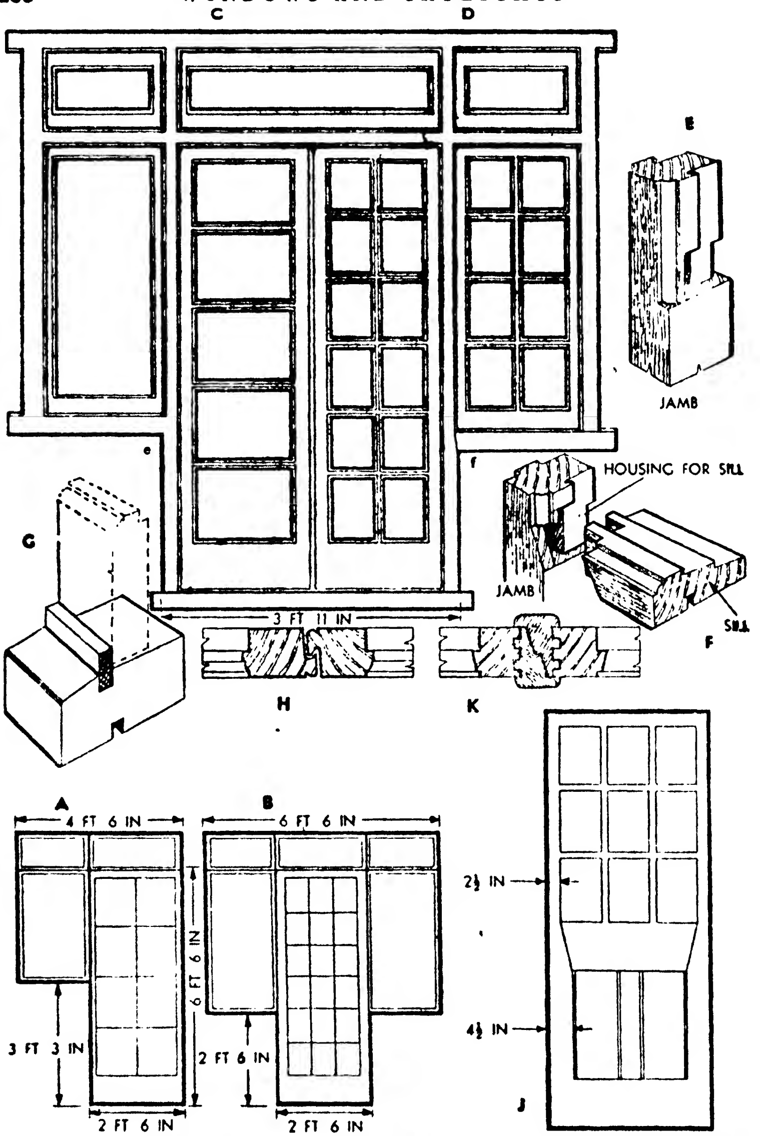


Fig. 17. Combined frames. *A.* Door frame with single wing-light and fanlights; *B.* door frame with double wing-lights and fanlights; *C.* half elevation of the frame with lay bars in the door; *D.* alternative elevation with small panes of glass; *E.* joint of the jamb at *e* and *F* the joint at *f.* In both cases the face of the sill is housed into the jamb to make a weatherproof joint. *G.* metal bar on the sill, giving better wear than a rebate cut in the wood; *H.* hook joint at the meeting stiles of the doors; *K.* alternative method of splayed and double-rebated edging tongued to the stiles; *J.* elevation of a half-glass door with diminished stiles.

Sight or glass lines should form a continuous horizontal line in both the door and the sashes, as shown in the elevations. Careful attention should also be given to the joint between the sill and the door jamb as shown in detail at E and F. In E the jamb moulding is run out on the spindle, and the sill is scribed over it, while in F the moulding is stopped and the shoulder of the sill is splayed. In both cases the overhang of the sill is housed into the face of the jamb in a manner similar to a transom housing in a casement window.

The sill forming the threshold of the door is not rebated, but has a metal bar tongued to the sill, as shown at G, to give a more lasting service against footwear.

The two casement doors are rebated together at the meeting stiles; to provide the necessary resistance against weather, the joint must be carefully made. Detail H shows a *hook* rebate joint, while K shows a double rebate and splayed joint in which separate members are tongued to the meeting stiles. This helps to stiffen the stiles, and prevents twisting as well as providing extra thickness for the additional rebates.

Sash doors are made to conform to the finish of a sash above the middle rail, and to the finish of a door below the rail. Detail J shows a half-glass door with diminished stiles whose upper part is glazed and whose lower portion is panelled with flush bead-butt panels.

Fastenings to sash doors are shown in Fig. 18 and should be of bronze or brass. In ordering certain casement *furniture*, that is, fittings and fastenings, the hand of the fitting should be stated. Reference to detail F shows how the correct hand is determined.

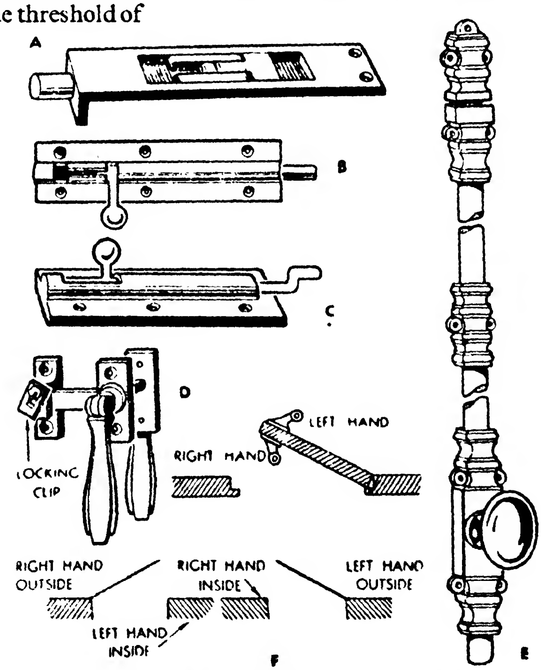


Fig. 18. Furniture to casement doors. Lever action flush bolt *A* is mortised or housed into the shutting stiles, and the bolt shoots into a plate on the sill. Barrel bolts may be straight as *B* or cranked as *C*. Casement door fastener *D* is accessible from inside and outside, but has a locking clip on the inside. *E*. espagnolette or casement bolt; *F*. how to determine the hand of casement fittings for ordering.

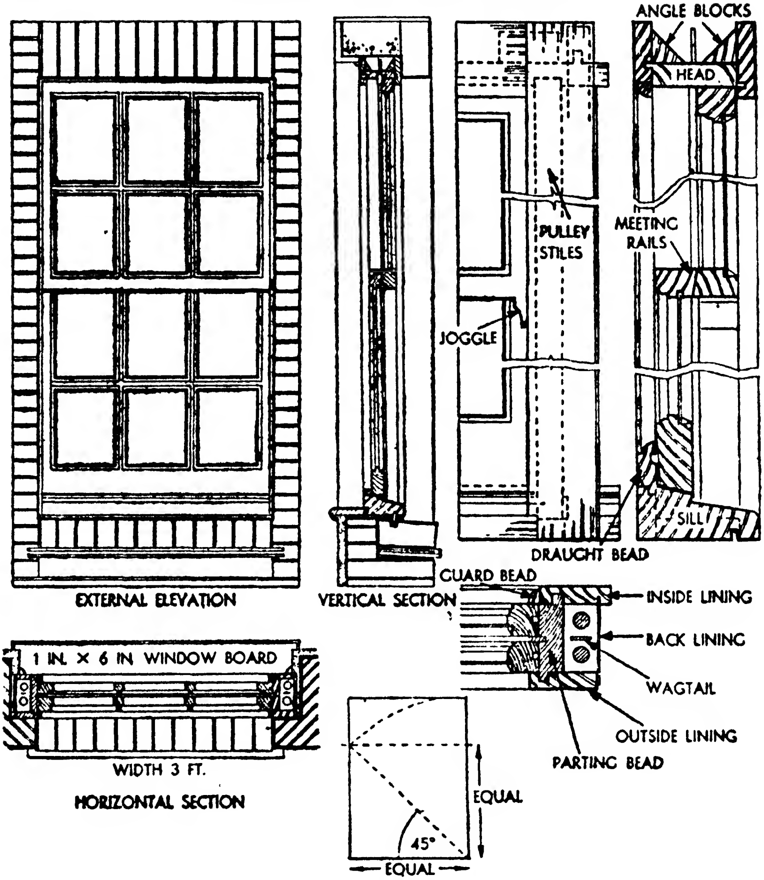


Fig. 19. External elevation and sections of double-hung sashes and frame. Sizes of frame should conform to brick sizes where possible. Measurement is overall sill and head for height, and overall box for width when fixed in square brick jambs ; between pulley stiles and under head to under sill when fixed in recessed brick jambs Inset shows how to determine a good proportion for panes of glass.

Sashes which slide vertically are known as *double hung sashes*, and sometimes as *cased* or *box frames*. Fig. 19 shows the external elevation and sections of a window of this type fixed in a wall 13½ in. thick with a 4½ in. recess.

The window is *sashed in squares*, that is, the sashes have vertical and horizontal glazing bars. A good proportion for the sizes of the panes is 5 units in width by 7 units in height. This can be set-out graphically as in the inset, where the diagonal of a square, whose side is equal to the width of the pane, is the height of the pane. This proportion is suitable for any door or window glazing. In practice the nearest convenient dimension for the window opening would be used, dependent on

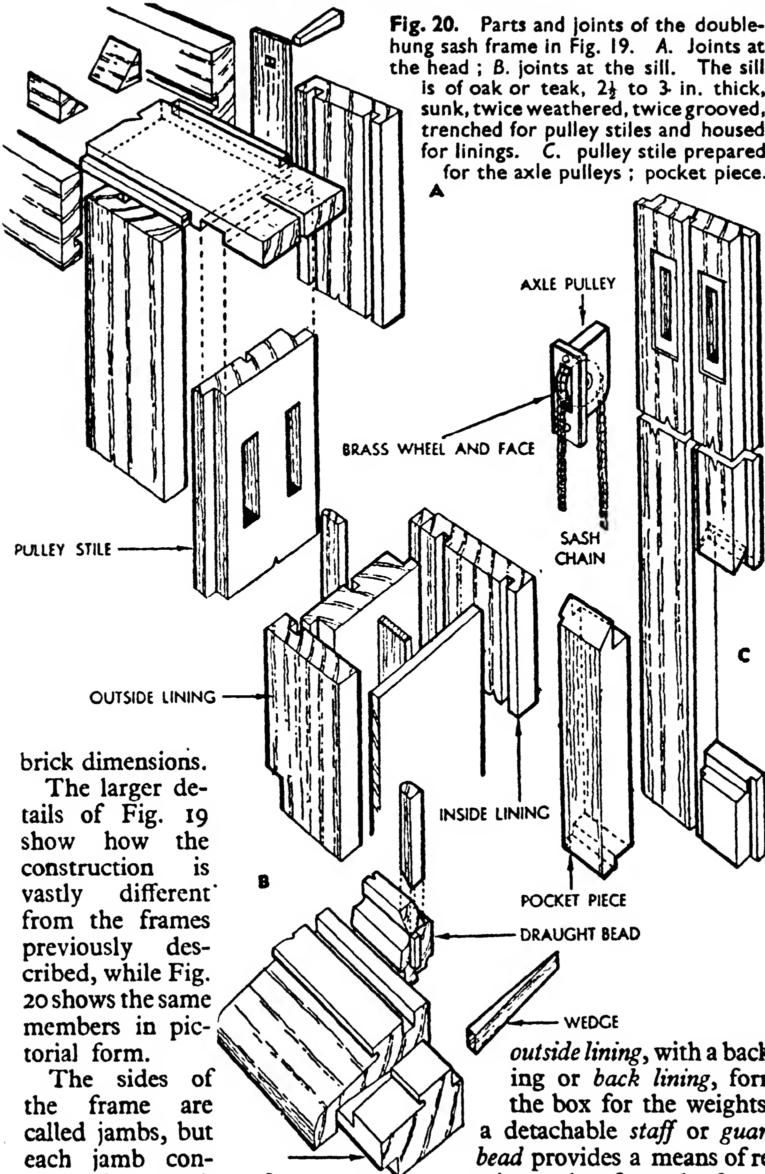


Fig. 20. Parts and joints of the double-hung sash frame in Fig. 19. *A.* Joints at the head ; *B.* joints at the sill. The sill is of oak or teak, $2\frac{1}{2}$ to 3 in. thick, sunk, twice weathered, twice grooved, trenched for pulley stiles and housed for linings. *C.* pulley stile prepared for the axle pulleys ; pocket piece.

brick dimensions.

The larger details of Fig. 19 show how the construction is vastly different from the frames previously described, while Fig. 20 shows the same members in pictorial form.

The sides of the frame are called jambs, but each jamb consists of a number of parts ; a *pulley stile* (Fig. 19), into which are housed the pulleys to hang the sashes, forms the main structure. An *inside lining* and an *outside lining*, with a backing or *back lining*, form the box for the weights ; a detachable *staff* or *guard bead* provides a means of removing sashes from the frame, while a *parting bead* divides the sashes, and a *parting slip* or *wag-tail* divides the weights.

The width of the pulley stile

is governed by the thickness of the sashes and the parting bead. Depth of box should be at least ¼ in. deeper than the thickness of the sash. Sashes are grooved at their top ends for the cords or chains to carry the balancing weights. Cords are nailed to the sashes with ¾ in. clout nails and are tied to the weights, while chains are fixed with a pin and staple to the sashes and with a split pin to the weights (Fig. 22 D). Weights, which must balance the fully glazed sash, are inserted into the box through a *pocket* cut in the pulley stile.

The pocket should be on the inside portion of the pulley stile and be the width between the guard bead and the parting bead. The tongue must be removed from the pocket to allow the pocket to be removed when re-cording the sash. A pocket should be 3 in. from the sill in a 3 ft. frame, to 6 in. for a 6 ft. frame. Length of pocket piece should be one-quarter the height of pulley stile.

The sill and head are housed for the pulley stile, as shown in Fig. 20, A and B. The sill may have a parallel housing or trenching similar to the head, or provision may be made for the insertion of a wedge as shown. The depth of the groove in the sill is governed by the amount of weathering, but in no case must less than 1¼ in. be left under the housing.

After the pulleys have been screwed into their housings in the stiles, the sill, head and pulley stiles are nailed together; the stiles must be parallel with each other and out-of-winding. If a wedge is used at the sill it should be glued and, after nailing, cut back to the pulley stile.

The skeleton frame should then be laid face downwards on the bench and held in position by screwing through a block fixed to the bench as shown in Fig. 21. The frame should then be squared with a rod, and the head temporarily fixed to the bench. Outer linings should then be nailed with 2 in. oval nails to the pulley stiles, sill and head. Any mitres at the head, or notchings to the sill, should be cut before the linings are fixed. Head linings are always fitted between the side or jamb linings.

After temporary fixings have been removed, the frame is

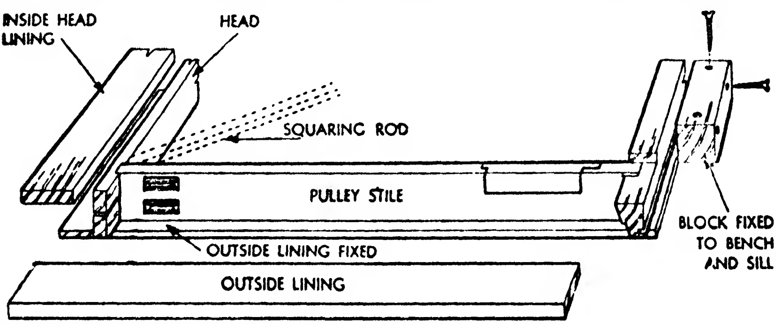


Fig. 21. How the window frame is held during the fixing of linings. A block is fixed to the bench and is screwed to the sill to hold the frame rigid. The frame is squared by use of a squaring rod to measure the diagonals.

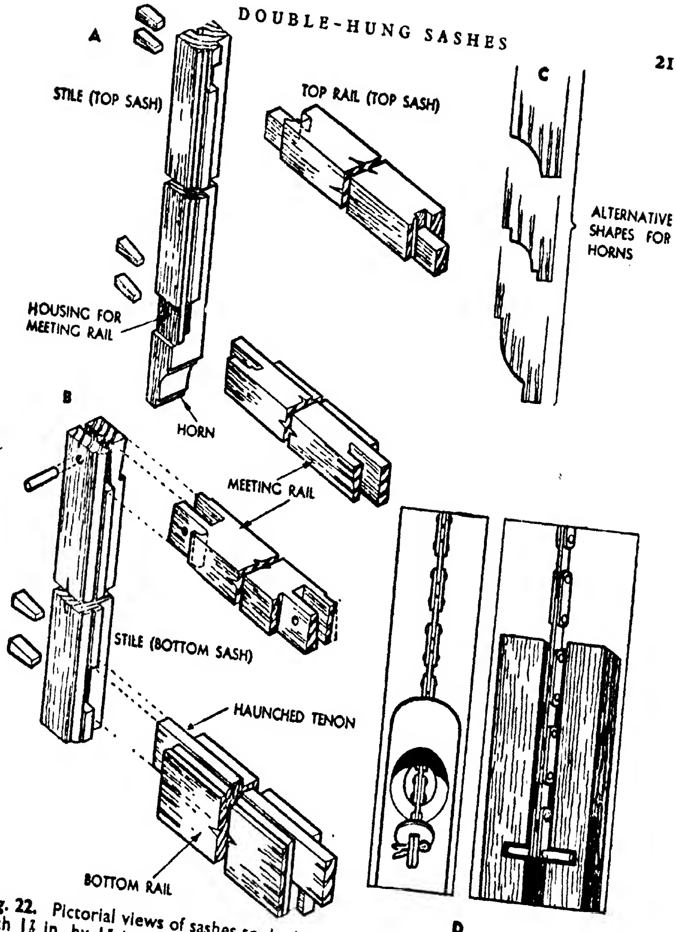


Fig. 22. Pictorial views of sashes to double-hung sashes and frame. *A.* Top stile with 1⅞ in. by 1⅞ in. top rail with haunched tenon and scribed moulding. The meeting rail is 1½ in. by 2¼ in., with a full width tenon and no moulding ; the horn or bracketted joggle gives support to the sash. *B.* meeting rail dovetailed to the stile in the bottom sash ; *C.* alternative shapes for horns ; *D.* method of connecting sash chain to weight by a split pin, and to sash by staples.

turned over, checked for square, and again fixed to the bench. Inside linings are then fixed in position. Where draught beads are used, they must be fixed before the linings. The pocket piece should next be released, if it has not already been done, and the parting slip inserted and the back lining nailed. Parting slips should be 2 in. to 3 in. off the sill and held at the top by a wedge or nail resting on the head.

Glued blocks are placed immediately behind the butt joints of the head and linings, with extra blocks between to give additional support. Parting beads and staff beads should then be cut to their respective places. The parting beads should be of a tight fit in the groove and should not require additional fixing, while the staff beads should be fixed temporarily until the sashes are inserted.

The top and bottom rails of the sashes are made as described for casements, but the meeting rails are of extra width to allow for rebating or bevelling over the parting bead as shown in detail in Figs. 19 and 22.

Vertical bars in sashes should be continued from the top or bottom rail to the meeting rail to give additional rigidity to the rails to resist the pushing and pulling in opening and closing the sashes. Horizontal or lay bars should be stub tenoned into the stiles and the vertical bars.

Fig. 22 shows the sash joints in pictorial form. When the joint between the meeting rail and the stile is a mortise and tenon, the end of the stile must be provided with a horn to give added strength. Sashes which finish flush at the meeting rail are slot dovetailed together and fixed with a screw or dowel, as shown at B. In both cases the wider meeting rail is housed into the stiles to a depth of ¼ in. as shown.

In ordinary domestic joinery, the tongue and groove joint to the pulley stiles is omitted and the linings merely nailed. Sashes are made from 1½ in. by 2 in. section and the linings from ¾ in. material. These sizes give a frame of just sufficient width to be accommodated in a 4½ in. recess.

Fig. 23 shows an alternative arrangement of sashes to slide vertically. A Pulman spring, housed into the jamb, provides the balance for the sashes, and instead of the complicated traditional boxing with weights, cords and pulleys, a frame similar in principle to a solid frame may be used.

Skylights

It is often necessary to provide additional lighting through the roof of a building, and to meet this need types of windows known as *skylights* are used.

All skylights present a difficult problem in maintaining weathertight joints

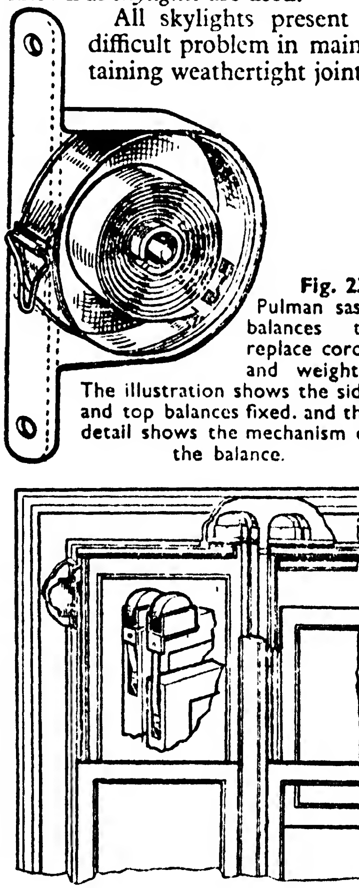


Fig. 23. Pulman sash balances to replace cords and weights. The illustration shows the side and top balances fixed, and the detail shows the mechanism of the balance.

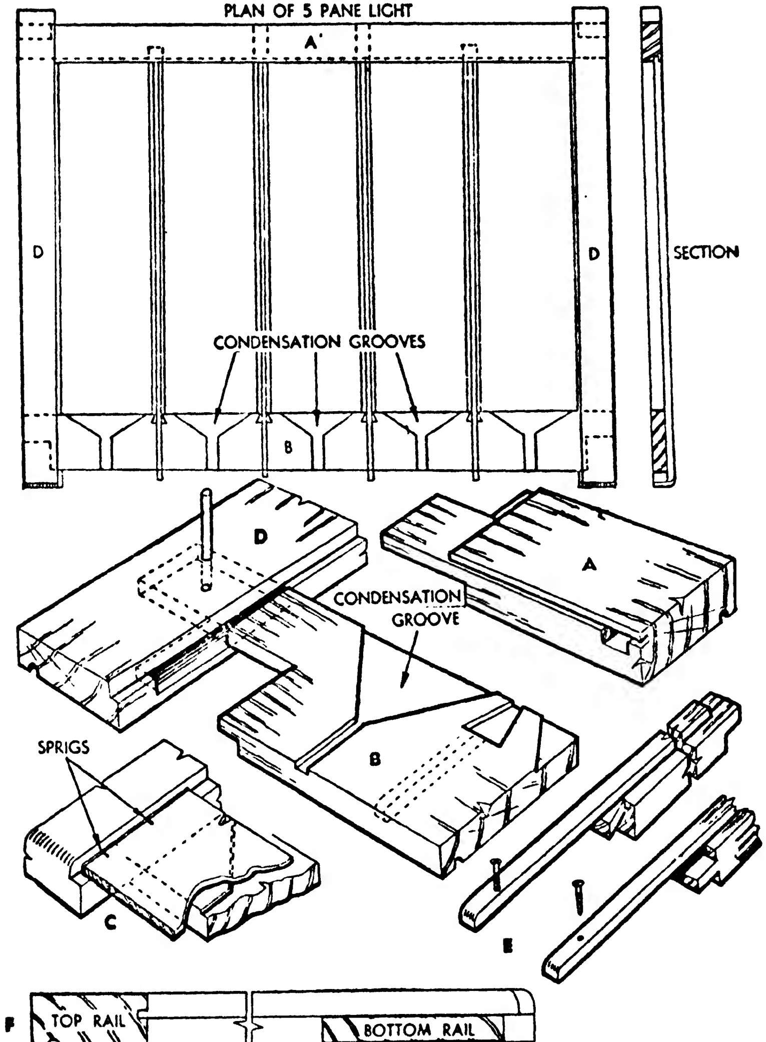


Fig. 24. Skylight details. *A.* Top rail grooved for glass ; *B.* bottom rail with barefaced tenon and sinking for condensation ; *C.* how the glass extends over the rail ; *D.* stile rebated for glass ; *E.* glazing bars and alternative methods of jointing by dovetailing or tenoning into the bottom rail ; *F.* top rail and stiles 4 in. to 6 in. by 2 in. to 2½ in. ; bottom rail 7 in. to 9 in. by 1¼ in. to 1½ in.

owing to their exposed position. With opening skylights the difficulty is increased. Furthermore, as the insulation properties of glass are low, condensation takes place on the underside of the glass in cold weather, and the accumulating moisture must be allowed to escape.

Fig. 24 shows the details of a

skylight with glazing bars to give support to the glass. Bars must be fixed in the direction of the fall, as cross bars would interrupt the flow of water down the face of the glass. For this reason glass should be in one piece whenever possible and cut close to the rebates to avoid unnecessary putty at the edges. When the glass has to be in several pieces, the sheets should be lapped like roof tiles.

The top rail is grooved for the glass in order to seal the top edge, and to counteract the unequal expansion between the glass and the wood. The bottom rail is made thinner to allow the glass to pass over it and shed the water clear from the light. Both rails are tenoned into the rebated stiles, and held by hardwood pins or brass screws. As the bottom rail is thinner by the amount of the rebate than the top rail, a barefaced tenon is used as shown.

Condensation grooves are made on the upper face of the bottom rail to allow the condensed moisture to escape. The bars are rebated for the glass, and tenoned into the top rail. In the case of wide skylights, every other bar should be mortised through the top rail and pinned or screwed, the remaining bars being stub tenoned.

The lower ends of the bars should be stub tenoned or dovetailed as shown, and the rebated portion carried across the face of the bottom rail. Glass should be bedded in mastic or white lead putty, and well sprigged.

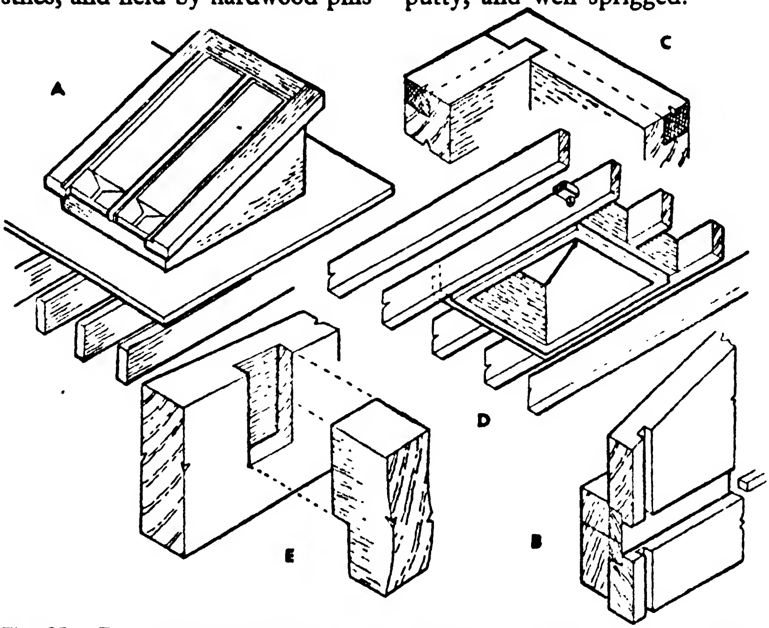


Fig. 25. Trimmings to skylights. A. Small skylight on a flat roof ; B. detail of the built-up curb ; C. detail of tongued and grooved corner. Sometimes the top edge is rebated as shown by the shaded portion. D. view of the underside of the roof trimming with the linings projecting, to finish level with the plastered ceiling. E. Joint suitable for trimming small spans.

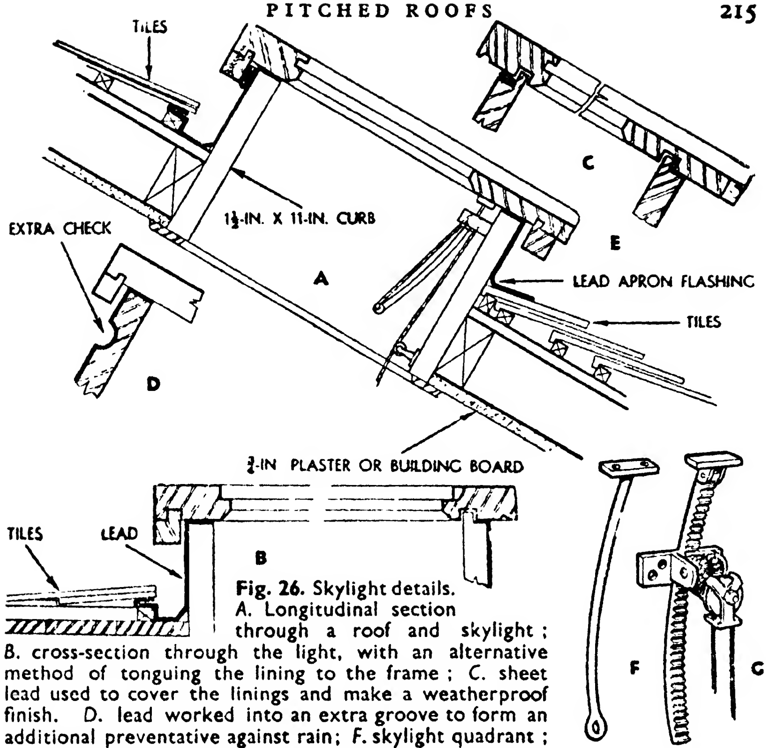


Fig. 26. Skylight details. A. Longitudinal section through a roof and skylight; *B.* cross-section through the light, with an alternative method of tonguing the lining to the frame; *C.* sheet lead used to cover the linings and make a weatherproof finish. *D.* lead worked into an extra groove to form an additional preventative against rain; *F.* skylight quadrant; *G.* geared opening arrangement manipulated by cords.

Skylights are fixed or hung to *curbs* which stand above the trimmed roof surface, and which also act as a lining to the opening. On pitched roofs the linings are formed from the solid wood, but on flat roofs the curb is often framed or built-up, and covered on the outside with boards and on the inside with matchboarding or panelling.

Fig. 25 A shows a sketch of a skylight in a flat roof, the curb of which is of sufficient depth to allow a reasonable slope to the light. It may be built-up as shown at B and have tongued and grooved corners as at C. D is a view of the underside of the trimmed joists with the curb projecting to form a finish with the plaster ceiling. For trimmers in a large span, a tusk tenon joint should be used, but for any joist or rafter less than 5 in. deep, a notched joint, as shown at E, is adequate when nailed with 4 in. nails.

Pitched roofs have parallel curbs to support the light, and may be of one piece as shown in Fig. 26 A. Provision must be made to prevent rain driving under the light, and gutters must be formed to carry off the rain. To make a waterproof light, a tongue may be screwed to the underside, or the curb may be tongued to the light as at C with throatings cut into the frame.

A minimum distance of 2½ in. should be maintained from under the light to the top of the roof covering. Lights are hung with non-corrosive butt hinges which should be fixed to the curb first and then to the light.

Joints to skylights should be as plain as possible, and need not be wedged, but it is important that all surfaces of all joints are painted with white or red lead mixed with boiled oil and gold size. If glue is used it should be of the waterproof type.

If the skylight is fixed in an inaccessible position, it is an advantage to cover the frame externally with sheet lead to reduce maintenance work. Wherever possible wired glass should be used from $\frac{3}{16}$ to $\frac{1}{4}$ in. thick.

Opening gear to skylights is usually of the quadrant type, operated direct with pulleys and cord, or by cord gear and worm wheel, as shown in Fig. 26 F and G.

Lantern Lights

Extra light and ventilation can also be obtained through the roof of a building by means of a *lantern light*. This form is superior to the ordinary skylight, as in addition to the top lights, there are vertical side lights.

Side lights may be described as casement frames constructed on the principle of a rectangular bay, with the sill and head mitred and bolted together, and mortised to receive the square corner posts. The roof portion may have a gable end or a hipped end, and may be framed up in sections similar to skylights, or the glazing bars may be built as rafters to an ordinary roof. In the latter case, the glazing bars are tenoned into a ridge piece, and bird's-mouthed over the head of the side frames.

Fig. 27 A shows a common type of lantern with hipped ends, framed sides, and pivot hung sashes. The roof is constructed of four frames similar to skylights, which are mitred at their intersections.

Lanterns with gable ends would have two top lights pitched together, and the ends filled with glazing bars or matchboarding. B shows the cross section through the trimming to a flat roof. The trimmer joist should be of larger section than the bridging joists because of the extra weight to be carried, and requires to be built up to form a curb at least 3 in. off the finished roof surface.

Side frames have pivot hung sashes which are most satisfactory for this position. C shows an alternative section with a fixed light; the sill is grooved to form a gutter, and a small zinc pipe is inserted through the sill to drain the moisture due to condensation. The roof is arranged with glazing bars bird's-mouthed over the head of the framing and stub tenoned to the solid ridge piece. Wind or scribing fillets are used to seal the opening between the head of the frame and the glass.

D shows the method of jointing the side frames of the top. Notice how the tenons are cut to avoid an undercut mortise; at E is shown the joint at the head of the top end frame. This must be halved together because of the difficulty of assembling if the frame was mortised and tenoned throughout. F shows the section at the hip, with a wood roll covered with lead.

The roof lights at B are arranged for patent glazing, the ridge, hips,

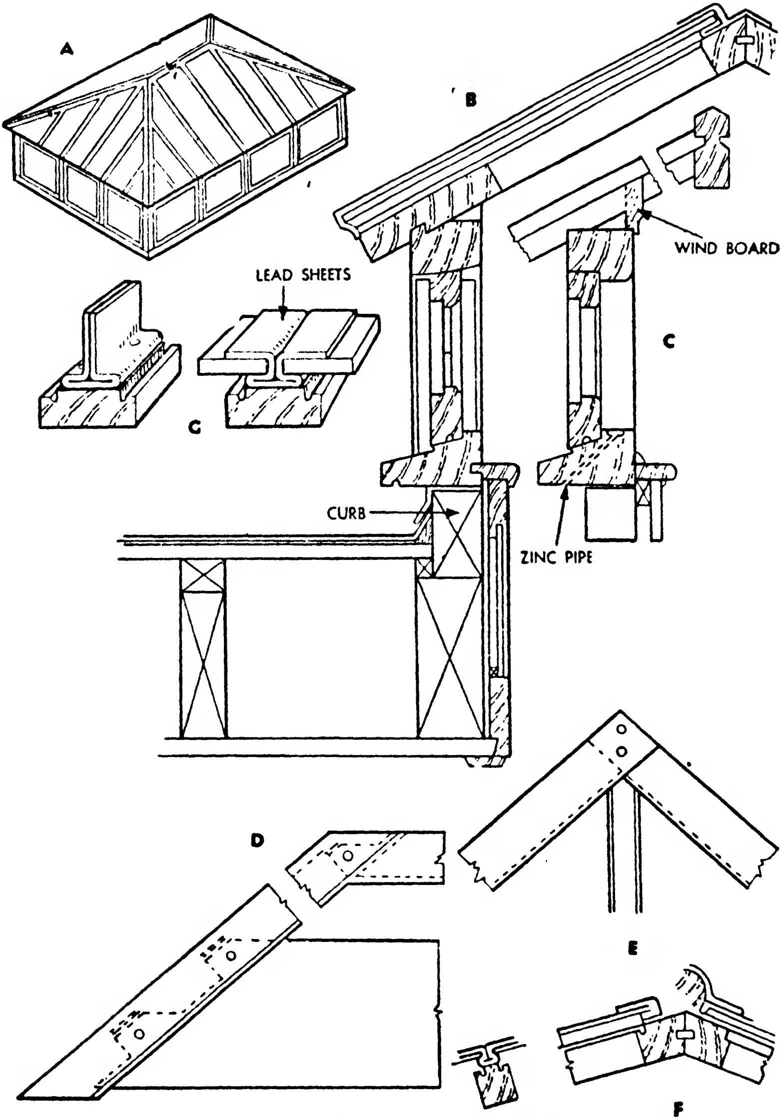


Fig. 27. Lantern light details. *A.* Common type of lantern with hipped ends, framed sides and pivot hung sashes ; *B.* vertical section with the trimming to a flat roof. The curb should project at least 3 in. above the roof surface ; *C.* alternative arrangement with a fixed sash and a gutter on the sill. Moisture is drained away by a zinc pipe. Note the wind board to close the space between the glass and the head ; *D.* method of jointing the side frames together ; *E.* end frame with the top joint halved ; *F.* section of the hip with a wood roll lead covered ; *G.* patent glazing. Sheets of lead are turned down over the glass.

Half the thickness of the sash plus the thickness of the bead is set out parallel to the upper face of the sash to give point p on the outside of the frame. A line is drawn from the centre of the pivot to point p. A line drawn at right angles to this will give the required cut for the outer bead, as shown. The inner bead is set out in the same manner, but only the depth of the bead is required to mark the point p.

The bevel on the underside of the head is set out in a similar manner as the beads, by drawing a line from the centre of the pivot to point K and drawing the bevel at right angles to it.

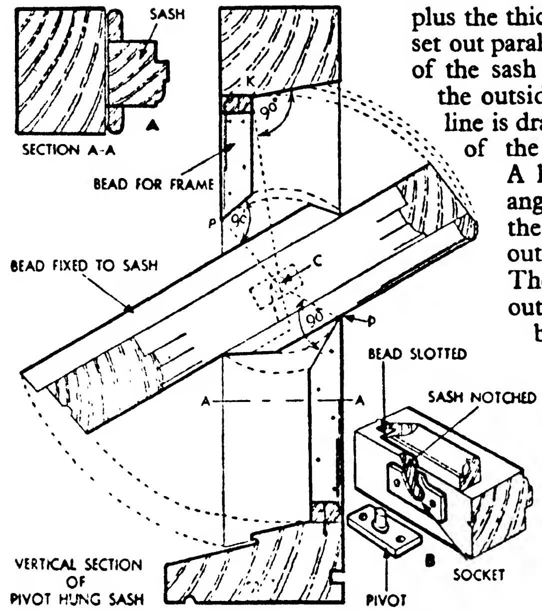


Fig. 28. Pivot hung sash with part of the bead fixed to the frame and part to the sash. A. Detail of the jamb and mullion. No bevels are required ; B. pivot and socket with the notchings cut into the sash.

rails and bars are of the same thickness in section and lead strips to hold the glass lie on the framework and completely cover the woodwork. A detail of this glazing is shown at G.

A *pivot-hung sash frame* has many points which differ from a casement frame, the main difference being that the rebates are formed by beaded stops. Part of the bead is fixed to the sash, and part to the frame with screws or 2 in. oval nails, as shown in Fig. 28. The pivots should be set 1 in. above the centre to allow the sash to close under its own weight.

To obtain the correct cuts for the beads, a section is set-out full size, and the sash is drawn at the desired maximum opening.

Post and mullions do not require a bevel, as shown in the section A. To enable the sash to be lifted out, the pin of the centre pivot C is fixed to the frame and the socket to the sash as shown. When the sash is notched and the bead slotted, the sash can be lifted up and withdrawn to the inside of the frame.

For corridors and non-habitable rooms, lighting other than direct lighting may be obtained by the inclusion of a sash fixed in the wall or partition. Such lights are known as *borrowed lights* and generally consist of a sash fixed to linings. When borrowed lights are fixed in the ceiling below a lantern or skylight they are generally known in the trade as *lay lights*.

CHAPTER 10

PRODUCTION METHODS FOR STANDARD JOINERY

DOMESTIC JOINERY. TIMBER YARD LAY-OUT. MACHINE AND ASSEMBLY SHOPS. TYPES OF MACHINES. STANDARD SECTIONS. PRODUCTION DOCKETS. STANDARD TIMBER SHEETS. DOORS AND FRAMES. SHOP FOREMAN'S DUTIES. CARCASE WORK. CONSTRUCTION OF LOCKERS: MACHINING OPERATIONS. ASSEMBLY. GENERAL MACHINING METHODS.

STANDARD joinery is that type of joinery which, owing to the great demand, is made in bulk quantities, which are frequently repeated later. As a consequence it lends itself to mass-production methods, to facilitate which specialized machinery has been evolved for the various operations which have to be carried out.

Lay-out of Plant

Owing to the repetitive nature of the work, special attention must be given to such things as lay-out of plant, division of labour, and quantities produced at a time, the aim being to eliminate all unnecessary labour in machining, handling, assembling and finishing in order to obtain the highest rate of production.

The term standard joinery also applies to special items produced in quantity, examples of which are given later in the chapter. These are sometimes to H.M.O.W or L.C.C. specifications and may indicate good or first-class joinery. The necessity for ensuring accuracy is important; standard doors, for example, must be interchangeable with standard frames.

As a general rule, standard joinery is made from softwood, such as the various pines and British Columbian pine, but oak and teak are sometimes used for gates and other external joinery. There are broadly speaking, various grades, but the operations are the same, the difference being that in the lower grades inferior timber and lack of finish are more obvious.

The following items are generally included under the heading of standard joinery.

Doors.—Internal wood-panelled and flush; external wood-panelled; wood-panelled and glazed; garage doors; sliding doors; combined doors and casements; French windows; gates and ledged-and-braced doors.

Windows. Double-hung sliding sashes; casements; bay windows (all shapes).

Miscellaneous. Simple staircases; serving hatches; kitchen fittings such as cupboards and tables; fireplace surrounds or mantels.

Standard joinery thus consists for the most part of what is known as 'domestic joinery,' and the British Standard Specifications should be referred to.

The various processes and the organization involved in the production of this type of joinery on a satisfactory basis should be carefully considered in detail, because the methods used can be applied to the better class of joinery.

The Timber Yard. The position of the timber yard relative to the factory layout is of importance. It should be accessible for delivery purposes, so that a minimum of labour is involved in unloading the timber. The selection of a site for the erection of a joinery works may well be governed by its proximity to road, railway or canal.

Timber Storage

The storage of timber may be entirely in the open, or in a semi- or fully-closed space; this depends to some extent on the condition of the timber when delivered, and the type of work undertaken.

Separate grades and different types of timber are always stacked separately, the most frequently used material being in the most accessible position. Some manufacturers favour the idea of ripping up timber in the rough in the yard, while others prefer to keep all the machinery together. If the timber is ripped up in the yard, the only handling of heavy timber is from the stack to the rip-saw, the sawn timber being put on to trolleys and wheeled straight into the mill for the next operation. Mechanical runabouts are sometimes used for this purpose.

Records of timber stock are kept in the timber yard, and are adjusted as material is taken and reduced to manufacturing size. The type of cutting list supplied for the 'yard' varies with the organization of the individual firm. Some firms carry a stock of sections used in the manufacture of the joinery being produced, these stocks being replenished from time to time by the issue of orders for the machining of batches of such stock sections, say 100,000 ft. These are usually known as stock job numbers. The cost of these sections can be calculated per foot run.

Yard Foreman. The duties of the yard foreman cover the reception of consignments of timber and responsibility for checking them in. He is also responsible for the stacking of timber in grades, sizes and different types of wood; for the selection of timber for different jobs, for ripping up and delivery to the mill. The keeping of stock records is an important part of his work.

The Mill (Machine shop). The layout of the mill so as to obtain the maximum production with the minimum of effort is of supreme importance. Machines must be conveniently placed to facilitate successive operations, without undue transport of the timber from place to place, e.g., the planer should not be placed at a great distance from the entrance to the mill, as planing is one of the first operations.

Placing the Machinery

The machines which perform the last operations before the job is ready for assembly should be the closest to the assembly shop. The ideal is for the raw material to enter at one end of the factory

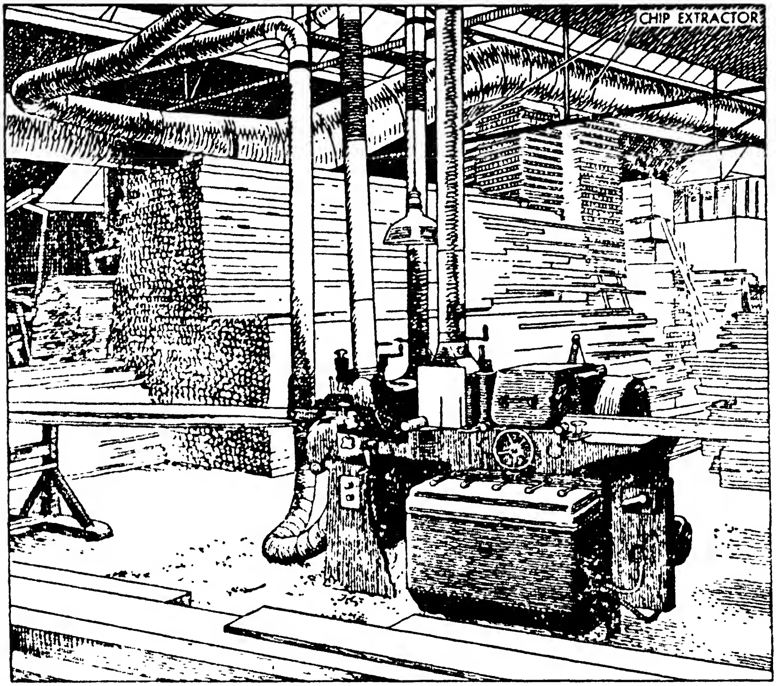


Fig. 1. Planing and moulding machine for producing stock sections for the store. Note the dust and chip extractor, and also the stacks of stock sections.

and the finished article to emerge at the other with the least possible effort in passing material from one machine to another. Sometimes machinery is even regrouped so as to tackle a job of special character in the most economical way.

The types of machines to be found in a mill are generally as follows :—

Circular saw ; band saw ; heavy crosscut saw ; light crosscut saw and trenching machine ; spindles (various types) ; surface planer and thickness planer ; planer and moulder ; four- or five-cutter planer moulders ; mortise machines ; tenoning machines ; router or trenching machines ; dovetailing machine ; sanding machine ; drilling machine ; grinding machine and saw-sharpening machines.

A suggested arrangement of these machines is given in Chapter 4, Fig. 1.

Most large firms have their own department for saw-sharpening and setting and for the general maintenance of machinery. An extractor system for the removal of chips and sawdust from the machines is another feature in general use in large concerns. The trunks for these can be seen in Fig. 1.

The mill foreman's duties consist of allotting the work to the various machines, adjusting any machining difficulties with a view to simplifying operations, and general supervision of machines and mill personnel.

The Assembly Shop. The layout of the assembly shop is governed by the type of work in hand, but in all cases the job is 'staged' or progressed in order of successive operations. This planning is the job of the production manager.

Production Manager. The duties of the production manager cover the planning of the various machining operations and assembly stages, co-ordinating the various departments and removing any bottlenecks which may hold up production, arranging at the same time priority of urgent requirements for delivery. He decides also by experience the economical number of job units which can be machined or assembled at a time, without the cost rising through monotony and lack of interest on the part of the workman.

Consider the production of a door with a solid lower panel and glazed squares above. The first section of the shop would be devoted to fitting up, in which the doors would be knocked up dry ready for gluing. The next section would be for gluing up, and would consist of a series of special cramping machines or tables specially set up for the job in hand.

This would be followed by the cleaning-off section, which in turn would be followed by the section set aside for fixing the glazing fillets to the bars. From here the door would proceed to the inspection or test department, to be marked and stacked ready for dispatch.

Standard Sections. The production of standard sections for the purpose of stock, or to contract, is quite a simple matter, and the speed with which it can be accomplished depends on the capacity of the available machinery. For this purpose four or five-cutter planer-moulders are generally used so that the rough-sawn timber is fed into the machine at one end (sometimes by automatic feed), and the finished section is ejected at the other.

This type of machine does not straighten the irregularities in the length of timber, so that reasonably straight stuff only is used for items which must be true, such as doors and windows, jambs and sills. For light sections such as picture rails and dado moulds, however, this does not apply.

In the production of these sections everything depends on the sharpness of the cutters and the set-up of the machine. Where the same sections have to be reproduced at regular intervals, standard samples of the section are kept for reference, together with female checking templets such as those shown in Fig. 2. The finished sections of such items as door jambs are stacked with slats between the layers to permit a free circulation of air, but where the timber has been dried to a given moisture content, they should be close stacked without the slats. A typical stack of machined sections for stock is shown in Fig. 1. Note how the sections are piled with one end of the stack flush. This enables the length of any piece to be readily ascertained.

Standard Jobs: the First Off. When the design of the article to

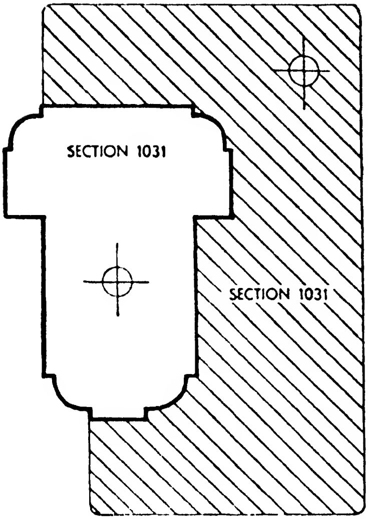


Fig. 2. Profile templet for testing machined sections. The templet is made from plywood or sheet zinc, and may be made to the shape of the required section or to the shaded portion (shown attached) known as a female checking templet.

be produced has been agreed upon, the setting-out is made, and the timber prepared for the manufacture of a 'first off' or prototype. This is marked out in the mill in the normal joinery fashion, and machined accordingly. The job is then assembled dry, noting any machining or assembly difficulties in the process. The 'first off' is then taken to pieces and the various members are used as patterns.

It is sometimes necessary to make jigs to facilitate production by avoiding repetition in marking out. Where these jigs need setting up for a multiple operation the 'set-up' should be carefully checked to minimise the possibility of error.

A standard timber sheet or section list is prepared and pasted to a board and varnished, the type reference being clearly marked at the top. A catalogue of standard sections should be in existence, being added to from time to time, and reference made to these standard section numbers on the timber sheet. A typical standard timber sheet for joinery items is shown in Fig. 3.

No. 261.

STANDARD TIMBER SHEET.

NAME. *Door Frame.* TYPE: *261.* JOB NO. *See Production Docket.*

Item.	*Description.*	*Quantity.*	*Length.*	*Width.*	*Thickness.*	*Sect. No.*	*Finish.*	*Material.*
1	*Door Jambs*	*2*	*6′ 10″ net.*	—	—	*1001*	*Square up*	*Deal.*
2	*Door Head*	*1*	*3′ 3¼″ net.*	—	—	*1001*	„	—
3	*Wedges.*	*4*				*1064*		*Deal.*

Fig. 3. Typical timber sheet. This is generally made out in triplicate; one is kept by the setter-out, one sent to office for costing, and one to the mill

The works order for the production of the bulk quantity of this particular item would be in the form of a production docket, or a job history card. The type of form used varies, but one idea is to have a printed card in an envelope. This job history card should clearly show all the operations involved, from the mill to the dispatch department. Once the job is booked into the store, however, the particular works order number would be closed, as the handling by the store department should be covered by separate job numbers. A typical production docket is shown on the opposite page (Fig. 5).

Now consider the actual production in quantity of a typical job, assuming that the method of carrying a stock of standard sections is employed, and that the job in hand is a door and frame. The door is made from pine, and has three vertical panels in the lower half, with a high lock rail, and a glazed panel in the upper half, as shown in Fig. 4. The door frame is from 4 in. by 3 in. material and the head is allowed to run through, the horns projecting 3 in. on each side of the jamb for fixing purposes. The door jambs are 3 in. longer than the size of the door. Extra length need not be allowed on the tenons of the jambs for draw pins, as special cramping tables are to be used. In the door itself the panel groove and moulding are stuck on the stiles, muntins, middle and bottom rails. In the upper panel the moulding is stuck on the front face only, the back being rebated to receive the glazing fillets.

The moulding must be designed to lend itself readily to machining,

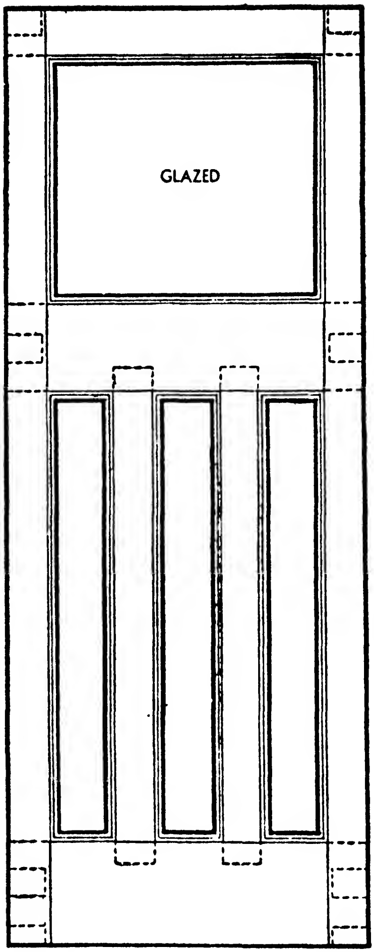


Fig. 4. Typical example of joinery which lends itself to mass-production methods. Panelled door made from pine with glazed panel in upper half.

bearing in mind the scribing of the rails and muntins. Mouldings which are flat do not make a satisfactory scribe, as they form a feather edge which easily breaks out. If such mouldings were used in ordinary joinery the difficulty could be overcome by mitring the intersection instead of scribing,

PRODUCTION DOCKET.

FOR :— *DOOR FRAME.*

TYPE No. *261*	BATCH. *250 off.*	JOB. No. *56841.*

EMPLOYEE'S NAME : *A. JOINER.*

Op. No.	Description	Time in Hours.	Total and Cost
1 *Jambs.*	*Square Stock Section to Length.* *(500 off)*	*8, 8, 8, 8, 8, 4.*	*44 hrs.*
2 *Jambs.*	*Form Tenons and Haunches.* *(500 off)*	*8, 8, 8, 7.*	*31 hrs.*
3 *Head*	*Square Stock Section to Length.* *(250 off)*	*8, 8, 6*	*22 hrs.*
4 *Head*	*Form Mortises.* *(500 off)*	*8, 8, 8, 6, 4.*	*34 hrs.*
5 *Head*	*Form Wedge Chasings.* *(1,000 off)*	*8, 8.*	*16 hrs.*
6	*Assemble and Glue. Trim off Wedges.* *(250 off)*	*8, 8, 8, 8, 8, 8, 8, 8, 8, 8, 2.*	*82 hrs.*
7	*Clean off face*	*8, 8, 7.*	*23 hrs.*
8	*Prime and send to Stores.*	*8, 8, 8, 6, 4.*	*34 hrs.*

Fig. 5. Typical production docket or job history card. These sheets are duplicated and supplied to all employees working on the job instead of time sheets. In practice one employee could not be economically used to execute all the operations shown on the docket, but it is given thus for clarity. The working hours shown are fictitious, as much depends upon the actual conditions in the shops, but the card clearly shows all the operations involved

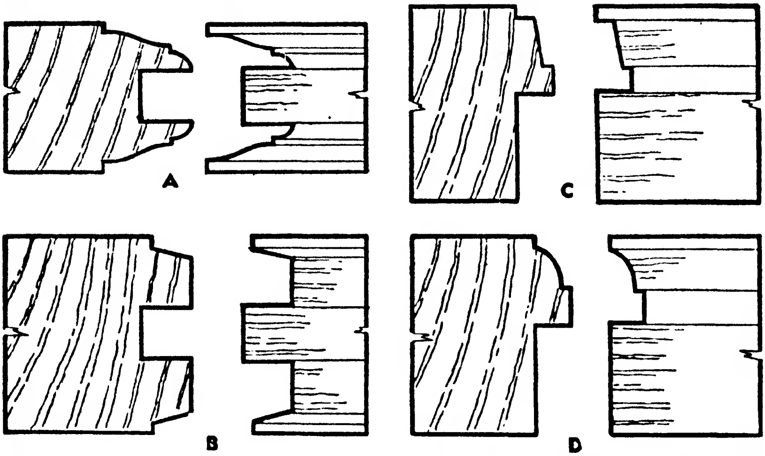


Fig. 6. Machining of mouldings. The sections shown at *A* and *B* are not suitable for machine scribing, as they are too flat and are liable to splinter. Those at *C* and *D* are better, being particularly suitable for scribing.

but this method is not practical in mass-produced joinery. Typical good and bad examples are given in Fig. 6. Note that the square on the moulding should not be less than $\frac{3}{32}$ in.

The Door Frame. The door jambs are taken from the stock of standard sections and cut to their approximate lengths by means of pendulum or other cross cut saw. This operation is necessary for ease of handling, and because the capacity of the tenoning machine is limited. The next operation is the formation of haunchings, which is followed by squaring to length and tenoning. This may be done in one operation on the tenoning machine, the modern type of which can cut both ends, form the tenon, and scribe the shoulder, all in one operation, as shown in Fig. 7. The jambs are laid in batches on a machine which has an automatic feed.

The door head is cut to a net length in one operation, and then mortised on the mortising machine. Sometimes this is of a gang-mortiser type which cuts several mortises at once, the chasing for wedges being subsequently formed.

The Door. In this particular case the door stiles would not come under the title of standard sections, although the timber for them is sometimes machined to a stock size in the square, *i.e.* without any mouldings or groovings stuck thereon. The position of the middle rail determines the finish of the grooving, and the beginning of the rebating; so, because a change in design may alter its position, it is not practicable to machine the stile as a stock section to any greater degree than that already mentioned.

The stiles are machined as square timber, squared up to length by cross-cut saws, marked-out and mortised. Mortising is much better if done while the timber is in the square, as when the timber is moulded the sizes of mortises are difficult to measure, and the mouldings tend to break. End stops are set on the mortise machine to give the correct distances between the mortises.

The mortising is followed by the sticking of the stiles, both rails and muntins being stuck at the same time. Where part of the stile has a moulding and groove, and part a moulding and rebate, two operations are required. These may be done on a twin spindle. The first operation is carried out on the first spindle, and the second operation on the second spindle. Either stops, fixed to the machine, or else jigs, should be used to govern the extent of the groove and the rebate. Rails and muntins are then tenoned and squared to length in the same operation.

The rails are first fed into the tenoner edgeways up for the machining of the haunchings, and then subsequently in the flatwise position for the scribing and forming of shoulders, being cut to length at the same time. The rebate in the upper panel is made to the same depth as the moulding, to avoid unequal shoulders on the rails. The panels would be squared up on suitable cross-cut saws, ready for immediate assembly.

Glazing fillets are machined on a four- or five-cutter moulder before ripping to size on the circular saw. From this stage they are moved to dimension saws for the cutting of mitres to pattern lengths ready for fixing to the framework.

The job is now ready for the assembly shop, and is delivered from the mill on trolleys to the fitting up benches. Here the doors are assembled dry to ensure the joints coming closely together.

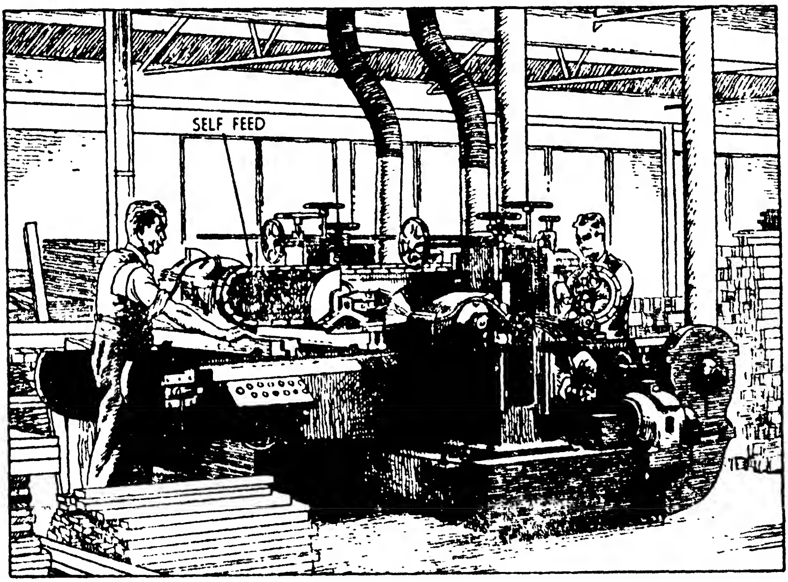


Fig. 7. Double-ended tenoning machine with automatic feed. This machine trims and scribes both ends of a rail in one operation.

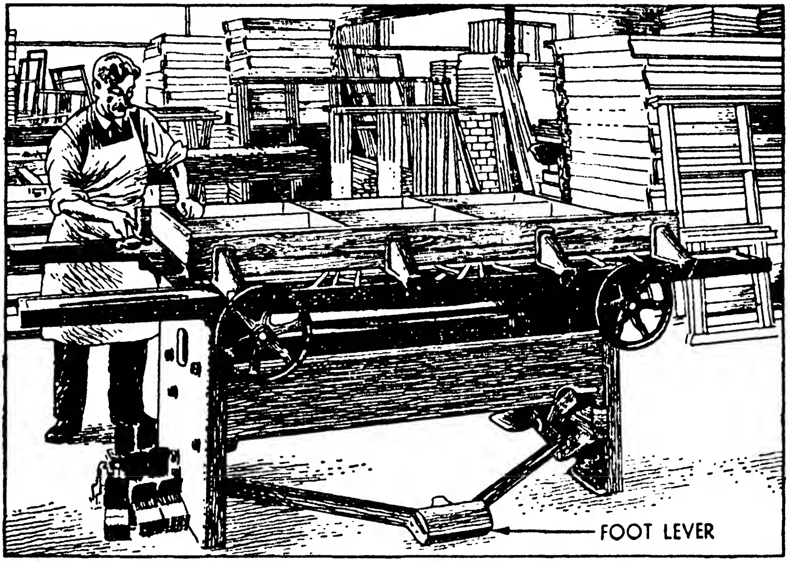


Fig. 8. Sash and door cramping machine designed for smooth, quick action with minimum effort on the part of the operator. Adjustable steel dogs, whose cramping action is controlled by a foot-lever, hold the joinery for wedging.

In the next stage they are passed on to the adjacent gluing-up benches. These benches are special quick-acting machines operated by foot-lever with comparatively small effort. Fig. 8 shows one of the types of machines employed. The surplus glue is removed while still wet, by the application of warm water with a brush. The glue is easier to remove at this stage; moreover, if left to harden, it dulls the edges of tools and cutters and clogs the glasspaper.

This being done, the doors are stacked for a limited drying period, care being taken that the bed is perfectly straight and true. Sticks or battens are used between the doors to preserve their trueness. The edges of the doors are then trimmed either by machine or hand, and the doors gauged to width. It is possible to carry out the machining with such accuracy that the edges do not need any adjustment. Only the ends of tenons need be cleaned-off in fitting.

The door now proceeds to the glazing benches where the fillets are temporarily tacked in, or, in certain specified cases, screwed into position. It has now reached the finishing stage which entails cleaning-off on the faces. This can be done either on a belt or thickness sander, from which operation the door is ready for inspection or test.

All standard joinery is checked with a gauge for standard size, and, after the full particulars have been recorded, is passed to the store ready for dispatch.

The door frame follows a similar procedure, but with fewer operations. It is stiffened for storage and transit by a rough batten fixed across the bottom to prevent the joints being broken through handling.

Joinery may be primed before entering the store, either by brush or spray application in special booths which are provided for the purpose.

These general production principles apply to various types of doors and windows, with multitudinous variations, governed by the capacity and initiative of the firms concerned. Where the joinery is required for external purposes, paint must be used for the joints instead of glue; consequently the operations are somewhat simplified, as the drying time after gluing is eliminated.

It may be taken as a general guide that the same amount of space is required for the local stacking in shop and mill as is required for production.

The Shop Foreman's duties cover the general supervision of assembly procedure and workmanship, as well as the control of production dockets for work passing through his hands and the checking of time sheets. His main function is to carry out the ideas planned by the production manager.

Carcase Work. The operations for carcase fitments are governed by the nature and quality of the job in question. An excellent example of this type of work is shown in Fig. 9. This is a type of bedside locker as supplied to hospitals. All details are to specification.

The locker consists of a carcase with bottom, ends, full back, and forward back, and with a linoleum-covered top and shelf. The upper flap, which is also covered with linoleum, lifts up and is held rigid in position by elbow stays. The seat is in the form of a lift-up flap for access to the locker, while the front flap is made to fall down and is fitted

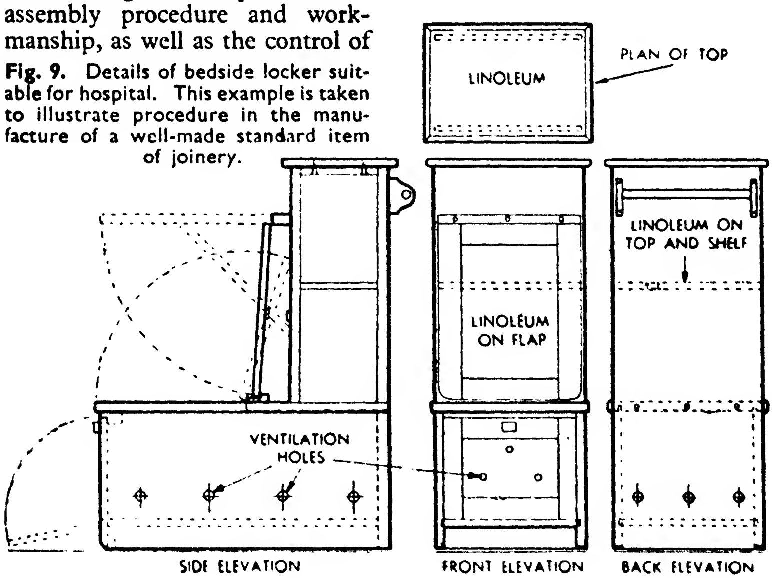


Fig. 9. Details of bedside locker suitable for hospital. This example is taken to illustrate procedure in the manufacture of a well-made standard item of joinery.

with a ball catch in the top edge for securing it in a closed position. The bottom, ends, and both full and short backs, are of solid timber. The fall-down flap and seat are framed with plywood panels made flush on the face, and recessed on the back. The upper flap is framed, the linoleum being let in flush with the face of the frame, and the panel recessed on the back. The top and shelf are of laminboard, while the entire job is in birch, French polished.

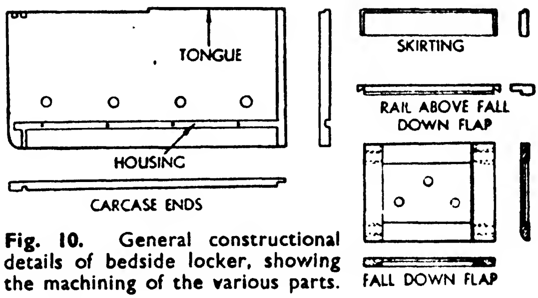


Fig. 10. General constructional details of bedside locker, showing the machining of the various parts.

Small Scale Production

This particular batch of lockers may be manufactured by a comparatively small firm, not set up for mass-production joinery, but with the normal machinery found in the average joiner's shop. It must not be imagined that mass-production work can only be carried out by large firms with special machinery, although it is true that mass-production at the highest production rate demands the latest machinery. The following procedure is given to show how a moderately equipped factory can successfully tackle a standardized job.

Assuming that the material available is in narrow boards of 8 to 9 in. in width and of 1 in. thickness, the jointing is done in the rough to suitable dimensions for the job, facing and thicknessing taking place after jointing. The jointing is done by normal methods of machining the edges, and by gluing in a jointing rack.

Alternatively, a modern combined jointing and gluing machine may be used, into which the two pieces for jointing are fed, one from each end. These two pieces are dovetailed and glued in one operation. When they reach the centre the two boards are brought together, one being pushed into the other. This double width board is finally ejected. By again placing double-width boards in the machine a board four times the original width is obtained. Although this machine is very expensive it is ideal for large outputs.

Construction of lockers.—The carcase as shown in the details in Fig. 10 is constructed in the following manner. The solid bottom is housed into the ends, a rebate being formed in the back edge of the latter to receive the solid back. The three flaps and the fixed frame adjoining the seat are all mortised and tenoned and wedged, and the skirting piece in the front is tongued and grooved into the bottom and ends.

The carcase rail above the fall-down flap is rebated and dovetailed into the ends, as also are the two top rails in the back portion. The forward back is housed into the seat frame and dry fixed by slot screwing, the full height back being screwed and plugged. The shelf is grooved in and left dry, and the top is fixed by screws through the carcase rails. The hanging rail for the upper flap is screwed through into the back and plugged in such a manner that it conceals the screws.

Machining Operations

The machining operations are broadly as follows :—

(1) *Carcase bottom.* Jointed in the rough in approximately 10 ft. lengths, then faced, thicknessed, edged and brought to width, finally being cut to the exact length on the cross-cut saw, the groove in the front edge worked on the spindle, and the inside face sanded.

(2) *Carcase ends.* As for the carcase bottom; then the stopped housing is formed by router or trenching machine, after which the short groove for the skirting member is worked on the spindle. The tongue on the top edge is cut on the spindle and the dovetails for top rail are machined.

The rebate on the back edge is also cut on the spindle together with the bead, and, finally, the slight rounding on the bottom edge and partly up the front, the radius corner being formed in the same operation by using a shaped jig. Sanding of both faces takes place after the drilling of fixing and ventilation holes.

(3) *The full-height back.* As for the carcase bottom; then the groove for the seat frame is formed; this runs right through, followed by the narrow groove for the shelf (which is stopped each end). The slots for the dovetails are formed by the dovetail machine, and the holes for fixing and ventilation drilled, and hence to the sander for sanding on both faces.

(4) *Short back (forward).* Apart from jointing, etc., the only machining is the trenching of the narrow groove for the shelf and the dovetailing of the top edge.

(5) *Carcase rails.* The two top rails are machined on the four-cutter, and cut to the exact length on cross-cut saws and from thence to the dovetailing machine. The lower rail has the rebate formed in the four-cutter operation. These are all sanded on one face only. The drilling and countersinking for fixing of the top and the drilling for the ball catch in the lower rail are also executed with the aid of jigs at this stage.

(6) *Framed panels.* This includes the fall-down flap, the lift-up seat, fixed seat frame, and the lift-up flap. The stiles and rails for these are sawn, planed, mortised, tenoned and grooved in the normal way, the panels being squared to size and the tongue spindled all round. The cutter for the spindle is made to remove the arrises off the tongue in the same operation to ensure entry into the groove. The back surface of the panels is then sanded, and the face of the panel to the top flap is sanded with a coarse paper to form a key for the gluing of the linoleum.

At this stage the parts are delivered to the assembly shop for the gluing-up of the frames. Here they are assembled, surplus glue removed while wet, and the wedges cut back flush with the stiles. After this operation, the frames are dried out and then returned to the mill for shaping, forming of housing for hinges, and sanding.

The upper flap has rounded corners as shown in the diagrams and is brought to size, shaped and spindled to section in one operation, the frame being located on a jig as shown by registrations which pick up on the inside of the stiles and rails (Fig. 11 A).

This method is also used for the other flaps, the fall-down flap having the bottom edge rounded in section after jigging to size. Next comes the formation of hinge housings which are only partially machined, the finishing being by hand.

The amount removed for the seat flap, frames and the top flap as shown in Fig. 11 B, is governed by the sweep of the spindle and, therefore, in order to remove the maximum a small diameter spindle, such as ½ in., is used. To locate the position a jig is also used for this operation.

In Fig. 12 A no jig is used, because the width of the housing for the hinge is governed by the height of the cutter from the spindle bed, and the extent of the spindling is governed by a pencil gauge mark. The depth of the recess is of course governed by the knuckle of the hinge. In view of the fact that the position of the hinges is finally fixed on these flaps, and slight variation is always experienced in fitting up on assembly, the housings on the carcase bottom are machined in the reverse manner (*i.e.*, similar to the other frames), and slightly less than the full width, in order to give adjustment (Fig. 12 B).

When assembly takes place the hinges are fitted and fixed to the flap, and the carcase bottom marked from this, the housings being finished by hand to suit. The recess for the striking plate is partly machined on the spindle, the rest being taken out by hand in the shop when the plate is fitted (Fig. 12 C). Finally, the ventilation holes are drilled through a jig on a solid base to prevent breaking the veneers of the plywood.

After these operations have been carried out, the frames

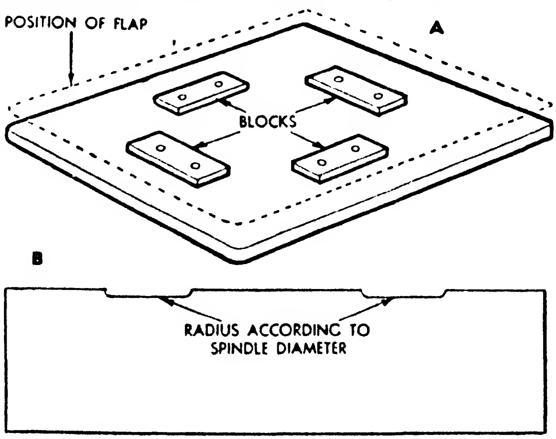


Fig. 11. A. Jig for the spindle to facilitate the machining of the edges of the flaps. The flap, shown by dotted lines, is fitted over the blocks which locate on the inner edges of the rails and stiles ; B. how the housings for the hinges are partially formed on the spindle.

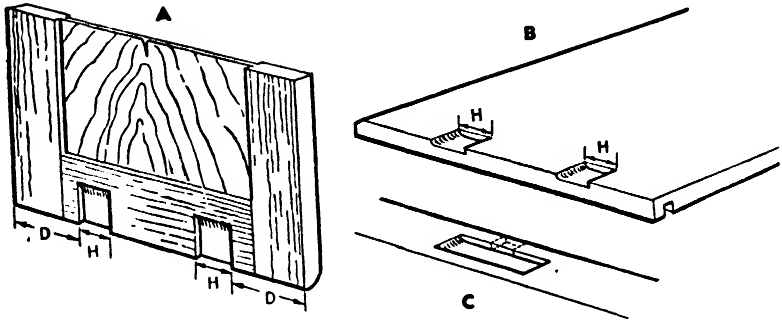


Fig. 12. A. Hinge housings for the fall flap. Note that D is a fixed distance and H is the exact length of the hinge. Any adjustment is made on the carcase bottom shown at B, which shows the hinge housings for the fall-down flap in the bottom carcase. H is slightly less than the length of the hinge to allow for any necessary adjustment. C. Housing for ball catch plate partially machined.

move forward for sanding, and from there back to the assembly shop. The hanging rail for the upper flap is prepared in a similar manner, including housing for hinges. It is then drilled and counter bored for the wood pellets, finally being sanded on both faces and on the ends, the latter being done on a disc sander.

(7) The shelf and top being of plywood are squared to size and sanded with coarse paper on one side to receive the linoleum. Alternatively, the linoleum could be laid on bigger boards in the veneer press, and the whole cut to size afterwards.

The fillets for both top and shelf are machined and drilled to pattern, the mitres for the top being cut on the dimension saw. These fillets are sanded on the necessary faces ready for fixing.

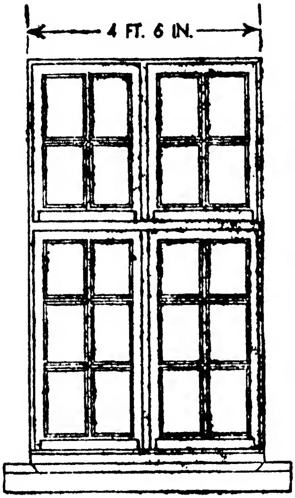
(8) Stock dowelling is used for the towel rail, the retaining cheeks being drilled to receive the ends, and either cut to shape on the band saw and worked on the spindle to a jig for final shape, or else routered to a jig. As with the checks, the screw holes for fixing are also drilled.

(9) *Assembly*. The assembly of the carcase is broken down to several sub-assembly stages to facilitate production. Although these are here given successively, in practice they occur simultaneously with the obvious purpose of ‘ feeding ’ one another.

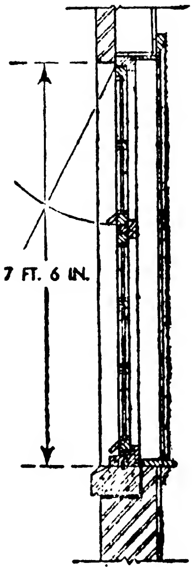
(*a*) The first stage is the gluing of the skirting member to the carcase bottom. When the glue blocks are fixed, a locating stop is used to maintain the ends of the skirting perfectly flush with the carcase bottom.

(*b*) The lower carcase is now assembled, gluing and screwing the bottom and ends and fixing the dovetailed carcase rail. The pellets in the ends are also glued at this stage, as well as the glue blocks underneath.

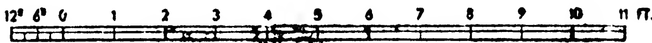
(*c*) The upper carcase is now assembled. The fillets to the shelf having already been fixed, the fixed seat frame is slot screwed to the forward and rear backs, and the dovetailed carcase rails glued in position. The pellets in the back are then glued, but are cleaned off later on.



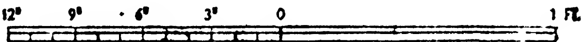
ELEVATION



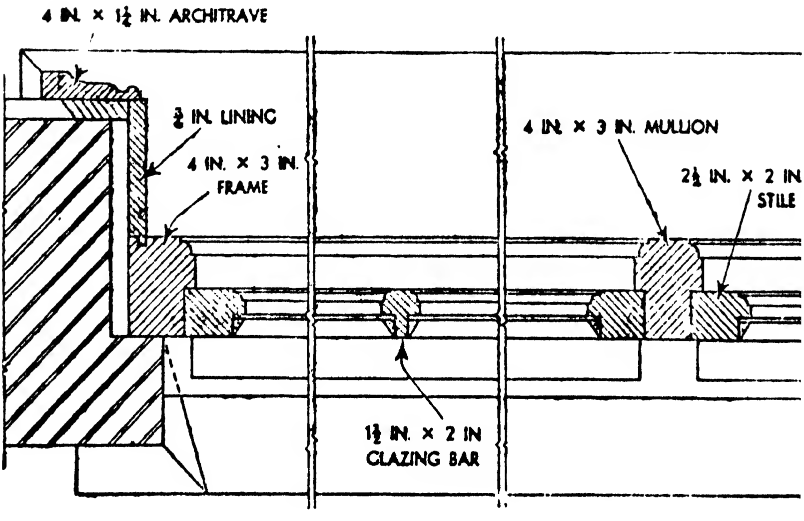
SECTION

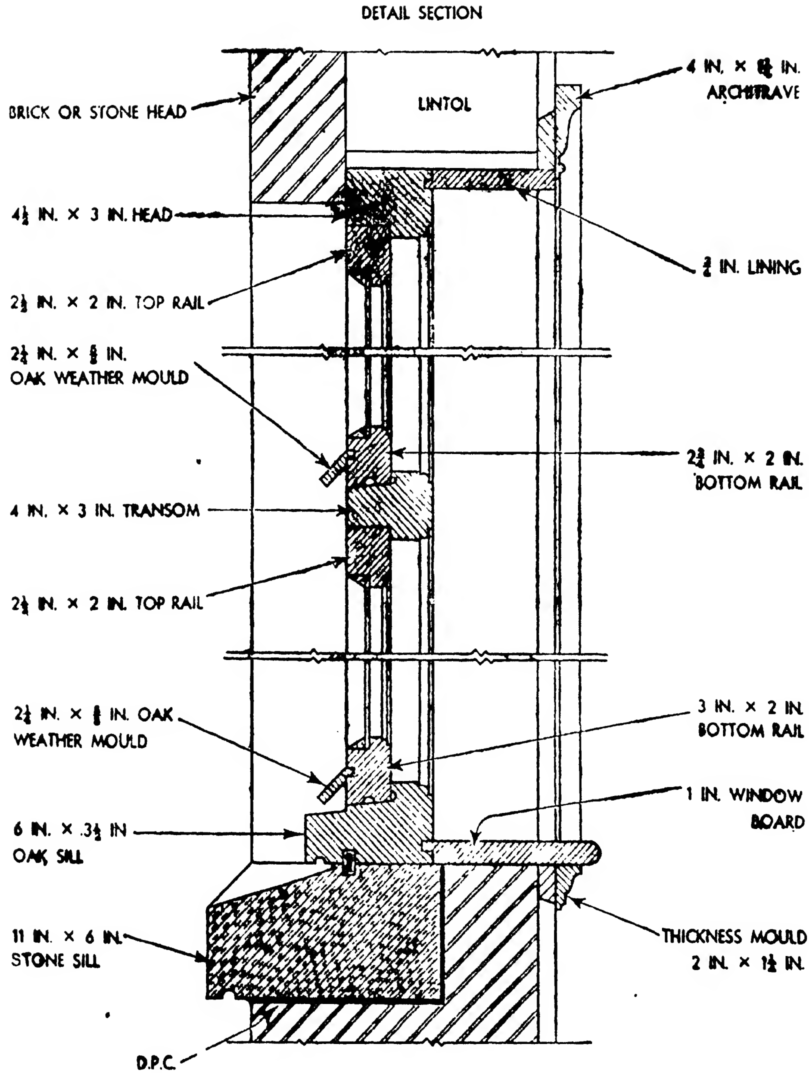


SCALE FOR ELEVATION AND SECTION



SCALE FOR DETAILS





Detailed drawing of a four-light casement window as prepared by an architect. Note how the sizes of the joinery are taken from the brickwork opening, and that although the detail gives definite sizes of all members, the joiner in setting-out the work must make allowance for the reduction in size which is due to machining the individual members.

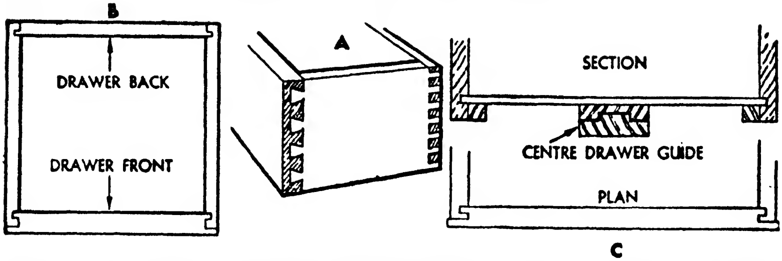


Fig. 13. A. Drawer machined with a lap dovetail at the front, and with a combed joint at the back ; B. alternative method of drawer construction where the front and back are tongued to the sides ; C. adjustment of drawer construction to eliminate fitting and to avoid binding and jamming. The drawer front overhangs and $\frac{1}{16}$ in. clearance is allowed on the sides. A central drawer guide is used, which acts as a pilot for the drawer.

(*d*) The two sub-assemblies are now brought together and glued and screwed in position, again pelleting where necessary.

(*e*) The job is now passed to the fitting section for the fixing of the seat and fall-down flap. The hinges of the seat and the back flaps of the flap, together with the ball-catch plate, are prefixed and the seat screwed into position. The fall flap is offered up and the position of hinges marked on the carcase bottom, and the housings completed.

(*f*) The towel rail and end cheeks are cleaned up and sent to the polishing shop, as are the tops when the edgings are screwed and glued in position. The carcase is now ready for cleaning off, the edges of the seat frames being flushed off and cleaned up.

(*g*) The upper flap is fitted with the linoleum insert which is glued down under pressure, after which the housings are completed. When a similar operation has been carried out on the hanging rail these two are assembled together, and are then ready for french polishing and the final fitting up.

In this operation the flap is fixed to the carcase by gluing and by screwing through the hanging rail and gluing same, the pellets being glued in, flushed off and the rail touched up. The top is screwed into position and the towel rail fixed, locating from a jig. Finally, the 'domes of silence,' and knob to fall-down flap are fixed.

(*i*) In this the fall-down flaps are examined to test the correct fitting of the ball-catches, and the general workmanship throughout the job.

(*j*) From this stage the job proceeds to the dispatch department where it is entered into the records of finished parts and is packed ready for dispatch.

Drawers. Various methods are used for the construction of drawers, the most prevalent being the dovetail. Sometimes a combed joint is used for the drawer backs, and dovetails for the fronts (Fig. 13 A). Again, they are sometimes tongued and grooved as shown in Fig. 13 B. Sometimes drawers are run on centre runners and the sides set in $\frac{1}{16}$ in. to give plenty of clearance and to prevent any possible tightness or binding in the carcase (Fig. 13 C).

CHAPTER 11

STAIR BUILDING

PARTS OF A STAIR. PLANNING THE LAY-OUT. MARKING-OUT STRING AND NEWELS. HOUSING THE STRINGS. FITTING UP. WEDGING UP. FIXING THE STAIR. WINDERS. LANDINGS. OPEN-STRING STAIRS. ROUNDED-END STEPS. SPANDREL FRAMING. TIMBER STOCK SIZES.

A STAIR is a means of access between floors or different levels. It may be straight or circular in plan, and may be plain or ornamental in design, but in each case it simply consists of a series of steps one upon another.

It should be emphasised at the outset that there is nothing remarkable in stairbuilding; any intelligent joiner can make a straightforward stair. This is stated because there is a widespread idea among joiners that the man engaged on stairbuilding is doing work far beyond their own capabilities.

In circular stairs and wreathed handrails this may be true, as a good working knowledge of plane geometry, considerable skill in the handling of tools, and a wealth of experience is essential. This chapter deals with straight work, and the stairs described should present no difficulties to the average practical man.

Types of Stairs

Straight stairs are of two general types:—

(*a*) Those fitted between walls, and (*b*) those fitted round a well, the well being the void round which the stair is built. The latter type of construction is known as the open newel stair.

The following are the names generally used for the component parts of a stair (Fig. 1):—

Tread. The board forming the horizontal face of the step.

Riser. The board forming the vertical face of the step.

Scotia Moulding. Small moulding fitted under the nosing of the tread. (Scotia is the joiner's term for a cavetto moulding.)

Flier (Fig 2). A step with its edges parallel as in a straight flight.

Stair String. The inclined board supporting the ends of the treads and risers.

Wall String. A string adjoining or against a wall.

Closed or Housed String. A string with one side housed to support the ends of the treads and risers; its outer face is exposed.

Cut and Mitred String. A string cut on the upper edge with a square abutment for the tread and a mitred edge for the riser.

Newel. The post at the end of a flight which supports the handrail and string, and which sometimes carries the weight of the stair to a lower floor.

Handrail. The rail fixed parallel above the string to serve as a guard rail, and to give assistance in ascending and descending the stair.

Baluster. Upright member

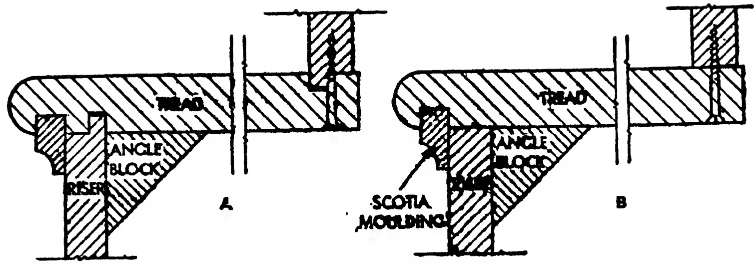


Fig. 1. Formation of steps. *A.* First-class construction. The tread is grooved to receive the riser ; *B.* simple construction. In both cases the scotia moulding is fitted in a groove in the tread.

between the string and handrail to give support to the latter ; may be shaped, square, round or square turned.

Balustrade. The combined framework, solid or open, between the handrail and string.

Winder (Fig. 3). A triangular step, used to change the direction of a flight of stairs.

Bullnose Step (Fig. 4). A step with a quadrant end.

Landing Nosing (Fig. 7). A member moulded to the same section as the tread, to make the finish to the ends and edges of the floor boards forming the landing.

Usually the architect supplies the layout and full-size details, and a note is inserted whereby the contractor is responsible for sizes to be taken on the site. The checking of sizes is a most necessary precaution, and any discrepancy should be reported to the architect, but the setter-out must satisfy himself that the

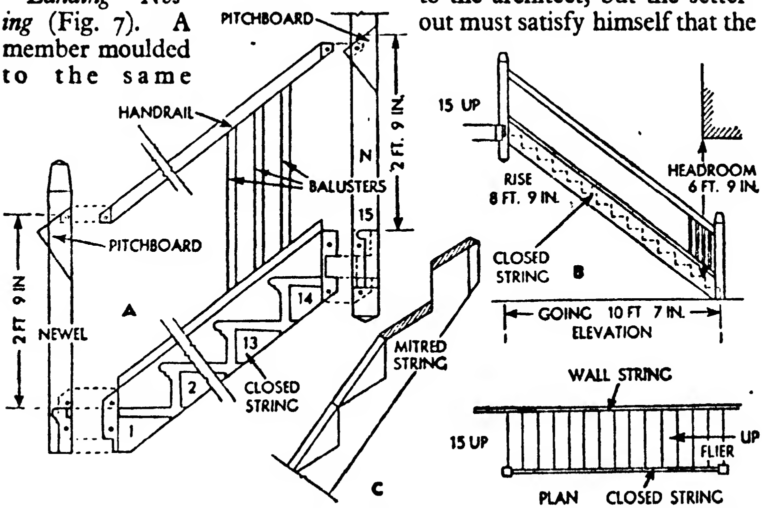


Fig. 2. Component parts of a stair. *A.* Part of a stair disassociated, and including the stair string, newel, handrail, and balusters. The newels, handrail and balusters form the balustrade. Note the position of the pitchboard to determine the angle of the rail ; *B.* plan and elevation of a straight flight of stairs, the construction of which is dealt with in the text ; *C.* cut and mitred string.

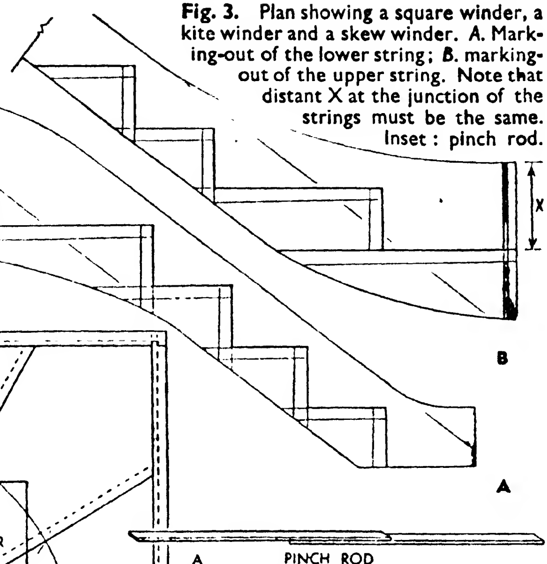
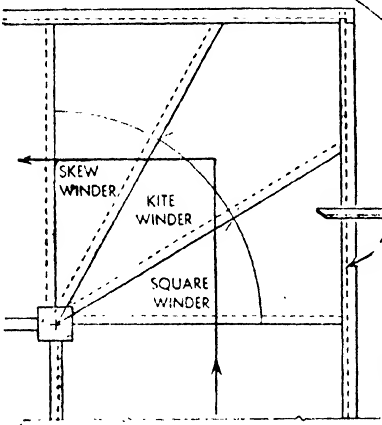


Fig. 3. Plan showing a square winder, a kite winder and a skew winder. A. Marking-out of the lower string; B. marking-out of the upper string. Note that distant X at the junction of the strings must be the same. Inset : pinch rod.



stair is 'workable,' that is, that the stair will fit the space provided, *e.g.*, that there is sufficient *headroom* (not less than 6 ft. 6 in.) and that the stair does not come across window or door openings.

A well-designed stair should not require undue exertion to ascend, or be dangerous to descend.

Every riser in a straight flight should be of the same height, but if there is a change of direction by means of a quarter-space (Fig. 5 A) or half-space landing (Fig. 5 B) so that the steps are interrupted, then a difference in the height of the risers of the flight is permissible. This difference in heights should not be tolerated if winders link up the flights, for then the stair is continuous.

The *rise* of a step is the vertical distance taken from the top of one tread to the top of the next tread.

The *going* is the horizontal distance taken from the face of one riser to the face of the next riser.

There are two simple methods of determining the proportion between the rise and the going of a stair.

(*a*) Going × rise = approximately 66.

(*b*) Twice the rise plus the going = approximately 23 in.

In practical setting-out these exact proportions are not often attainable, but serious variation will cause a difficult step. Also there are limits to which the rise and going should be taken; a rise over $7\frac{1}{2}$ in. gives a very narrow tread and under 4 in. gives a very wide tread; moreover,

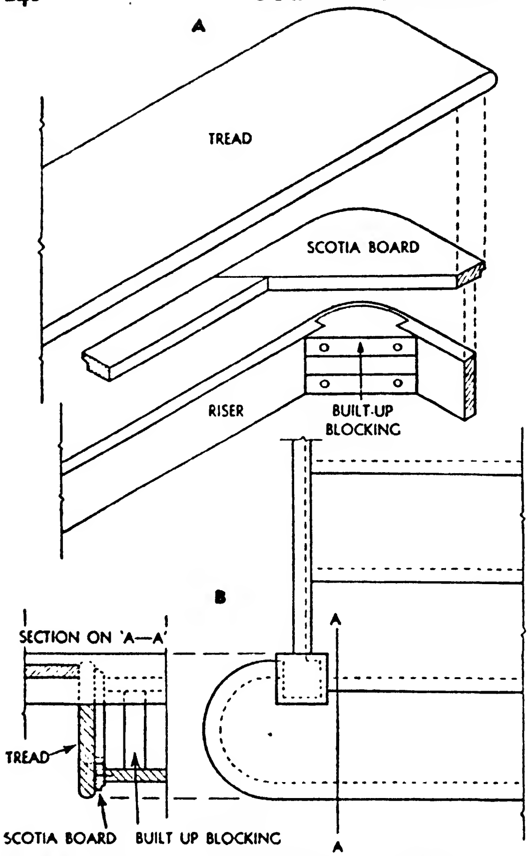


Fig. 4. Construction of shaped steps at the foot of a stair. A. The parts of a bull-nose step with tread, scotia board, and built-up blocking; the riser is cut down to about ⅛ in. thick at the bend. B. half-round or dee-end step; the section shows the built-up blocking and the scotia board.

be used for the treads. B shows the elevation of an 'easy' stair. Note that in both cases the total rise is the vertical distance from the top of the finished floor to the top of the finished floor above, and that the total going is the horizontal distance from the face of the first riser to the face of the last riser at the top.

The actual construction of a stair is best understood by an explanation in detail of the various operations in making and fixing a stair from start to finish. For this purpose the stair shown in Fig. 2 B has been selected, as better-class work only consists of improvements in construction and design. Hand methods are described, because if the joiner can understand these he can easily deal with machine-made parts.

a steep step is difficult to climb and a shallow step is dangerous. The limits then should only be exceeded if the circumstances are such that they cannot be avoided.

Fig. 6 shows the extremes to which stairs are made. At A is shown the elevation of a step ladder, which is constructed without risers so that a good foothold can be obtained. Because there are no risers, stouter timber must

First, dimensions must be taken on the building site. These measurements are usually made on a long batten or floor board. Procedure is to mark the top of the finished floor on the batten by standing it upright and resting on the lower floor. It should be remembered that the total rise required is from the finished floor to the finished floor, and if the floor boards are not laid at the time of measuring allowance must be made for them.

The total going is then measured on the batten; the positions of adjacent window and door openings checked; the depth of the first floor measured, and the positions of the trimmers round the well recorded. These dimensions should be entered into a note book together with all data that might be useful.

It should be realised that the job may be some distance away from the workshop, and it is a waste of time and money to revisit the site for some forgotten detail. Therefore, check all sizes twice and leave nothing to chance.

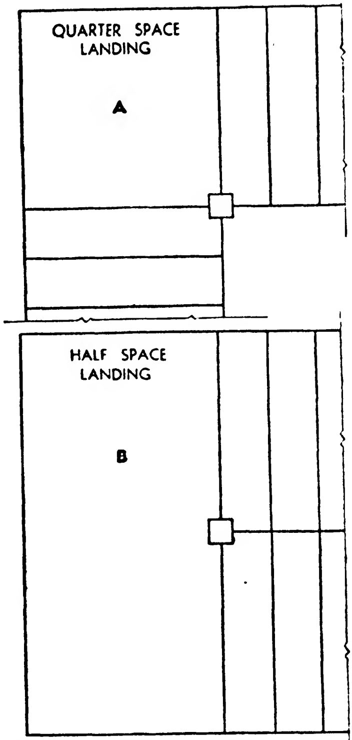


Fig. 5. Types of landings to stairs. A. Quarter-space landing whose width is the width of the stair; B. half-space landing, whose width is twice the width of the stair.

In the Workshop

On a straight batten, mark the total rise (which in this case is 8 ft. 9 in.) and with a pair of dividers step out 15 equal divisions. Square these lines across the batten and number 1 to 15. This riser batten is known as a *story rod*. In the example, the rise is found by calculation to be 7 in., but this is an exception, as the rise generally works out to inches and fractions of an inch. In such a case, it may be necessary to step out the divisions several times before the spacings become equal.

Next mark out the total going of 10 ft. 7 in. on the rod, but deduct 1 in. for the

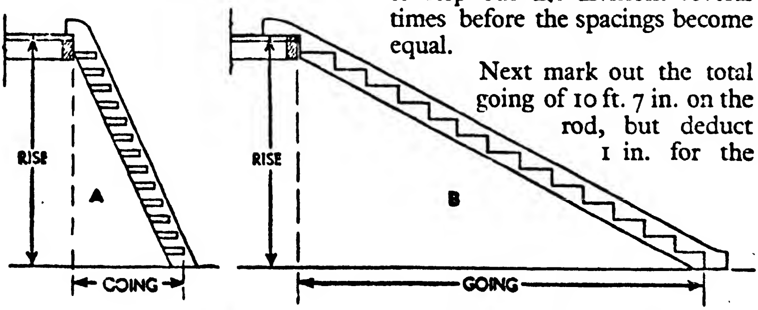


Fig. 6. Pitch or inclination of stairs. A. Step ladder with no riser boards. A steep pitch is permissible; B. 'easy stair of low pitch. The total rise of a stair is from the top of the floor to the top of the floor above, and the total 'Going' is from the face of the first riser to the face of the last riser.

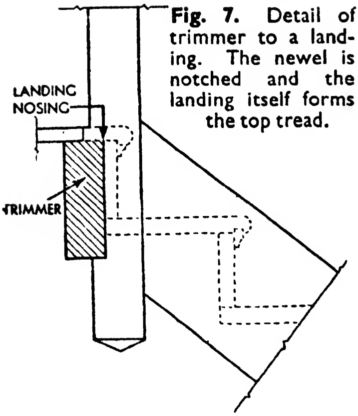


Fig. 7. Detail of trimmer to a landing. The newel is notched and the landing itself forms the top tread.

thickness of the top riser which butts against the trimmer (Fig. 7). This gives 10 ft. 6 in. and this distance is divided into 14 equal parts to give a going of 9 in. Notice there are 15 risers but only 14 treads, as the tread of the 15th riser is the floor above. A rebated nosing, as shown, is required to finish the top step.

A *Pitch board* (Fig. 8 A) is used to mark out the steps. A piece of plywood of $\frac{1}{8}$ in. or $\frac{1}{4}$ in. thickness is admirable for this purpose. Procedure is to plane two edges perfectly square and mark on one edge the going and on the other edge the rise. Carefully cut and plane the triangular templet to the marks.

At this stage it is a wise precaution to check over the sizes, so that any error may be found before the work on the stair is commenced. 15 times the rise on the pitchboard = 8 ft. 9 in.; 14 times the going on the pitchboard = 10 ft. 6 in. plus 1 in. for top riser = 10 ft. 7 in. Fig 8 B shows a *margin templet* which is used to gauge the distance from the edge of the string to the intersection of the riser face with the top of

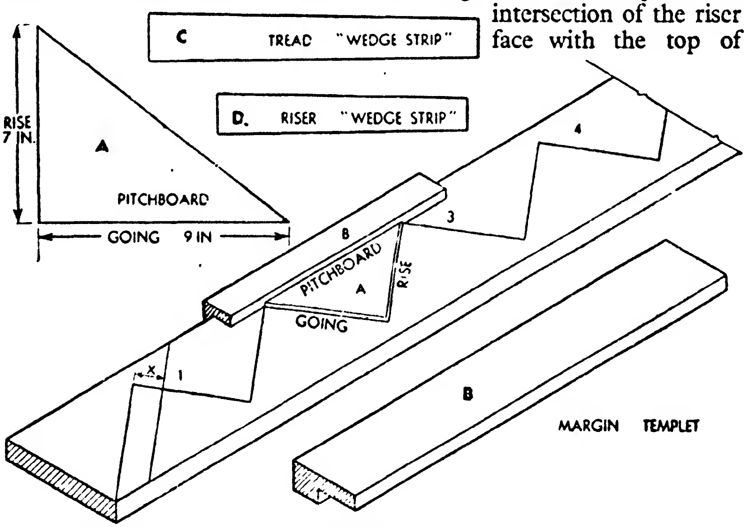


Fig. 8. Marking-out appliances and their use in marking out a string. A. Pitchboard or templet to give the exact rise and going of a step ; B. margin templet to gauge the distance from the edge of the string ; C. tread wedge-strip to mark the thickness of the tread and allow wedge room ; D. riser wedge-strip to mark out for riser. Note the distance X is equal to half the thickness of the newel and is the set-back for the shoulder lines on the tenon.

tread. A distance of 1½ in. is ample unless there is to be a moulded edge, in which case the templet must be made to suit.

Marking out the Strings

Procedure is to lay the string on the bench with the margin templet on its top edge (Fig. 8) and mark out each step by sliding the margin templet and pitch-board along the string; number all steps in blue pencil 1 to 15. Next mark out the other string to form a pair.

Two *wedge strips* made of thin wood are required, one for the tread housing and one for the riser housing (Figs. 8 C and D). The tread wedge strip is tapered, one end is made to the thickness of the tread plus ¼ in. and the wider end equal to the thickness of the tread plus ½ in. The riser wedge strip has its narrow end equal to the thickness of the riser plus ¼ in. and the taper is made to the same angle as the tread strip. This enables a standard wedge to be used for the tread and the riser.

The housings for the treads are marked out by keeping the tread strip to the face of the treads, and the housings for the risers are marked by keeping the riser strip to the face of the risers.

Next mark the positions of the newels on the outer string. As the faces of the risers are in the centre of the newels, measure half the thickness of the newel from riser No. 1 and from riser No. 15 to give the shoulder lines of the tenons (Fig. 8 X).

The width of the mortise holes is taken from the shoulders of the string, and the housings for the risers are marked as shown in Fig. 9. Mortise holes for the handrail are marked out as in Fig. 2 A by using the pitch-board to determine the inclination.

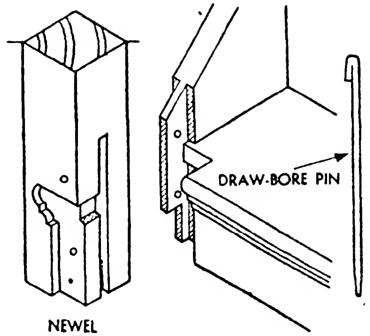


Fig. 9. Jointing the newel to the stair string. The newel is housed for the tread and riser, and the tread is cut to fit the newel. A draw-bore pin is used for the purpose of pulling the tenon to the newel.

For ordinary stairs the height of the handrail is from 2 ft. 7 in. to 2 ft. 9 in. measured vertically from the top of the riser face to the top of the rail. On landings the height is made 3 ft. to 3 ft. 2 in.

Housing the Strings

Procedure is to fix the string to the bench with a handscrew and bore holes with a sharp centre bit ½ in. deep, as shown in Fig. 10 A. With practice the depth can be judged without much testing. Next cut out the corner as shown at B by using a 1 in. or 1½ in. chisel, slightly under-cutting the lines. With the bevel of the chisel down, roughly clear the waste wood and finish the housing with a router plane set to ½ in.

The router should be used to gauge the depth of the housings by sliding the sole of the plane along the string so that the cutter marks the edge as shown in Fig. 10.

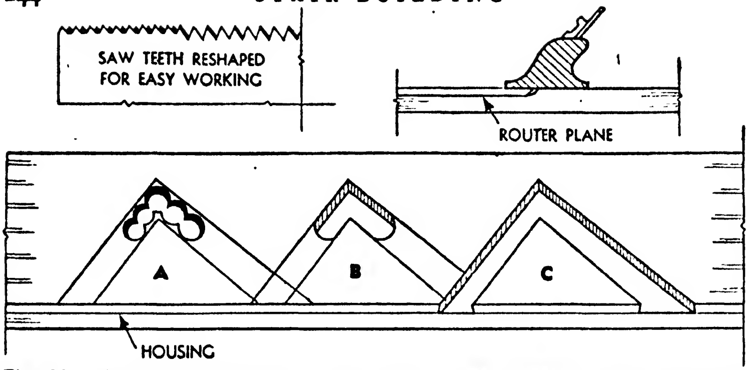


Fig. 10. Housing a stair string. The router plane is used to gauge the depth of the housing. The procedure in cutting a string is :—Bore holes as at *A* with a centre bit, cut housing as at *B* to enable the toe of the saw to work in the corner, and complete as at *C*. A portion of the saw, made from an old tenon saw, is shown with teeth adapted for easy working.

With a 10 in. or 12 in. tenon saw, cut the tread housings slightly undercut. Roughly cut the waste out with a chisel held bevel downwards, then finish with the router to the stage shown in Fig. 10 C. Repeat the process on the riser housings.

An excellent saw for stair work may be made from an old tenon saw by breaking off every other tooth with a pair of pincers and resharpening as shown in Fig. 10.

Tenons on the outer string are gauged and cut out with a chisel instead of sawing. This method is easier than ripping such wide material, and it gives a much cleaner tenon.

The shoulders are first cut down to the gauge lines, then with the string fixed in the vice the cheeks of the tenons are chopped off with a 1½ in. chisel and mallet. (Fig. 11 A.) Using the shoulder of the tenon as a fence, the face is planed down to the gauge lines with a rebate plane to the stage shown at B and is completed as shown at C with a jack plane. The haunch of the tenon is then cut in order to complete the string.

Newels are mortised, housed for the risers, and bored for ½ in. dowels. The newels are then fitted to the string, care being taken to ensure that the tread line on the string corresponds with the tread line on the newels.

While in position the ½ in. twist bit is inserted in the drilled holes on the newel, and the point of the bit marked on the tenon for draw-boring. The newel is then removed and the tenons bored with the ½ in. bit $\frac{1}{16}$ in. nearer to the shoulder, so that when the dowels are driven in the shoulders are pulled up tight.

The bottom newel should then be refitted, and a pair of *draw-bore pins* used to pull the joint together. These pins (Fig. 9) are made from $\frac{7}{16}$ in. wrought iron, and are about 12 in. long; the pins are then removed and replaced by wooden dowels.

The nosing and scotia moulding of No. 1 tread is then marked on the newel, bored out and cut with a chisel and gouge, slightly undercutting the housing. (Fig. 9). The tread should then be cut so as to fit exactly over the newel.

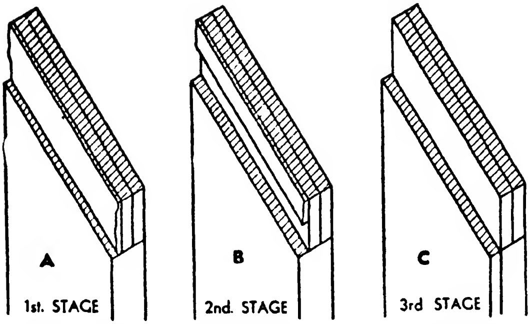


Fig. 11. Paring sides of tenon to a string in preference to sawing. *A.* First stage, tenon gauged and cheeks chopped off with chisel ; *B.* second stage, tenon thicknessed with rebate plane ; *C.* final stage, cleaned off with jack plane.

When the steps are dry they should be fitted by marking the profile of the moulding and nosing on the string. The width of the risers should be marked off the housings at the same time. (Fig. 14.) Steps should be numbered on the underside to correspond with the strings.

Nosings are bored and cut out with a sharp chisel and gouge, keeping the housing slightly undercut as before. Edges of the risers are then planed to the tread marks with a slight bevel, and the edge is slightly rounded as shown in

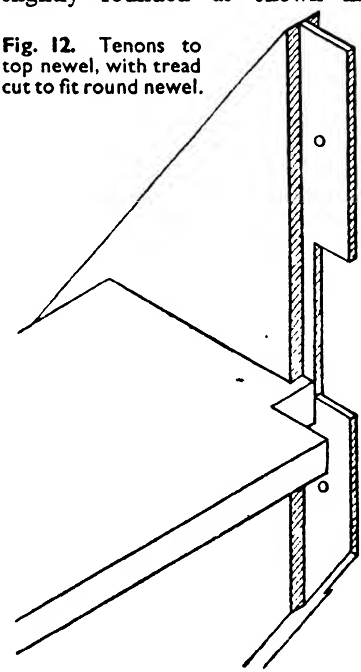
Sometimes the top newel is fitted and the back of No. 14 tread cut out (Fig. 12) or alternatively, the cutting may be left until the stair is assembled.

Treads and risers should then be cut to their correct length, that is, to the distance between the strings plus the depth of two housings. Treads and risers are generally made $\frac{1}{8}$ in. short, because they rarely fit well down in the housings.

Grooves are then made in the treads for the scotia mouldings ; the nosing moulded on the front edge, and the treads cleaned up and stacked on the bench with their mouldings inserted as shown in Fig. 13 A. Angle blocks 3 in. to 5 in. in length are then prepared and placed in some convenient place for gluing up.

Treads and risers should be glued together before fixing in the strings. Procedure is to draw the glue brush along the tread and moulding, well rub the riser against the glued surface, glue and rub in three angle blocks to a tread, roughly check for square and stack as in Fig. 13 B.

Fig. 12. Tenons to top newel, with tread cut to fit round newel.



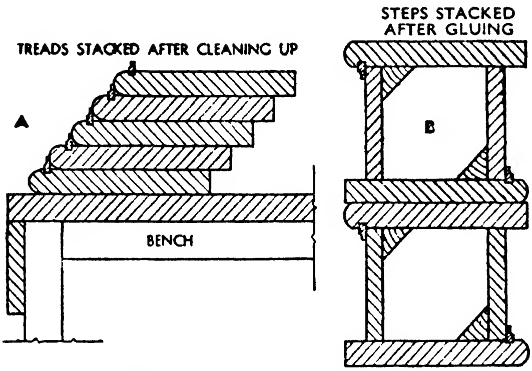


Fig. 13. Methods of stacking treads and risers. *A*. Treads stacked after cleaning up ; *B*. steps stacked after squaring and gluing up.

Fig. 15. This convex edge ensures a good fit when wedged up.

Wedging up

The stair is assembled on the bench and strutted from the ceiling joists with a pair of folding wedges to give the necessary pressure. Fig. 16 shows the stair in position with the struts wedged.

Wedges for the stair are cut to a pattern so that they fit tight on driving. A number are put into the glue pot with their thin ends down. They are then inserted hand-tight in the tread housings. One string should be dealt with at a time, starting with the string already on the bench. The back edge of the tread is tapped to make the nosing tight against the nosing housing, and the wedges are driven in with a hammer.

This process is repeated to the upper string, using a dry wedge for the bottom tread that enters the newel. Surplus tread wedges are cut off, and if the back edges of the treads project over the risers they are chopped off with a chisel to enable the wedges of the risers to be fitted. Risers are then wedged, one string at a time.

The back edges of the treads are then bored for screws, two or three for each tread as may be necessary. The bottom tread is left until the newel is fixed.

When the wedging is completed, the stair is taken off the bench to fit the newel. This is fixed with draw-bore pins, and the bottom tread fitted and screwed from the back.

The landing nosing is then fitted to the top newel and wall string; note that the scotia moulding is not grooved into the underside of the nosing, but is reduced in width and nailed with fine brads as shown in Fig. 7.

The back of the top newel,

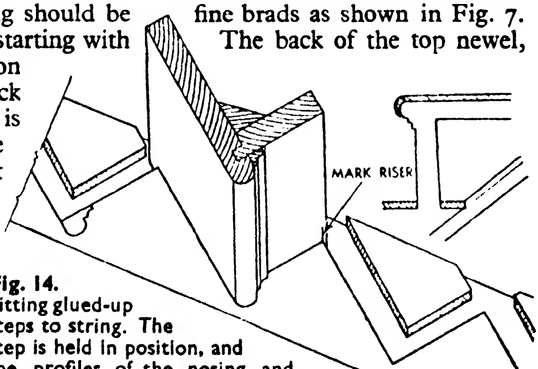


Fig. 14. Fitting glued-up steps to string. The step is held in position, and the profiles of the nosing and scotia moulding are marked. The inset shows the housing complete.

to fit over the trimmer, may be cut as shown at Fig. 7 or, as is more usual, it can be left until the stair is fixed on the site.

To fix the handrail the shoulders are marked from the outer string, cut and fitted to the newels, and draw-bore pinned as previously described.

A good plan is to make a box similar to a mitre box, and to make a saw-cut to the angle of the pitchboard as shown in Fig. 17. It is always difficult to cut a moulded handrail square, and the box may be used for cutting the capping and the balusters.

Everything possible should be fitted in the workshop, even though the final assembling is done on the job. Usually it is difficult to get the stair on the site complete, as there may be door openings and awkward corners to negotiate.

Fixing the Stair

On the site, the wall string is cut to fit the landing floor (Fig. 18 A) and the newels, handrail, nosing and riser are fixed to the stair. The whole stair is then hoisted into position, and 4 in. nails are driven through the underside of the wall string into the joints.

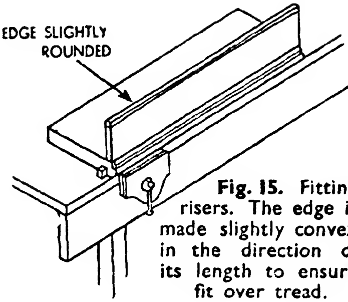


Fig. 15. Fitting risers. The edge is made slightly convex in the direction of its length to ensure fit over tread.

The top newel is then fixed to the trimmer, using a plumb-bob to make sure that the newel is upright. The capping to the top edge of the outer string is cut and nailed in position, and the balusters are nailed to the string and handrail with $1\frac{1}{2}$ in. oval nails (Fig. 18 B).

When nailing balusters, especially on a long flight of stairs, one or two balusters should be fixed in the centre first, otherwise there

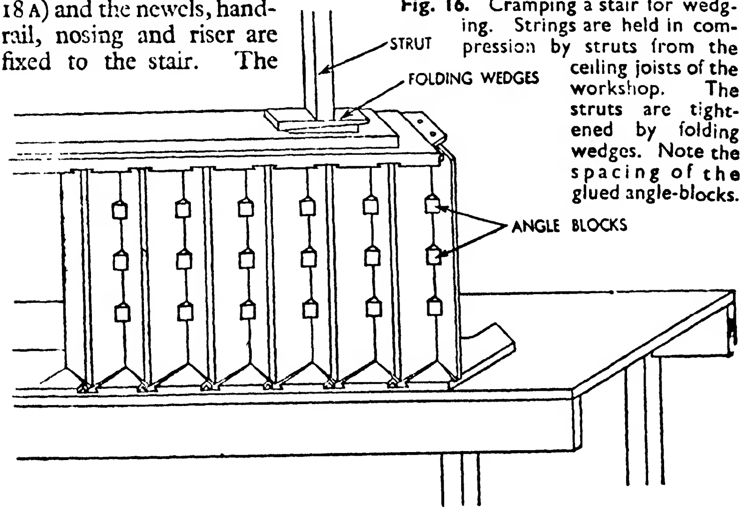


Fig. 16. Cramping a stair for wedging. Strings are held in compression by struts from the ceiling joists of the workshop. The struts are tightened by folding wedges. Note the spacing of the glued angle-blocks.

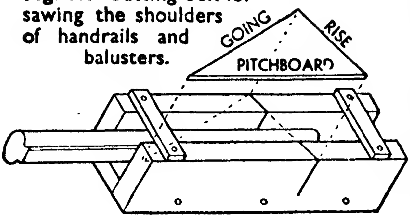


Fig. 17. Cutting-box for sawing the shoulders of handrails and balusters.

is a tendency for the rail to be fixed with a convex edge, as each baluster tends to push the rail up slightly.

A point to note here; where possible not more than 12 treads should be fixed in a straight flight without a landing to give a rest in the effort of climbing. In the example dealt with there are 15 steps, but this is one instance where it was assumed that no alternative was possible.

Winders should be avoided wherever possible, but sometimes they are a necessary evil. Often they afford the only means of obtaining a reasonable headroom when a stair is in a confined space. The setting out of the newels and strings is the only elaboration to that of a straight flight.

Fig. 3 shows the plan of the top portion of a stair with winders, the first winder is known as the *square winder*, the second is the *kite*, and the third is the *skew*. In setting-out for winders, lay the plan out full size on a board. Show the positions of the strings and newel. and with a dotted line show the depth of the housing in the strings.

It should be noted that the faces of the risers radiate from the centre of the newel. They are set out with the compasses by drawing a quadrant of any radius and stepping round three equal spaces. Lines are drawn from the centre of the newel through these points to the wall strings to represent the faces of the risers. Nosing lines are marked in front of these riser lines, and the thickness of the riser is shown at the back of the lines.

The plan length of the winders on the inside face of the wall strings gives the sizes required for setting out, while the plan of the newel gives the position of the housings of the risers on the respective faces of the newel.

The two strings are tongued and grooved together at their intersection, with the height X above the tread on each string the same. The actual height is left to the discretion of the setter-out, but it should be enough to give a flowing curve on both strings. The curve is usually obtained by bending a thin lath to a suitable shape and marking round it, the margin being ignored.

When taking sizes for stairs on the site, the corner of the wall

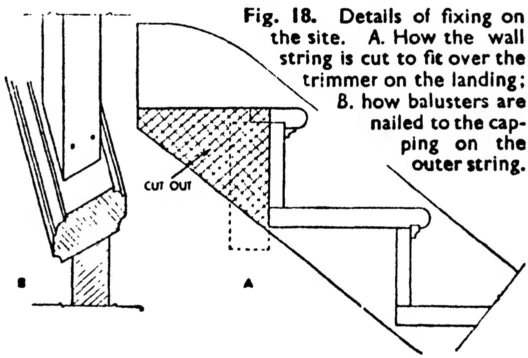


Fig. 18. Details of fixing on the site. A. How the wall string is cut to fit over the trimmer on the landing; B. how balusters are nailed to the capping on the outer string.

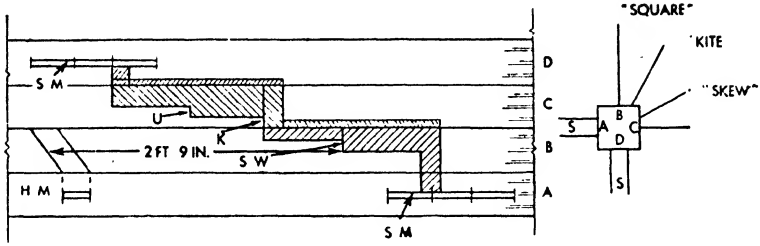


Fig. 19. Setting-out the newel. The drawing shows the plan and elevation of the four faces of a newel marked out for winders. All risers are of the same height ; but the width of tread varies for *SW*, the square winder ; *K* the kite winder ; and *U* the skew winder. *SM* is the mortise for the strings and *HM* the mortise for the handrail. The housings for the risers are cut back to the edge of the newel ; this enables the risers to be fitted and fixed.

should always be tested for squareness. It is as easy to make a stair to suit an angle as it is to make it square, but if the walls are out-of-square and this is only discovered when the stairs are being fixed, there is quite a lot of trouble involved.

In fixing, the square and skew winders present no difficulty, but the kite is usually fairly troublesome unless the newel is well cut back for the end of the winder. Always measure the front edge of the winder from the housing in the string to the housing in the newel before cutting. The distance is measured on a pair of pinch rods, that is, two strips of wood held together to span the length required. (Fig. 3.)

Fig. 19 shows the plan and elevations of the four faces of a newel which is set out for winders.

Fig. 20 gives a practical example of making a stair workable by introducing winders. The plan shows a stair with 15 steps up, and a quarter-space

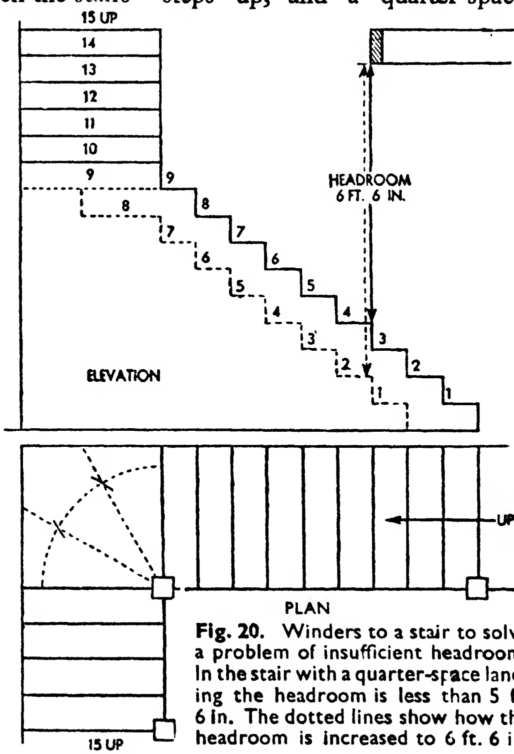


Fig. 20. Winders to a stair to solve a problem of insufficient headroom. In the stair with a quarter-space landing the headroom is less than 5 ft. 6 in. The dotted lines show how the headroom is increased to 6 ft. 6 in.

landing; the trimming round the well is fixed. The sizes show there is insufficient headroom to allow one to pass up the stair.

By introducing winders in place of the quarter-space landing two treads can be taken out at the bottom of the stair so as to give ample headroom. The dotted lines indicate the new position of the stair. Note that the introduction of three winders only gives a gain of two treads, as the landing already counts as one.

Sometimes if there is sufficient room, the trimmer can be adjusted, in which case the bottom going can be decreased by two treads and the top going increased by two treads.

If at any time a stair is found to be impracticable, look out for alternative methods of construction, and put the suggestions to the architect or builder for their decision, but never deviate from a plan without written authority.

Stairs with Landings

The setting-out of a stair with a *quarter-space* or *half-space landing* is exactly similar to that of a straight flight, only instead of one flight there are two. The newel on the turn of the stair is set out as previously described, but instead of one mortise for the string and one for the handrail there are two for each. (Fig. 5.)

If the setting-out is considered as the finish of one flight and the start of another, with one newel instead of two, a clearer idea is obtained.

Sometimes the wall strings are ramped in a similar way to the strings of a winder, with a grooved and tongued corner. The landing

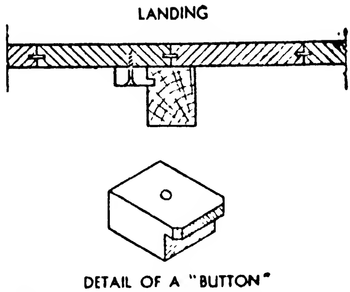


Fig. 21. A landing buttoned to bearers This allows the wide surface of the landing to swell and shrink without splitting or exposing joints.

itself should be cross tongued, and buttoned to the landing bearers. This method of fixing allows for the wide surface to shrink without splitting the joints. (Fig. 21.)

Alternatively, the top of the string may finish with a short ramp, and the start of the next string with a short easing.

Landings may be of ordinary flooring nailed to short joists and finished with a rebated nosing and scotia similar to the finish of the treads.

Cut String Stair

In the next example to be treated in detail, it is assumed that the outer or face string is of the type known as *cut* or *open string*. The pitchboard and the setting-out of the wall string and newels are carried out as previously described.

Fig. 22 A shows the elevation of a cut string. The string is marked out on the outer face without the use of a margin templet. A straight-edge, which can be about $1\frac{1}{2}$ in. by $1\frac{1}{2}$ in. by 1 ft. 6 in., is held against the top edge of the string to form a fence for the pitchboard; and the treads and risers are marked in the usual manner. Obviously no wedge strips are required.

The string is laid with its face uppermost on two sawing stools, and the lines of the tread sawn down to the riser lines. Then with the string fixed in the vice, the mitres for the risers are marked and cut down to the tread lines, as shown in Fig. 2 C. Before this right-angled piece of waste is free, the saw must be inserted in the tread cut to complete the cut to the inside of the mitre.

Notice that the mitre is not at 45 deg. but is the intersection between the thickness of the riser and the thickness of the string, as shown at Fig. 22 B.

A full-size rod should be set out to give the width of the stair and thickness of the strings. The net length of the tread is equal to the distance from the depth of the housing in the wall string to the outside of the cut string plus the overhang of the tread nosing. The tread is cut to length plus ¼ in. waste, and grooved for scotia moulding.

Mitres on the treads are marked with a templet, as shown in Fig. 23 A, and cut about half-way, while the tread is cut across to the mitre and sawn off square, so that a portion (marked *X* in Fig. 23 A) is left on to protect the mitre during nosing and cleaning up operations.

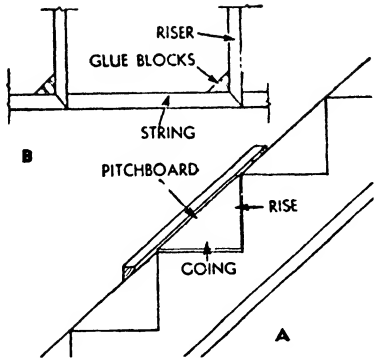


Fig. 22. Method of marking-out a cut and mitred string. A. The string being marked on its outside face, by holding the pitchboard against a straight edge. The mitre of the string with the riser face is not cut at 45 deg., as can be seen in the part plan at B.

The risers are then cut to their correct length, that is, from the depth of the housing in the wall string to the outer face of the cut string. The cut on one end is made to the mitre shown on the rod in Fig. 22 B. Mitres on the risers should be planed true, and the scotia mouldings cut to length and mitred.

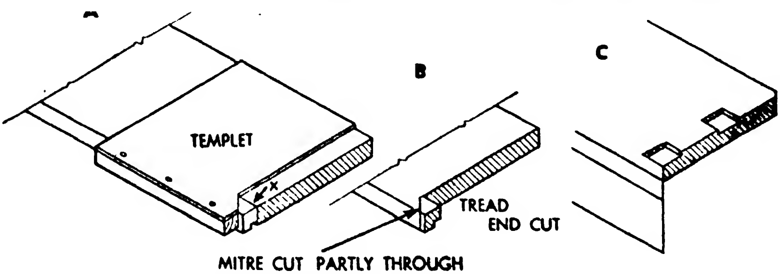
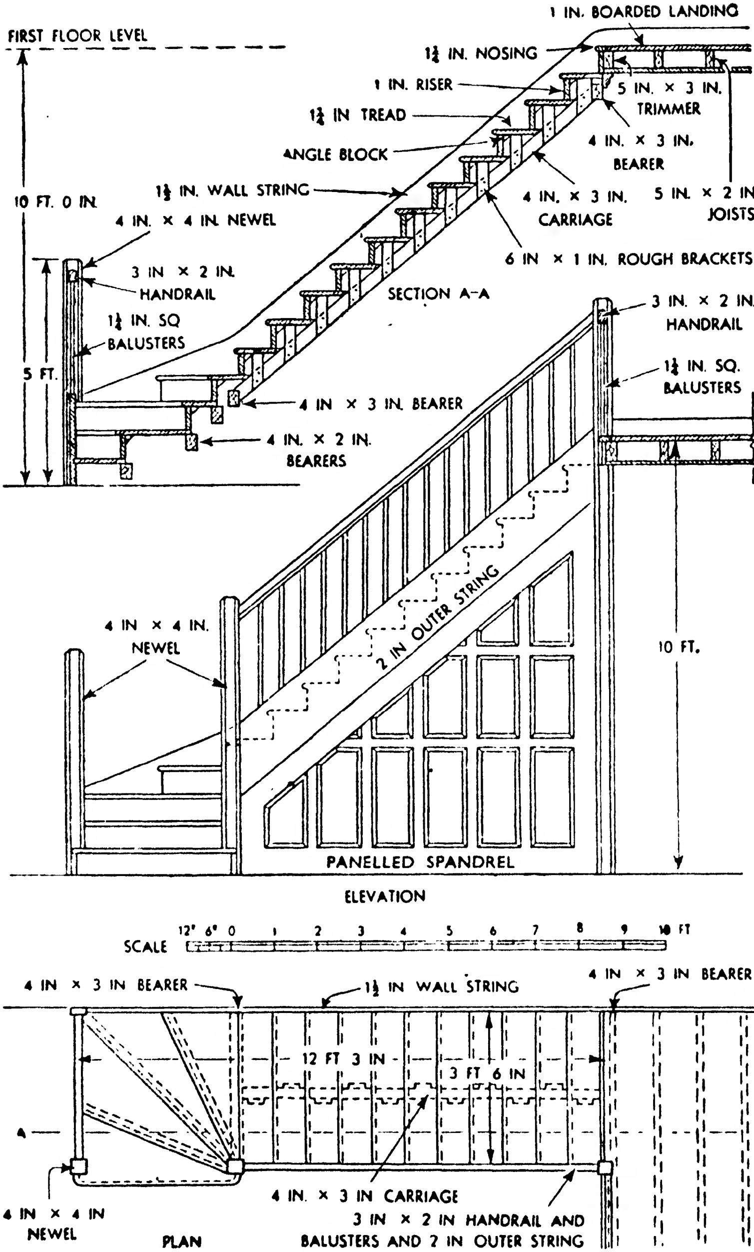


Fig. 23. A. Marking-out a tread with a templet to obtain the mitre to the nosing; B. the mitre partly cut. This waste piece is left on to protect the mitre until the tread is cleaned up; C. treads cut to house the ends of the balusters.



Architect's detail drawing of a staircase, giving all essential information.

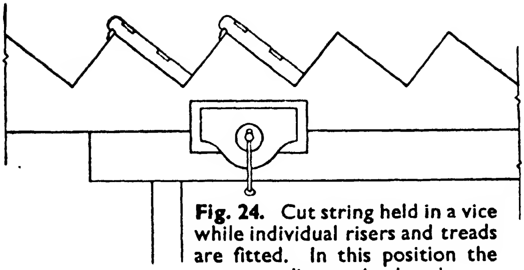


Fig. 24. Cut string held in a vice while individual risers and treads are fitted. In this position the steps lie on the bench.

be held in the vice so that the steps lie across the bench, as shown in Fig. 24.

After fitting the bottom tread to the newel the steps should be fitted to the cut string, and held by screws inserted through the baluster housings. Any risers which are slightly wide, and therefore prevent the tread "bedding" down tightly to the string, should be planed off. When the fitting is complete, the treads are unscrewed and the face of the string cleaned up.

To glue the stair, one step should be fixed at a time by gluing the riser mitre, screwing the tread to the string and nailing the riser with oval nails. When this is complete, the stair should be turned over on to the

Treads and risers are then glued up in a manner previously explained, but the mitred ends must be in alignment. The nosings and mouldings are then fitted to the housings of the wall string and clearly marked.

Housings should then be cut in the ends of the treads for the balusters, and the incomplete mitres on the nosings cut through as shown in Fig. 23 C.

When the steps are being fitted to the cut string, the work should

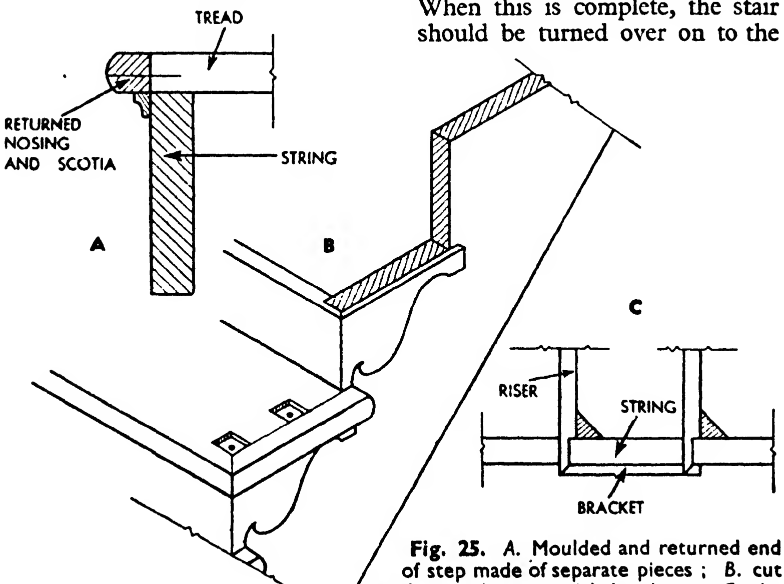


Fig. 25. A. Moulded and returned end of step made of separate pieces; B. cut and mitred string with brackets; C. the risers are longer by the thickness of the bracket.

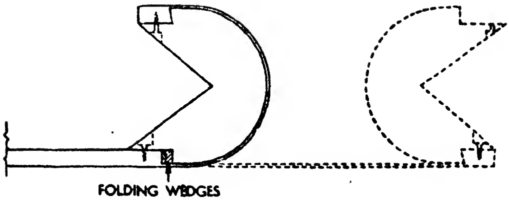


Fig. 26. Forming a half-round step. The riser is reduced to the thickness of a veneer, bent round a laminated block, and glued and wedged as shown. The dotted line indicates the position of the block before bending round the riser.

wall string and wedges inserted.

When the treads are screwed to the risers, angle blocks should be glued at the backs of the risers and the cut string. The returned moulded ends should then be glued and nailed with 2 in. nails.

These moulded ends may be made from the solid or the nosing and scotia may be made separately as shown in Fig. 25 A.

If brackets are required for ornamental purposes, the risers should be made longer by the thickness of the brackets, and the width of the overhang of the returned end increased by a similar amount as shown in Fig. 25 B. Note that in this case the vertical cut on the string is square to the face of the string and is not mitred, the riser being rebated and mitred to the bracket.

Finishings to a Stair

Fig. 4 shows a part plan of a stair with a *rounded-end step* with the riser in one piece cut to a thin veneer to fit round a solid block. The plan of the step should be set out with the compasses on a piece of thin board to form a templet. Short ends of timber are then cut to this shape, and glued and nailed together.

When the block is dry it should be fixed in the vice and smoothed to shape with a sharp plane. The riser must be made from carefully selected timber, free from knots, and the block should be rolled round the back of the riser to obtain the length of surface to be cut. An allowance of $\frac{3}{4}$ in. should be made on this length for the insertion of folding wedges to tighten the veneer.

The end of the riser should be fixed to the block with screws as shown in Fig. 26 and the veneered portion well soaked in boiling water, carefully given a trial roll, then well coated with glue, rolled and screwed. Before driving in the folding wedges, boiling water should again be poured over the veneer to liquefy the glue. Then the wedges are finally driven to pull the veneer tight over the block.

Fig. 27 A shows a section of the usual finish to the trimmers round the well-hole. Notice that the linings must be wide enough to project below the trimmer to allow for plaster ceiling.

Fig. 27 B shows the elevation of a typical *spandrel framing* to fit under a stair. It is usual either to rebate the bottom edge of the string and the newels to receive the framing, or simply to butt the frame against the string and cover the joint with a small fillet or moulding.

Fig. 27 C shows a part elevation of a stair with a *carriage*, that is, a beam to give additional support to the stair. Stairs over 3 ft. wide must have these additional supports. It is usual to put one

4 in. by 3 in. rough scantling in the centre of an ordinary stair to give stability; rough brackets, with glued angle blocks to the tread, are fixed to the carriage.

Fig. 27 D also shows a detail of a handrail which is tenoned and housed into the newel. The shoulders are cut ¼ in. longer than the sight-line of the handrail, the tenon fitted into the newel, and the profile of the handrail section marked on the newel for housing. The handrail is then cut square from the shoulders to the sight-line to avoid deep undercutting on the newel face.

To complete the chapter here are a few suggestions for the stair builder.

For ordinary work wrought British Columbia pine, redwood, and yellow or white deal can be obtained from the timber merchants in stock sizes as follows :—

Strings	...	1¼″ × 9″ or 11″ wide.
„	...	1½″ × 9″ or 11″ „
„	...	2″ × 9″ or 11″ „
Treads	...	1¼″ × 11″ wide.
„	...	1½″ × 11″ „
„	...	2″ × 11″ „
Risers	...	¾″ × 7″ wide.
„	...	1″ × 7″ „
„	...	1¼″ × 7″ „
Newels	...	4″ × 4″
„	...	5″ × 5″
„	...	6″ × 6″

Scotia moulding, usually 1 in. by ½ in. finished size, can be obtained in two or three different sections.

Capping and handrail in soft or hardwoods can be obtained from stock from some merchants in a variety of sizes and sections, also various types of square or round-turned balusters.

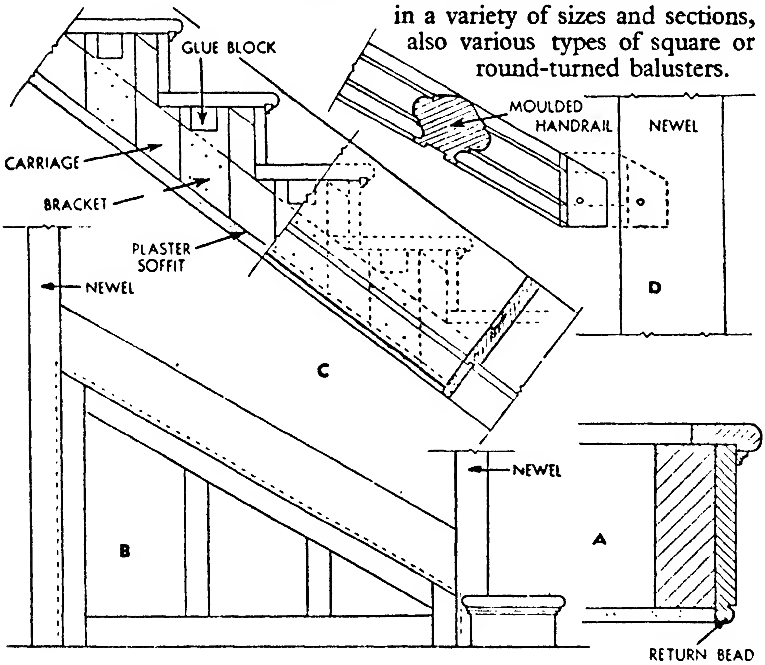


Fig. 27. Miscellaneous finishes to stairs. A. Finish to a trimmer round a well ; B. elevation of a spandrel frame fitted to the string of a stair ; C. part elevation of a stair with a carriage and rough brackets ; D. detail of a moulded handrail.

CHAPTER 12

SETTING-OUT RODS

WORKING DRAWINGS. MAIN POINTS IN SETTING-OUT. LAY-OUT PRINCIPLES. "WORKING UP" THE PLAN. PRACTICAL EXAMPLES. DUSTPROOF AND AIRTIGHT FITTINGS. SCREENS AND PANELLING. TAKING-OFF MATERIAL. TYPICAL TIMBER SHEETS. ORDERING GLASS AND FURNITURE. SITE MEASUREMENTS. ARCHITECTS' DRAWINGS. SETTING-OUT TOOLS.

SETTING-OUT of joinery may be defined as "a means of conveying to another the form, dimensions, materials, construction, fixing and finish of any given item of joinery." Furthermore, it is a detailed record of the work in hand to which reference can be made for the purpose of machining and assembling the work, and later for the fixing.

Reading Drawings

For modern work it is imperative that a joiner be acquainted with the elements of setting-out, so that he can "read" or understand a *working drawing*. Working drawings as used in the workshop are termed *rods*, because simple items are drawn on thin wooden boards. The term rod is also used to describe the more complicated and involved problems drawn on detail paper.

A good craftsman can make a simple piece of joinery without a rod. He can decide in his own mind how to construct it, what size to make it, and what sizes to use. But directly one man plans the work and others have to carry it out, the details must be conveyed by some means that can be clearly understood. Due to the peculiar nature of joinery work, a full-size drawing is the only adequate means of giving the necessary information.

A rod should be easy to read, and should give all the required information without being confusing. The main points to note in setting-out a rod are :—

(1) The dimensions must be accurate.
(2) It should be clearly and easily interpreted.
(3) Adequate fixing allowances must be made.
(4) It must show how the work is to be constructed in a practical manner.
(5) The amount of work to be done both in the shop and on the site, must be clearly stated.

A rod should be as simple as possible. To achieve this, the same detail should not be drawn twice if it can be avoided. Some involved jobs cannot be described as simple, but they must be clear, and this should be the cardinal aim of the setter-out.

As well as being simple and clear, a rod should be definite. For example, if the size of a door opening is taken from the site, the fixing allowance should not be left for the joiner or foreman to decide, but a definite dimension should be given on the rod to

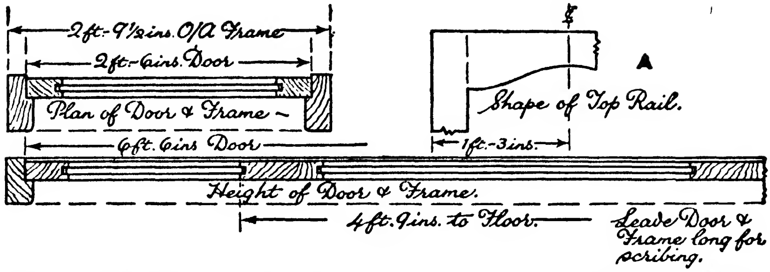


Fig. 1. Typical example of joiner's rod for a door and frame, showing heights and widths. Elevations are only required for shaped work such as is used in the top rail of the door which is shown at A.

cover this work. By adopting this attitude everyone concerned with the work has a clear idea of what is wanted, and the fixer can arrange his fixings before the frame is delivered to the site.

Another important principle is a proper *lay-out* of detail. Setting-out consists of drawing a series of full-size sections, which show the actual sizes of the various members and their relation to each other. Except for shaped or complicated work, elevations need not be given. Vertical sections known as *heights*, and horizontal sections known as *plans* give all the details.

For a simple job, such as a door and frame, two sections give sufficient information, as shown in Fig. 1. If a shaped top rail to the door were required, a part elevation would be required as shown in Fig. 1 A.

For a more complex structure such as a counter with panelled front and sides, framed standards, and carcased bottom, additional sections would have to be given. In such a case, a general height section must be given with subsidiary sections to show the heights of counter front, counter ends and standards. In a similar way, a general horizontal section

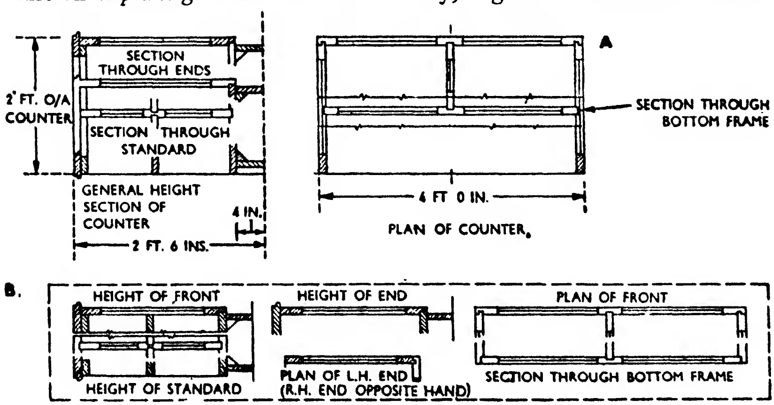


Fig. 2. Methods of setting-out rods. A rod of a counter is shown set out on detail paper 30 in. wide at A. The same counter is shown set out on a board 10 in. wide at B. Note the different arrangement of the sections.

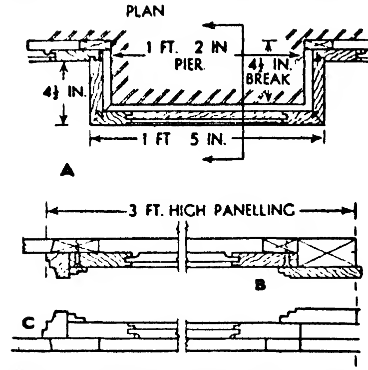


Fig. 3. Proper lay-out of rod. *A*. On the plan a height section is indicated and taken in the direction of the arrows; sizes are always figured in feet and inches; *B*. correct method of laying down a height section; face of work is towards front edge of board; *C*. incorrect method of laying down a height section; face is away from front edge of board.

should have extra plans to show all the members clearly.

The disposition of the various sections on the setting-out depends upon their size, and may vary according to the type of rod used, whether a 10-in. board or a 30-in. wide detail-paper, as shown in Figs. 2 A and B. Confusion is sometimes caused by the sections being drawn the wrong way round. All sections should be drawn as though looking from right to left, as shown in Fig. 3 A, while the face of the work should be towards the front edge of the setting-out board or table, as shown at B and not as shown at C.

There are, of course, exceptions to this rule. A typical example is shown at Fig. 4 A, where the height sections are given of the inner and outer doors of a vestibule with cornice round the soffit. In this case the inner faces are drawn opposite each other. They must be set out in this manner, otherwise, if the doors were painted on one side and polished on the other, a mistake could easily occur.

The third principle concerns relative points. This applies most particularly to height sections, where several heights have to be put down side by side. It often happens that sections are

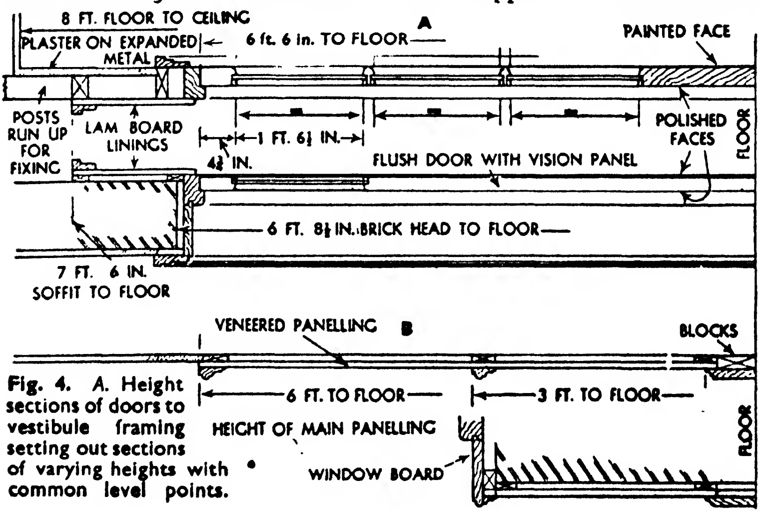


Fig. 4. *A*. Height sections of doors to vestibule framing setting out sections of varying heights with common level points.

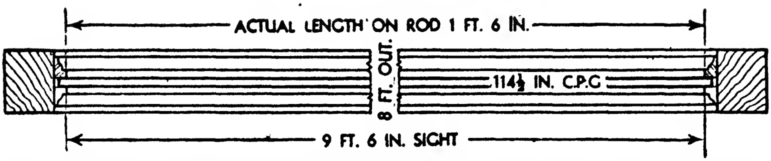


Fig. 5. Method of breaking down size of setting-out. The actual 'sight' dimension and the amount deducted must be clearly stated.

not identical in height, but have some focal point from which they begin; for example, in the case of a panelled room there may be some panelling which only extends to window board, while other portions extend to the cornice. The focal or common point in this case is the floor, and it is advisable to draw the floor levels in line, as shown in Fig. 4 B.

Where there are different floor levels, it is advisable to establish a *datum* or fixed point from which all sizes may be measured. This datum point is decided upon, and marked, when measuring on the site, and is used throughout the setting-out. A good rule is to fix the datum at about 2 ft. 6 in. above the highest floor level, so that window openings will not interfere with the measurements.

It is very important that all main dimensions are figured in, and no dependence be placed upon taking measurements from the rod. In view of the fact that some rods are drawn on paper, which shrinks and swells considerably, no reliance can be placed on the method of laying the material on the rod and marking off sizes from it. Sizes must be stated on the rod, for example, the sight size of frames, and the size between jambs of a doorway opening.

The speed of modern contracts no longer allows of the old practice of waiting until the frame is made before the glass is measured and placed on order; often the glass is ordered before the joinery is made.

With the exception of glass sizes, which are always given in inches, all sizes should be figured in feet and inches. Where several running dimensions are given, care must be taken that the total of these agrees with the overall size.

Methods of Setting-out

It is generally convenient to commence the height section first, and to 'work up' the plan in conjunction with it. This ensures the correct intersection of the various members, and gives a clear picture of any projections either on the job being set-out or on the surrounding work.

It is not always convenient or necessary to set the work out to full height or full plan. To avoid unnecessary work and wastage of paper, a system is adopted whereby the size of the setting-out is reduced by using 'broken lines.' In using this method the size of the setting-out should be reduced by an even amount such as a number of feet, or 9 in. or 6 in., the reduction being inserted between the broken lines.

For example, if the sight size of a glazed frame is 9 ft. 6 in., and the drawing is made to 1 ft. 6 in. sight, insert between the broken lines '8 ft. 0 in. out,' or 'add 8 ft. 0 in.' (Fig. 5) and figure in 9 ft. 6 in. sight. This method of indicating how much is left out will greatly assist when taking off sizes of material for ordering.

Consider Fig. 4, in which two doors of similar overall height, but of different construction, are shown; it will be seen that the breakout cannot be put down indiscriminately. If 2 ft. 0 in. were taken out of the forward door a proportion of this amount would need to be taken out of each of the glazed panels of the rear door, adding up to 2 ft. 0 in. in all.

This point has to be watched in particular when a datum line is used, so that the amount taken out is indicated in the correct relative position; that is, *above* or *below* the datum line as the case may be. Failure to observe this can lead to serious errors.

Conventional Signs

Various means are used to indicate different materials and sections. One method is to hatch all hardwood with ordinary black lead pencil, and softwood with red pencil; blocks are indicated by diagonal lines on the section. Another method is to hatch all height sections in blue, and plan sections in red. The former procedure is to be preferred, as it differentiates between hard and soft wood, thereby eliminating unnecessary writing. Brickwork is usually indicated by double red lines drawn diagonally, ironwork by blue diagonals, brass and bronze by yellow lines and plaster by red dots.

Where a point is indicated by drawing it need not be explained by writing unless the indication is only diagrammatic; for example in the hanging of a door. Where one section is superimposed on another, either in height or plan, edge hatching is used to pick it out from the main section. It is often better to adopt this method rather than make a separate section, as one can see immediately any change in the section of a member. This method is illustrated in Fig. 6 A, and can be compared with the separate sections shown at Fig. 6 B and C.

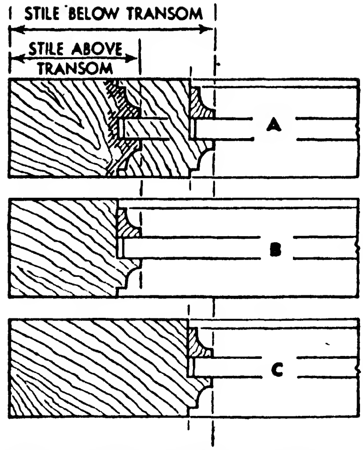


Fig. 6. Superimposed width sections. A. The section below and above the transom on the same drawing; B. and C. show separate sections.

The construction of jobs should be arranged for speedy manufacture, so that various parts can be prepared by different men, and fitted together in the main assembly. Take the case of a display counter with a stepped front portion, shown in Fig. 7. By setting this out in the manner shown, the display portion could be made up quite separately from the rest of the counter, and the whole work can be fitted together on

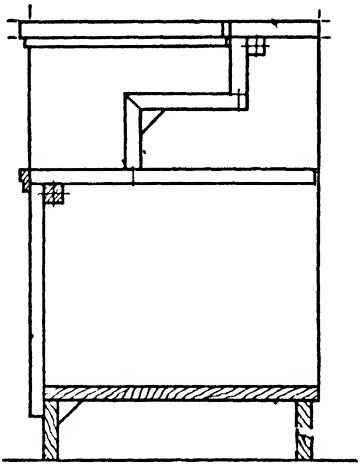


Fig. 7. Construction arranged in setting-out to enable different parts to be made in sections. The stepped front portion of the counter can be made separately.

completion. This procedure is also necessary in view of modern decorated finishes, where oftentimes painted and polished surfaces occur on the same piece of work.

For example, if the job constitutes a polished square edge frame with a decorated panel, it would obviously be necessary to bead the panel in and not groove it, so that the panel could be decorated separately. Again, if panels are to be polished before fitting to their frame, they could be beaded in, instead of grooved, provided that this was without detriment to the job. By this adjustment there would be no need to wait for the panels to be polished before gluing up the frame.

Available materials and machinery also influence the construction employed. With regard to materials, for instance, the sizes of stock sheets of ply should be borne in mind. Consider for this purpose a carcase with ply panels. A 2½-in. muntin may be sufficient for strength, but the use of a 3-in. muntin may just make it possible to get two panels out of one stock sheet of ply. On this point, however, the question of 'proportion' relative to design must not be overlooked, especially when working to architects' drawings.

Time Saving Methods

Good setting-out saves time in the shop. Take, for example, the section of a moulded counter-top in Fig. 8 A, which is 12 ft. long and 2 ft. 6 in. wide; it will be observed that this bulky piece of timber has to be spindled on four edges. In a small shop this operation is an awkward job, and certainly costly; while, due to the long grain of the thickness mould on the ends, there is no proper shrinkage allowance. By a little thought, both the machining and shrinkage difficulties can be avoided, as shown at Fig. 8 B. At A the spindle operations are (1) mould edging; (2) groove edging; (3) tongue counter top.

At B the moulding is the only thing to be spindled. Again, in the second method the thickness mould can be thinner, thereby using less hardwood and enabling it to be glued to the carcase rail, so as to mitre up with return edgings. This example is typical of many such instances which occur.

When setting out carcases with standards and shelves, the members should be arranged to avoid unnecessary flushing off, providing the architect's details do not prevent such action. The standards

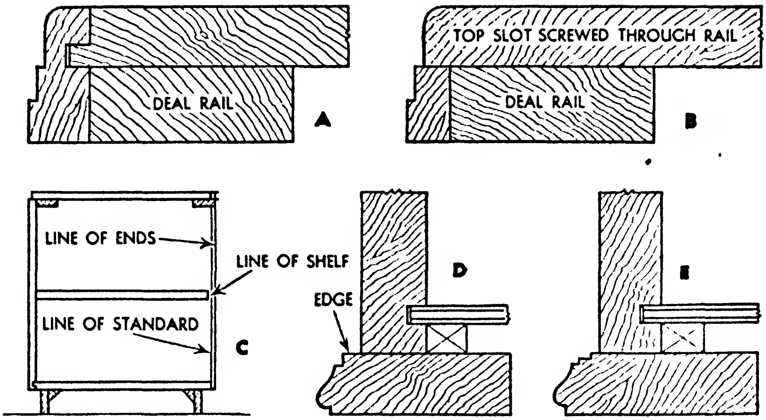


Fig. 8. Adjusting details to simplify production. Detail at *A* shows part of a large counter top; the top and edging have to be machined on the spindle. *B*. How the construction can be adjusted so that the hardwood edging only needs machining on the spindle; *C*. edges of standards and shelves set back from each other to avoid unnecessary cleaning off; *D*. the edge will wear and spoil the appearance of the work; a better arrangement is shown at *E*.

could be set back a bare $\frac{1}{8}$ in. beyond top and bottom carcase rails, and the shelves set back the same amount again beyond the standards. The edges of the shelves and standards can then be cleaned up before assembly, and the rest of the carcase cleaned off without danger of bruising the edges (Fig. 8 C).

Another point to watch, especially in good class work, is relative to ledges below drawers. Consider Fig. 8 D. This is bad design, as the surbase moulding will become worn and disfigured by the drawer sliding in and out. A better section is as shown at Fig. 8 E.

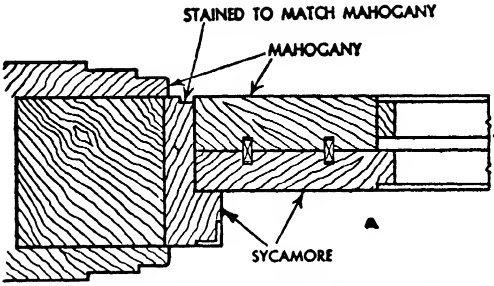
Solid and framed work must not be mixed indiscriminately. There are, however, cases where it is quite unavoidable, but at such times adequate shrinkage allowances must be made.

A very prevalent practice is that of backing hardwood with softwood. The purpose of this is twofold; first, to conserve hardwood, and secondly, to avoid casting or warping. Each case is dealt with on its merits, as the extra labour involved might outweigh the saving of hardwood. This method gives the best results in multiple jobs. The examples given in Fig. 9 show the methods adopted, with comments on their respective merits.

It is generally advisable to glue up the pieces before moulding, so that the edges can be flushed off by the machine. This gluing up generally takes place in the mill, as is the case where different timber is required for each face of the work.

Setting-out Practice

The method of setting-out single doors is generally as shown in Fig. 1. Where single-action springs are used on double doors, it is practicable to have a rebate on the frame. Where doors are not fastened open during the



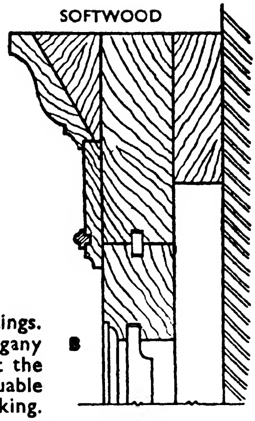


Fig. 9. Arranging softwood backings to hardwood facings. A. Typical example of door jamb faced with mahogany on one side and sycamore on the other. Note that the facing stops at the door head, thereby saving valuable hardwood. *B.* cornice construction with softwood backing.

day it is better to omit the rebate at the centre stiles, as a person approaching the doors cannot tell which to open first, especially if a strong spring is used. Where it is desirable to exclude all possible draught, and therefore imperative to have a rebate, this difficulty of opening can be partly overcome by fixing an engraved 'push' or 'pull' plate on the door concerned (Fig. 10 A and B).

Where the centre rebate is omitted, flush bolts should not be fixed on the *edge* of the door, as they can be easily broken open. Where floor springs are used, the

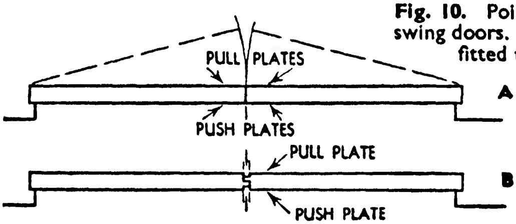
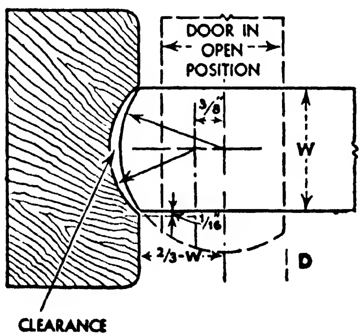
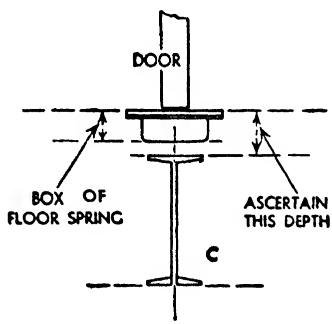


Fig. 10. Points to note in setting-out swing doors. *A.* "Push-and-Pull" plates fitted to doors; *B.* where meeting stiles are rebated, plates are fixed on one door only; *C.* the need to ascertain position of steelwork liable to foul the floor springs; *D.* method of setting-out the hanging stile and door jamb for double-action swing doors.





position of any steel joist liable to foul the box of the spring must be ascertained. Special shallow boxes (Fig. 10 C) are made to overcome this difficulty, and the conditions should be stated when ordering the springs.

With single-action floor springs ordinary butts can be used at centre and top, or alternatively top pivots may be used. In the case of double-action floor springs, top pivots only are used. Rebates are not used at the hanging side or the centre. A special radius is required for the hanging stile of the door, and a quicker radius for the door jambs, in order to give clearance to overcome any slight bow in the door. The method of determining the radius is shown in Fig. 10 D.

The projection of door handles should also be shown on the plan in order to ensure that they do not foul one another when the doors are swinging (Fig. 11 A).

A typical plan and height section are shown in Fig. 11 A and B. Batteries of doors are generally used in large stores and public buildings, such as cinemas and town halls. A typical battery is shown in plan in Fig. 11 C. Where such batteries are used there must always be some batches of double-doors in the battery to give sufficient clearance for the passage of perambulators. Generally the arrangement and construction of these batteries are governed by fire regulations and require special consideration on that account.

Sometimes it is necessary to introduce steelwork into the door-head to give the necessary rigidity, as these batteries may extend up to 16 doors in width. Where doors have fanlights provision

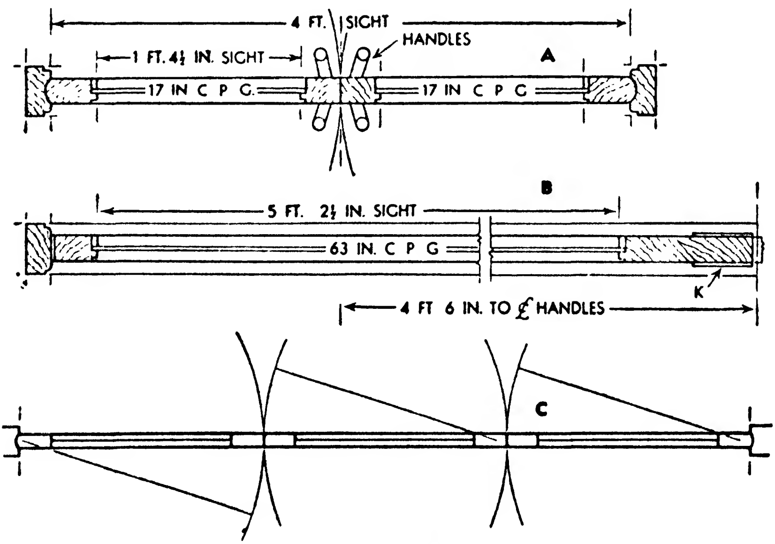


Fig. 11. Rods for doors fitted with double-action floor springs and top pivots. A. Plan of doors, indicating the position of the handles ; B. height section, showing at K. 6-in. kicking plates on both sides ; C. plan of typical battery of doors.

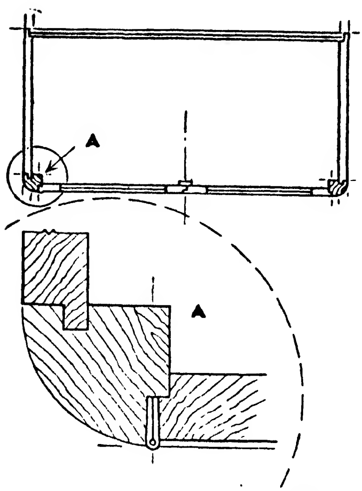


Fig. 12. Plan of dust-proof case. A. shows enlarged section of angle post and the hanging stile of the door.

must be made for the necessary gear to be fitted, and full details should be given when ordering the fittings.

Normal dustproof construction consists of double rebates, as shown in Fig. 12. The rebates should be of sufficient depth to receive the butts for hanging the doors. The type of fastening also determines the section at the meeting stiles.

In airtight case work the protection against change of air is obtained by a system of grooves and beads. Height and plan details of an airtight case are shown in Fig. 13. The vertical hanging stile has two beads, and these should be arranged so that the butt does not penetrate the inner bead. A hook joint is used at the meeting stiles and a single bead at the top and bottom; in the latter place it is better to set the bead $\frac{1}{8}$ in. on. All beads must be of good fit, and this should be emphasized on the setting-out.

Where a straight joint is used for fixing the back it should be sealed by a strip glued as shown; where vee-jointed matching is used it must be rebated to the carcase as well. If the case is lined with fabric the sealing is

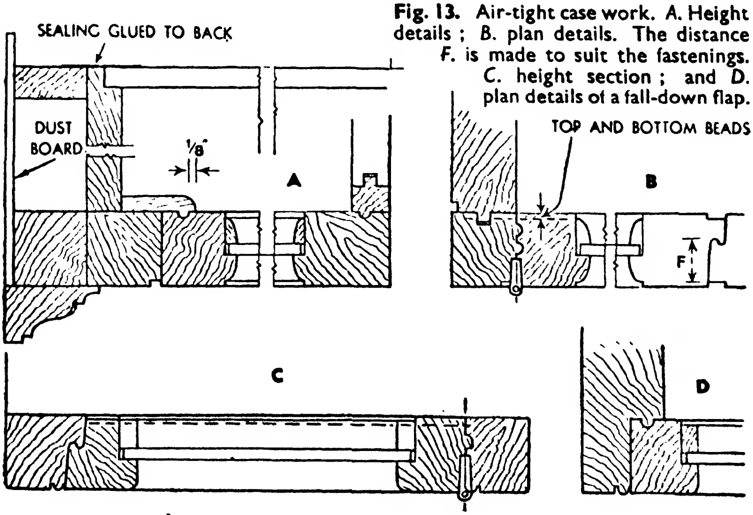


Fig. 13. Air-tight case work. A. Height details; B. plan details. The distance F. is made to suit the fastenings. C. height section; and D. plan details of a fall-down flap.

further improved. The set-back of the inner bead on the hanging stile should be at least $\frac{1}{16}$ in. more than the depth of the beads on the top and bottom rail to prevent breaking out during machining. On fall-down flaps a slightly different arrangement occurs. A single bead is employed on the rear face of the flap at the vertical and bottom edges, and either a hook joint or a single bead on the top edge as shown in Fig. 13 C and D.

Where sashes are glazed, the glass must be puttied in.

General Fittings

Where fittings are to be laid out in groups, as in shopfitting, the adjacent fittings must be considered when setting-out. Suppose the job which is being set-out has a top carcase with a glazed sash and a bottom carcase with drawers, and in front of the fitting is a counter, arranged as in sketch plan Fig. 14 A. It is essential to see that either the bottom edge of the sash is at a higher level than the counter, or else that the width of the gangway is greater than the sash to enable the sash to be fully opened.

The former method is to be preferred because, if the gangway is subsequently narrowed the sash will still clear (Fig. 14 B). Or, again, if the lower carcase had fall-down flaps or bins, the gangway should be wide enough to give sufficient working space. If an architect had planned the fittings and this allowance had not been made, it would be the responsibility of the setter-out to bring the omission at once to the architect's notice.

Where drawers or trays are fitted to a carcase enclosed by doors, distance pieces must be inserted to enable the drawers to clear the doors when opened at 90 deg. (Fig. 15).

Sliding Doors

The same principle must be watched where sliding-doors occur. The parting bead at the centre must be fixed to the rear door, so that no marks are made on the face of the adjacent door (Fig. 16 A and B) during sliding action. The general arrangement of sliding sashes is as shown in

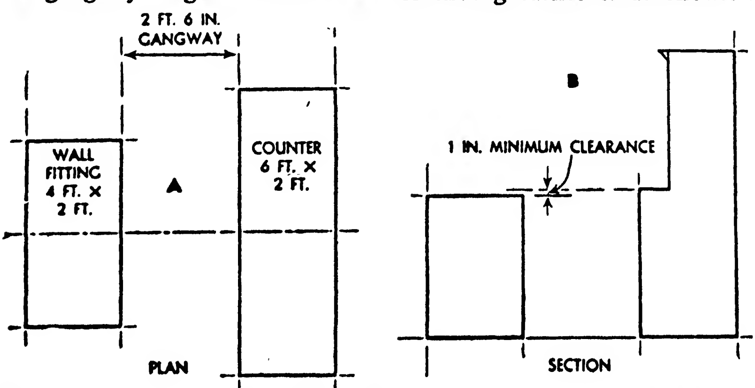


Fig. 14. General arrangement of fittings must always be considered. A. Sketch plan of gangway required ; B. clearance of doors over an adjacent counter.

Fig. 16 C. It is better to run the sashes on steel tracks $\frac{1}{2}$ in. by $\frac{1}{8}$ in. using patent ball-bearing rollers let into the bottom edge of the doors. At the top a hardwood guide is fixed, preferably oak. Alternative methods are shown in Fig. 16 D, E and F. The example in Fig. 16 C shows a small cupboard with sliding doors, which has veneered ends and flush veneered doors. The back is simply a ply panel, and could alternatively be vee-jointed matching, or else a panelled frame.

It will be noticed that a frame is constructed to receive the sliding doors, and is tongued to the carcase ends. The doors and ends could be framed if required.

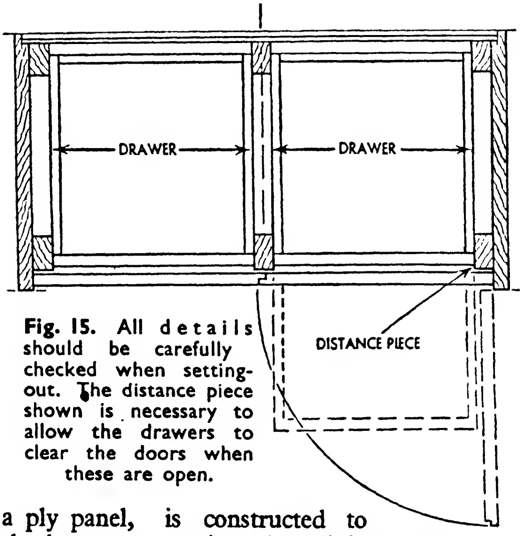


Fig. 15. All details should be carefully checked when setting-out. The distance piece shown is necessary to allow the drawers to clear the doors when these are open.

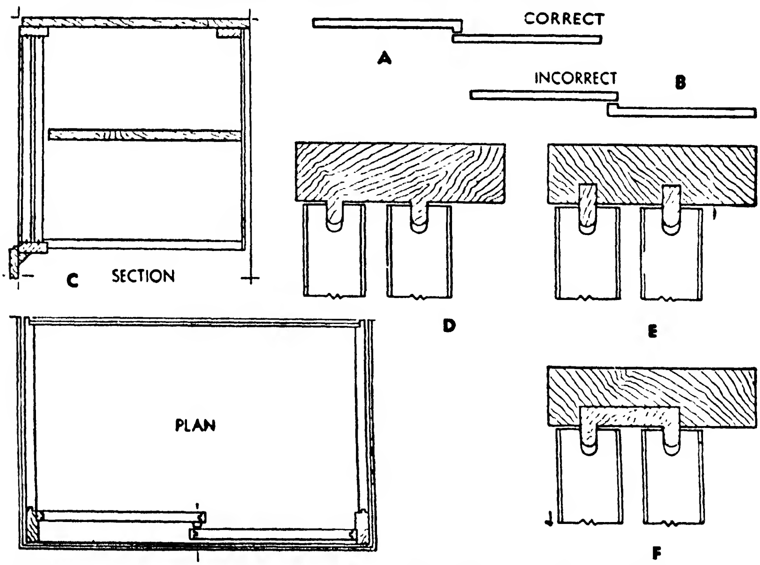


Fig. 16. Setting-out sliding doors. A. Plan-rod of doors showing correct method of fixing parting bead to rear door; B. incorrect method; C. height rod and plan of cupboard with sliding doors; D. E. and F. show other methods of construction of the top tracks of sliding doors.

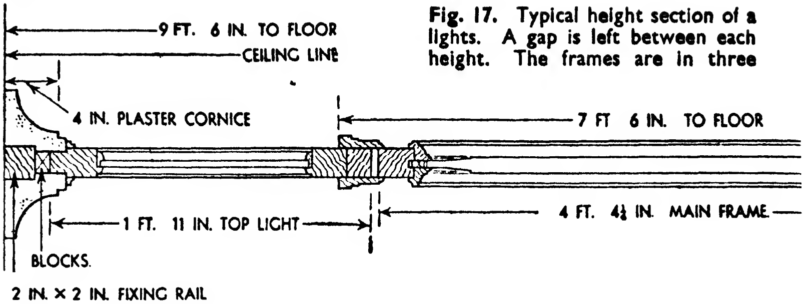


Fig. 17. Typical height section of a lights. A gap is left between each height. The frames are in three

Sometimes the vertical edges of the sashes are tongued and grooved into the carcase ends, but such edges are liable to damage.

Partitions and Screens

Full height partitions or screens must be given particular consideration, from the point of view of size and construction, bearing in mind transport difficulties and the need to get the job through doors and up stairs. This often predetermines the construction to be adopted, and if the design does not lend itself to dividing up the frames, it may be necessary to assemble the parts on the site.

Convenient points at which frames can be divided are at dado

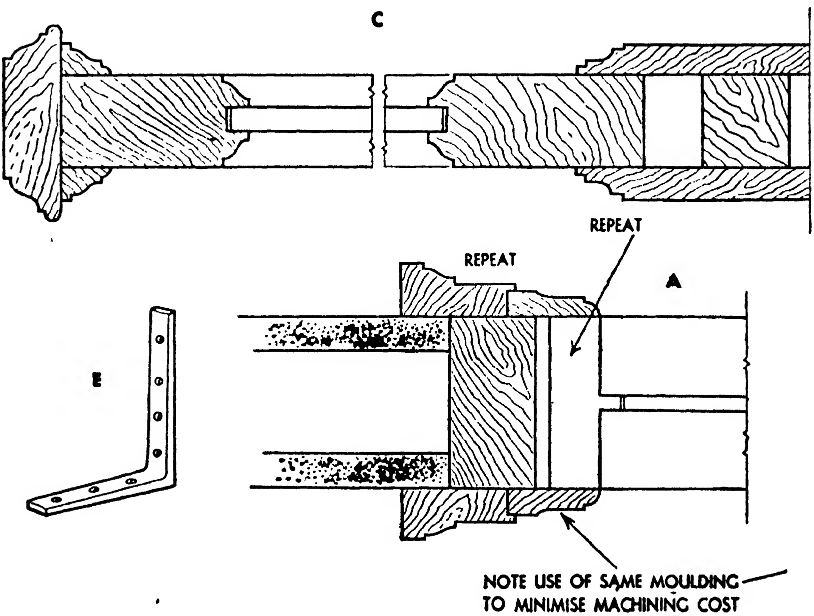
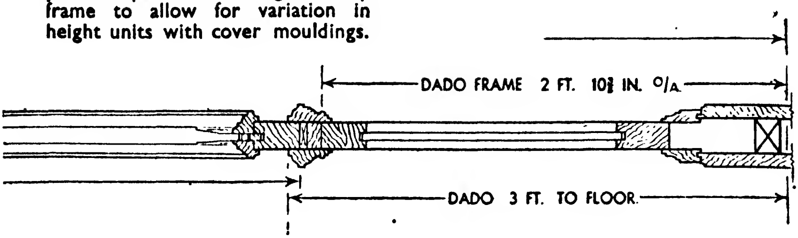


Fig. 18. Screen of a different type from that shown in Fig. 17. It consists above. A. Height rod of panelling to dwarf wall of breeze blocks ; *B.* vertical to dwarf screen, showing setting-out of

panelled partition with glazed top frame to allow for variation in height units with cover mouldings.

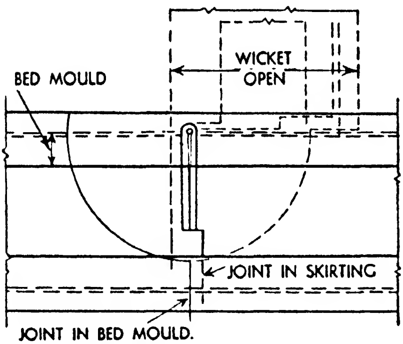


height and at transom height. On plan, double stiles can be used, jointed and fixed with bolts.

A typical height section is shown in Fig. 17. Gaps are left between the frames to allow for variation in height. The frames are packed at these points, thus saving unnecessary fitting. If the frames were split in this way, any long run would have to be stiffened up by vertical members.

A different type of screen is shown in Fig. 18 A. Here there is a breeze-block dwarf wall to dado height and flush veneered panelling below, with a glazed frame above.

A typical vertical joint in the upper screen is shown at Fig. 18 B. The lower panelling could be



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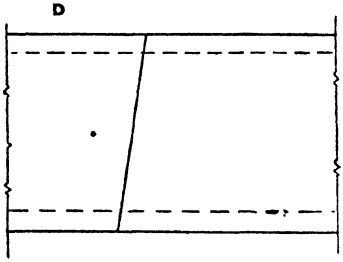
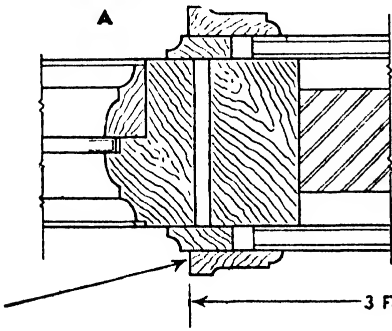
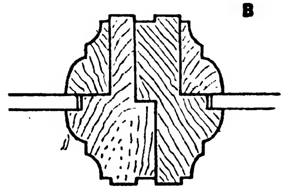


A



B



of a breeze-block dwarf wall with flush veneered panelling below and glazed panelling joint in upper screen ; C. dwarf screen height section. D. plan of wicket gate rule joint to capping. E. floor bracket.

made up to 16 ft. long (the length of laminboard), which is long enough for most purposes.

In the case of dwarf screening this nearly always includes a wicket door, and generally has to be stiffened up by floor brackets where any great length occurs. It is sometimes necessary to conceal these brackets, which must then be built into the framing so that they are hidden.

The section of a typical dwarf screen is shown in Fig. 18 C. Where the wicket door occurs a rule joint in the capping must be arranged to enable it to open; and the hinges must have wide flaps so that the centre of the hinge projects slightly more than the thickness of the skirting or bed mould, whichever is greater.

The open position of the door should be shown on the plan (Fig. 18 D), with all the various projections produced to make sure that the required amount of opening has been allowed for. An alternative method is to return the bed mould and skirting mould in themselves and stop them sufficiently far back to avoid fouling; in this case ordinary butts can be used, but the capping must still be set-out as shown. Floor brackets of the type shown in Fig. 18 E must be well fixed to screens and floors.

Radiator casings must be lined with 'heat-resisting' material, and provision must be made for access to the various unions and cocks. Whenever hot pipes or flues have to be cased in, the same precaution against heat must be taken.

Several methods are used for edging laminboard in veneered work with varying merits. It is a well-known fact that where veneer is applied over a joint between laminboard and a solid edging, the edging or laminboard subsequently shrinks, and the joint shows through the veneer. The alternative to this is to apply the edging after veneering the board, thus showing the grain of the edging on the face of the job. Where there is no objection to the edging showing in this manner, this method should be adopted.

If, however, the veneer is required for purposes of design to extend to the edge of the panel, the edging can be mitred in and still applied after veneering; but this should not be adopted unless essential, as due to the structure of laminboard it is a difficult operation to carry out. Where external corners occur, again a solid edging is to be preferred, as this will obviously stand up to harder wear and give much better all-round service.

Typical sections and plans of the panelling and tables depicted in Fig. 19 are shown in Fig. 20. These, while not necessarily the sections which were used, serve to illustrate the method employed, and the manner of setting-out.

'Taking-off' Material

In 'taking off' timber, that is, preparing a cutting list from the rod, sufficient allowance must be made on the cutting size for machining down to the finished size. This allowance varies according to the size and the type of member. Joinery shops generally make an allowance of $\frac{1}{8}$ in. on width and thickness, while in the shop-fitting trade allowance of $\frac{3}{16}$ in. is invariably made.

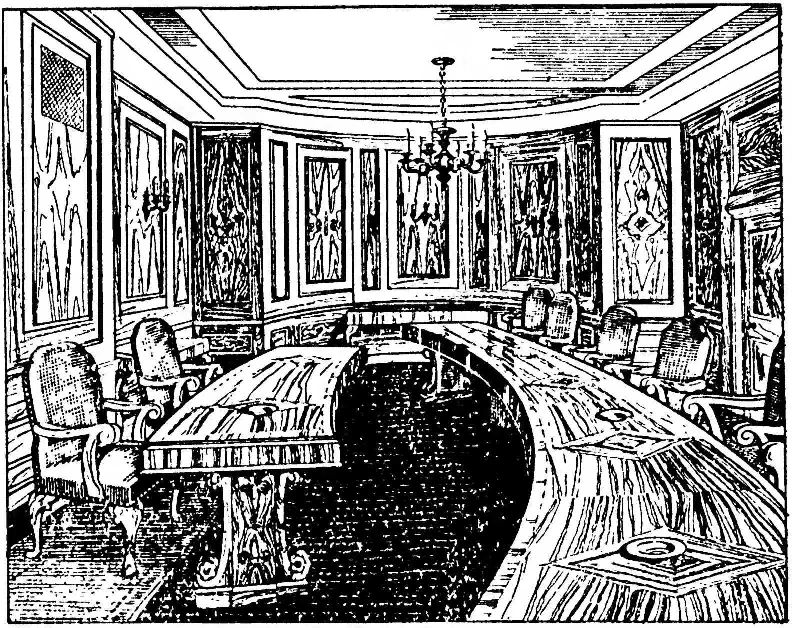


Fig. 19. Pictorial view of a modern commercial Board-room with veneered panelling and tables. Detailed sections of the members in the above illustration are shown in Fig. 20 on the following page

Additional allowance is made on members of frames which have to be fitted, such as door stiles and rails. Sufficient for this purpose can be obtained by setting-out the stile tight in the rebate and showing, for example, a 4-in. stile as $3\frac{15}{16}$ in., and by omitting the finished width when ordering the timber.

A typical entry on the timber sheet would read thus: Door stiles—2 off 6 ft. 7 in. by 4 in. by 2 in. oak, fin. $1\frac{15}{16}$ in.; a section of the stile would also be shown on the sheet. The machinist would then plane to thickness, but face up one edge only of the stile, leaving the maximum amount for fitting.

On rebated stiles an extra allowance of $\frac{1}{8}$ in. is wisely provided. On items which have to be scribed, such as skirting, $\frac{1}{2}$ in. is allowed on the width, and no finished width is given on the timber sheet. On long lengths of big sections, such as heavy transom rails (which must be perfectly true and straight) a bigger planing allowance is necessary. For example, a $6\frac{1}{2}$ in. × $2\frac{1}{2}$ in. finished size would be ordered out of 7 in. × 3 in.

It would be a mark of good setting-out to anticipate this factor by setting the member down as $6\frac{1}{2}$ in. × $2\frac{1}{2}$ in.

As a general rule members are not drawn as finishing to even sizes such as 4 in. × 2 in. or 4 in. × 3 in. Allowance is always made for them to be produced from stock size timber.

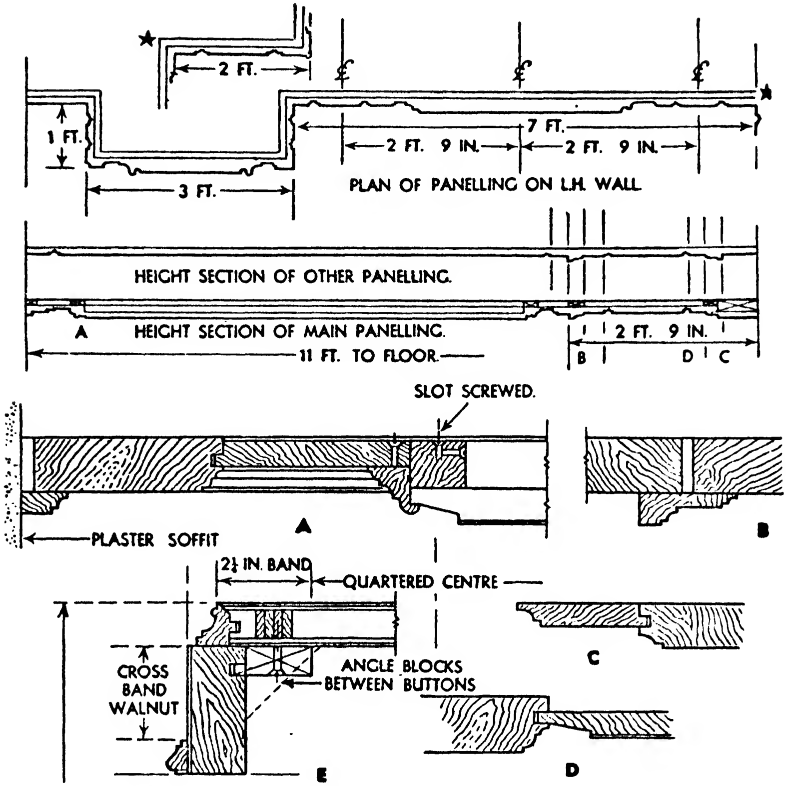


Fig. 20. Panelling of the Board-room shown in Fig. 19. Arrangement of sections to show lay-out of work. *A.* Enlarged detail of panelling ; *B.* dado moulding ; *C.* skirting board ; *D.* dado panelling ; *E.* vertical section through table top.

In length, an inch minimum should be allowed up to about 6 ft., and more on greater lengths, rising to 5 in. or 6 in. on 15 ft. When this amount is allowed, a minimum length should also be stated on the timber list to enable the use of a length of stuff under the size called for, but sufficient for the job.

Mouldings which have to be mitred up into panels are not ordered as separate pieces, but are batched together into convenient lengths. Slightly more than the width of the moulding should be added to the length to allow for a wrongly cut mitre. More, of course, must be added when several mitres are to be cut from one length. Lengths of a section which may be jointed up indiscriminately are simply ordered in 'feet run.' If sufficient quantity is required, a separate timber sheet is made out marked 'Four (or five) cutter work.'

A typical timber sheet or cutting list is shown on p. 273. It is for the pair of doors, as shown in Fig. 4 A, assuming the

TIMBER SHEET

VESTIBULE DOORS. *Job No.:* 84231. *Date* ....

Title.	Quan.	Cutting Sizes. Length.	Width.	Thick-ness.	Material.	Finish Sizes.
		ft. in.	ft. in.	in.		inches.
Stiles ...	4	6 8	0 5	2	Oak ...	— × $1\frac{13}{16}$
Top rails ...	1	4 2	0 5	2	Oak (cut 2)	— × $1\frac{13}{16}$
Btm. rails...	1	4 2	1 5	2	Oak (cut 2)	— × $1\frac{13}{16}$
Bars ...	4	2 1	0 $1\frac{1}{4}$	2	Oak (cut 2)	1 × $1\frac{13}{16}$
Glazing vert	4	5 0	0 1	$\frac{1}{2}$	Oak (cut 3)	$\frac{13}{16}$ × $\frac{5}{16}$
Glazing lay	6	2 8	0 1	$\frac{1}{2}$	Oak (cut 2)	$\frac{13}{16}$ × $\frac{5}{16}$

door frame to be 4 ft. between the rebates.

Note.—On polished hardwood doors it is desirable to order the rails for a pair of doors in one length so that the grain matches up; but it is not essential, and is, of course, never done on softwood doors.

Write each item out separately and never use ditto marks to indicate a repetition of size. Subsequently it may be necessary to alter an item on the list, and if the ditto marks are overlooked all subsequent items automatically become altered as well.

When ordering glass state the size in inches, giving the height first. State whether the edges are to be clean cut, ground or polished, and if some edges differ draw a small diagram indicating this fact. A $\frac{1}{4}$-in. cover is generally allowed, but on big plates of 6 feet or more $\frac{5}{16}$ in. or $\frac{3}{8}$ in. is to be preferred. Any fraction of an inch is reckoned as a whole inch in charging for glass, therefore the setting-out should be arranged to avoid this wherever possible.

In ordering sheet glass state the weight required, *e.g.*, 16 oz., 21 oz. or 32 oz. In ordering plate-glass, state whether 'clear plate-glass' or 'drawn plate' is required.

In the case of leaded lights and 'copperlites,' a sight size must be given, together with a diagram showing the rebate allowance. Finally, make all data relative to ordering of glass very clear, as mistakes in this matter are generally very costly. If carbon copies are made, make sure that all dimensions are clear on each copy.

Furniture

In ordering locks or handles give a full-size detail of the shutting or meeting stiles. When ordering door springs state the size and construction of the door to enable the supplier to assess the weight. A typical order would be:—

'Supply 1 pair of double action floor springs (1 L.H., 1 R.H.), in bronze finish, suitable for a pair of doors each approx. 6 ft. 6 in. by 2 ft. 6 in. by $1\frac{7}{8}$ in., in mahogany, with full glazed $\frac{1}{4}$-in. C.P.G. panel.'

When ordering butts, state if steel washered or plain, and quote thickness and size of doors. In the case of fanlight gear, give full details so that lengths of controls and fixings can be arranged.

Measurements on Site

When a visit to the site is made for the purpose of taking sizes, spend a reasonable time in looking round for any possible difficulties before commencing actual measurement. Look for such things as projecting pipes and radiators, ramps and falls in the floor and similar problems.

With regard to the actual measuring, first of all make a sketch plan of the area to be measured, showing all the projections, of which details must be taken, and then insert dimension arrows to all required sizes. The measurements can then be systematically taken and filled in on the plan as they are made.

The simple heights, such as 'floor to ceiling' or 'door openings' can be shown on the plan in small circles. 'Check sizes' should always be taken to determine the angles of walls, and these are usually known as diagonals, the idea being to make a succession of adjacent triangles by which the shape of the building can be plotted.

Where a number of short running sizes are taken, an overall size should be made, and the small sizes added up *on the site* to see that they agree. When help is obtained for measuring long lengths, make sure that your assistant realises that the link of the tape must *not* be folded over, as it is included in the dimension (Fig. 21 A). Where necessary, sketch height-sections are made and a similar procedure adopted,

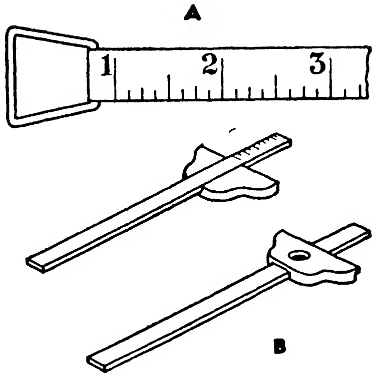


Fig. 21. A. It is important to note that with a steel tape the link is included in the measurement; *B.* two types of liners or 'runners' for drawing parallel lines on a setting-out board.

omitting, of course, the diagonals. The walls should be plumbed to see if the size taken is a true record. Indicate clearly whether sizes are to brick or plaster, and always make the size sheets in such a manner that another person could pick up the job and carry on with it.

Every size-sheet should be headed with the date, name, and address of the site, and the floor on which the job is situated. On returning to the shop the 'scale-plan as existing' is first put down. Then a piece of tracing paper is put over this and an overlay made of the new work. On this the dimensions of the new work are calculated and figured in. Setting out can then proceed.

Levelling is done by a 6 ft. level, or else a smaller level on a straight edge. Always check the level before commencing. On big sites the use of a dumpy level saves much time, and is more accurate.

Carefully study the drawings

and ascertain the scale, looking for particular features and levels to be carried, *e.g.*, dado panelling may be shown, and may measure by scale 3 ft. 6 in. high, but the capping mould may be shown intersecting with the existing window-board. Obviously the actual height must be determined by measurement on the site.

Architect's Drawings

If any serious discrepancy occurs between the architect's drawings and the site the architect must be notified and written agreement obtained before proceeding with the altered layout, a copy of the revised plan being sent to him.

Such things as panels being centralised under beams in the ceiling, and pier casings made of similar size, though the actual piers are quite different, are the type of things to look for.

Never do anything which is contrary in dimension or design to an architect's drawing without consulting him.

Oftentimes the site will be dimensioned on an architect's drawing, but these sizes should never be accepted, the site itself being checked by the setter-out.

Two points are frequently found on architects' drawings to be contrary to joinery practice: (1) The construction may not be practical; (2) timber may be shown to nominal sizes instead of allowing for machining.

In the first case the construction should be altered, and in the latter the detail modified to suit normal timber sizes; if, however, alteration in design is entailed the architect must be consulted.

The types of rods used for setting-out are:—(*a*) Thin boards of pine; (*b*) sheets of ply for small shaped work; (*c*) sheets of hardboard or laminboard for large shaped jobs; (*d*) detail paper. (Some firms use tracing-paper to facilitate the taking of prints.)

In the case of the first three, these are usually varnished, it they are required for repetition work, in order to preserve the lines.

Each rod should have clearly stated the date, the job number, the title, the address, and a brief description of the job.

Rod boards can be stored one on top of the other, with a thin ply label nailed on the end bearing an index number. A catalogue of these numbers being kept handy and bearing against the index number a fuller description of job, date and title.

Paper rods can be rolled or folded and indexed in the same way.

Setting-out Tools

A good setting-out kit consists of the following tools:—

One tee-square; one runner or pencil-liner (with long and short blades) (Fig. 21 B); one trammel; one adjustable tee-square; one each 12-in. 45 deg. and 60 deg. set-squares, and one 6-in. 45 deg. set-square; one set of drawing instruments; one 2 ft. or 3 ft. rule; one 5 ft. five-fold rule, one 5 ft. two-fold rule; one 10 ft. four-fold rule; one 100 ft. steel tape; one 12 in. and one 6 ft. level; three assorted french curves; one plumb-bob, line and chalk; one heel ball.

When measuring the site, a few joiners' tools are necessary for various purposes which may arise.

CHAPTER 13

SHAPED WORK

SOLID SHAPES. SAW KERFS. BENDING VENEERS. SPACING THE SAW-CUTS. CONCAVE CURVES. LAGGINGS AND STAVES. PLYWOOD AND MULTI-PLYS. USE OF CAULS. COOPER JOINTING. SEMI-CIRCULAR SASHES AND FRAMES. USE OF TEMPLETS. BENDING BY MEANS OF STEAM.

THERE are various methods of producing shaped work, but each job must be treated on its merits. The main points to be considered are whether the work is to be of hard or soft wood, whether a painted or polished finish is required, and whether the suggested method is practicable for the job. This latter point can only be determined by the craftsman who is doing the work, but whenever bending of any description is to be undertaken it is important to start right by selecting clean straight-grained wood.

Solid Shapes

For any type of curved work the job should be set out full-size on a board, and plywood templets prepared for the shapes required.

Fig. 1 shows the bottom rail of a semi-circular sash. The shape is marked out with the aid of a plywood templet placed on the timber, which in this example is 4 in. thick. It is cut out with the bow-saw or band-saw 'full'; in other words, the lines are left on; the inside curve is planed down to the pencil line with the spokeshave, and the outside curve with the smoothing plane, or, preferably, both surfaces are planed with a steel plane having a flexible sole which can be adjusted to a curve.

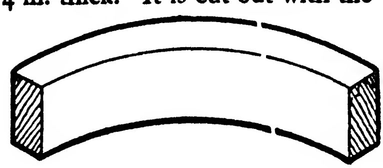


Fig. 1. Bottom rail of a semi-circular sash cut from solid wood.

Where a wider rail is required, say the bottom rail of a door, two or three pieces may be cut out and glued together, and when dry they can be cleaned up in the usual manner. It should be noted that if the curve required is of a small radius, the tenons will have 'short' grain, and thus be liable to snap off. In a case of this description the rail would be better if built up of multi-plys, so that the grain of the tenon would be straight.

Saw Kerfs

For bending boards such as a skirting round a curved wall, or even a bullnose step for a stair, a method of *saw kerfing* can be used. This consists of a series of saw-cuts across the grain. In practically every case it is necessary to bend the board round a *core* or *drum* to maintain the required shape. The saw-cuts are obviously unsightly, but this

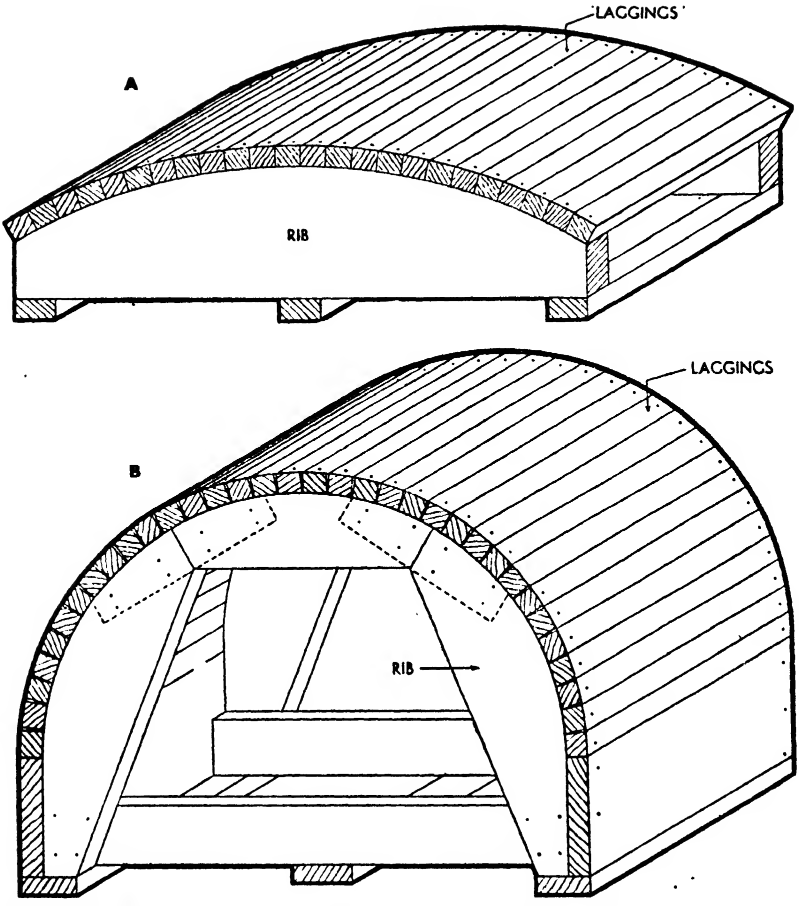


Fig. 2. Types of core or drum for bending thick veneers. *A.* As used for flat curves ; *B.* for larger curves and curves of small radius.

is not a serious matter if they are made on the face that is not seen, and the edges are covered.

Fig. 2 shows two types of core or drum used for bending a thick veneer or saw-kerfed board. A is suitable for flat curves; the ribs can be out of stock-width timber; B is suitable for larger curves, in which the ribs of the drum have to be built-up.. In both cases the thickness of the ribs are from 1 in. to 2 in. A sufficient number of ribs should be used to stiffen the drum. The 'laggings' are pieces of timber from 1 in. to 2 in. in width, and from 1 in. to 1½ in. in thickness; the width is not important, in fact random width pieces may be used. Notice that the construction is similar to a 'center' for an arch, with the exception that laggings are screwed to the ribs. It is not necessary to bevel the joints and fit the laggings. When the laggings are fixed the sharp corners are planed off with a jack plane to complete the drum.

Spacing the Saw-cuts

Fig. 3 shows a simple method of determining the spacing of the saw-cuts for any semi-circular job, the example given being the riser of a bullnose step.

The procedure is to get out the plan of the riser to full size and then to obtain a thin piece of wood ⅛ in. to ¼ in. thick, of length a few inches longer than the radius of the inside of the riser, and of width equal to the thickness of the riser. Mark out the radius, and with the saw that is to be used for the saw-kerfing make a cut across the lath as shown, stopping ⅛ in. from the edge. This is the depth of all the saw-kerfs in the riser. Hold the saw-cut against the centre of the quadrant and bend the

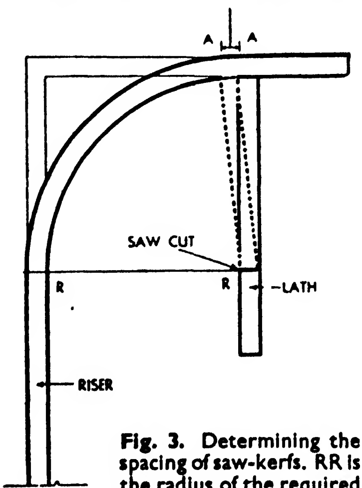


Fig. 3. Determining the spacing of saw-kerfs. RR is the radius of the required curve; the distance AA that a lath moves in the closing of one saw kerf is the distance which two saw-kerfs will be apart.

lath so that the saw-cut closes.

The distance the end of the lath travels round the arc is the distance the saw-cuts will be apart. A pair of dividers is used to step round the semi-circle, so as to give the position of saw-kerfs required. Obtain a block of about 1 in. thick, screw one end to the riser, well glue the saw-kerfs, and bend the riser round the block and screw the other end. The block in this case can be left in (Fig. 4 A).

It is as well, when the glue is set, to clean off the face, traversing the surface with a sharp smoothing plane held on the skew, and finish off with glasspaper. It will be noticed, however, that in most cases the saw-cuts are discernible on the finished surface.

Fig. 4 B shows the method used when the concave or inner side of the curve is the face of the board. When the riser is bent round the drum, the saw-cuts open.

Prepare wedge-shaped pieces called 'feathers,' and 'shoot' them with a plane so that they are just tight, glue and lightly tap them in with a hammer. *Do not* fit and drive in tight, otherwise, due to the tension on the convex surface, there will be a considerable alteration in the shape of the curve when taken off the drum.

Laggings and Staves

Fig. 5 shows a method of building up a curve with laggings or staves; this is suitable for curves of small radius. A veneer of suitable thickness for bending, say, ⅛ in. thick, is bent round the drum and fixed at the ends.

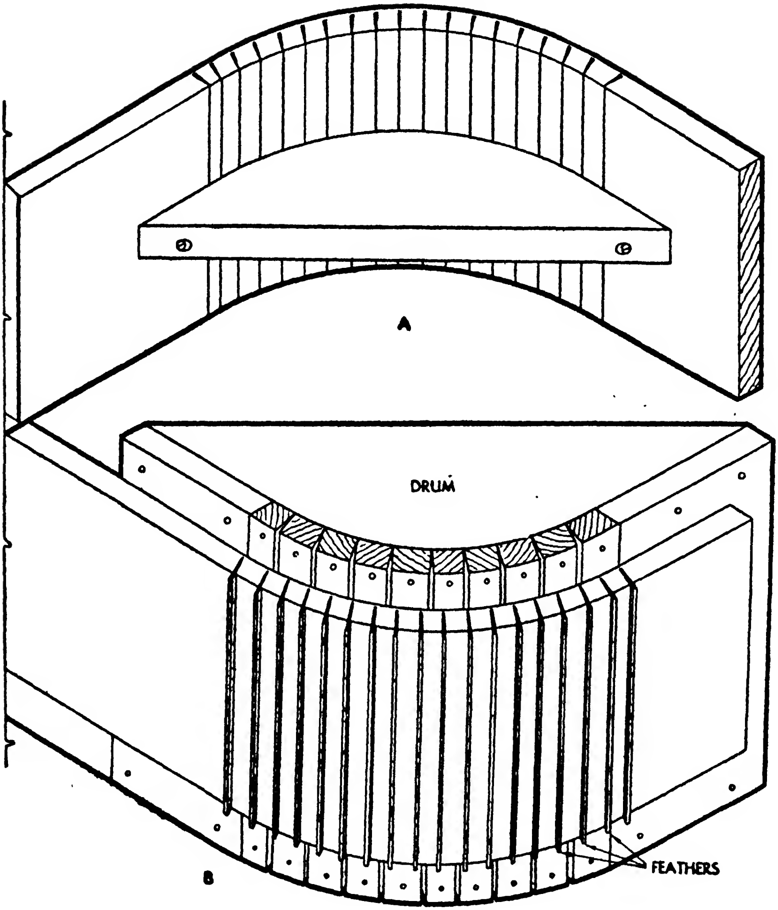


Fig. 4. Bending boards by means of saw-kerfs. A. Convex surface with 1 inch block to hold the board in position ; B. concave surface bent round a drum.

Before fixing, the veneer should be damped with boiling water to help in the bending and lower the risk of breaking. A series of wedge-shaped staves is fitted, glued and rubbed in, one after another, until the curve is complete. When dry they are cleaned off, and if the face is hidden, canvas or hessian is well glued over the surface in order to strengthen the whole structure.

Where both faces are seen the method is as before, but instead of canvas over the staves, another veneer is fixed. Before attempting to lay this veneer a number of pieces of timber are required for cramping down. The length of these should be from 4 to 6 in. longer than the width of the veneer. Bore a hole for a screw at

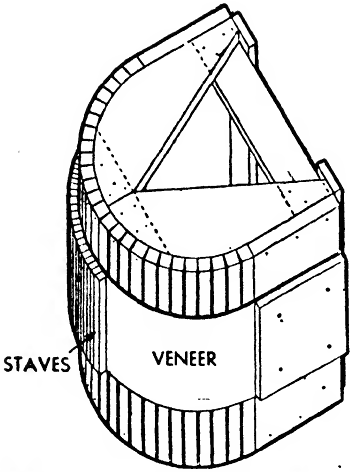


Fig. 5. Stave and veneer method. A veneer is bent round the drum and laggings or staves are fitted and glued in position so as to form the necessary thickness.

each end, have everything handy, damp the veneer with boiling water, well glue the core and the veneer, lay the veneer and rapidly screw on the cramp pieces (Fig. 6). Have a heated flat iron and damp cloth handy for warming up the glue if it should have chilled off.

When laying the outer veneer of a large curve do not glue the whole of the surface at one time, but start at one end. Glue about 12 to 18 ins. at a time, get the cramp pieces screwed on rapidly, then glue the next section, and so on. The veneer can be lifted to get the glue well under.

For ordinary work $\frac{1}{8}$ in. plywood should be used for veneers wherever possible, for it bends very easily when the grain is kept 'across' the curve. First quality plywood is sound, well made, and very strong, and is of very convenient thickness for this type of work, but it is not advisable to damp the surface unless one is sure that a waterproof glue has been used in the manufacture.

Fig. 7 A shows a solid flush cupboard door circular in plan. A core or drum should be made as previously described, and the 'thick' veneer ($\frac{1}{8}$ in. plywood) should first be bent round and fixed at both ends. Then 'shoot' and glue in the laggings, clean off when dry, and glue and lay the outer 'thick' veneer with wood cramps screwed to the drum. Where the surface is rather large have the wood cramps rounded in their length to pull the veneer well down in the centre ; the wood cramps will bend in their length

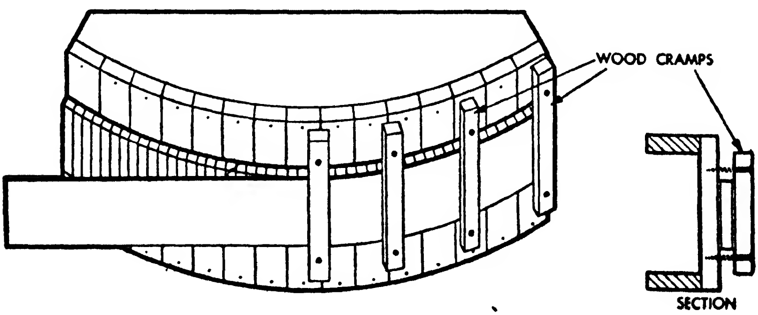


Fig. 6. Fitting an outer veneer on the staves. The strips of wood are screwed to the drum to hold and cramp the veneer until the glue is set.

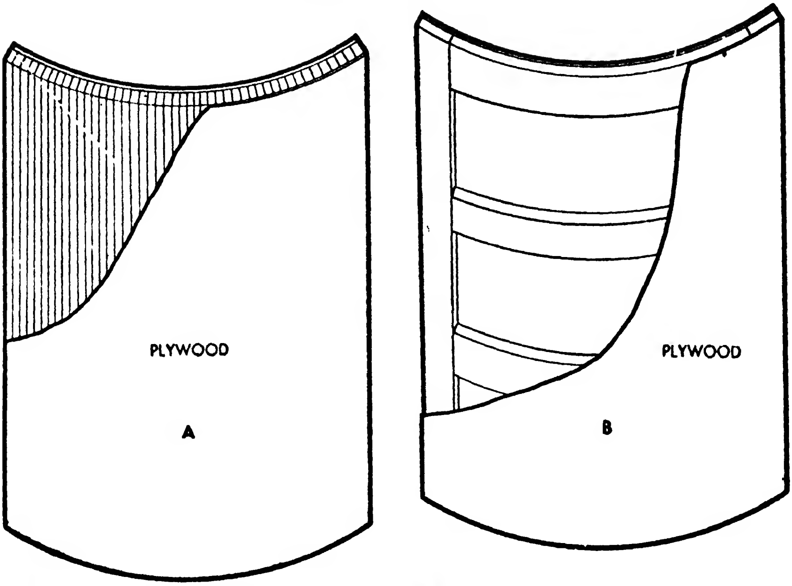


Fig. 7. A. Cupboard door formed on the "stave and veneer" principle with plywood facings ; B. door with a framed core covered with plywood sheets.

so that they will 'bed' down on the ends when the screws are driven in.

For a flat curve the wood cramps may not be required, as the outer veneer can be glued and nailed on with fine pins. It will be noted that the foregoing construction is similar to the construction of a mass-produced laminated or block-board door.

Fig. 7 B shows a curved door with a framed core. The rails are cut out of the solid, and the whole is mortised and tenoned together and covered on both sides with $\frac{1}{8}$-in. plywood glued and nailed on with fine pins.

Fig. 8 shows a curved framed-up panelled corner, with a $\frac{1}{4}$-in. panel. In this case a double layer of $\frac{1}{8}$-in. plywood is laid 'dry.' These will bend quite easily, and the grooves in the framing will hold them securely in position.

For a curved 'bead flush' panel the construction can be similar to that mentioned previously for a solid flush door; the beads should be out of the solid, the panel rebated and the beads nailed on.

Multi-Plys

Panels, rails (or, for that matter, practically any type of shape) can be built up to any thickness by means of a series of layers of thin sheets of wood about $\frac{1}{16}$ in. thick, impregnated with a cement, with the grain of each sheet laid alternately at right-angles to the adjoining sheet and subjected to great pressure. Usually this is carried out by firms which specialise in this type of work.

Many examples of modernistic furniture and fitments which are built up of multi-plys may be

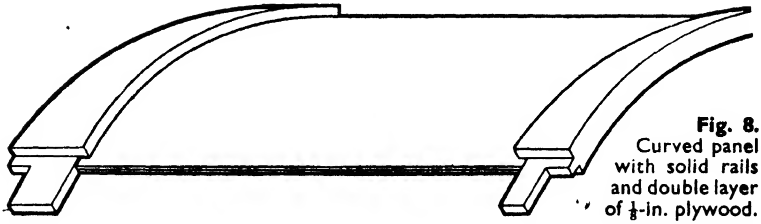


Fig. 8. Curved panel with solid rails and double layer of ⅛-in. plywood.

seen. Fig. 9 shows a sketch of what can be done in this respect, but types such as these are made by special machinery and presses for mass-production. For the usual type of shape met with in a joinery shop, multi-plys can, of course, be used. Generally it will be found possible to use 'thick' veneers and keep the grain in the same direction.

Fig. 10 A shows a rail built up by this method, which consists of a series of thin layers of wood about ⅛ in. thick, which are bent and fixed round a drum. Before gluing, warm thoroughly all the pieces so that the glue will remain liquid, then give them a coating of glue, and bend the whole

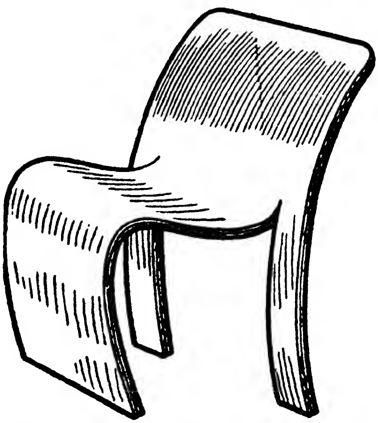


Fig. 9. Illustrating the possibilities of multi-plys. The diagram shows a streamline chair made from multi-plys, special machinery being employed.

round the drum, fixing down to the drum with wood cramps. For this type of work it will be found that it is better to use one of the cold-water glues which are now made; this will obviate any warming and thereby simplify the job.

Fig. 10 B shows an alternative method of gluing up by using *cauls*, that is, two blocks, one cut to the shape of the inside curve and one to the outside. The plys are glued as before, and the whole cramped or handscrewed together and left until dry. Another method used has a core built up of narrow pieces cut to shape (Fig. 10 D); the butt joints should be staggered, and both surfaces veneered and cramped with cauls.

Cooper-jointing

Fig. 11 shows a method generally used for wood columns, panels and for semi-circular corners such as those in a cupboard front. This method consists of gluing up a series of narrow boards, usually with a 'cross-tongued' joint; this is known as *cooper-jointing*. Set out the section to full-size, mark the number of pieces required and the position of the tongues, making sure that there is sufficient material left on so that when rounding with the plane the tongues and grooves do not

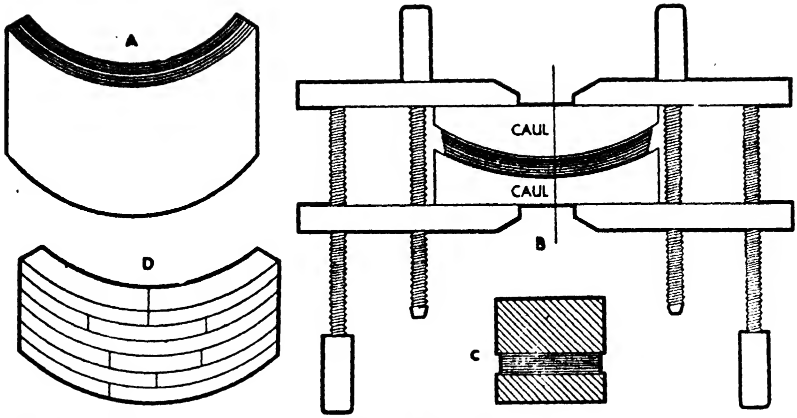


Fig. 10. Building up curved surfaces. *A.* Shaped rail of multi-plys made by gluing many ⅛-in. plywood sheets together on a shaped drum ; *B.* an alternative method of gluing-up by using shaped cauls held by handscrews ; *C.* section through the rail and the cauls in detail ; *D.* alternative construction of the core.

show through the face. ' Shoot ' the bevels for glued joints and plane the arrises off square to the edges, as shown in the detail. This gives a face for the fence of the plough to work up to. Groove for the cross tongue, glue up, and when dry mark the shape on the ends with a templet and work up the whole to a finish.

This is the method which is generally employed for building up a column. When consisting of a number of pieces it is much better to glue up the four quarters, when dry, glue into two halves, and finally glue the two halves together. In the case of

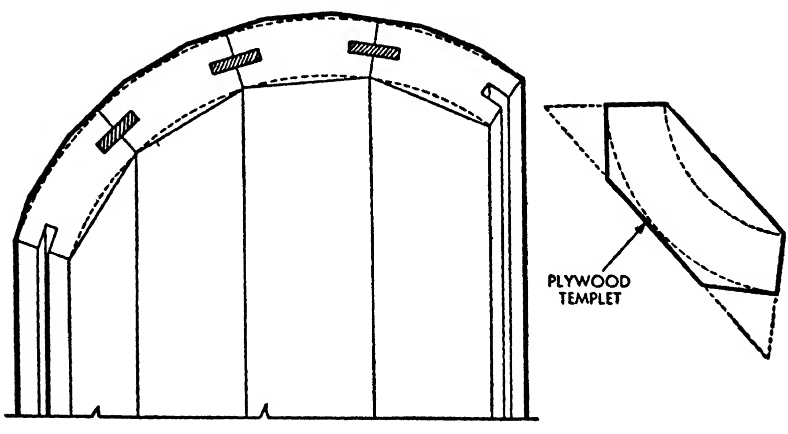


Fig. 11. Cooper-jointing whereby a series of narrow boards can be jointed together and then worked to the required shape. Each board is marked out by a plywood templet as shown in the detail drawing.

columns to be used for casing in a stanchion, they are turned up on a lathe, especially if an 'entasis' is formed.

The construction for building up is as before, but when the two halves are prepared they should be glued together with thick paper in the joints. Remember to slip in the plough grooves several short ends of tongue before gluing, and keep them free from glue to ensure the grooves of the two halves coming together when finally gluing up round the stanchion. The ends are filled in ready for the turner. After turning, the two halves can easily be split apart down the paper joints to enable the column to be fitted and glued up round the stanchion.

Fig. 12 A shows the elevation of the top portion of a semi-circular headed door and frame. On a job of this description always set out the circular elevation to full size.

Prepare a plywood templet to a part segment of the curve. The size of this is governed by the material from which the shape is to be cut, and it is well to remember that it is to be cut from standard size timber, *i.e.*, 9 in. or 11 in. wide. Fig. 12 B shows how, in a flat sweep the templet is reversed to obtain the maximum number of members without waste. In this example it is assumed the frame is 4 in. by 3 in. fitted with a 2 in. door.

Fig. 12 C shows how the head can be built up of three layers. The butt joints are 'staggered,' and the whole glued and screwed together, with the screw holes pelleted up. Alternatively, the

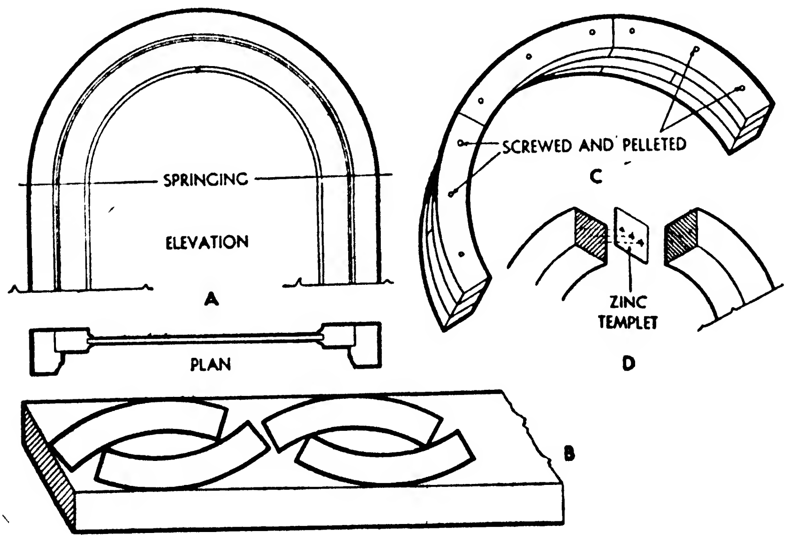


Fig. 12. *A.* Top portion of a semi-circular headed door and frame; *B.* shaped pieces are economically marked out on the material by reversing the plywood templet; *C.* built-up head with the pieces laminated together; *D.* shows the joint between two solid pieces and how to mark the position of the dowels and handrail bolt.

head can be made out of the solid. The joint of each segment is 'shot' and laid on the full size setting-out to enable each piece to be tried up to the next in turn. Any slight error in the joints can thus be rectified by a shaving or two to ensure it conforms to the outline.

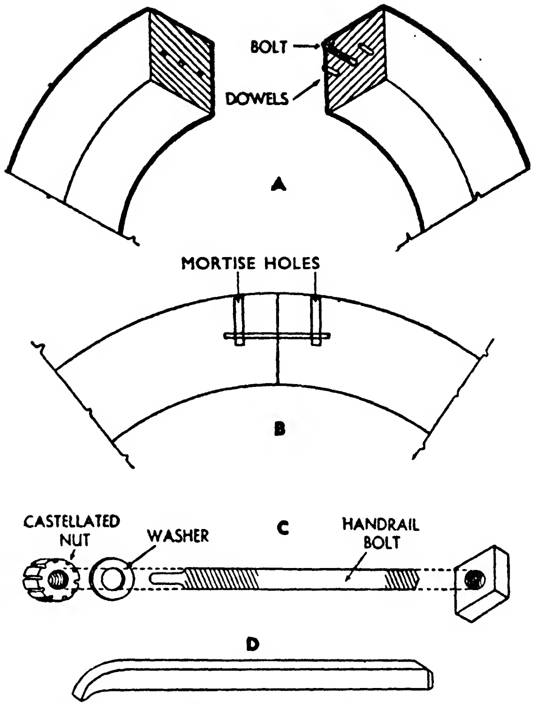


Fig. 13. Jointing solid pieces together with a handrail bolt. *A.* Position of the bolt and the dowels in the joint ; *B.* elevation showing the mortise holes for inserting the nuts ; *C.* handrail bolt ; *D.* common type of handrail punch used to tighten the slotted nut when the latter is in the joint.

Zinc Templets

When all the joints are prepared a zinc templet is made to the shape of the square section. (Note the edges of zinc can be planed with a steel plane without damage to the plane iron or sole.) Punch-holes are made in the templet for pricking through into the wood with a point to mark the position of the handrail screw and dowels (Fig. 12 D).

Always put a face mark on the templet, so that when using it the face can always be kept to one face of the joint. This method will be found easier than using the gauges. This is also a useful tip to remember when jointing up mouldings which require dowels, handrail screws or both.

Bore holes for the dowels and handrail screws, and remember that while the dowels should be a tight fit, the holes for the handrail bolt should be $\frac{1}{16}$ in. larger than the bolt (Fig. 13 A).

Fig. 13 B shows a section through a joint showing the mortises for the nuts. As the edge of the frame will not be seen there is no need to fill up the holes. Where the mortise holes are exposed remember to keep the grain of the pellets in the same direction as the material they enter.

It will be noticed in Fig. 13 C that a double-ended handrail bolt has a square nut on one end and on the other a 'castellated' or slotted nut and washer. In fitting the bolt, drop the square nut in the mortise cut to receive it and screw in the bolt, put the slotted nut and washer in the opposite mortise, then push up the bolt and turn the slotted nut by means of a handrail punch (Fig. 13 D) to work on the nut. Finish off by punching it round with a hammer so that the joint is pulled up tight. The joint between the curved head and the straight jambs can be made in a similar manner, or, as shown in Fig. 14 A, it can be mortised and tenoned, glued, screwed and pelleted or dowelled through the face. An alternative method of jointing is shown at Fig. 14 B by a single hammer-headed tenon.

Fig. 14 C shows a separate double hammer-headed tenon which should invariably be of hardwood.

The construction of the door is carried out in a similar manner to the frame, the top rail being either cut out of the solid or built up in two or three layers, glued, screwed and pelleted with the joints staggered, the joint between the head and stiles mortised and tenoned together.

The moulding and rebate of the frame and the moulding and groove of the door may be worked either by hand or, which is more usual, on the spindle, the curved shapes being worked against the 'French head.'

Semi-Circular Sashes

Fig. 15 shows part elevation and section of a semi-circular headed box frame and sashes. The lower part of the window has been omitted, because the construction is similar in every respect to the ordinary sash and frame. The head can be built up either by the saw-kerf method as shown, or by bending a $\frac{1}{8}$ in. veneer round a drum and gluing staves with canvas or hessian.

The procedure is to set out the detail full-size on a board, and prepare plywood templets—one

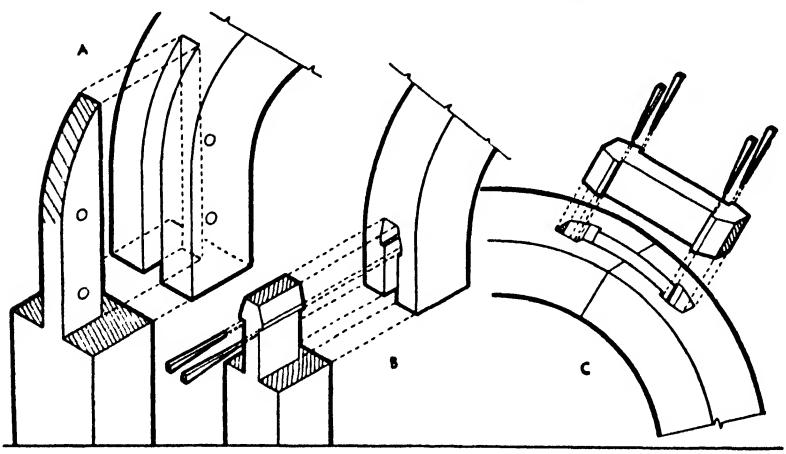


Fig. 14. *A.* Alternative joint between the shaped head and the jamb. The tenon is glued, screwed and pelleted, or dowelled through the face. *B.* single hammer-headed tenon ; *C.* double hammer-headed tenon made from hardwood. Note the wedges which are used to tighten the joint.

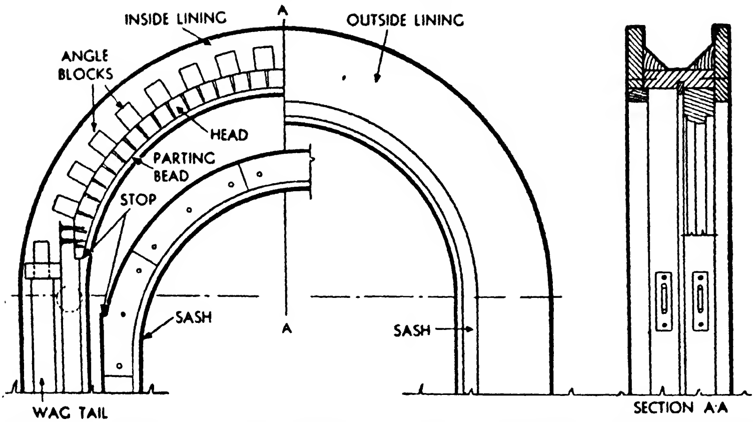


Fig. 15. Semi-circular headed sash and frame. The head of the pulley stile is bent to shape by making saw-kerfs in the back and inserting glued feathers.

for the ribs of the drum, one for the sash, and one for the linings. Note that the joint of the head to the pulley stile is made two or three inches above the springing to form a stop for the sash. There are two reasons for this; first, to prevent the sashes from binding when pushed up to the head, and secondly, in order to avoid the impact of the sash on the crown.

The pulley stiles are tongued into the linings in the usual manner, but the tongues are generally omitted on the head owing to the cost of labour involved in forming the grooves in the linings. The linings are nailed to the head and stiffened with glued angle blocks.

The pulley stiles are carried up above the springing and are screwed to the head. A block is cut in and fixed to the pulley stiles above the pulleys to support the wag-tail or parting slip. The linings are cut out to the required shape with the joints butted and grooved for a cross tongue.

The semi-circular parting bead is cut to the required shape in suitable lengths, and extends down to the springing line.

The semi-circular cover bead can be saw-serfed, cut out of the solid, or steamed and bent.

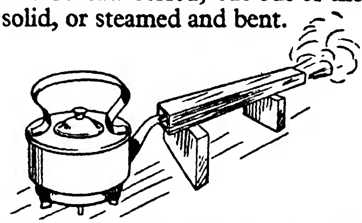


Fig. 16. Simple workshop appliance for steam-bending small members. The box is to localise the steam from the primitive generator.

For bending by steam, a rough box, left open at both ends, should be made. Put the bead in the box and arrange this so that the steam from a boiling kettle enters in at one end (Fig. 16). After steaming for a while, take out the bead and try for pliability. If satisfactory, bend round the lining and fix with nails, or cups and screws. If the bead is still found to be stiff, it should be put back in the steam-box for a further period.

CHAPTER 14

FIXING JOINERY ON SITE

THE JOINER-FIXER. ERECTION OF POT WALLS. FIXING BATTENS. VENTILATION. FITTING PANELS, FRAMES AND LININGS. USE OF DATUM LINE. BUILT-IN DOOR FRAMES. THE FIXER'S WORK. CUTTING-IN LOCK MORTISES. WINDOW OPENINGS. BATTENING FOR LIGHTING SWITCHES. FIXING OF SKIRTING AND ARCHITRAVES. CORNICE WORK. PILASTERS AND COLUMNS. DOVETAILED BLOCKS. BRACKETING ROUND STEELWORK.

THERE is a strong line of demarcation to be drawn between first and second fixing, and one that is not generally appreciated by anyone except the practical man.

First fixing is mainly the concern of the carpenter, and *second fixing* that of the joiner.

An examination of the different operations executed under these two headings clearly indicates a need for this sub-division of labour. Briefly, a carpenter is concerned with the fabrication of timber on the site and for use as carcasing, while the joiner has to deal with the finishings, or trimmings, not only in the making, but also in the fixing (see page 15).

This chapter is concerned with the work of the joiner-fixer.

The Joiner-Fixer

A good fixer must have experience in all branches of carpentry and joinery, and be able to organise his activities to suit the progress of the other trades concerned in the erection of a building. It is this experience, intelligently used, that accounts for the fact that many of the key men who are now engaged in the building industry are practical men whose trade was formerly that of the carpenter or joiner.

No trade exists which offers greater scope for pride of craftsmanship, interest, advancement of position, or as an outlet for individual enterprise and initiative.

During the constructive stages of a building, provision has to be made for the various finishings, especially where woodwork is concerned. The bricklayer or stonemason can build-in fixing blocks of breeze, or wood pads or pallets the same thickness as the joints, as shown in Fig 1. There are other ways, but the main thing to remember is that the carpenter on the site must know where the fixings have to be inserted.

Fig. 1 also shows the positions of required fixings at a door opening.

Wood pads are useful for fixing skirtings, picture rails, framed grounds, window boards, architraves, built-in furniture, brackets for shelving, and numerous other articles of wood used in house or building.

In many large buildings, the internal walls are formed of 2 in., 3 in., or 4 in. partition slabs known as 'pots,' which often present special difficulties in the fixing of the respective finishings.

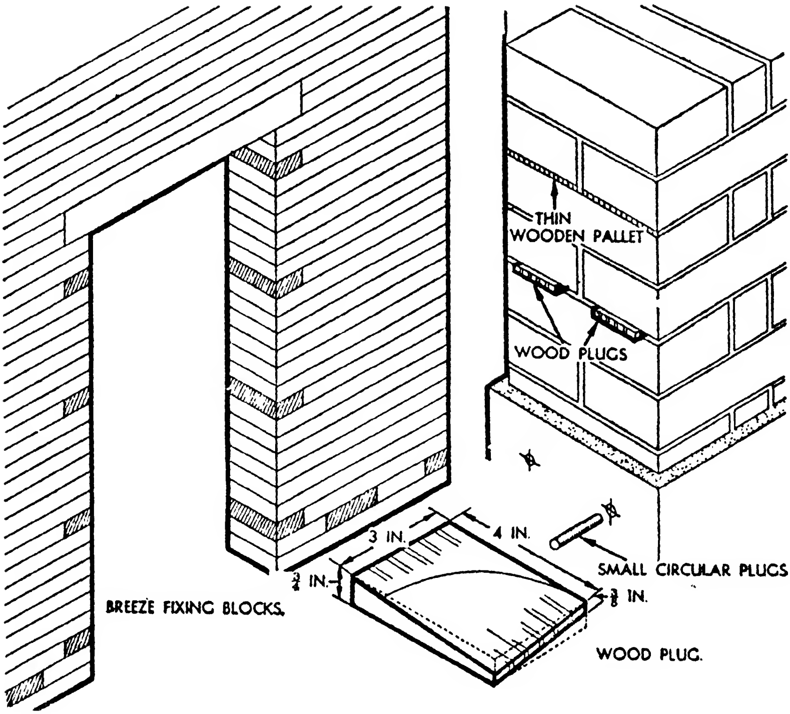


Fig. 1. Fixings to brick wall. The diagrams show the amount and types of fixings required. Fixing may be provided by breeze blocks, built-in, thin wood pallets, wood plugs, or, in plastered walls, small circular plugs. The enlarged sketch in the foreground shows a wood plug with twisted faces.

Reference to Fig. 2 A shows how to effect an efficient treatment around the door opening in a pot wall.

The core or buck frame can be erected first, care being taken to strut securely the frame at the ceiling and floor level, and to see that the frame has at least one stretcher to prevent the bricklayer forcing the frame out of parallel (see Fig. 4).

The pot walls can then be erected on each side of the core frame; later the projection of the frame can be utilised by the plasterer as a screed. This form of construction greatly facilitates the second fixing of door linings and architraves, speeds up completion, and most important of all where first-class work is concerned, ensures the minimum amount of damage being done to either painted or polished work.

Another great advantage is that, should shrinkage take place, the door frames can always be refixed without a lot of disturbance.

Another method of fixing the frame is shown at Fig. 2 B. This method has the disadvantages just

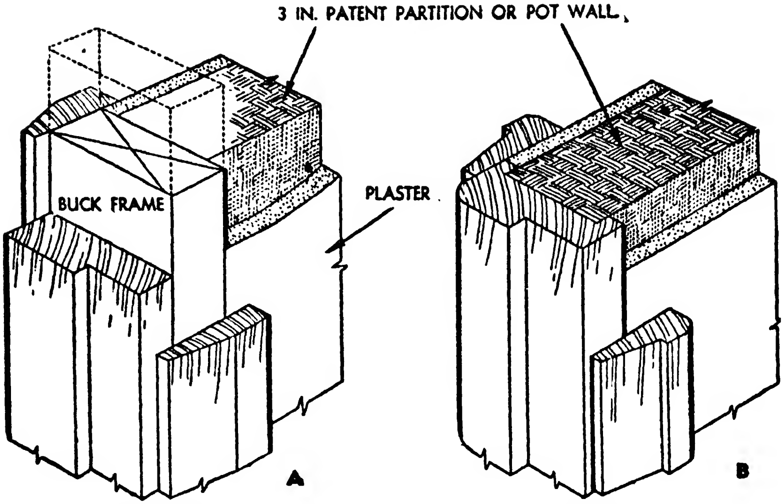


Fig. 2. Fixing door frames to "pot walls." A. Use of the core or buck frame, with 4 in. by $1\frac{1}{2}$ in. lining ; B. frame fixed direct to the wall.

mentioned, hence is used on the cheaper class of work.

The problems of shrinkage, moisture content and heat must all be borne in mind when fixing; in fact the proper care of joinery during fixing is the whole secret of good work.

Wherever possible, joinery should be fixed to battens, called 'rough grounds,' securely nailed to the wall. The battens not only provide a good fixing, but they are made to afford a true and flat surface on which to fix the joinery.

When fixing battens to thin pot walls, a little foresight will prevent a lot of trouble. Battens should be at least $\frac{3}{4}$ in. thick, because thinner battens give poor fixing and do not allow the fixer to straighten his work if the walls are out of plumb.

If pads or breeze blocks are not built in the walls, the joints are raked out and plugs (Fig. 3 A) or folding wedges (Fig. 3 B) inserted. For hollow pot or tile walls, neither of these methods can be considered satisfactory. Plugs are difficult to use; to be effective, they should be well driven in.

This can be accomplished quite well with a brick wall, but the nature of the lighter types of walls prevent the plug obtaining a firm hold. The face of the wall will break away if struck with a hammer, and the plug, instead of being compressed, simply 'spalls' or flakes the surface surrounding the joint, as clearly illustrated in Fig. 3 A.

Where battens have to be fixed on both sides of the wall the best way is by small bolts, as shown at Fig. 3 C. The heads and nuts can be sunk into the battens, or a counter batten can be used. Where battens are required on one side only, small expanding bolts can be grouted in the joints and the batten bolted on as shown in Fig. 3 D, or the bolts can pass through the wall as shown in Fig. 3 E.

On many contracts sub-letting is a prevalent practice, and if the sub-contractor has to plug the walls and fix the battens, this should be carried out before the surfaces on the reverse sides of the walls are plastered. If plugs or wedges are used the vibration set up by hammering will disturb the plaster. This is an important point, and one that can cause much trouble when the question of responsibility has to be decided at a later date.

To prevent corrosion the heads of the bolts should be treated before being covered with plaster.

Battening is used for numerous fixing purposes; it is essential for fixing panelling, either solid or plywood, tapestry and leather panels, matching and wainscoting, various forms of composite building boards, glass and other vitreous materials apart from the constructional side of the building.

Before battening is fixed, it should be treated with one of the many preservatives now available, either by painting or by means of tank immersion.

Framed Grounds

The question of *framed grounds* versus *battening* fixed direct on the walls is one that has to be decided by the quality of the work and the condition of the building. Framed grounds are much easier to fix and are a more speedy job, but the cost of framing precludes their use except on good class work.

Both types demand the greatest of care in fixing; the battens must be in alignment and plumb, otherwise the angles of the finished work will give trouble. If the ground work is correct, the rest of the work will come right.

Another very important point concerns ventilation. Vertical battens should be used, especially for panelling; then if small vents are made in the skirting and slots cut in the cornice, a through

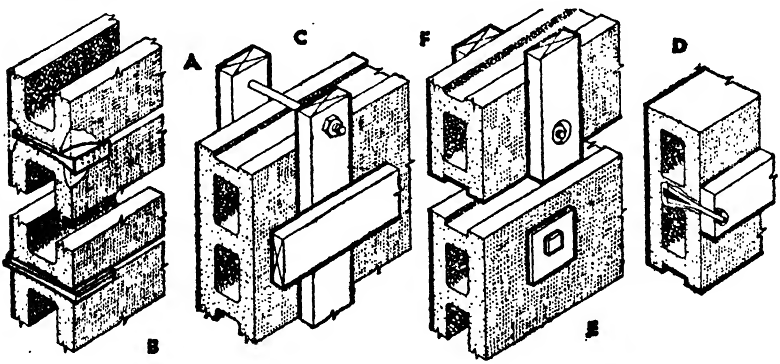


Fig. 3. Fixing battens to "pot walls." A. Plugs tend to "spall" the face of blocks if driven in joints; B. hardwood folding wedges; C. battens bolted through wall, on horizontal counter battens; D. small bolt with expanding plug; E. ½ in. black iron bolts with 2 in. by 2 in. washer. Note that these bolts pass right through the wall; F. fixing bolt, flush with batten face.

current of air is obtained. The value of this ventilation will be readily appreciated by the following example.

A board-room in a new building was fitted with oak panelling from floor to ceiling. When the heating system was installed the panels buckled, some of the muntins started to split the rails, and the entire appearance of a first-class job was ruined. The panelling had been painted on the back before erection, and the walls were sealed with a bitumastic paint, but the importance of ventilation had been overlooked.

The remedy was quite simple. By easing the skirting and dado mould from the panelling, fresh air was introduced and within a week the various members were resuming their normal appearance. Later, permanent vents were cut in the skirting and cornice, and no further trouble was experienced.

To the uninitiated, battening may seem a very simple and unimportant job, yet the reverse is the case. It is a skilled man's job, and while seemingly carpenters' work, it is better if carried out by the joiner-fixer. Most builders employ a staff of joiners whose work is always done on the building site.

Fixing Methods

The importance of proper fixing methods is illustrated by the operation involved in fixing panelling. Assuming that all the preliminary work has been well carried out, such as measuring up, setting-out, preparing the joinery, that the walls have been battened, or the framed grounds well and truly fixed, the joinery, which in this case includes panelling, door frames, window linings, chimney-pieces, skirtings and cornices, is delivered to the site and stacked in an accessible store. The pieces of joinery are marked to correspond with the key plan previously prepared by the setter-out.

The fixer first marks his datum line round the room. If possible, the marking should be done on the batten face, as the process of transferring marks from the brickwork to the battens may lead to inaccuracies. Assuming that the

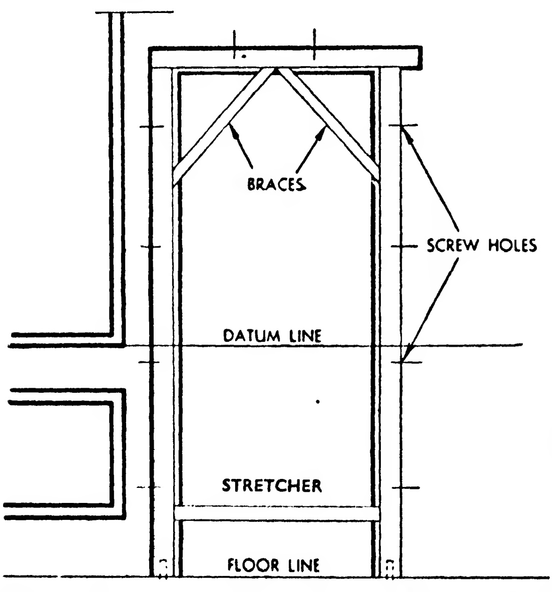


Fig. 4. Use of the datum line to set out correct heights. The diagram also shows the spacing of fixings.

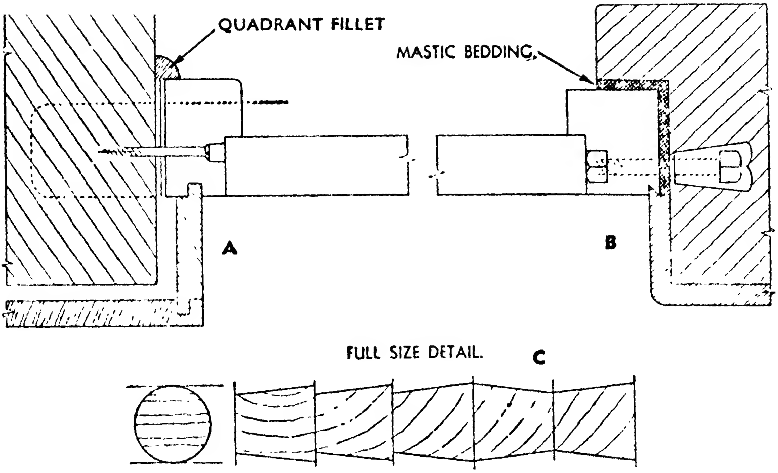


Fig. 5. Various methods of fixing a door frame. *A.* Frame screwed through jamb to fixing plug or built-in pallet ; *B.* $\frac{3}{8}$-in. expanding bolt for fixing jamb to stone reveals ; *C.* detail of $\frac{1}{2}$-in. turned pellets used to cover screws.

datum line is to be a level line 3 ft. above the finished floor level, the work must agree with the floor level outside the room, and all levels must be taken from this position.

In the absence of a dumpy level, a true straight-edge and spirit level are essential for the work. Always reverse the straight-edge when moving from one point to another to ensure small errors being equalised. If great care is taken, it is possible to commence levelling at one side of the room, level round the room and finish up ' dead level ' at the same spot.

A datum line is a great help, especially on work in an old building, as the fixer can arrange where best to take up the different levels. By marking a height rod of the panelling at the 3 ft. level, Fig. 4, and then transferring this mark on to the framing of the panelling, it is quite a simple matter to make certain that the mark agrees with the datum line.

In a room with many small breaks in the wall surface it is easy to fix framing out of level, with the consequence that when the skirting and cornice are fixed, the margins show different widths.

It is good practice to fix the door frame first. First check up the overall size and make sure that the joiner has made the linings or frame to the correct width and size. Make any adjustment necessary, and see that the angles of the frame are square and braced and that the bottom stretcher is of the same length as the distance between the rebates at the head (Figs. 4 and 6).

The frame is then bored at intervals of about four holes to each jamb and two in the head. Care must be taken to avoid the positions where the butts and striking plate are to be fixed, but they should be bored fairly close to these positions. A $\frac{1}{4}$ in. bit should be used for the actual screw holes and a $\frac{1}{2}$ in. bit for

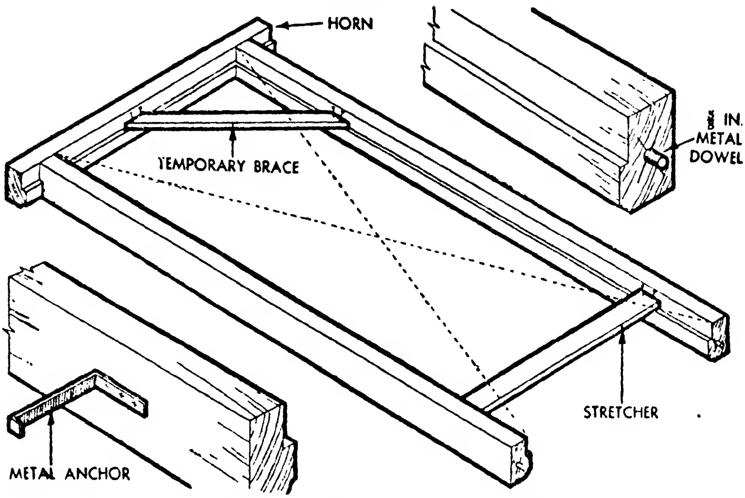


Fig. 6. Solid door frame as delivered to site for building-in. Dotted lines indicate the position of squaring-rod to check diagonals. Diagram also shows horn for building into brickwork ; temporary brace to remain on until the frame is fixed; ⅜ in. metal dowel to secure feet of jambs ; metal anchor and stretcher to keep jambs parallel. Three of these ties should be on each jamb.

the wooden pellets used to conceal the screw heads (Fig. 5 A).

The frame can then be placed in position and held by wedges until the marking for the fitting is made. When the head of the frame is level, the difference between the datum line and the previously marked datum line on the frame is taken on the compasses and the foot of each jamb is scribed from the floor. By this means the frame can be cut to size to suit both the door and the datum.

The actual fixing is a fairly easy task. Test the edges of the frame for being plumb, and adjust wedges to ensure that the rebates remain parallel with each other when the screws are driven in. If the adjoining battens have been properly fixed, a straight-edge across the door opening will prove if the frame is in alignment.

It is a good plan to allow the head of the frame to fall back slightly out of plumb, not more than $\frac{1}{16}$ in. This helps the door to close and also throws the bottom of the door up when it is opened so that it clears the floor better. It is a small point, but one worth remembering unless rising butts are used.

Should the door frame be an external one, the feet of the jambs may be fixed by metal dowels. ¾ in. gas barrel driven into the frame and left protruding to be grouted into the sill makes an excellent anchorage.

It is not always possible to utilise the bedding joints or hardwood pads when stone reveals are used. One can either use the expanding bolt system, as shown in Fig. 5 B, or holes can be drilled in the stonework and either wood or lead plugs inserted. Then the frame can be screwed into position and pelleted in the usual way.

In using bolts, the frame has to be fixed in sections, the jambs first and the head last. There are no mortise and tenon joints at the angles, but the bolts are more than sufficient fixing. This method of fixing has proved to be very successful.

Built-in Door Frames

When door frames are 'built-in' as the work proceeds (a practice not to be recommended) the back of the frame should be painted, and galvanised iron ties, as shown in Fig. 6, should be screwed to the back of the frame and bedded in the joint. Three of these ties on each jamb are advisable.

Where frames are to be fixed in $4\frac{1}{2}$ in. brick walls, two or more bricks may be left out where the ties are to be. The frame can then be fixed later on and the brickwork made good round the ties. This method has its good points inasmuch as the woodwork can be fixed when the brickwork is dry and the frame is not liable to damage by scaffolding.

If frames have to be built-in, protection from moisture and damage is essential. Roofing felts should be fixed on the back edges, and packing pieces, especially round the rebates, should be used to guard the exposed surfaces.

From the foregoing it will be realised that finished joinery either painted or polished should not be fixed until the risk of damage has been eliminated; it also emphasises the essential difference between first and second fixing.

On large housing schemes the door frames and windows are usually 'built-in', the door linings nailed up, and the skirtings fixed before any plastering is carried out. This method is not good practice and is mainly responsible for the bad finish attached to this class of work. A typical detail of this cheap kind of fixing is shown in Fig. 7.

Reverting to the panelled room again, the next operation is to hang or hinge the door in its frame. This may be left until the last, especially if the surface of the door is veneered; but it is a matter of judgment on the part of the fixer.

If dealing with the mass-produced article, it is usual to receive the door with the mortise cut for the lock and the recesses cut for the butts. Where speed is essential, the whole unit can be delivered to the site with the door hung in its frame, complete with mortise lock, leaving only the furniture to be screwed on and the striking plate cut in.

Then the architraves could also be framed up before delivery to

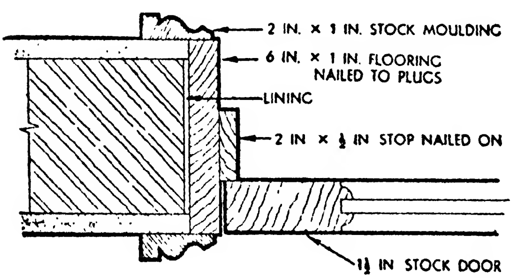


Fig. 7. Internal door lining of cheaper type. The lining is formed ex. 6 in. floor board nailed to plugs, with 2 in. by ½ in. planted stop.

the site, thus saving time spent on the endless cutting of mitres on a sawing stool.

When dealing with a small contract such as the one being considered, all these operations have to be carried out by the fixer.

Fitting the Door

The first operation is fitting the door, and if made of hardwood the work must be carefully done. Procedure is to take a pinch rod of the frame at the top and bottom to test the width of the door; shoot the edges straight and slightly out of square, then offer the door into position and ease where necessary. Next fit the top of the door, keeping the joint fairly close on the shutting corner to allow for the tendency of the door to droop.

Next scribe the bottom of the door to the floor, leaving sufficient space for the door to clear the floor covering. If a flush door is being hung, the question of parallel margins does not arise, but with panelled doors it is necessary to work to the datum line so as to ensure that the rails of the door coincide with the rails of the wall panelling.

The position of the butts while the door is in the frame can now be marked. A good rule for this is to keep the top hinge 6 in. down from the top of the door and the bottom hinge 9 in. up from the floor, or lineable with the top and bottom rails.

Having marked the position of

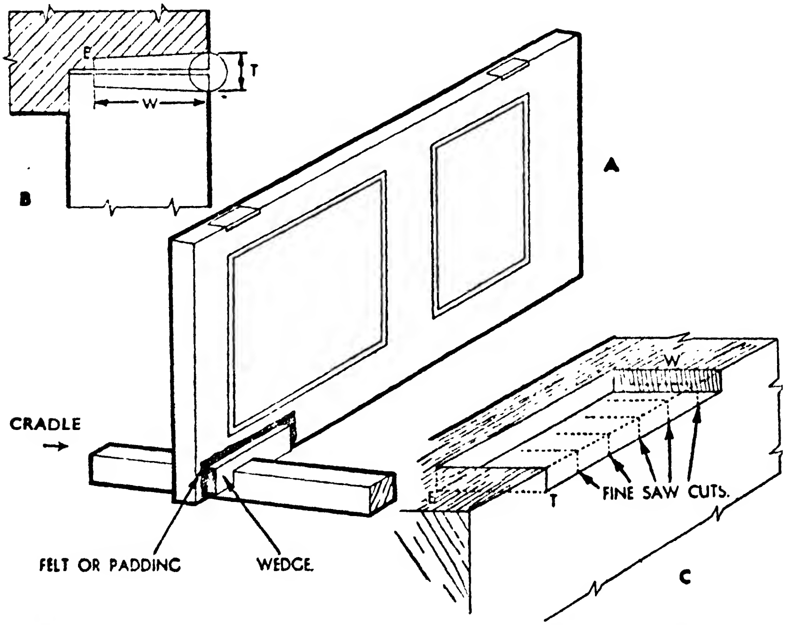


Fig. 8. Hanging the door. A. Door held in cradle for shooting the edges and fitting the hinges ; B. section of ' butt ' to show settings of gauges ; C. recess for the button edge of door stile. Note that the sinking is not parallel.

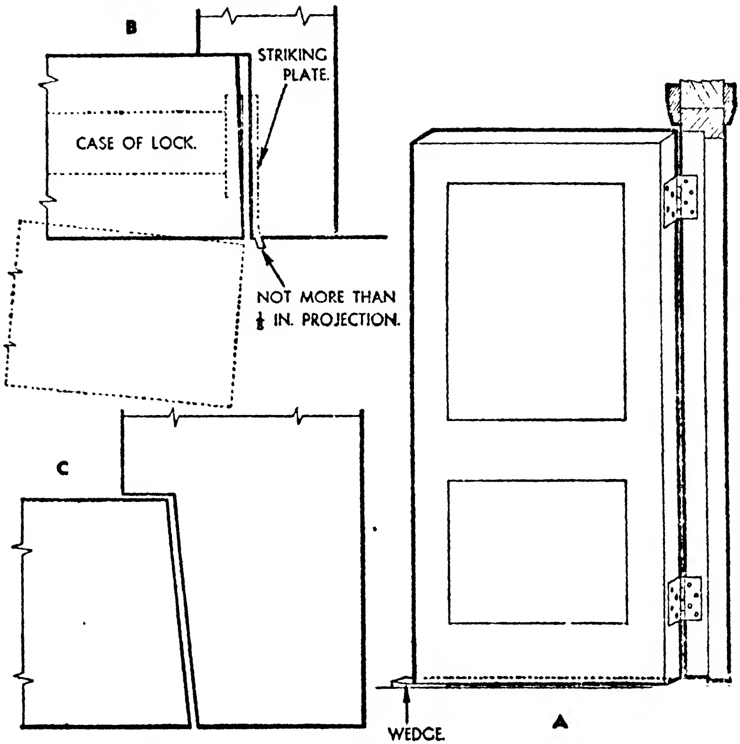


Fig. 9. *A.* Wedging the door open while screwing to the frame ; *B.* bevel on edge of the door to give clearance ; *C.* bevel on frame for thick doors.

the hinges on the door and frame, remove the door and lay it down edgeways in a cradle, using felt or similar softening against the face of the door to protect its surface. The door can be held quite firmly by the wedge as shown in Fig. 8 A.

When fixing joinery, great care must be taken not to damage the work. Treat the joinery with the respect due to it, and never put any finished work on the bench or sawing stool without first putting down some form of felt as a protection against scratching and damage to the mouldings. Do not use the surface as a writing desk to make out time sheets, as the pencil marks will show on the surface.

To fix the hinges, square over the marks previously made to the edge of the door. Set a gauge to the width of the butts from the knuckle to the edge as shown in Fig. 8 B, and set another gauge to the thickness of half the butt, as in Fig. 8 B. Having marked the outline of the butts on the edge of the door, as Fig. 8 C, use a dovetail saw as shown, and chop away the recess. As the butt tapers slightly, the sinking will not be parallel. Having cleared the recess, fit the butt and drill holes for two screws—always drill the holes with either a hand or wheel brace, and not by means of a bradawl.

When the recessing is completed in the door and frame, screw the butts on the door, and insert two screws only in the frame, so that should any slight adjustment be necessary, there are two screw holes not drilled.

Now remove the wedge from the bottom of the door (Fig. 9 A) and swing the door to find out possible faults. Possibly the top edge of the door fouls the frame, or the bevel to the edge is not enough, or perhaps the recess has been cut below the gauge line and the door is what is commonly called '*hinge bound.*' These small snags should be rectified and the door made to swing properly before the remainder of the screws are driven in.

In hardwood, brass screws easily break, and the slot in the head soon becomes jagged and unsightly. When using brass screws drive in iron screws first.

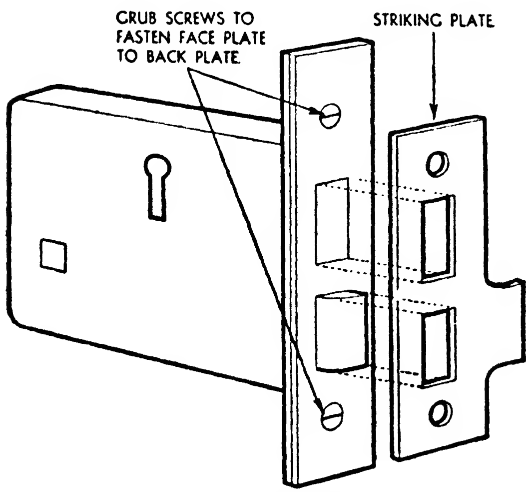


Fig. 10. Detail drawing of a mortise lock showing face plate and striking plate.

There are many little details which greatly assist the work of hanging doors. A special combination gauge is on the market for marking the butt recesses, but the clearance allowed in this type of gauge is too big for high-class hardwood fixing.

Some shops make a practice of fitting the door and polishing the edges before delivery to the site, but this is open to the objection that should the door swell in the interim, then the fixer has the unenviable job of scraping off the polish before he can ease the door. Even the edges on flush doors have been known to swell, and when the clerk of works insists that the joint round the door should not be thicker than the thickness of a visiting card, it is much better to leave the edges clean so that any slight adjustment can be easily made by the fixer.

The cutting-in of the mortise lock and the fixing of the furniture is a job which does not present much difficulty. Procedure is to wedge the door about half-way open, determine the correct height of the lock, mark the position of the keyhole and gauge for the mortise slot. Test the lock case for thickness (usually $\frac{9}{16}$ in. or $\frac{5}{8}$ in.), set the gauge stick for the depth of the lock plus the thickness of the face plate, then bore a series of holes inside the mortise slot lines.

Having bored out as much waste timber as possible, clean out the remainder with a swan neck chisel and a wide paring chisel.

Care must be taken to bore parallel with the face of the door, otherwise, when the face plate is fitted it will not be square with the face of the door.

When fitting the door, do not plane the edges out of square more than is necessary to give clearance (Fig. 9 B). In the case of a door over 2 in. in thickness it is better to bevel the rebate of the door frame (Fig. 9 C) to enable the door to maintain a good joint parallel with the rebate. This is more fully explained in Chapter 6 on Joinery Joints.

If the door is to be fitted with rising butts, a bevelled frame facilitates the fixing of the butts considerably. It does away with the feather edge on the top of the door caused by the excessive bevel necessary to give clearance when the door is closing and opening.

Face and Striking Plates

After the lock case is inserted, cut round for the face plate, then cut the key hole and bore for the spindle. This operation can be carried out before mortising, and is a matter of personal opinion. Great care must be taken when cutting for the face plate and making the sinking, otherwise the grub screws (Fig. 10) will not engage properly in the lock case.

Having tested the spindle hole and keyhole, insert the iron screws to secure the lock case, then fix the face plate and attach the furniture.

Equal care must be taken in fixing the striking plate on the frame, otherwise the latch will not engage properly. Careful marking and neatness in cutting the recesses are essential. Before the final fixing of the plate, cut the projecting portion so that it protrudes about $\frac{1}{8}$ in. beyond the edge of the frame, and at the same time, give it a slight bend. This enables the latch to slide past the plate more easily, and, to a certain extent, eliminates noise in closing the door.

Panelling

The panelling may be fixed next. As the battening is ready, and the setting-out rods all checked, deal with one section of the wall first, say, from an internal angle up to the door frame, Fig. 11 A. The first thing to do is to check the actual piece of panelling, and if this is correct, mark the position of the plough groove at the internal angle (Fig. 11 B).

The making of this joint should be left to the fixer, who can make any slight adjustment in the position of the groove. The tongue on the corresponding piece of panelling can be machined before the framing is glued up.

The question of what portions can be glued up in the shop, and where to leave dry joints, is dealt with in the manufacturing stages, so it can be assumed in this instance that the framing is ready for use.

Before ploughing, the framing should be levelled in the same way as the door frame; the datum line marked on the two extremes and scribed to the floor. Any adjustments should be made by cutting the horns on the angle stiles.

If the battening is plumb and

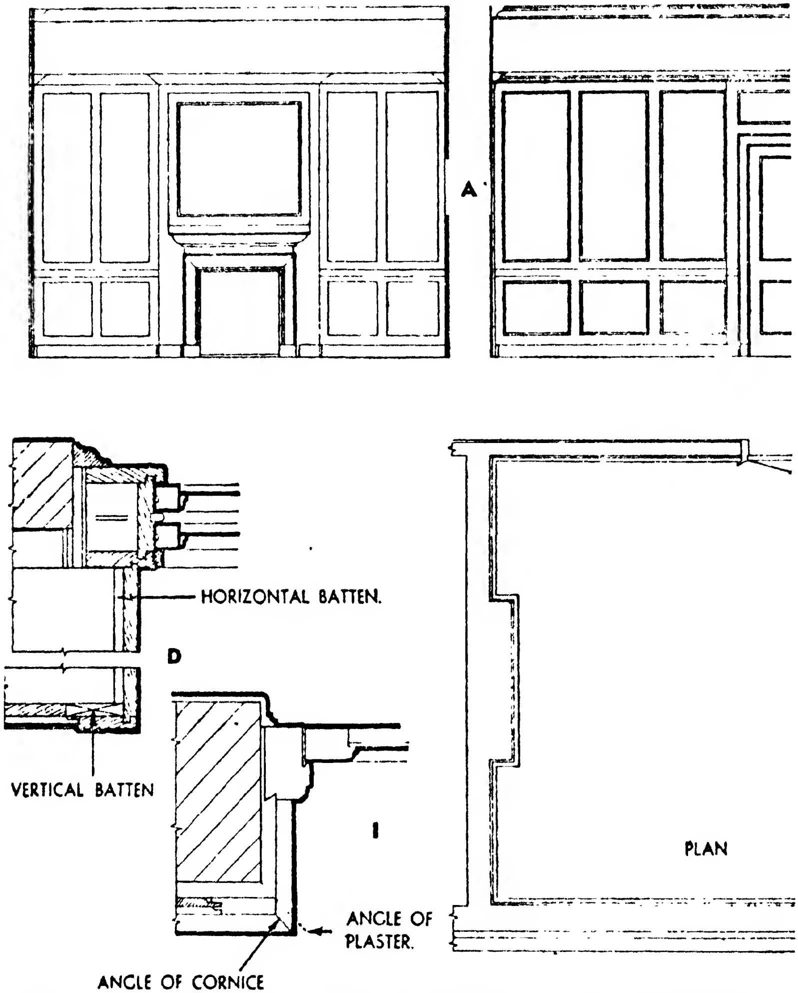
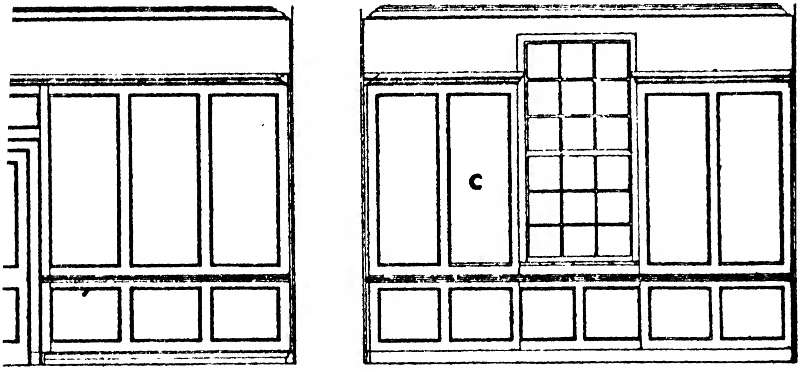
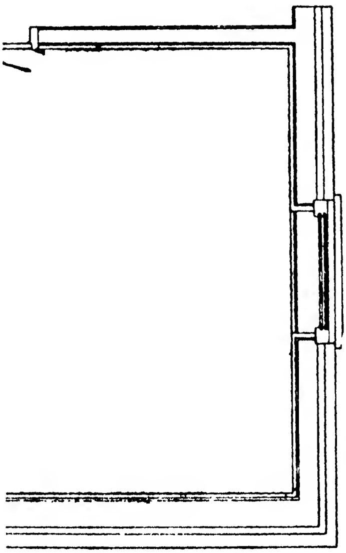


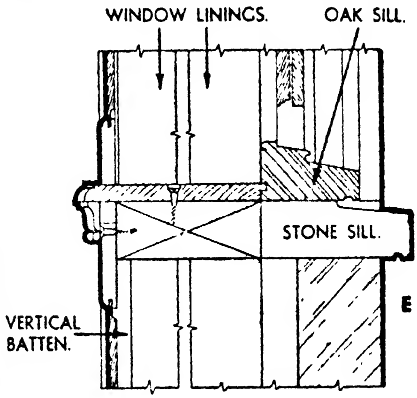
Fig. 11. Plan and elevations of panelling. A. Elevation; B. internal angle fixed panelling with window opening; D. detail of window lining; E. detail of joints at external angle with window lining; I Mitres of window lining

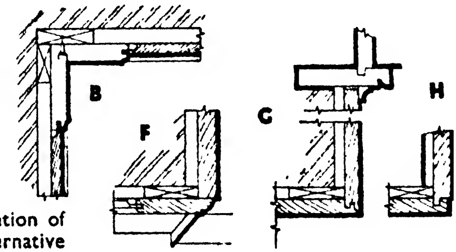
the framing level, the edge can be gauged for ploughing, but if the walls are not plumb, or the framing has been glued up out of square, then the end stile to the return wall face must be fitted before ploughing. This point will serve to emphasise the importance of correct battening, and why the joiner-fixer should do his own battening. He will then know where to make any allowance in the margins of the framing.

Suppose, for instance, an internal angle has two tongues worked on the framing, then the fixer has to decide whether to









to vertical battens ; *C.* elevation of window board ; *F, G, H.* alternative and panelling must coincide.

cut off one tongue and plant a new piece, or if there is enough margin to allow for ploughing.

When the framing is flat on the bench or stools, bore the holes by which the framing will be fixed to the battening—three or four screws in the plough groove and about 3 ft. apart in the bottom, middle and top rails will give sufficient fixing.

Keep the holes as near the edge of the rails as possible, otherwise it will be found that the screw heads will not be covered by the skirting or cornice. The screws in the middle rail are covered by the dado, which is fixed later.

In some instances, it is better to have the framing in two heights, especially if access to the room is difficult; the end stiles can be sent to the job loose, and glued up afterwards; in either case the operations are exactly the same.

After fixing the first piece of panelling, deal with the small piece over the door. This piece should have shoulders on each end of the rails, which can be eased slightly if necessary. Do not fix this piece of panelling until the framing on the right hand side has been tested. A pinch rod taken from the batten face will show the amount of adjustment necessary to make to the end stile before ploughing.

When these operations have been carried out, glue the tenons on the small panel and push on the large piece of framing; it can then be fixed as before to complete one wall of panelling.

Window Openings

Fig. 11 C shows a wall with a window opening; in this case it will be necessary to fix the window linings first (Fig. 11 D) and the window board (Fig. 11 E). Actually the linings do not require much fixing as they are held in position by the tongues and grooves and, in the case of wide reveals, are best left like this, then any subsequent shrinkage will not cause splitting.

Here again the necessity for accurate battening is emphasised. The linings must be square to the window frame and the panelling, otherwise the tongues will have to be eased.

The window board can be levelled in and the grooves marked at the end for the linings. Make sure that the right amount of projection is obtained, so that when the bed mould is fixed under the window board no easing is required.

Where there is no dado mould, the return ends of the window board should be housed into the angle stile. To do this it is necessary to remove the linings and window board, and fit up the piece of framing on the left hand side. Test the framing from the back edge of the tongue at the internal angle up to the face of the battens in the window reveal, and then plough the groove for the lining.

Fit in the lining and push the framing into position; slide the window board into position until the notching meets the face of the stile, then mark the outline of the window board moulding on the stile. When the housing is done, and a good fit obtained, repeat all the operations at the right hand side.

The piece of framing under the window can be fitted in a similar manner to that over the door. Reference to the plan of the room will show where to arrange the joints at the angles, and will give the sequence in which it is intended to erect the framing.

Referring to the window again, the joint at the external angle can be varied as shown in Figs. 11 F, G and H, but these are points which can be arranged in the workshop. Should the window not have a plough groove for the linings, a small scribing fillet should be fitted against the frame, as illustrated in Fig. 11 G. This is also necessary should the groove be in the wrong place.

Very often the builder supplies and fixes the frame, and consequently only puts in a plaster groove, with the result that, if this is used for wood linings, the plaster angle above the panelling will not cut with the mitre of the cornice. Fig. 11 (I) shows how not to treat an angle of this description.

Another point to watch when fitting up window linings is to make sufficient clearance under the window board, as shown in Fig. 11 E, so that the front edge can drop down to clear the tongues on the bottom of the linings.

Extra Fittings

When the whole of the window wall framing has been fixed, including the window linings, extra fixing may be required at the centre of the window board by means of screws and pellets. The grain of the pellets must be in the same direction as the grain of the window board, and they should not be cleaned off until the glue or Seccotine is dry.

The fixing of the framing around the rest of the room should present no difficulty.

The long wall opposite the door will have to be erected in sections. Here again the position of the dry joints should be arranged by the setter-out when he is planning production.

The fireplace wall may give some trouble. The example shows a stone fireplace and this must always be fixed before the panelling is erected, and, if possible, before the setter-out takes his dimensions.

It is a good plan to contact the electrician before any battening is commenced, and to arrange with him the positions of the light switches and plugs. The switches should always be placed central on the stiles; if this is not possible they should be placed in the centre of the panels or rails. Nothing looks more unsightly than points fixed indiscriminately.

With regard to power plugs, these should be arranged in the centre of the skirting, otherwise the plate will cut the mouldings and cause all sorts of making good. The electrician should fix his boxes beforehand so that the fixer will not be held up.

A lot of time can be wasted unless similar small details are arranged beforehand. Bell pushes also have to be considered; these generally come on the fireplace wall and should be fixed at a convenient height. The bell-push, radio and telephone wires can usually be accommodated in the space behind the skirting. This often means that the skirting, for a certain distance, has to be fixed with cups and screws so that in the event of a breakdown it is quite a simple matter to trace the fault.

Fixing Skirting

The fixing of ordinary skirting looks quite simple, but there are many pitfalls. If the floor is out of level, a certain amount of scribing is necessary, and unless the setter-out has had experience as a fixer, he is almost sure to prepare the different members to the net section. Then the fixer has to put pieces on the bottom edge in order to keep a good margin between the top edge of the skirting and the moulding on the bottom rail.

All internal angles should be stop grooved and tongued with the top mouldings mitred or scribed, as shown in Fig. 12 A. The external angles can be mitred right through, and this is where a good craftsman proves his worth. It is far different doing this sort of work out on the job from doing it in the shop.

One has to improvise in many things. Some firms send collapsible benches to the site, and these are a great help, but the most convenient appliance usually available is the sawing stool. When supplied with good plant, look after it and see that it is distinctly marked. On large contracts it is very easy to lose things, and nothing is more annoying or distracting.

For cutting the mitres to the skirting, a mitre box is essential. One made from ¾ in. blockboard or plywood is more serviceable than one made from floor boards. If the sides warp a true mitre cannot be made, so that the best material available is cheapest in the long run.

Make the box deep enough to take the widest member and long enough so that when the cuts are made there is enough material at the ends to give rigidity to the sides, as shown in Fig. 12 B. A sharp panel saw should be used for making the cuts and this saw should be used all the time the box is in use. No two saws have exactly the same set, and the finer the saw cuts, the more accurate will be the mitres.

After constant use it is advisable to make a new set of cuts in the box, otherwise the mitres will have to be planed before they fit, and in hardwood this takes time.

In many shops it is the practice

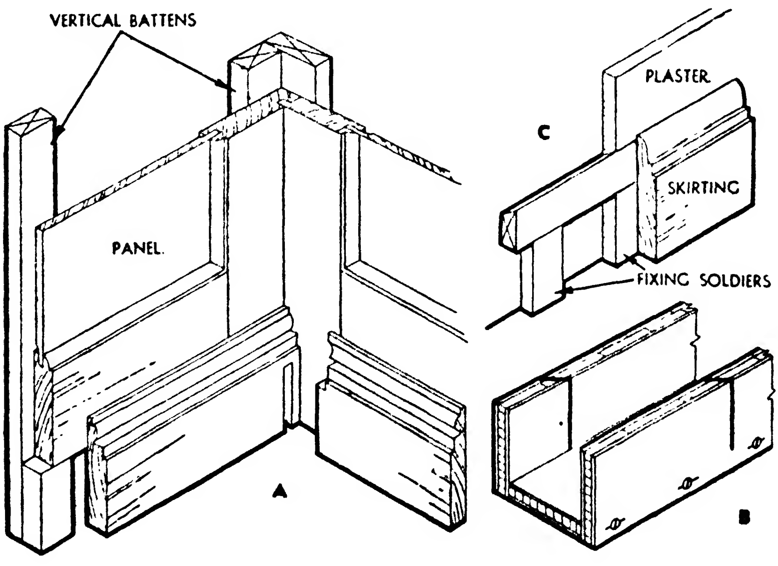


Fig. 12. Method of jointing a skirting board. A. Internal angle tongued and grooved with moulded members scribed ; B. mitre box made from blockboard ; C. plastered wall showing plaster ground or batten, skirting and fixing soldiers.

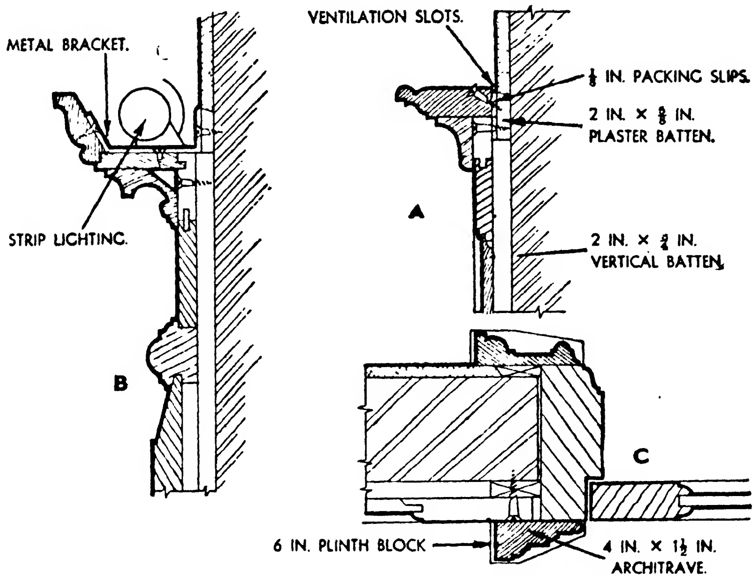


Fig. 13. Further details of panelling. A. Combined picture and plate rail; B. concealed strip lighting in cornice; C. detail of jamb finishings at door opening.

to cut and fit both the skirting and cornice on certain pieces of framing, leaving the fixer to connect up on the site. If this is done the datum must be erected before fixing to avoid trouble when the sections are linked together.

On the long wall it is probable that a joint will be necessary in the cornice and skirting. If these members can be permanently fixed, then a splayed joint is better than a butt joint. The splay should be cut in the mitre box and well glued. If cups and screws are used, then a butt joint is preferable.

The skirting blocks or soldiers fixed while battening out the room need very careful alignment, otherwise it may mean chopping away in order to get a tight joint on the top edge (Fig. 12 A). These soldiers can be nailed to the face of the battens or to their sides, but they should not project in front of the framing.

Where walls are plastered, the batten shown in Fig. 12 C should be fixed first, to keep the plaster straight and prevent unsightly cracks between the skirting and plasterwork.

It is not good practice to fix any form of finishing direct to plugs driven into the wall as a satisfactory fixing cannot be obtained. A twisted piece of skirting is difficult to hold, and a few saw kerfs on the back face will ease matters considerably. The ventilation grilles and plug boxes must not be forgotten; many lengths of skirting are ruined by this oversight.

Cornice work should be screwed wherever possible, especially if it

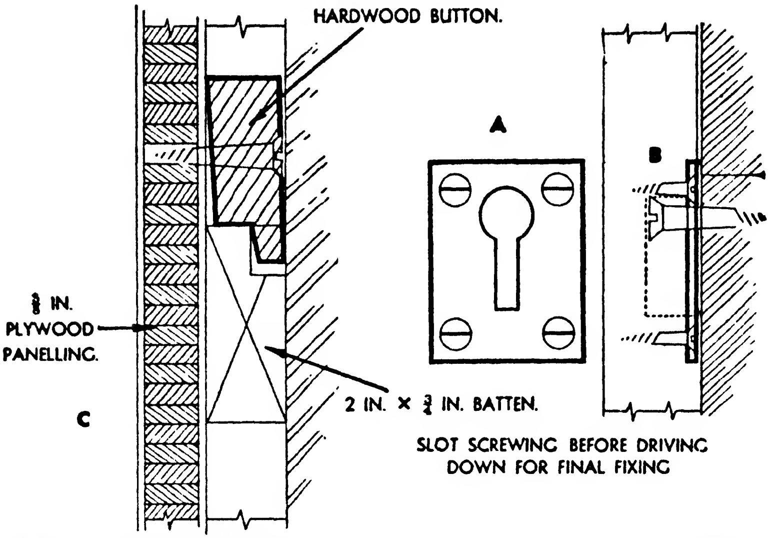


Fig. 14. Methods of secret fixing. *A.* Key plate for slot screwing ; *B.* position of screw before driving down for final fixing ; *C.* turnbutton which engages in a groove for securing panelling to rebated batten.

is a combined picture and plate rail, as in Fig. 13 A. If concealed lighting is used as Fig. 13 B small metal brackets make the best job ; these brackets should be fixed first of all to the cornice and afterwards attached to the plaster batten.

There is considerable heat given off by the lighting, so mitres and scribes must fit well and have canvas glued on the back. This helps to strengthen the mitre and when the wood shrinks, light will not be seen through the joints. The trough used for this type of lighting can also be utilised for running the wires instead of behind the skirting.

Architraves

The fixing of the architraves around the door opening can be carried out in a number of ways. If they are framed up complete with plinth blocks in the shop, a correct margin all the way round must be maintained, as shown in Fig. 13 C, and this again shows how necessary it is for accuracy both in the shop and on the job. The easiest way in this instance is to fix through the face, or by means of slot screws.

The latter method is expensive and certainly not a job for anyone except an experienced fixer. The whole secret lies in marking out the work accurately. Small metal plates, called key plates, Fig. 14 A and B, can be sunk in flush on the lining after drilling a hole slightly larger than the screw head, and cutting the slot the same width as the diameter of the shank of the screw. The bevelled portion of the head of the screw then cuts its own track in the slot when driven downwards.

Should it be necessary for any reason to remove the architrave, always turn the screw in half a

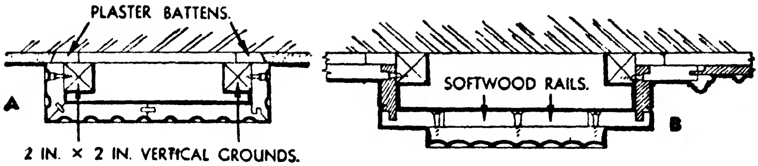


Fig. 15. Fixing pilasters : *A.* To a plastered wall ; *B.* to a panelled wall. The screw holes in the framing are slotted to allow movement of the hardwood facing.

turn before refixing. By this means a secure fixing is obtained in a new track.

This method of fixing is satisfactory for fixing small memorial tablets, etc., where the article to be fixed can be easily handled, but for large framings, such as panelling, the number of screws required makes it very cumbersome.

Another disadvantage to slot-screw fixing is that having once driven the framing down to the floor line, it is difficult to remove. There is always the danger of damage to the bottom edge when levering up off the screw heads.

A much easier way for secret fixing, especially for veneered surfaces, is by means of turnbuttons as shown in Fig. 14 C. Once the turnbutton engages in the groove the job is secure and this method has the advantage of quickness and simplicity for removal.

There are many methods of fixing that can be improvised by the fixer, but the old maxim still applies : 'The simpler the better.'

Pilasters and Columns

In fixing pilasters and columns, any of the foregoing methods can be applied. The fixing of pilasters is shown in Fig. 15 A. The vertical battens must be parallel and plumb, then the fixing can be made at the sides by means of screws and pellets. This is one instance where the skirting and cornice can be fixed in the shop before delivery to the site.

Fixing the pilasters as in Fig. 15 B is quite easy. The screws can be put in the plough groove. If the pilasters run above the panelling, then screws can be inserted in the side.

In Fig. 16 is shown a free standing column ; the beam casing should be fixed first, then the shaft and cap, leaving the skirting to the base as the last operation. Soldiers can be fixed inside the shaft and these can be fixed to the floor by means of screws to the floor plate.

If the column casing is to fit round stanchions, as shown in plan of Fig. 16, provision has to be made for assembling the half portions round the stanchion. The column can be delivered to the site as one unit, but with brown paper joints opposite each other which can be split with a chisel. Two fixers are better for this job. The brown paper actually splits in itself, and after breaking the joint the paper can be cleaned off so as to obtain a good joint for reassembling round the stanchion.

The tongues should be well glued and the joint cramped by means of a rope applied as a tourniquet, or by special chains

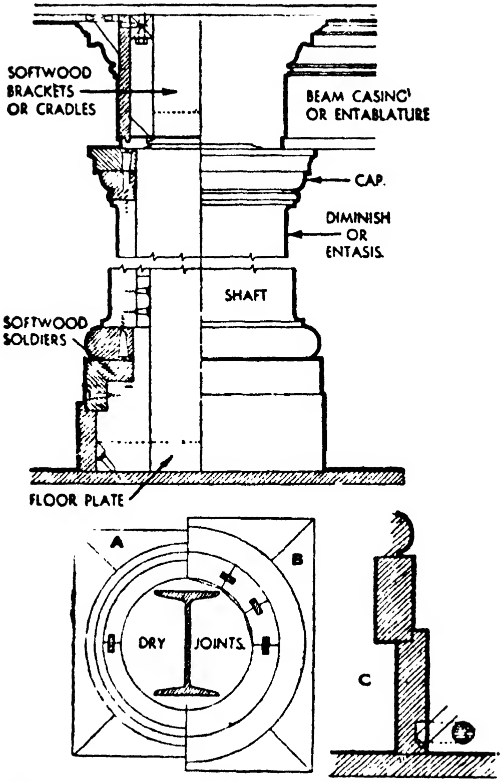


Fig. 16. How to fix a free standing column. Section on left-hand side of elevation shows how members are built up. Plan shows the casing fitted round a steel stanchion. A. Half-plan of cap; B. half-plan of base; C. detail of "Tosh" or oblique screwing.

member is turned in the solid. Care must be taken in boring the holes for the pellets; also when cleaning off. Cut the end of a pellet with a saw rather than split it off with a chisel. The disadvantage of 'tosh' fixing is the filling of the screw hole. If a large centre bit is used for an inch hole as Fig. 16 C there is less danger of the screw head damaging the edge of the hole when screwed in.

To fix moulded boarding, as in Fig. 17, level in the skirting first, and fix this; then start erecting boarding with the tongue and groove on the angle A. This time both tongue and groove can be made on the machine in the shop as any small difference can be adjusted on the square edge of the alternating boarding. The details of this wall boarding are shown in Fig. 18.

which have a coupling similar to that used for railway coaches.

Whichever method is used, plenty of padding should be put round the column before applying any pressure. There is no need for blocking to the stanchion as the weight of the column plus its own strength makes it practically self supporting. Fixing at the top and bottom, of course, is necessary.

'Tosh' or oblique screwing can be used for the base if the bottom

The external angles can also be glued up ready for fixing. When the internal angle is adjusted, and fixed plumb, the boards can be driven on and nailed to the battens.

If the boarding is about 7 ft. high, three rows of horizontal battens will be necessary, and in order to induce ventilation, the back of the boarding should be treated as shown. Reference to some of our most ancient buildings will show that this form of wall decoration was very popular even in those days.

In many public buildings the staircase is generally concrete and then covered with wood or rubber and wood, or wood treads with marble risers. This combination of materials still gives the fixer scope for his knowledge of how to fix timber without causing splitting and buckling.

Dove-tailed blocks, as shown in Fig. 19, are employed for holding these coverings. These blocks should be set in the concrete while the steps are being cast, and they should project about ¼ in. above the top of the concrete. This projection gives a small air space and also prevents the wood tread from making contact with the concrete. In the illustration on page 311 the risers are of marble, but these should also have a space at the back.

The three back screws are slotted to allow for movement, while the front screws are pelleted as previously described in this chapter.

It is imperative that the dovetail blocks are set level from back to front and are in alignment. Under no circumstances whatever should the fixing of the treads be commenced until it is known that

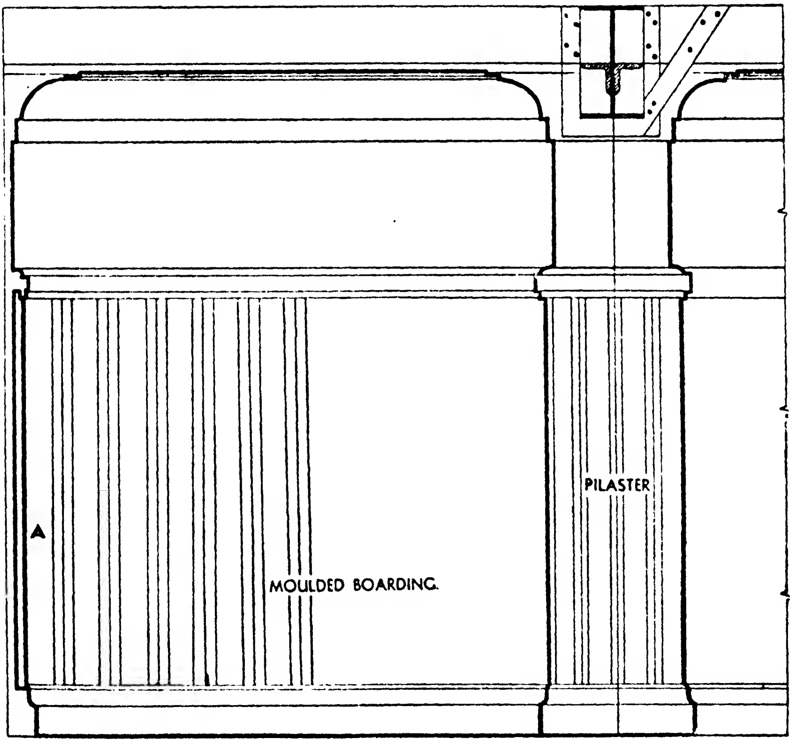


Fig. 17. Elevation of moulded boarding. Skirting is levelled and fixed first; the fixing of other boarding is then started at the internal angle A. Details of this wall boarding are shown in Fig. 18.

the concrete is thoroughly dry and the surface treated with a sealing coat. Once dampness starts to penetrate to the underside of the tread, swelling, buckling and splitting will start.

A similar condition is met with in flooring laid on concrete; even narrow widths of flooring have been known to swell and lift the floor off the fillets laid in the concrete. A general maxim is to paint everything in close contact with brick, concrete or similar material liable to dampness. This applies to skirtings, door and window frames, flooring, treads and risers, window boards and architraves.

Prepared joinery usually has a moisture content varying between 10 and 15 per cent., and unless the exposed surfaces are protected in transit and on the site, the moisture content will rise, with the consequence that when the building is heated, excessive shrinkage will take place.

Joinery should never be exposed to the rain. This applies to loading and unloading joinery. Protection is essential if a good job is required. Too often one sees window and door frames just dumped down on the site; before long all the priming is washed off and the rain gets into the joints and starts decay.

With carcasing material, the moisture content is considerably

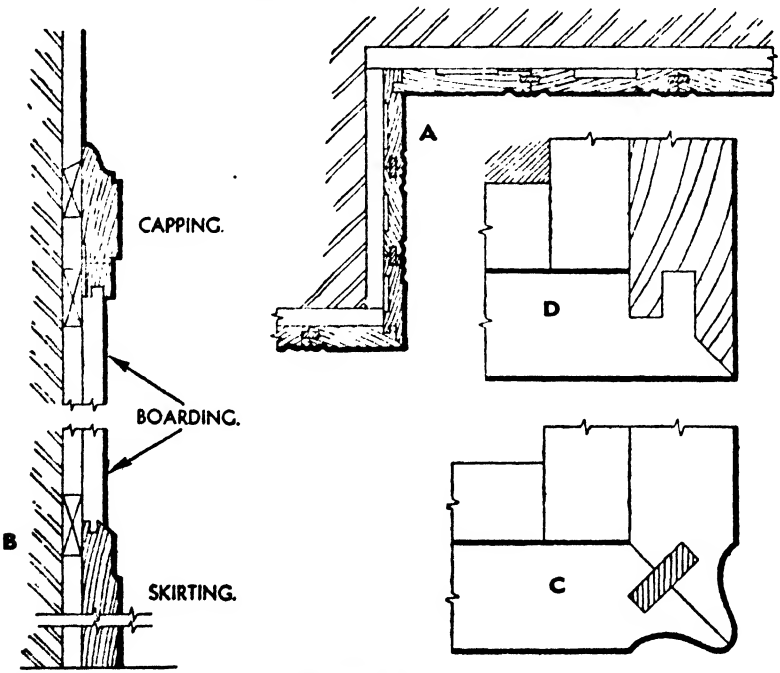
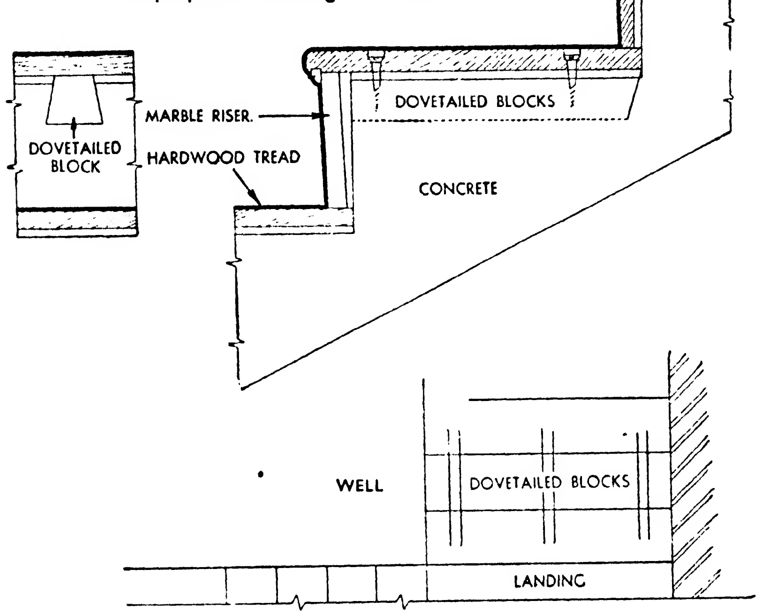


Fig. 18. Details of moulded boarding. *A.* Horizontal section of joints to vertical boards. Note ventilation sinkings at back. *B.* vertical section of boarding showing capping and skirting fixed to horizontal battens. *C* and *D* show alternative joints for external angle, plain and moulded respectively.

Fig. 19. Concrete steps with hardwood treads and marble risers, showing dovetailed fixing blocks cast in concrete for the purpose of securing the treads.



higher than in joinery, and the cells of the timber soon reach saturation point. Carcasing material is not kiln dried, and consequently is more able to stand the weather, but the most careful consideration should be given to this detail.

Where bracketing to girders is required, the timber should be fairly dry. A common practice in fixing beam casing is to drive blocks of timber between the flanges as shown in Fig. 20 A. If the girders are under cover, the timber will dry out and the blocks will tend to become loose. Although timber shrinks very little

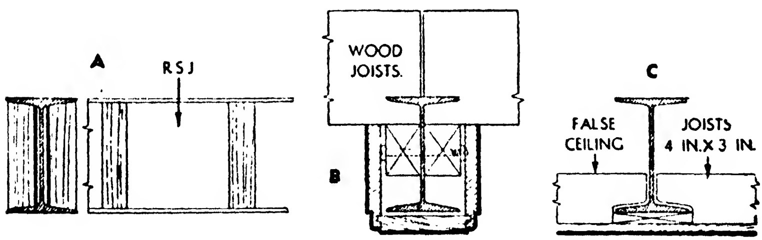


Fig. 20. Method of bracketing timber to girders. *A.* 3 in. by 2 in. blocking driven tight between flanges of a steel joist ; *B.* provides support to wood joists by wooden plates bolted to the web of the joist ; *C.* shows wooden ceiling joists supported on steel joist and ceiled with plywood or building board.

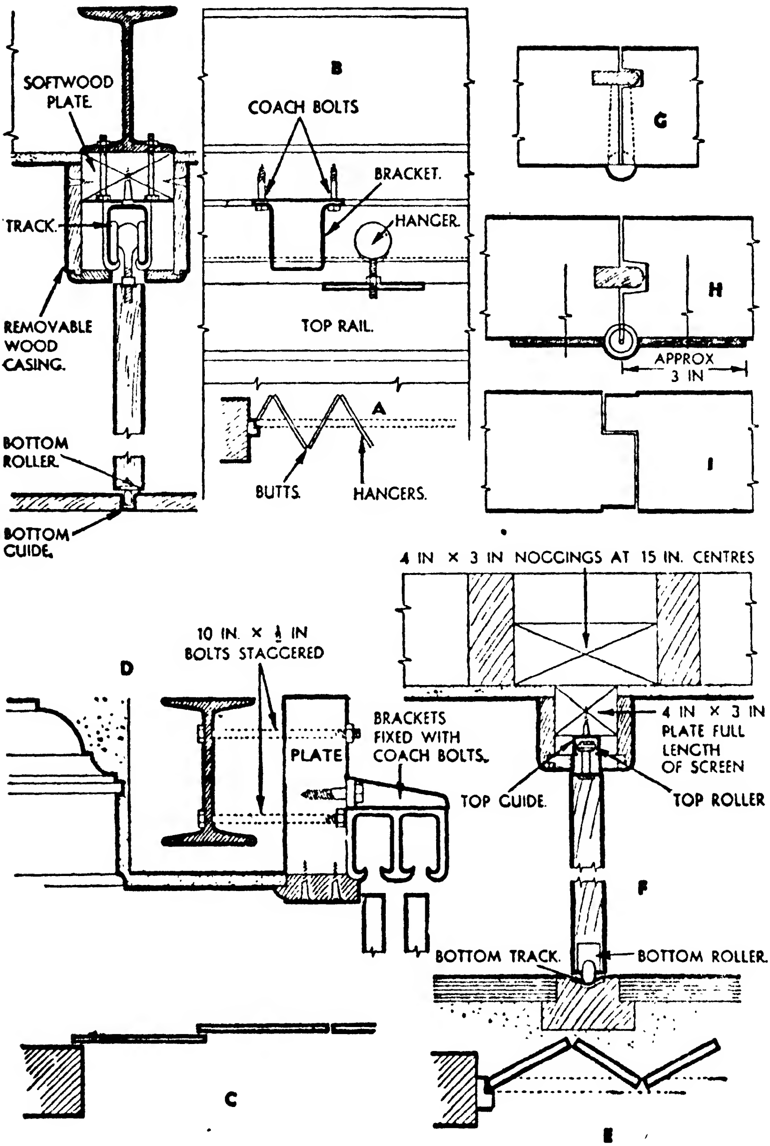


Fig. 21. Fixing sliding doors. *A.* Part plan of centre folding-partition top hung; *B.* detail of runners; *C.* part plan of straight run doors top hung; *D.* detail of head. *Note*: bolts are inserted before girder is cased in concrete, while plate is fixed after the shuttering is struck; *E.* part plan of bottom roller, end-folding partition; *F.* detail of head; *G.* joint in leaves of partition fitted with butts; *H.* joint fitted with back flaps; *I.* rebated joint.

in the direction of the grain, it shrinks enough to make the fixing loose.

Fig. 20 B shows a better method, providing the engineer raises no objection to the girder being drilled. Much of the bracketing formerly used for carrying plaster cornices is now replaced by light steel and wire, but on small contracts the carpenter still has to do the groundwork.

Generally, the whole work of bracketing around steelwork can be erected on the basis shown in Fig. 20. For ceiling joisting at right angles to the beam, the method shown in Fig. 20 C can be used, or the joists can be cut flush with the underside of the girder and the intervening space covered with expanded metal.

For sliding doors, the treatment is similar to that shown in Fig. 21. Where the brackets have to be fixed to the underside of the girder, it is much better to fix a wooden plate than to attempt to bolt the brackets direct to the flanges. This allows for adjustments if the beam should be out of level, besides being much easier for fixing purposes.

There are many kinds of folding-door gear now available, but whichever type is used, make sure that the bottom track is set perfectly level and in the correct position in relation to the brackets above.

Much of the work in connection with sliding and folding doors can be carried out in the shop; the leaves can be hinged together (providing they are not too heavy), the bolts, pulls, guides and trolleys can also be fitted, leaving the fixer just the brackets and track to fix.

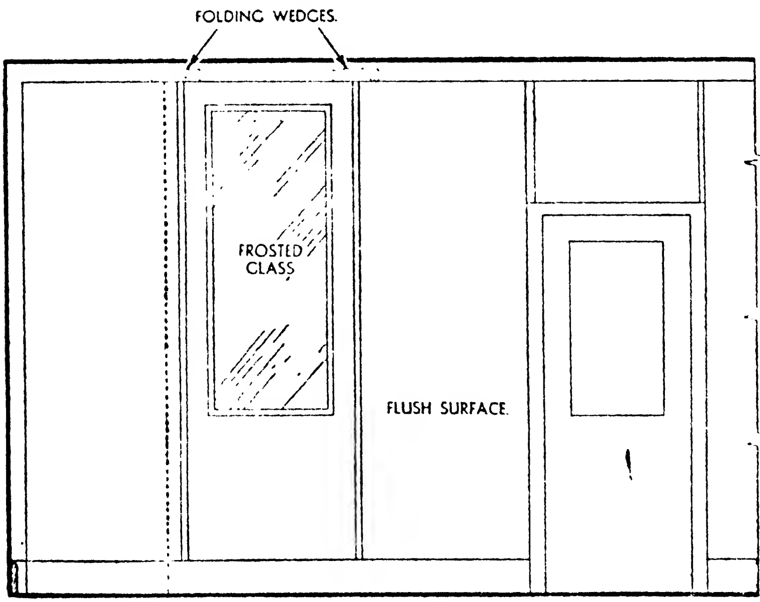


Fig. 22. Typical office-screen elevation, showing flush surface of veneered plywood, a glazed portion with frosted glass, and a doorway opening.

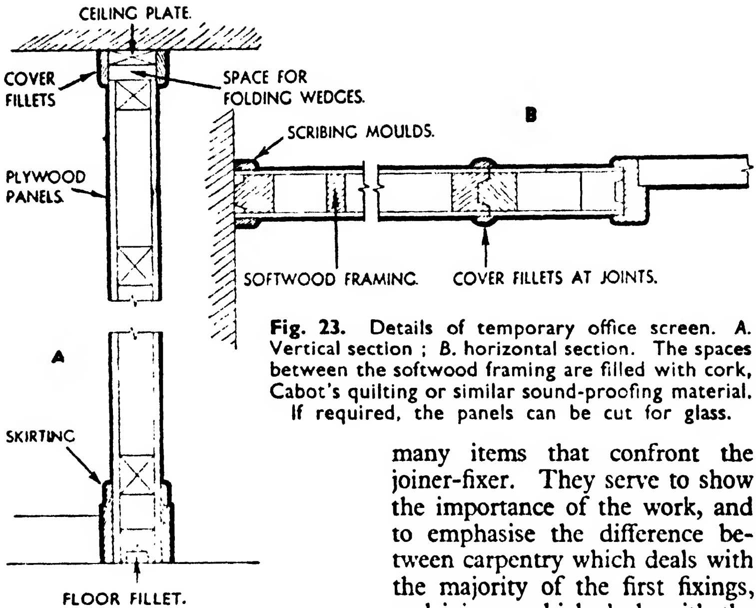


Fig. 23. Details of temporary office screen. A. Vertical section ; B. horizontal section. The spaces between the softwood framing are filled with cork, Cabot's quilting or similar sound-proofing material. If required, the panels can be cut for glass.

Temporary partitions are now very popular, especially in large offices where a firm sublets some of its floor space. Much of this work is made under various patents, but the whole principle is to erect sections of framing covered with plywood or glass, and to wedge the panels together, so that when the lease expires they can be removed without damage to the property.

Figs. 22 and 23 are typical examples of this class of work. All the panels are prepared in the shop, leaving finishings such as skirting, cover moulds, top frieze and glazing to the fixer. A surprising amount of work can be erected in a day, but as the work is mainly repetition, it is not as interesting as the rest of the fixer's work.

The examples given in this chapter are only a few of the many items that confront the joiner-fixer. They serve to show the importance of the work, and to emphasise the difference between carpentry which deals with the majority of the first fixings, and joinery which deals with the second fixings. The fixer on the site has to be a combination of carpenter and joiner; he has practically two sets of tools. A saw used for cutting off plugs is no use for cutting mitres; a small block plane is better for shooting mitres than a wooden smoothing plane; bevelled edge chisels are necessary for cutting in face plates and the finer work, but are no use for carcassing or framing joints.

The damage and loss of tools is considerable on the site, and the wear and tear on clothes all add up; in effect, the fixer should, and usually does, get a higher rate of pay than the joiner in the shop. In addition to this, the work is interesting, teaches one self-reliance, increases confidence to undertake larger jobs and last, but most important of all, trains one to accept responsibility.

CHAPTER 15

CENTERS AND SHORING

SUITABLE TIMBER. PORTABLE HUTS. HOARDINGS. FENCES. LIFTING TACKLE. TEMPLETS. CENTERS FOR ARCHES. LAGGINGS. LAMINATED CENTERS. GANTRIES. TYPES OF SHORES. TIMBER SIZES FOR SHORES. FUNCTIONS OF RAKING AND INTERNAL STRUTS.

THE carpenter is called upon to undertake a great deal of temporary work in connection with building operations. Much of the work is in the nature of assistance to other trades. At the outset he may have to provide temporary staging and hoardings. During the progress of the job he may be called upon to provide centers for arches, shores, timbering to trenches and shuttering for concrete. The last two items are dealt with in Chapter 16.

Much of this work is carried out in unwrought material—that is, timber used as it comes from the saw, which has not been planed or prepared to exact sectional dimensions.

Points to Watch

The material generally used for such work is soft wood, such as European red or white wood and British Columbia pine. For heavy loads pitchpine may be specified, and in some cases oak.

Elaborate joints are avoided as far as possible. In temporary work the connection of one timber to another must be of adequate strength, but the appearance of the work is of no importance, nor is it expected to last for any great time.

To reduce the cost of temporary carpentry it is necessary to make frequent re-use of the material. Timber should, therefore, be used in lengths as long as possible, and cutting should be reduced to a minimum. At the same time temporary work must be of adequate strength, and where necessary, notched, halved or other cut joints, must be made.

Iron dogs are largely used in connecting timbers of large section. These are made with their points at right angles to the main bar, or at greater or less angles to suit the type of connection. Bolts are used for some connections—chiefly in lengthening timbers. For connecting timbers of rather small section nails or spikes may be used.

The sizes of sawn timbers are not constant or uniform. This must be allowed for in making joints and in calculating dimensions. For certain work it is very inconvenient to have to use timbers of non-uniform size. Where accurate shapes are required, as in centering, it is essential to use accurate sections.

Where the end of a post rests on a plate the end of the post must be cut square, so that an even bearing is obtained. A similar precaution must be taken in making joints. Temporary work should not be regarded as of less importance than permanent work. In fact, it is of great importance that, where heavy loads must be supported, the structural details of temporary work should be of the best workmanship, however simple in design.

In carrying out temporary work for other trades the carpenter needs some knowledge of those trades. In particular, he should make himself acquainted with the loads which temporary carpentry of various kinds must support, and with the best way of doing the job so that it is convenient to the other tradesmen.

It is advisable to treat timber for temporary work with a preservative, so as to lengthen its life. Posts and shores in contact with the ground in particular benefit from preservative treatment. Brush treatment is not permanently effective. It should be renewed every twelve months.

When not in use, the material should be stacked and covered in such a way that air can circulate all round it. Timber deteriorates by faulty storage more quickly than by constant use.

Temporary Hoardings

For the protection of the site and also the protection of the public, it is necessary on many jobs to enclose the site with a temporary hoarding.

Posts, not less than 5 in. by 4 in., are spaced at centres from 8 ft. to 10 ft. apart. For very tall hoardings, 6 in. by 6 in. timber may be required. The rails may be 4 in. by 3 in., nailed on to the face of the posts. Boards may be of any kind, depending upon what materials are available.

A sound hoarding does not

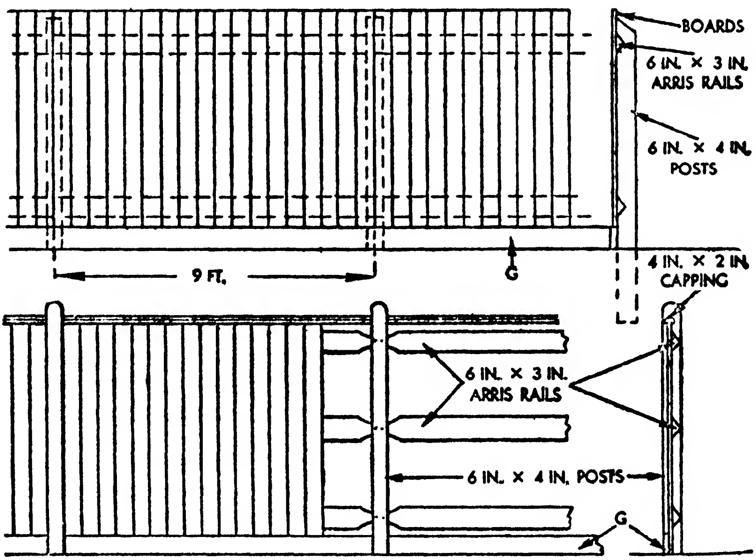


Fig. 1. Boarded fences and hoardings. Top section shows a hoarding with arris rails 6 in. by 3 in. A ground board 7 in. by 1½ in. is shown at G.

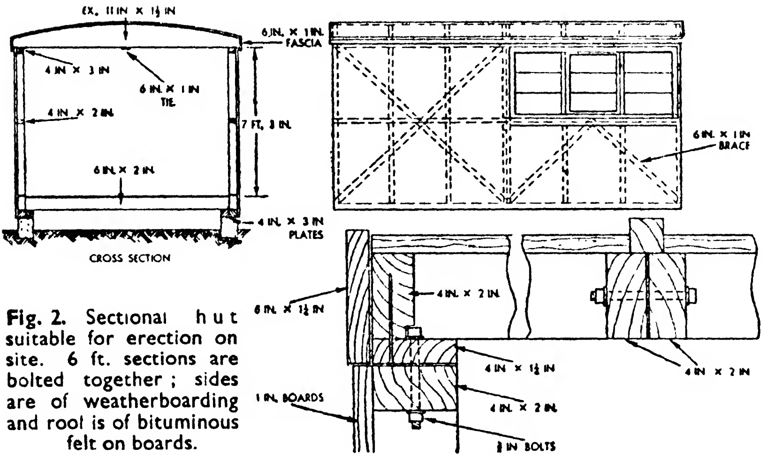


Fig. 2. Sectional hut suitable for erection on site. 6 ft. sections are bolted together; sides are of weatherboarding and roof is of bituminous felt on boards.

differ from a sound close-boarded fence. Posts should be driven about 2 ft. into the ground, and the ground well rammed. It is advisable to use a ground board, as in Fig. 1. The fence boards stand on top of the ground board, and are thus well clear of the ground. This allows the part of the fence most liable to decay to be easily replaced.

Arris rails are often used instead of rails of rectangular section. A hoarding with arris rails 6 in. by 3 in. is illustrated at the top of Fig. 1. When the fence is above 7 ft. in height, a third rail should be added.

Gates must be arranged at suitable positions in the hoarding. For wide double gates to admit lorries, the posts must be of extra size, not less than 6 in. by 6 in., to bear the weight of the gates. These should be set at least 3 ft. into the ground. If the posts are of sufficient height, a top rail or head may be fixed to connect them, to prevent the gates pulling them inwards. This head piece should be notched over the posts.

Fans or splayed boardings are sometimes fixed to the top of a hoarding to prevent debris from the building falling outside the hoarding. The fan studs may be nailed to the sides of the posts, but if the fan extends far, or is set at a rather low angle, this may not be sufficiently secure. Additional security may be gained by fixing raking struts at intervals of about 10 ft.

Fans are also fixed to scaffolding and are sometimes secured to the face of the building for demolition work. In the latter case the bearers are passed through window openings and secured to the floor of the building either by securing to existing floors or by lashing a heavy spar to the ends of the bearers. But this work is usually the scaffolder's job.

Contractor's Hut

Portable huts for foremen, clerks of works, and other executives are usually of sectional construction. An example is illustrated in Fig. 2. Framing timbers may be 3 in. by 2 in. for

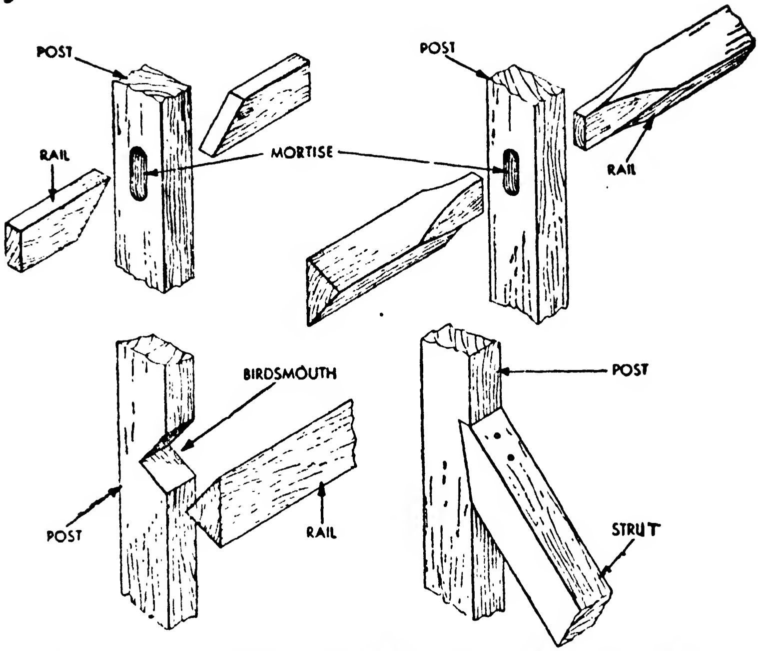


Fig. 3. Illustrating typical jointing details which are employed in fencing.

small huts and 4 in. by 2 in. for larger huts. The sections should be in sizes convenient for transport. Widths of 6 ft. are suitable. The adjoining studs of two sections are bolted together. The roof, too, is of sectional construction.

It is advisable to re-cover with new felting, secured by nailing through battens, for every time of use. Alternatively, corrugated iron sheets may be bolted to purlins.

The floor of the hut, which is also of sectional construction, should be laid on creosoted sleepers or brick piers in lime mortar. It is advisable to creosote the floor timbers. The wall sections are usually painted. A well-made sectional hut will last a considerable time if care is taken in erection and removal.

A permanent fence should be rot-proof, have joints which will not fail if the timber shrinks or warps within reasonable limits, and should be of good appearance. Vertical posts support horizontal rails. To the latter the pales or boards are nailed.

Typical jointing details are illustrated in Fig. 3. The rails may be secured to the posts by mortising the post and nailing or pegging the rail into the mortise. If the rails are splayed to overlap they need not be nailed or pegged. With this method, however, there is always a risk that if the timber warps very badly the rails may spring out of the mortises.

If arris rails (of triangular section—two being cut out of a square section of timber) are used, they may be fitted into a triangular notch cut in the post, as shown in Fig. 3, or squared at the ends to fit into a mortise in the post.

Ground boards should be used in all fences. As already explained they keep the feet of the boards or pales off the ground.

Lifting Appliances

For moving weights horizontally or making slight lifts, the lever, the jack and the wedge are commonly used.

The principle of the lever is described in Chapter 7. Its use is familiar but the importance of a firm fulcrum may be stressed. A fulcrum is often provided by placing a baulk of timber in a suitable position. Crowbars and pinchbars are often used as levers.

Levers may be used to make a slight lift or to move a heavy weight a short distance, but if the weight must be moved a considerable distance, it should be levered up and rollers placed underneath it. Movable rollers are of hardwood, 5 in. to 12 in. diameter, but for moderate weights any suitable lengths of round timber may be used. The ground should be fairly level and firm.

The power required to move a weight on a level plank roadway on hardwood rollers is about one-sixteenth of the weight to start it, and about one-twenty-fifth to keep it moving. The weight moves at twice the speed of the rollers and so passes off the rollers. At least three rollers are required, so that one can be

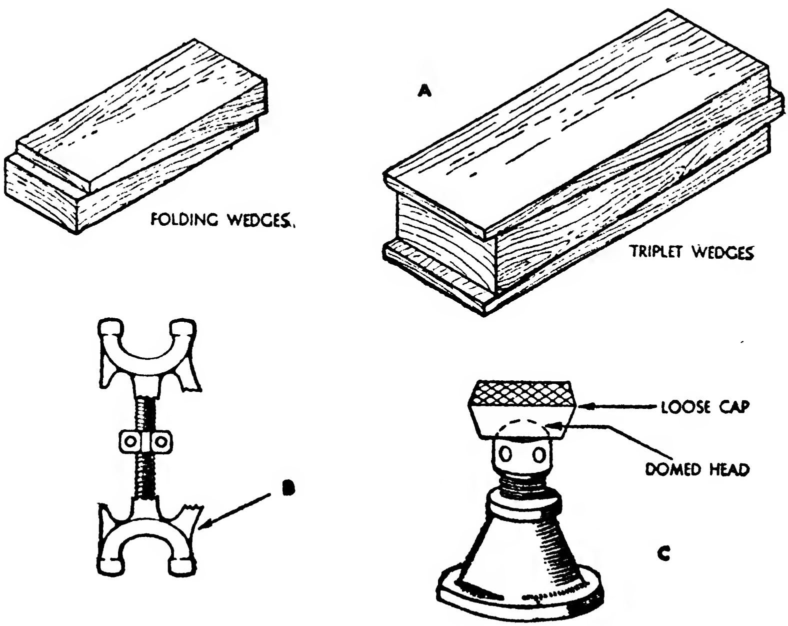


Fig. 4. Appliances for moving and lifting heavy weights for short distances. A. Two types of wedges. B. " lift-pull-push and cramp " jack ; C. shoring jack.

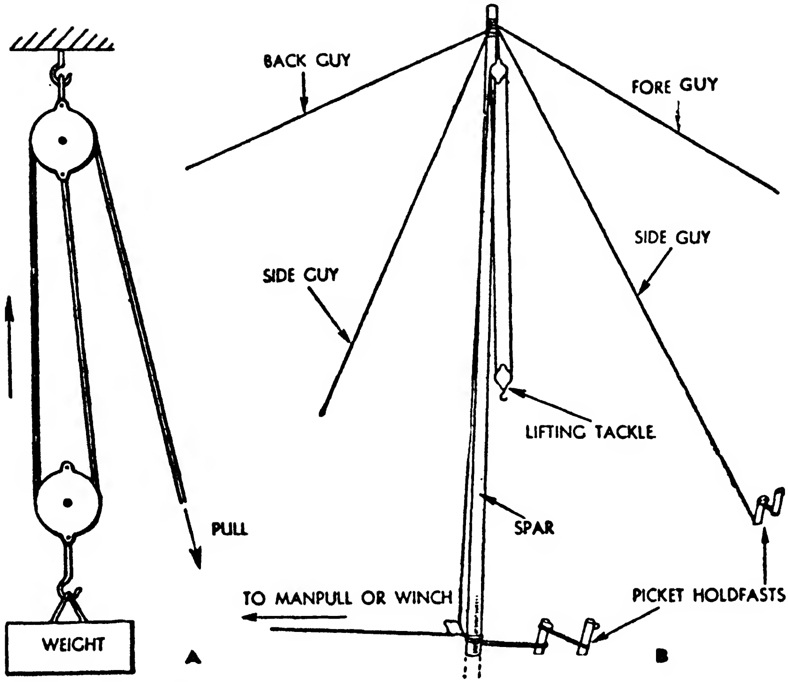


Fig. 5. Lifting and hoisting tackle. A. Pair of single-sheave pulley blocks. A pull of 32 lb. is required to hoist 56 lb. B. standing derrick for supporting tackle.

placed ahead, and, as the weight moves along, the uncovered roller at the rear is picked up and placed ahead.

For moving very heavy weights, rollers mounted on trunnions fixed to a frame are used. The friction is thus greatly reduced.

When the weight is on the rollers it may be moved along by leverage or direct pushing, or pulling on ropes. Great care should be taken to prevent the weight running away—especially on a slight incline. Ropes should be attached, with men on them to check the movement if it becomes dangerously fast.

Wedges are useful for lifting weights very slightly, but they are more useful as a means of easing down weights. Folding wedges are commonly used, but for heavy loads triplet wedges are better. Both are illustrated in Fig. 4 A. They are much used in centering and shoring, as described later in this chapter.

Types of Jacks

Jacks are made to lift up to 20 tons by hand operation. The ordinary screw jack is familiar. Lever jacks, as used in garages, are not generally suitable for weight lifting in building operations. Hydraulic jacks are smooth working. The ratchet jack is a convenient type.

The lift of jacks varies from about 6 in. to 18 in. Two special types of screw jack are illustrated in Fig. 4, B and C. The 'lift-pull-push and cramp' is obviously useful for a variety of purposes. The 'shoring' jack has a domed head with a loose cap, so that it can support the load at any angle. It is useful for tightening and easing heavy shores.

Lifting tackle in its various forms consists of a system of hoisting with ropes, blocks and hooks. The simplest lifting device is the gin wheel, which is a grooved pulley wheel in a frame with a hook attached to it, so that it can be suspended from any convenient point. A rope passed over the pulley enables a light weight to be hoisted. The pull must be slightly in excess of the weight to hoist it and overcome the friction of the pulley.

A pair of single sheave pulley blocks, as illustrated in Fig. 5 A, gives what is called a mechanical advantage in hoisting. Briefly, this means that a weight may be hoisted by exerting a pull less than that weight, but the running end of the rope must be pulled through a distance greater than the hoist distance.

With a pair of single sheave blocks, the standing end of the rope is secured to the becket of the top block and is then rove round the sheaves, the running end hanging from the top block. For every 1 ft. of rope pulled over the sheave of the top block, the bottom block will rise 6 in.

If there were no friction, a weight could be hoisted by exerting a pull of only half that weight. But an extra pull of about 20 per cent. must be exerted to overcome friction. In practice, a pair of

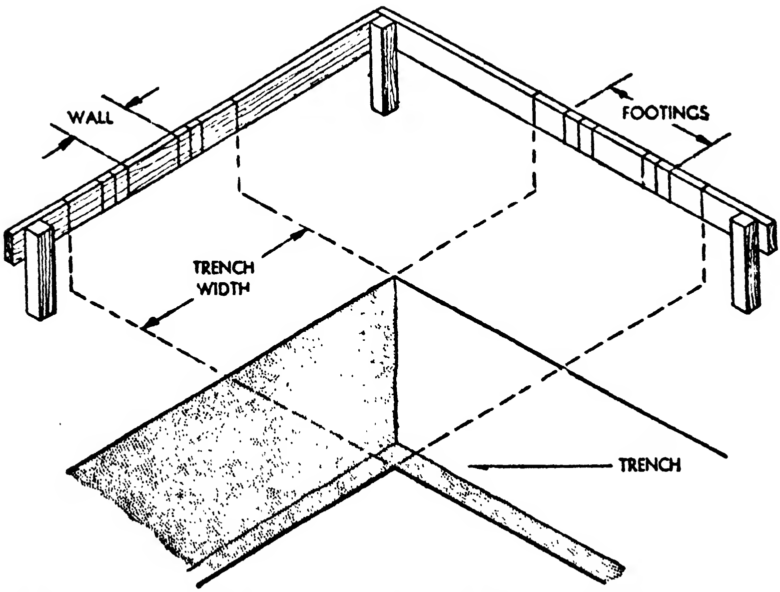
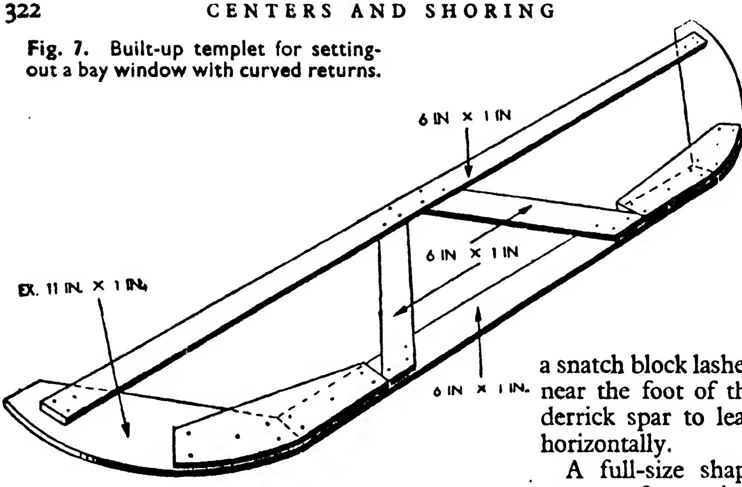


Fig. 6. Method of using profile boards for the setting-out on the ground of foundations. The boards used are generally about 6 in. by 1 in.

Fig. 7. Built-up templet for setting-out a bay window with curved returns.



single sheave blocks would require a pull of about 32 lbs. to hoist 56 lbs.

By using blocks of two or more pulleys in various combinations the mechanical advantage can be further increased, though the speed of hoisting as compared with the speed of pulling will be decreased. Also the greater the number of pulleys, the greater the friction losses. As an example, lifting tackle consisting of a pair of double pulley blocks with 6 in. diameter sheaves, rove with 1 in. diameter hemp rope, has a lifting capacity of 40 cwts.

If sufficient hand-power is not available, the running end of the rope can be led through a snatch block (a single sheave block with an opening strap enabling the rope to be slipped on to the sheave) to the drum of a hand or power winch.

In building operations lifting tackle is often secured to a pair of sheer legs or a standing derrick. A standing derrick is illustrated in Fig. 5 B. The running end of the rope is shown passing through a snatch block lashed near the foot of the derrick spar to lead horizontally.

A full-size shape cut out of one piece of wood or built up, as convenient, of some part or unit of a structure, is called a *templet*. Certain templets are usually called profiles —meaning outline.

The setting out on the ground of foundations is done with the aid of profile boards. These are boards about 6 in. by 1 in., with saw-cuts on the face accurately made to the thickness of the wall and foundation offsets. The profiles are nailed to stakes, about 2 in. by 2 in., which are driven into the ground, well clear of the ground to be excavated. Fig. 6 illustrates the usual type.

Walls curved on plan are built to a wood templet. Small templets may be cut out of a wide board. In the case of a curved bay window, or a bay with a straight front and curved returns, a complete templet is made to the size of the bay, the edge of the templet being the line of the wall face. Such a templet is built-up and braced, as shown in Fig. 7.

Profiles and templets are also used in setting out structural steelwork. In masonry, too, templets are used for the mason to work to. These templets are usually prepared by the setter out.

Gauge and mould boxes are needed by the bricklayer for the preparation of rubber bricks for gauged brickwork. The sides of the box are made to conform with the desired shape of the brick. The edges are protected with zinc so that they do not wear as the saw is worked along them.

Gauge rods are required by the bricklayer and mason for the purpose of accurately working the courses of bricks or stones. A simple gauge rod is a length of wood, about 2½ in. by 1 in. with the courses marked with saw cuts. Positions of sills and string courses, should be marked in red paint.

Large gauge rods and profiles for rather complicated work are often fixed in position on the scaffolding. The bricklayer or mason generally indicates what is required.

Design of Centers

Certain parts of a building need temporary support while the mortar or cement mix sets and hardens. This support is called *centering*. The centering described in this chapter is the type required for temporary support in brick and masonry arches.

The design and construction of a center depend upon the span, the weight and thickness of the arch, and on the material available. The type of arch must also be taken into account. A center must be able to take the weight of the arch without movement or

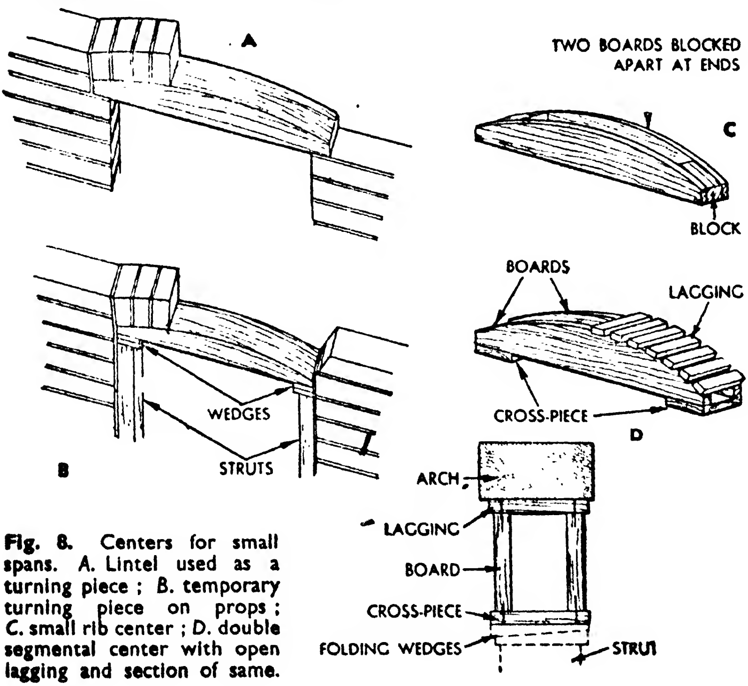


Fig. 8. Centers for small spans. A. Lintel used as a turning piece ; B. temporary turning piece on props ; C. small rib center ; D. double segmental center with open lagging and section of same.

deflection. It must be fixed in such a way that it will not move on its supports and cannot be readily disturbed.

At the same time consideration must be given to the means of striking the center and, in most cases, of easing it before striking. To *strike* a center means to remove it. To *ease* a center means to let it down very slightly and gently from the work it supports. It is good practice to ease the center gently before striking, so that any settlement of the arch takes place slowly and without shock.

Easing is usually accomplished by means of folding wedges placed under the supports to the center. These wedges have already been described (Fig. 4 A). For large centers carrying heavy loads jacks are sometimes used. The wedges or jacks are also useful in adjusting the center to the exact level.

Turning Pieces

The simplest form of center is the *turning piece.* This is used in 4½ in. brick walls to support segmental arches of moderate rise. Two types are shown in Fig. 8. The turning piece is sawn out of a solid timber—4 in. by 5 in. is usually sufficient. A temporary turning piece (Fig. 8 B) is supported on props. Sometimes easing wedges are used, and sometimes the props are cut to the exact length and are struck when the arch has set. A permanent turning piece (really a lintel) is also shown in Fig. 8 A. This is made long enough to bear on the wall at each end.

Segmental centers for arches with a rise of not more than 10 in. are constructed out of 1 in. boards. Two 1 in. boards are set out to the curve of the soffit or intrados of the arch and to the clear span, allowing about 1 in. for clearance between the jambs. The two boards are separated by blocks nailed between them, as shown in Fig. 8 C. The overall thickness of the center should be an inch less than the thickness of the wall, so that the center does not interfere with the bricklayer's line stretched across the opening.

The double segmental center, also illustrated in Fig. 8 D, consists of a pair of ribs cut out of 1 in. boards, but the ribs are connected differently from the center described above. On the underside they are connected by two short boards or cross pieces and the curved tops are connected with laggings. The type of lagging shown is called *open lagging.* The laggings may be 1½ in. by ¾ in. or 2 in. by 1 in. If, as in a thick wall with a thick arch, the ribs are rather widely separated, a thicker lagging should be used. It is important to allow for the thickness of the laggings when setting out the curved ribs.

Supporting Centers

Small centers in common brickwork arches are sometimes supported on nails driven into the mortar joints in the jambs. These nails must be secure in the joint, otherwise the center may be forced down by the weight of the arch.

If the rise of the arch is greater than 10 in. it is impossible to form the center out of a pair of boards, as described for the simple segmental centre. For small spans of about 4 ft., two rib boards and a tie board on each side are used, as shown in the semi-circular center illustrated in Fig. 9. The ribs are connected both top and bottom with tie boards, the ties being placed inside. The boards lap over each other and are nailed together.

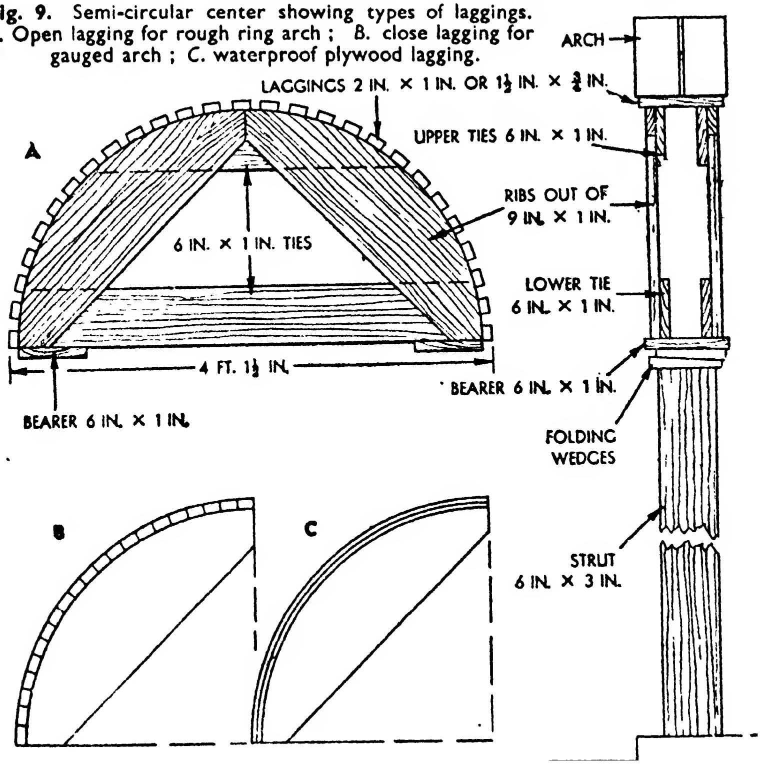
The two parts of the center are connected at the underside with bearers or cross boards, which also provide a bearing on the struts, or on the folding wedges. Along the semi-circle the two sections are connected with laggings, as before described.

Laggings

There are types of laggings for various purposes. Open laggings have already been described; the gaps between the laggings may be from ½ in. to 1 in. Open lagging is suitable for rough ring or axed arches, or for moulded brick arches with joints of ordinary thickness.

Gauged brick arches have very thin joints and are accurately worked to the arch curve, so they require an accurate surface of support on which the joints can be set out for perfect placing. *Close lagging* is therefore necessary, and the curved surface should be smooth and true. Waterproof plywood and fibreboard sheets can be used to provide smooth faced lagging. Such sheets bend easily to the curves of centers, and make a perfectly regular curve. Various laggings are shown in Fig. 9 at A, B, and C.

Fig. 9. Semi-circular center showing types of laggings. A. Open lagging for rough ring arch; B. close lagging for gauged arch; C. waterproof plywood lagging.



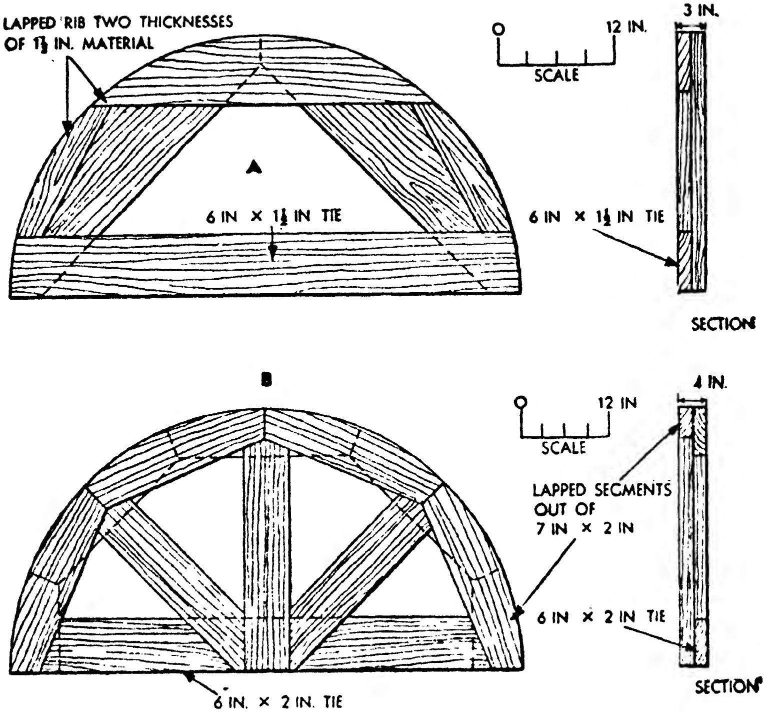


Fig. 10. Centers for shallow face arches. Ribs are built-up or laminated together. Note the arrangement of the struts in the lower diagram.

If the arch is a facing arch only, it is sometimes convenient to use a laminated templet, instead of the center having two sections connected with laggings and bearer boards. The required thickness is built-up by nailing thick boards or planks together, as illustrated in the two examples in Fig. 10. The timber may be 1½ in., or 2 in. thick, so that centers 3 in or 4 in. thick can be built up in two thicknesses.

Arch Templets

The arch templet shown in Fig. 10 A is quite simple to construct. Notice that the ribs must be the full 3 in. thickness along the curve only. Where the ties lap the ribs this thickness is obtained. In the portions between ties small pieces are nailed to make up the thickness.

The center shown in Fig. 10 B also employs a mode of construction which differs from the centers so far considered. It is rather like a truss, though as a laminated center the boards or planks are lapped and nailed and no cut joints are required beyond simple butting. This form of construction is adopted for spans wider than those so far considered. It enables comparatively small widths of timber to be used in constructing centers from 5 ft. to 15 ft.

spans. The construction of the rib should be carefully noticed in this example. The boards are lapped along the curve so that they break joint and provide a means of securing the braces to the rib. Exactly the same kind of rib construction can be adopted for centers of two sections connected with laggings.

Propping Centers

Usually centers are propped. The system of propping must depend on the size and type of center and the weight to be supported. One thick board or plank on each side is sufficient in some cases. In $4\frac{1}{2}$ in. walls single 4 in. by 4 in. struts are sufficient. Much depends upon the height of the props or struts.

While 6 in. by $1\frac{1}{4}$ in. boards are sufficient in the case of a window about 3 ft. high, these boards might buckle if used unbraced as struts to a tall doorway with a center of wide span. The examples illustrated indicate some methods and dimensions, but experience is the best guide.

Struts must not only be strong enough, they must also be secured from movement. If a pair of struts is used on each side, as in the center for masonry arch shown in Fig. 11, they should be braced together, as shown. It is advisable also to connect the top of the struts with a head plate and the bottom with a sole plate, as also shown by the section in Fig. 11. It is important to give the struts an adequate bearing at the foot. If they bear on the ground sole

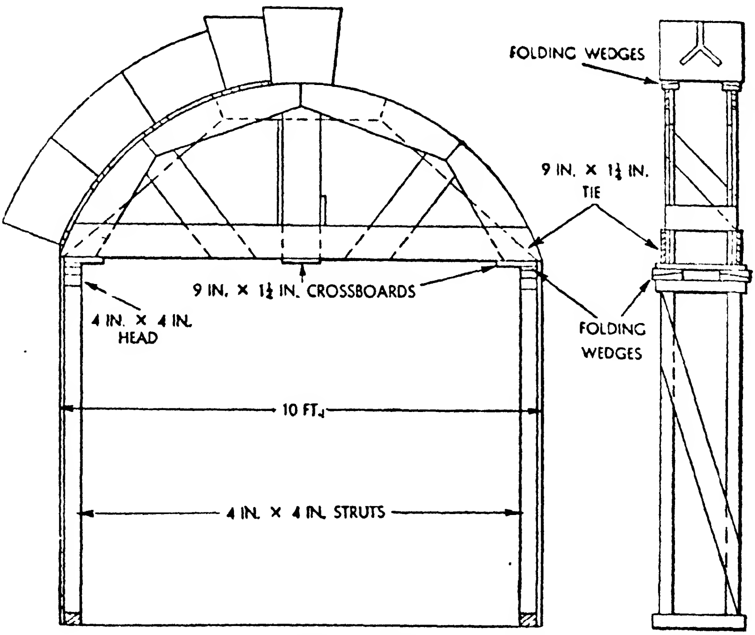


Fig. 11. Detail drawing showing a center for a segmental arch in stone.

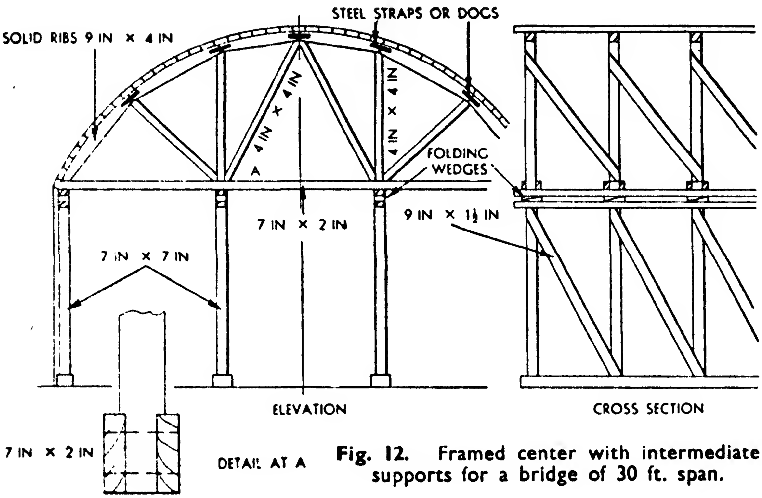


Fig. 12. Framed center with intermediate supports for a bridge of 30 ft. span.

plates should be laid on well rammed ground.

For supporting stone arches it is usual to support the stones on wedges placed between the center rib and the arch stones, as in Fig. 11. Ordinary laggings are not therefore required, but the two sections of the center must be securely braced together, front to back, and, of course, the usual bearer boards also strengthen the connection. Notice the struts in the diagram, how they are braced.

The center shown in Fig. 11 is segmental and the bracing is different from that used in a semi-circular center, but notice that the rib construction is similar to the center shown in Fig. 10. This type of rib construction can be used for a center of any size above 5 ft. Below that the simpler form of rib construction previously described is usual.

Intermediate supports should be specially designed. An example of centering for a bridge of 30 ft. span is illustrated in Fig. 12. If intermediate struts can be used it is obvious that the construction of the center itself can be much lighter than a center of the same span without intermediate struts.

Ribs, struts and braces are solid and strong joints can be easily made, with steel straps or dogs connecting the rib sections. The tie consists of two 7 in by 2 in. timbers and the detail at A in Fig. 12 shows how the solid timbers are sandwiched between the double tie timbers.

The load on a center is always greatest at the crown or top. Consider the various parts of an arch and it is obvious that near the springing of a semi-circular arch the first voussoirs (the brick or stone arch units) bear most of their weight downwards to the springing point.

But as the arch rises, more and more of its weight bears on the center, until at the crown the voussoirs are practically bearing their full weight on the crown of the center. Support of the crown is therefore of special importance. In Fig. 12, for example, it will be seen that the rib sections at the crown are of comparatively small span and are well supported.

Without ties the center would tend to spread under load. The interior braces and struts of a center serve to stiffen the rib and tie and to transmit loads from one point to another, so that stress is fairly evenly distributed throughout. The centers illustrated cover the essentials of the subject for the spans met with in ordinary buildings.

The term *gantry* is applied to elevated platform and tower structures, erected for the purpose of supporting loads in connection with many building operations.

The timber gantry illustrated in Fig. 13 is an elevated working platform. It enables the ground space underneath to be kept clear of building material, and is a type often erected over street pavements.

The gantry consists of posts resting on sills and supporting heads. The posts are braced to the heads. On the two lines of supports thus provided, joists are laid and the platform is completed by laying scaffold planks. The planking is usually 3 in. thick. If it is required to make the platform proof against dust and grit falling through between the planks, double planking may be used, or a covering of underfelt may be laid over the joists.

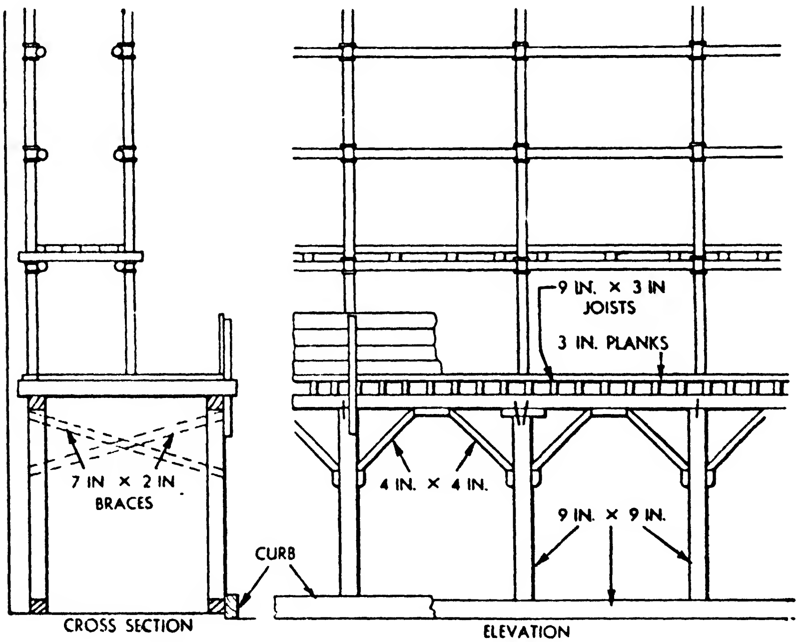


Fig. 13. Platform gantry erected during building operations. It enables the ground space underneath to be kept clear of building material. This type is often erected over street pavements when construction work is in progress.

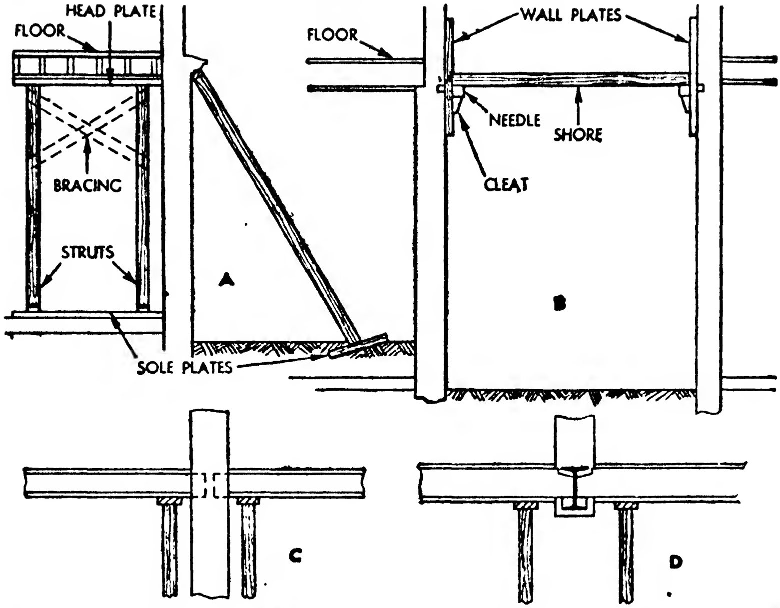


Fig. 14. Simple shores for temporary support. *A.* Single raking shore ; *B.* single flying shore ; *C.* struts to relieve wall of floor load ; *D.* struts to relieve beam of floor load. Note the timber plates at the head and feet of the struts.

The posts are spaced 8 ft. apart and are usually 9 in. by 9 in. The width in cross section is in the region of 10 ft. A fender is fixed against the outer sill to protect the gantry from wheeled traffic. Sills and heads are usually 9 in. by 9 in. and struts or braces 6 in. by 6 in.

The joints are secured by iron dogs. Notice the ends of heads where they butt together are placed over a post with a 3 in. thick hardwood cap to give a good bearing. These are secured with two iron dogs.

Shoring

Shoring is the temporary strengthening of a building the stability of which is threatened by damage, decay or adjacent building operations. It is also used when alterations to the building involve the removal of certain permanent supports—as in converting a house front to a shop front.

Safe shoring depends largely upon the judgment and skill of the foreman. Shoring is often a delicate and even dangerous job. While the temporary supports must be strong enough to bear the loads which will be imposed upon them, it is quite possible to shore excessively so that a heavy raking shore may tend to thrust a wall over instead of supporting it, and dead shores and struts placed wrongly may so alter the stresses in the existing structure that failure may occur.

For safe shoring a sound knowledge of general building construction is required, to which must be added common sense. Each job should be treated on its merits. There are few golden rules.

If a damaged or endangered wall tends to lean outwards it is fairly obvious that a number of inclined struts, called *raking shores*, so placed as to resist the outward movement of the wall, will guard against the danger. In Fig. 14 A a raking shore of a very simple type is shown. It is merely an inclined strut wedged under a cornice and supported at the foot on a short sleeper or sole plate.

If a narrow passage or road runs between two buildings and one, or both, buildings tend to lean outwards, a *flying shore* may be used as a safeguard. A single flying shore is illustrated in Fig. 14 B. This is merely a horizontal timber placed in the space between the buildings, with wall plates to spread the thrust and needles with cleats to support the timbers.

Simple Shores

If it is desired to relieve a wall, main beam or column of the load of a floor, the floor may be strutted from the ground or from the floor below. Two cases are illustrated in Fig. 14 C and D. Notice that timber plates are placed at the head and feet of the struts to spread the loads.

Although the cases shown in Fig. 14 are simple ones, various snags may arise in practice. If the raking shores are very long and slender and the wall is badly

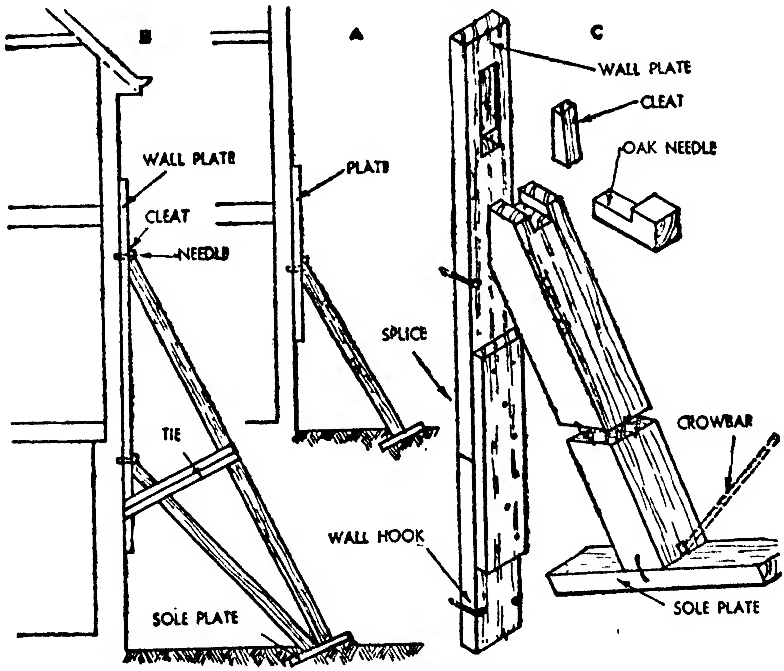


Fig. 15. Single and double raking shores. *A.* Single raker ; *B.* double raker ; *C.* drawing of head and foot of raker showing spliced joint for long member.

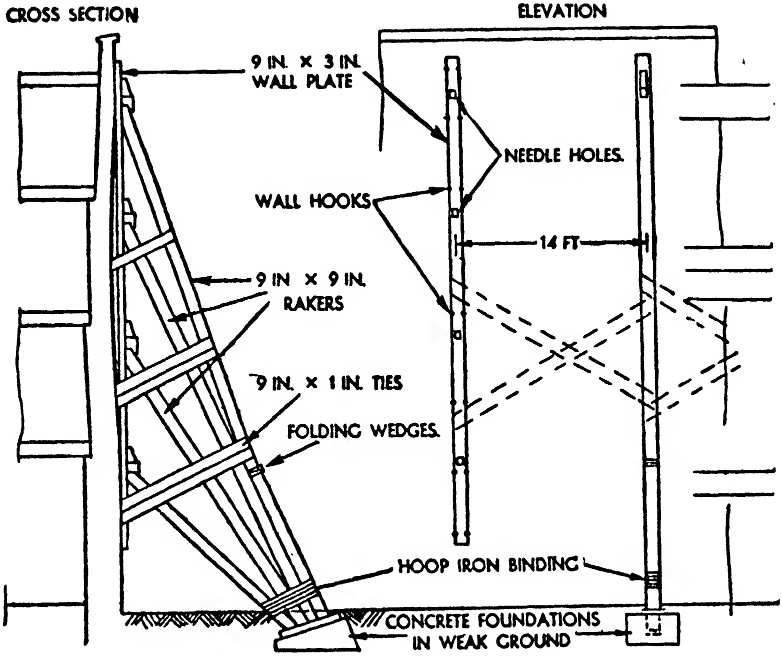


Fig. 16. Multiple raking shore. Cross section and elevation. Note how the floors counter the thrust of the shores. Shaped packing is fitted to the bulging wall.

damaged, the shores may bend or snap under the load. On the other hand the shores exert a thrust by their own weight, so if there are many heavy timbers the wall may be pushed inwards.

Here we come to an important principle. Generally, heavy raking shores should be placed so that the thrust of each shore is counteracted by adequate cross support within the building. A cross wall gives such support; so does a floor built into the wall to be supported.

Even a timber floor with joists running parallel to the wall to be supported gives some support along the lines of the floor strutting (by this is meant the internal floor strutting, not the temporary struts previously described). The same principle applies to flying shores.

If no internal support which could balance the thrust of the shores exists, it may be necessary to shore both sides of the wall. Sometimes, for example, the thrust of a heavy raking shore must be counterbalanced by a flying shore erected within the building.

Raking Shores

Fig. 15 illustrates single and double raking shores, with isometric details. This is the accepted method of shoring. A wall plate is used to spread the thrust and to give support to the wall over as extensive an area as possible. The plate is fixed to the wall by a timber needle, the head of which projects to take the head of the raker.

In setting out a raking shore, the centre line of the raker should intersect the floor bearing, so that the thrust of the raker is partly taken by the floor. A study of Fig. 15 will make this point clear.

In erecting a raking shore, first prepare the wall plate and cut the holes for the needles. Raise the wall plates and secure in position with wall hooks. If the wall is distorted, the surface must be packed behind the wall plate.

Holes are now cut in the walls for the needles, 3 in. to $4\frac{1}{2}$ in. deep. Having prepared the oak needles, ex. 4 in, by 3 in. or 4 in. by 4 in., drive them into position. Nail a cleat above each needle, as shown in Fig. 15 C, and the wall is then ready for the rakers.

The rakers must have a good foundation. A timber sole plate may be used, or with a multiple shore a grid of sleepers, or even a concrete foundation. The lengths for the rakers are taken by running a line from the needles to the raker foundations; and the bevel cuts for the rakers by holding pieces of plywood or board against the line at the needle position for the head and the foundation position for the foot. The angles are then marked in pencil, and the rakers prepared and hoisted into position.

The sole plate should not be at right-angles to the raker, but the internal angle should be a little less than 90 deg. The raker can then be tightened against the needle by forcing it inwards with

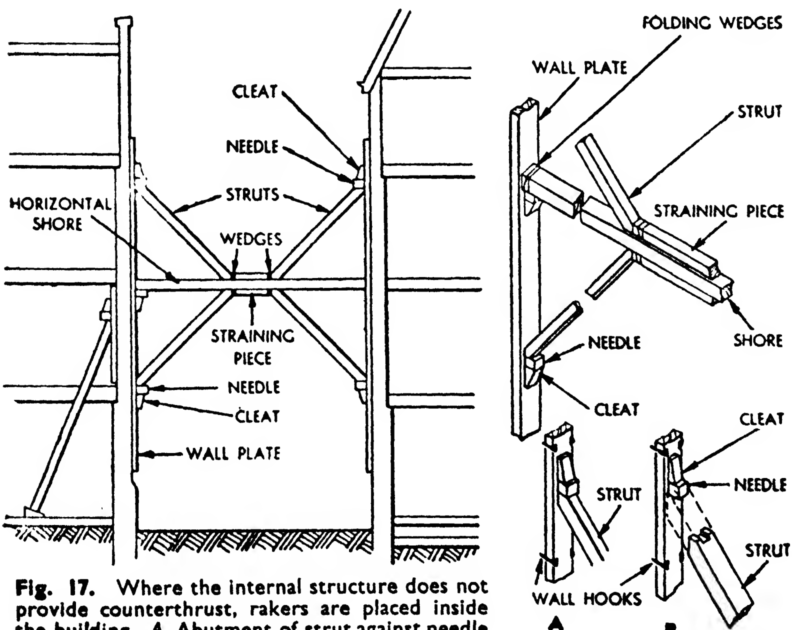


Fig. 17. Where the internal structure does not provide counterthrust, rakers are placed inside the building. A. Abutment of strut against needle B. abutment of wider strut to raker.

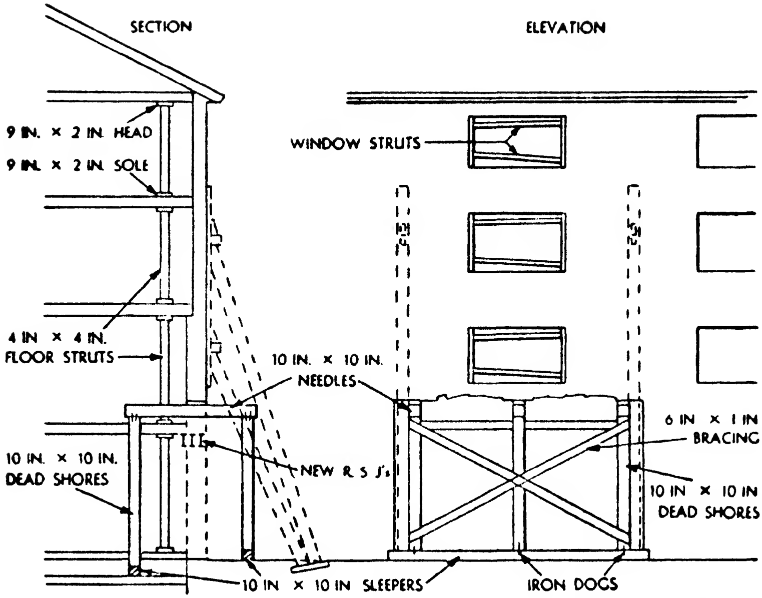


Fig. 18. Dead shores are used for the support of walls during cutting and removal to form an opening in the lower portion. Raking shores (as shown by dotted lines) may also be necessary to steady the upper parts of the structure.

a crowbar, as shown in Fig. 15 C. Iron dogs should be used to secure the foot of the raker to the sole plate. Wall plates, can be spliced, as indicated.

A multiple raking shore is illustrated in Fig. 16. Notice that the outer raker is in two lengths with folding wedges between. The rakers are bound together at the bottom with hoop iron or boards, and are tied together with boards which also connect to the sides of the wall plate. A series of raking shores should be cross braced together, as shown in Fig. 16 by the dotted lines. A series of raking shores should be spaced at intervals of 8 ft. to 15 ft., though the merits of the case must decide this.

The principle of the single flying shore has already been explained. In Fig. 17 a flying shore with raking struts is illustrated. This gives support at three floor levels. The principles of construction regarding wall plate and needles are similar to the raking shore, but notice that with the horizontal shore and the lower struts, the positions of needles and cleats are reversed. The struts bear against straining pieces and wedges are often used to facilitate tightening and easing. When in position all members are secured with iron dogs.

Fig. 17 A shows the simple abutment of a strut against the needle when the strut is about the same width as the needle. Fig. 17 B shows how the head of the strut is shaped when it is at least

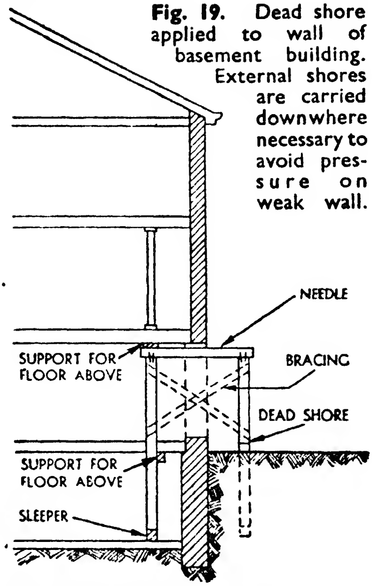


Fig. 19. Dead shore applied to wall of basement building. External shores are carried downwhere necessary to avoid pressure on weak wall.

$1\frac{1}{2}$ in. wider than the needle. Notice in the section in Fig. 17 that a single raking shore is placed inside the building at one point.

This is an illustration of a method of meeting the thrust of the horizontal shore when the internal structure does not provide a proper counterthrust.

A *dead shore* is a vertical strut, but the term is used to describe the type of shore illustrated in Fig. 18. Two vertical timbers, one inside the building and one outside, support a timber beam, called a needle, which passes through the wall.

Dead shoring is often accompanied by strutting of the interior from floor to floor and *ground* to *ground floor*, and by supporting the exterior with raking shores. The window openings may be strutted, as shown in Fig. 18. All these measures are intended to ensure the safety of the building while the rather delicate operation of shoring and the removal or repair of the wall below is carried out.

Dead shores are sometimes erected in basement buildings, as illustrated in Fig. 19. Notice how the floors are supported on the interior dead shore.

Raking struts used with flying shores vary from 4 in. by 4 in. to 6 in. by 6 in. according to length and the conditions of the job. Straining pieces are usually 4 in. by 2 in. Wall plates 9 in. by 2 in. or 3 in. Needles and cleats as already described for raking shores.

The correct method of finding the suitable timber sizes is by calculation; taking the needle as a beam and the dead shores as columns. For ordinary wall loads with dead shore sets placed about 6 ft. apart and the needles spanning not more than 7 ft. 6 in., 9 in. by 9 in. timbers are sufficient. The shorter the span of the needle the greater its strength, and it is advisable to make the span as short as possible if the material available is found to be on the light side.

STRUTS.—The function of internal struts between floors has already been described. Struts may be from 4 in. by 4 in. to 6 in. by 6 in. Head and sole plates may be 2 in. thick and an inch or two wider than the struts. It is extremely important that the plates should be placed at right angles to the direction of the floor joists.

Adjustable steel tubular struts are available for use in conjunction with steel ceiling plates of I section. The head of the strut is fitted with a clip for ready attachment to the rolled steel I plate.

CHAPTER 16

SHUTTERING FOR CONCRETE

CLASSES OF TIMBERING. MAIN CONCRETE GROUPS. MONOLITHIC CONSTRUCTION. ANGLES AND JOINTS. STEEL STANCHIONS. STRAINING WIRES. FLOOR SUPPORTS. PLYWOOD SHEETS. EXPANDING SCAFFOLD POLES. STAIR CONSTRUCTION. WALL CORNERS. PATENT CRAMPS. INTERNAL WALLS AND PARTITIONS. COLUMNS AND PIERS.

TEMPORARY timbering is necessary to support the sides of trenches during excavation. For simple excavations, timbering is divided into four classes according to the nature of the soil, as follows :—

(1) Hard ground: compressed chalk and blue clay.
(2) Firm ground : hard chalk and dense gravel.
(3) Moderately firm ground: compact clay, loose gravel and soft chalk.
(4) Loose ground: dry running sand, soft clay, and loamy soils.

The timbers used are known as :—

Poling Boards, which are members placed vertically. Sizes vary from 7 in. by 1½ in. to 9 in. by 2 in. and are usually from 2 ft. to 4 ft. long.

Walings, which are members placed horizontally next to the earth or against poling boards, or used as horizontal supports to shuttering.

Struts, which are short lengths of timber driven between the poling boards or walings at a maximum distance of 6 ft. centres. They are usually of 3 in. by 4 in. section when new timber is available, but often they are made from unserviceable putlogs or scaffold poles.

Sheeting consists of members placed horizontally, of similar section to polings and from 8 ft. to 14 ft. long.

Timbering Trenches

Fig. 1 shows these members in position in the trenches. The sides of the cutting taper inwards at the bottom for about 3 in. in 4 ft. of height. This is necessary in order that the struts may be driven in tightly, and so that any person walking on the struts will force them in more tightly. It is essential that the struts be cut to fit tightly without wedges or packing pieces.

Where a cutting is over 4 ft. in depth it must be carried out in two or more stages. Fig. 2 shows a cross section through a two-stage excavation with a sketch of the arrangement. When the first depth is timbered, the second is started and the earth thrown on to a platform which rests on the struts. This earth in turn is then thrown out, and the second depth is dug until sufficient

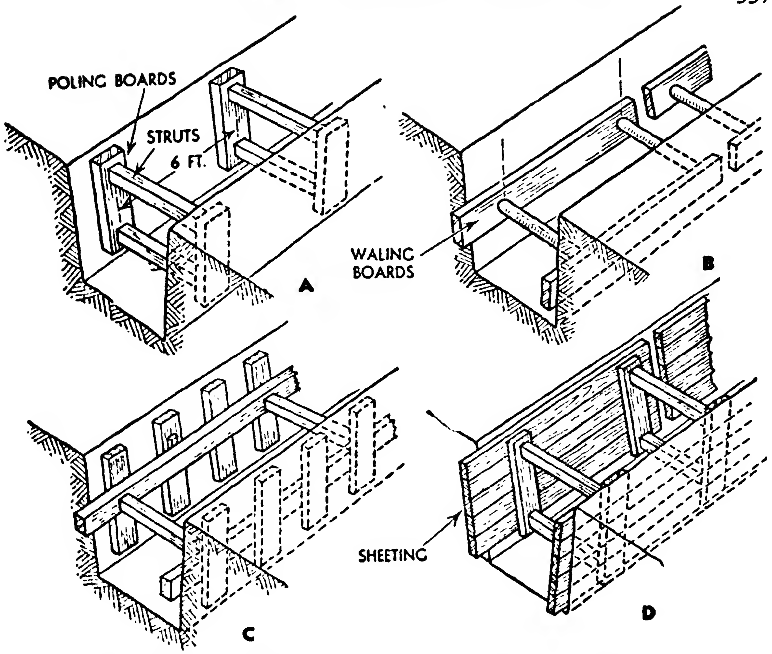
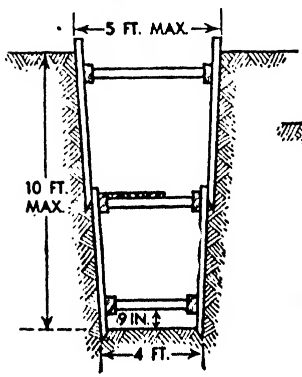


Fig. 1. Methods of timbering trenches. *A.* Arrangement used for firm ground ; *B.* for moderately firm ground ; *C.* for moderately firm to loose ground ; *D.* for loose or water-logged ground and loamy soils.

has been excavated for timbering.

Fig. 3 shows how a three-stage excavation is carried out. The platforms are moved along as the excavation is completed.

Note that in each case, the lowest strut is at least 9 in. above the bottom portion of the trench.



Concrete work is divided into two main groups. The principles of shuttering and the work of the carpenter are the same in both cases. These groups are known as (*a*) *precast* and (*b*) *cast in situ.* The first type consists of separate concrete units which are moulded on the ground and set in their correct position during erection of the building.

Work classed in the (*b*) group

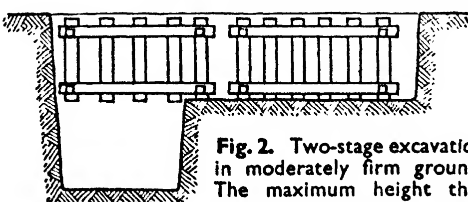


Fig. 2. Two-stage excavation in moderately firm ground. The maximum height that earth can be thrown is taken as 5 ft., hence platforms are provided for deep excavations.

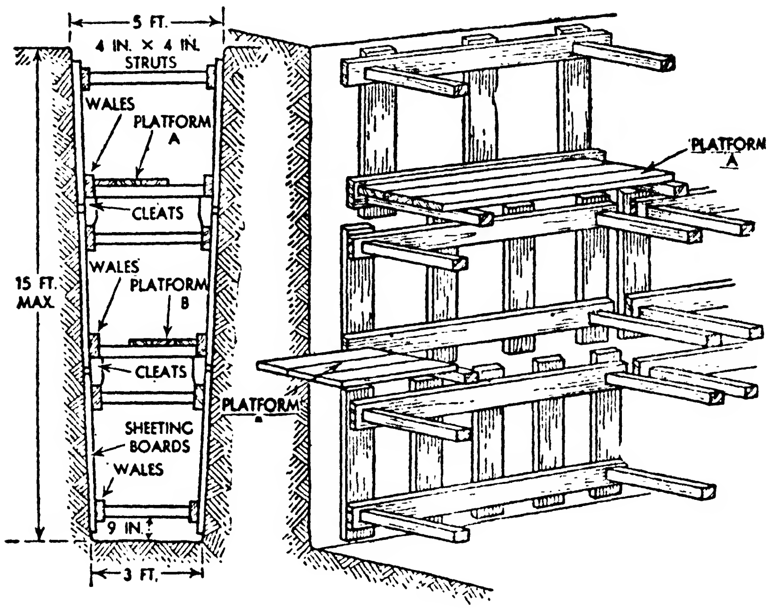


Fig. 3. Section and sketch of a three-stage timbering for drain trench in firm ground. The earth is first thrown on to platform *B*, from there to platform *A*, and from platform *A* it is thrown clear from the trench.

includes all concrete moulded in the actual position it is to occupy. When a structure consists of steel rods or mesh clothed with concrete the system is termed *monolithic* construction, but the concreting is described as *in situ*.

Mould Boxes

The requirements for group (*a*) are: a fairly level surface, easy access to materials, and suitable boxes in which to mould the units. The work is either carried out at the builders' yard or in a space allocated on the building site. The mould boxes take to pieces for ease of stripping, and the joints require to be of such a nature that the boxes can be quickly re-assembled.

With ordinary work, the mould shape rests on an even soffit or base board, and the parts are held together with metal clamps, folding wedges and wire nails. In all concrete work wire nails should be used, which should be driven so that their heads protrude about half-an-inch above the surface to facilitate withdrawal. Folding wedges should always be cut to the same bevel of, say, 1 inch in 12, to avoid loss of time in pairing wedges. Moreover, they can be collected from any part of the site and used with confidence without additional cutting.

The class of work decides the particular type of construction in forming the mould boxes. Where highly finished surfaces are required, as in artificial stone work, the box sides are made of either *zinc-faced* boards or waterproof ply, plain or metal covered. This of course is costly and is only used where high-class mass-production justifies the cost.

A box can be used for a number of times provided that all parts are carefully cleaned after each moulding. Concrete tends to stick to the surfaces, and in order to prevent this all the parts coming into contact with the concrete should be thinly coated with a special oil made for this purpose, or covered with a thin coat of soft soap, heavy lime wash, or machine oil. Concrete will not adhere to an oily surface. This applies to all concrete shuttering whether precast or in situ.

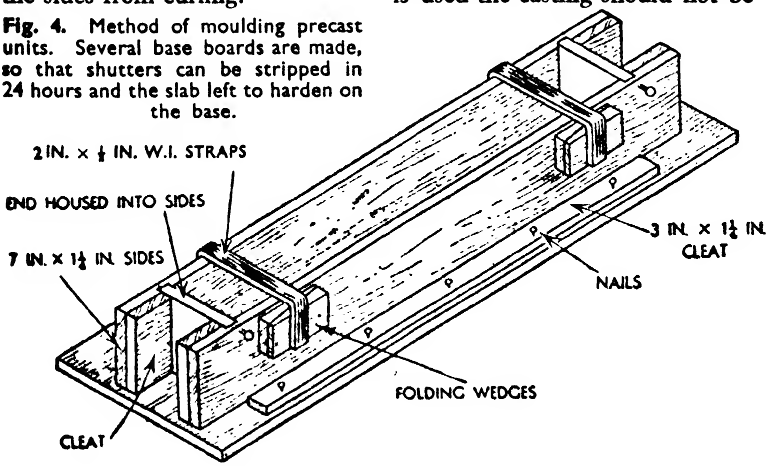
Fig. 4 shows a box suitable for a lintel. The timbers are 1 in. to 1½ in. thick prepared, and when the length is over 2 ft. 6 in. iron clamps are used to hold the sides from bulging. The ends of the mould box are housed ½ in. into the sides. These have a cleat securely fixed at each end which gives additional support at the housing and also serves to keep the sides from curling.

All types of concrete formwork must be prevented from spreading, as it is almost impossible to correct a distortion should this occur when filling. Where the mould is not required to have a high finish, ordinary boards can be used. These leave the mark of the grain showing clearly on the concrete surface.

Box sides can be stripped after 24 hours and a light rubbing with a fine stone will quickly remove marks if a good surface is required. It is essential that any making good to air holes or rubbing down of arrises should be carried out within a few hours after stripping. Once the surface hardens it is not only difficult to work, but new cement will not adhere, and tends to crack away.

The top of the work is usually at the top of the mould. The reason for this is that the box is first covered with a ¾ in. coat of fine concrete, any reinforcement added, and then the mass filled in. This gives an even surface to the underside which is desirable for bedding. If ordinary cement is used the casting should not be

Fig. 4. Method of moulding precast units. Several base boards are made, so that shutters can be stripped in 24 hours and the slab left to harden on the base.



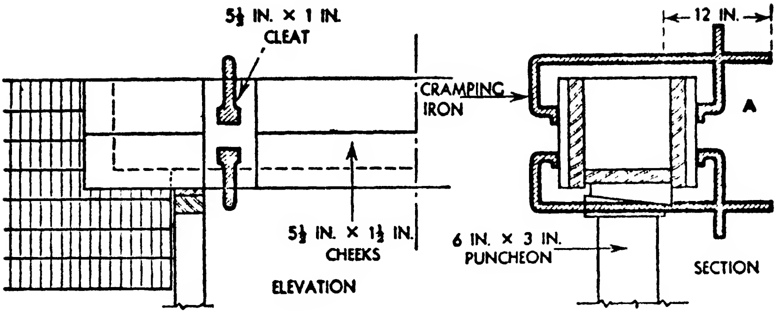


Fig. 5. Cross section and elevation of shutters to a lintel which is the full width of a wall without brick facing. The shutters are cramped with ⅜-in. irons and the arm marked *A* is drilled and tapped and screws down the iron as a nut.

moved from the base before seven days.

Formwork for concrete is variously termed as shuttering, centering, decking, sheeting and falsework.

Designing the Formwork

Concrete cast in situ gives most work to the carpenter, and several principles must be considered to produce a sound job. As work in the past has been very crude and has involved much waste, it is essential to design the formwork scientifically.

The component parts must be strong and rigid enough to carry the dead load of the concrete safely without distortion. In addition, a moving load must be allowed for, as men cross the formwork with barrows of concrete and this vibration tends to disturb joints and wedges.

All angles and joints should be carefully made to ensure true, flat surfaces and arrises, while having no leak holes through which the concrete can seep. Provision should be made for easy striking so that costs can be reduced to a minimum. All joints should be as simple as possible to allow speedy re-erection and at the same time prevent undue cutting and waste. The aim should be to use the same prepared shutters throughout the building where possible.

Now consider an actual case. Fig. 5 shows the cross section and elevation of the shutters to a lintel which is the full width of the wall without a brick facing. Patent metal cramps are used to hold the sides together; these have 12 in. of thread for adjustment and are usually 2 ft. to 3 ft. long. The shutter to the soffit is the net width of the lintel with bearers spaced at 2 ft. to 2 ft. 6 in. centres and supported on posts with wedges for adjustment. The sides are made up, cleated, and rest on the bearers to bring the top level with the finished depth of the lintel. This edge gives a straight line for the concreter. The sides lap over the wall to a length of 9 in. and are held in place by the cramps. Between the cramps the sides are nailed to the soffit at 6 in. centres with the nail heads left protruding about ½ in. as already described.

Sometimes a course of bricks is built in the sides of the opening with sand instead of mortar. These are removed and the bearers rest in the notch so formed, as shown in Fig. 6.

By using strong bearers no supporting posts are necessary, thus saving timber and labour. Where the opening is over 5 ft. the bearers should be of 9 in. by 3 in. section or the centre should be supported by struts as shown by the line diagrams. A is suitable for spans of 8 or 9 ft. For convenience, another brick would be knocked out to give additional support at the bottom. B is for wide spans where the centre must be left clear to form a run for men passing with material. C shows the support for the foot of the strut.

Fig. 7 shows the method of casing a steel stanchion or a reinforced pier, and Fig. 8 indicates how variations in shape are formed. The shutters are assembled round the steel and carefully strutted from it so that the margin of concrete is kept even on both sides. The usual amount of concrete that covers steel is: 4 in. to sides of pillars on the outside

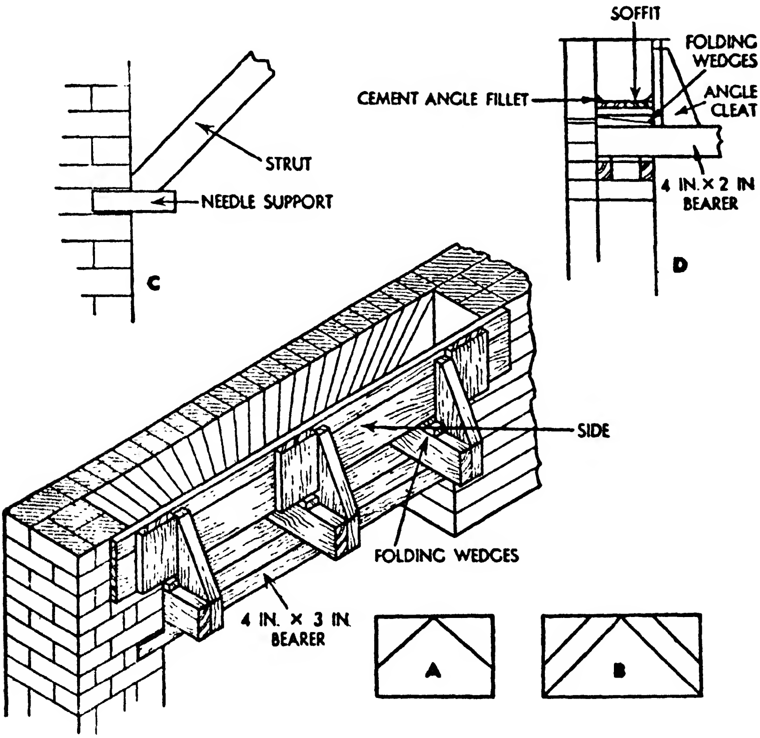
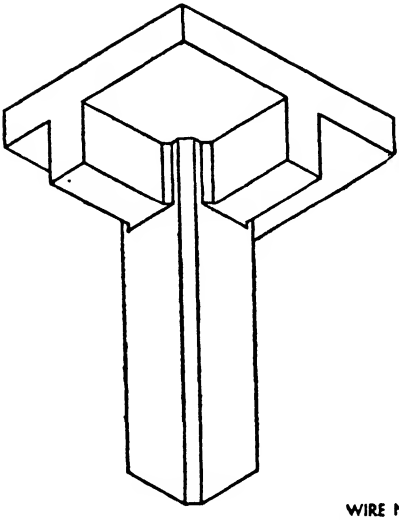


Fig. 6. Shuttering to a lintel with brick facing. A. Suitable supports for a span of 8 to 9 ft.; B. two struts with wide span allowing middle to be clear; C. 9 in. by 3 in. by 4 in. needle to support the foot of a strut; D. section showing in detail the cement angle fillet to the soffits, also folding wedges and angle cleat.



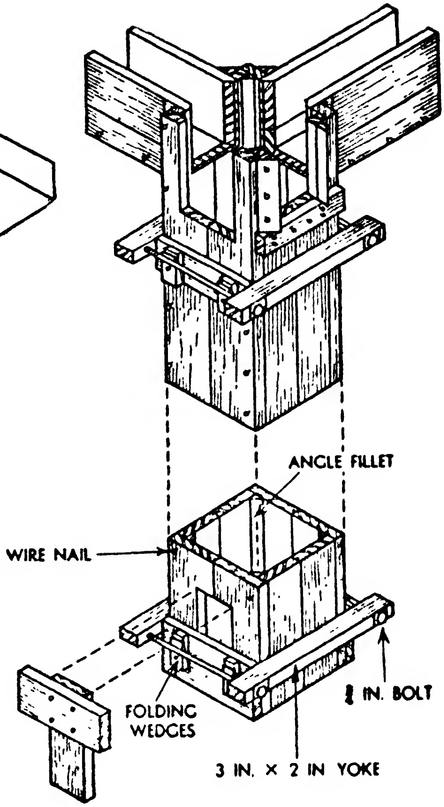


Fig. 7. Method of casing a steel stanchion or reinforced pier. Junction of beam and column casing. The sketches show the required shape of the concrete, and the formwork necessary.

of a building; 2 in. on the sides of beams, pillars and soffits on the inside of a building, with 1 in. to the soffit of floors, roofs and lintels. These distances are maintained by casting a number of small concrete blocks to the required size and inserting them between the boarding and steelwork.

Shutters to the stanchion are made so that two of them are the net width of the stanchion and the other sides are made wide enough to cover the width plus the thickness of two shutters. A sound method of holding the sides together is shown with ¾ in. to ¾ in. bolts through the yokes. The yokes are spaced 2 ft. to 2 ft. 6 in. apart and are of 4 in. or 3 in. by 2 in. placed edge to the inside. Folding wedges behind the bolts keep the sides together. Between the yokes, 2½ in. wire nails are driven through the edges at 6 in. centres. A small detachable shutter is made at the bottom of the casing for cleaning purposes.

The maximum height that concrete should be poured is 10 ft. Above this, the heavy material tends to sink to the bottom, and the concrete is not of even consistency. Where pillars are over

10 ft., three of the sides extend the full height and the fourth is stepped in lifts of 8 to 10 ft.

Straining wires can be used instead of bolts, or, if the finished pillar section is not over 9 in., the bearers can be nailed together. Concrete weighs approximately 140 lbs. per ft. cube, and, when poured, exerts pressure in all directions, which increases with the depth. This weight tends to spread the wires, and because of this, bolts are most often used.

The question of material arises and some difference of opinion exists as to whether tongued and grooved boards are better to use than square edged. Where a smooth finish is required, tongued and grooved boards give a better surface as the tongues keep the face straight. Against this, the grooves are liable to become filled with cement and rearrangement is difficult.

Quantity surveyors allow for the timber to be used twice.

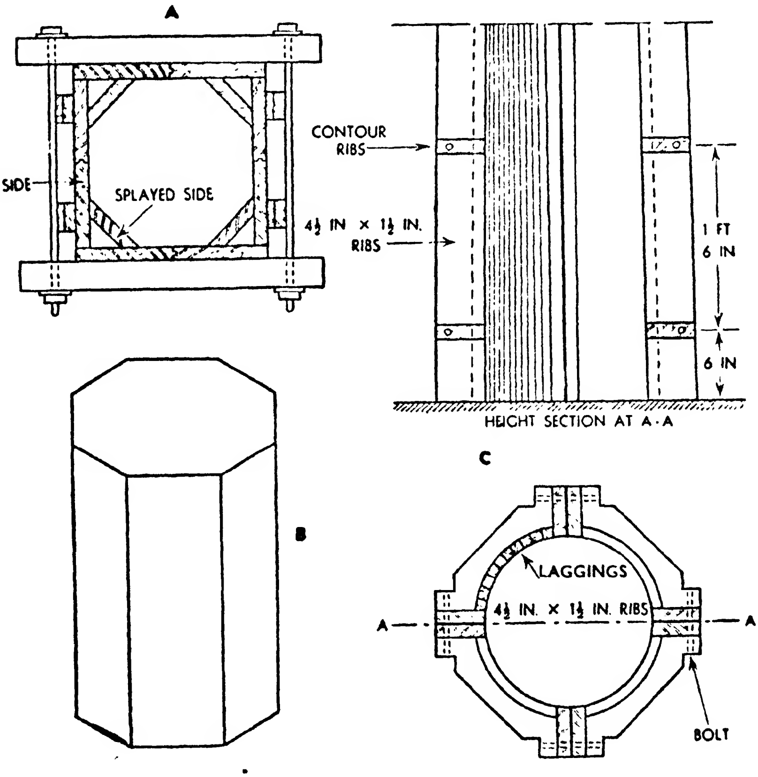


Fig. 8. Shuttering to columns. *A.* Casing for an octagonal column. The splayed side is nailed to the side and blocked in the corners to hold the edges from lifting ; *B.* finished shape of the column ; *C.* casing to a round column, 4½ in. by 1½ in. contour ribs are spaced at 1 ft. 6 in. centres, and stiffened by 4 in. by 1½ in. ribs. to form a fixing for the 1 in. by 1 in. laggings. The whole is held by ¾ in. bolts.

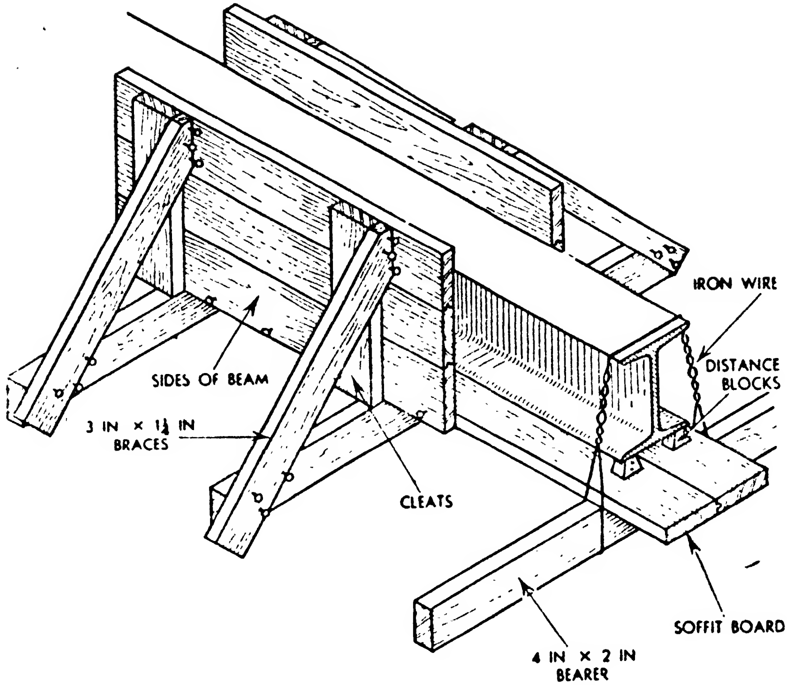


Fig. 9. Soffit board rests on 4 in. by 2 in. bearers, which are supported by a double strand of 10-gauge malleable iron wire. Sides of beam are nailed to cleats spaced at 2 ft. 6 in. centres. 3 in. by 1½ in. braces hold the sides in position, and concrete distance blocks 2 in. high are used between steel and board to maintain an equal depth of concrete round steelwork.

When stripping, boards get damaged, and the same sizes do not fit on all floors and this constant cutting involves waste. The boarding is usually burnt after a contract is finished as the edges become coated with cement and the surfaces uneven. It has been found in practice that the labour in cleaning and the extra time in fitting does not justify the use of boards for more than six or seven times.

A cross-section through the formwork for a girder is shown in Fig. 9. As bolts cannot be used through the box because of the steel girder it becomes necessary to strut the beam sides. The soffit is first made out of 1½ in. boards to the net width of the beam. They are nailed to long bearers of 4 in. by 2 in. on edge spaced at 2 ft. 6 in. centres. These bearers overhang the soffit proportionately to the depth of beam side and should not be less than 12 in. A 3 in. by 1½ in. strut supports the sides which rest on the soffit. The sides are nailed at 6 in. centres to the soffit with a small block on the bearer to give additional support.

The whole is slung to the steelwork and held by soft iron wire, of 10-gauge, doubled and bent around the bearers and over the top of the steel. Cement distance-blocks are used between steel and board, and the wires are tightened until all the blocks grip the steel. This tightening is done by twisting the wire with a bent steel rod with tapered ends. A sketch of this tool, which is of $\frac{3}{8}$ in. rod about 9 in. long, is shown in Fig. 10, together with a stripping bar.

Selection of Wire

The wire must be malleable, and free from crystallised pockets. Should the wire tend to be brittle, the whole consignment should be immediately rejected, as the entire weight of the shuttering and concrete is supported by it. It is cheaper to scrap the wire than replace damaged work. Because of the occasional mishaps with wire, some contractors always try to support the girder box underneath by means of strong posts which rest on a sole plate with folding wedges for adjustment.

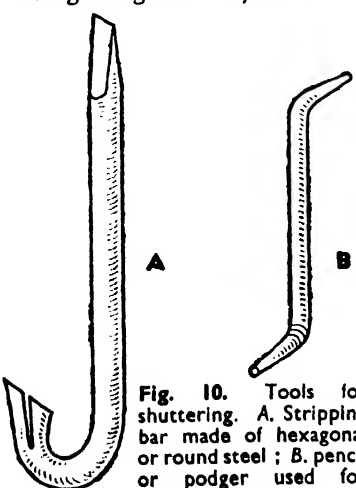


Fig. 10. Tools for shuttering. A. Stripping bar made of hexagonal or round steel ; B. pencil or podger used for tightening wire.

There is no reason why wire should not be used provided that a sufficient number of strands is used and that they are not over-twisted when tightening. Fig. 11 shows how a floor would be supported from the ground and shows a section through a girder box. It will be noted that the girder soffit rests on stout bearers which in turn are fixed to the posts by fish plates, with braces from the ends back to the post. Where floors are supported, a system similar to a joist floor is arranged. The decking is of 1 in. tongued and grooved boards, which rest on 6 or 7 in. by 2 in. joists spaced at 2 ft. centres. These in turn rest on 9 in. by 3 in. stringers spaced 8 to 10 ft. apart and running the full length of the room.

Final Adjustments

Butt joints in stringers can be made over a post as shown in Fig. 12. Special attention should be given to the fish plates, as this is the standard method of holding cross pieces in position on a post or strut. The main members or stringers are supported on 4 in. by 3 in. posts on sole plates with folding wedges.

Wedges are given a final adjustment to level up the soffit on completion and just before concreting. It is advisable that two men go round and level up the whole structure immediately before the concrete is laid, to ensure that all wedges and struts are in their proper place. Sometimes wedges are inserted at the top of a post instead of at the foot, to prevent them being disturbed. One nail is driven through the wedges into the sole plate and

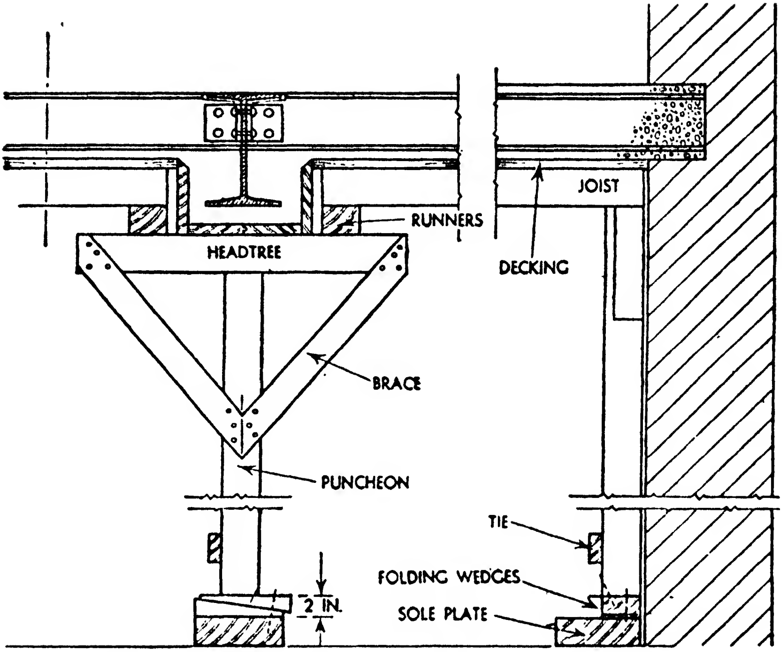


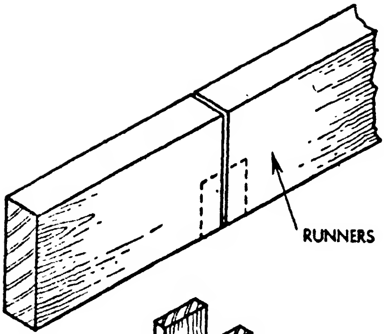
Fig. 11. Shuttering to floor with steel girders. This method of supporting floors is usually carried out in a brick building, and the steelwork is fixed after the shutters are in position. The decking is supported by joists at 2 ft. centres, which in turn are supported by runners resting on a headtree. The whole is supported by stout puncheons well braced and tied. Folding wedges are used to adjust the levels and to ease the work prior to striking. It will be seen that sole plates are also employed as they distribute the weight over a greater area ; on many jobs scaffold boards are used for this purpose.

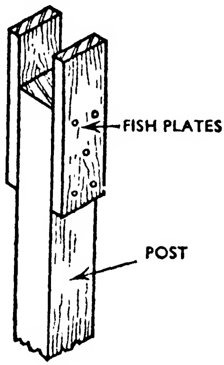
another secures the post to the wedges.

Holes are left in concrete floors to take drains and electrical junction boxes. These are arranged by forming a box having all sides tapered a ¼ in. in 6 in., well oiled and nailed to the soffit. A hole should not be formed with parallel sides, as the pressure of the concrete binds the members and makes them almost impossible to move after the concrete is set.

Floors can be either supported or slung by wires, as shown in Fig. 13. If the height is over 12 ft. it is uneconomical to give support from underneath; up to this height opinion differs, as with all but steel-framed buildings the shuttering is first fixed and this serves as a scaffold from which the steel can be easily positioned.

With a steel-framed building where the shuttering is suspended, a scaffold must be erected underneath each floor. The timber joists are then suspended from the filler joists. The soffit boards are inserted underneath the steel by the men working on the scaffold, which is left in position for stripping. On the other hand, as the centre of the filler joists are





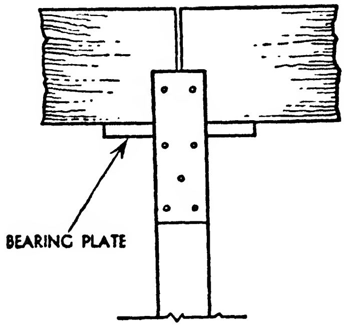


Fig. 12. Method of jointing runners over posts. The runners butt against each other over the post and are held by fish-plates. Sometimes a bearing plate is fixed under the runners as shown.

usually up to 2 ft. 6 in., the distance between the wires can be the same, therefore timbers need only be of 4 in. by 2 in. section, so that the saving of timber with a slung formwork is more than half.

Ply-wood sheets are used instead of boards in many cases, and are more easily positioned on a supported floor. To give an even surface, the shutters can be covered with a building-board of the reconstructed type. This saves a coat of plaster as the setting can be applied direct to the board, which is held firmly by the suction of the concrete.

Expanding scaffold poles are also available instead of posts and wedges, and metal panels in place of the timber soffit.

The timbering to a stair is shown in Figs. 14 and 15. Stairs are usually inserted before the building is completed, and it is common to erect all the steelwork, then concrete it, put in the stairs, then the floors, and lastly, put in the wall panels between the piers.

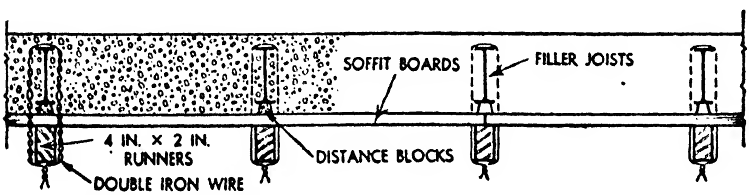


Fig. 13. Vertical section through suspended shuttering to a floor. Soffit boards are supported by 4 in. by 2 in. runners, which are suspended by a double strand of 10 gauge iron wire to filler joists. 1½ in. square by 1 in. deep distance blocks enable boards to be tightened up into position.

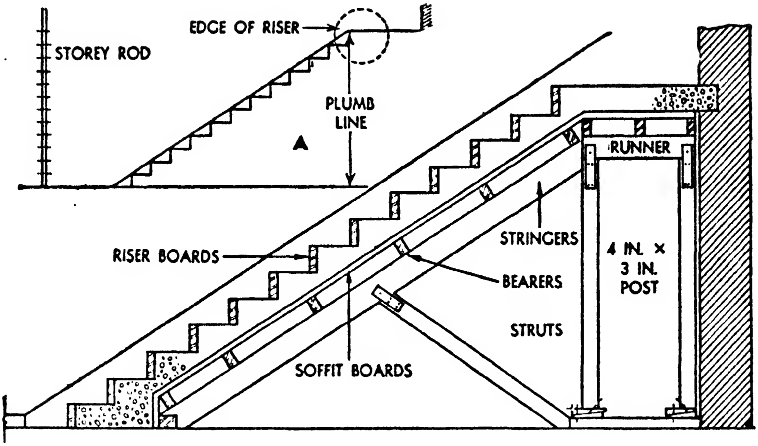


Fig. 14. Shuttering to a stair. A. Method of setting out, by dropping a plumb line from the edge of the riser, and marking a storey rod. 1 in. soffit boards are supported by 4 in. by 2 in. bearers, which are carried by 6 in. by 2 in. stringers and supported by struts. The landing is formed of boards and supported by 6 in. by 2 in. runners or heads and 4 in. by 3 in. posts. The steps are formed by 1½ in. riser boards which are held by strings spiked to the walls.

The height of the stair is carefully measured from floor finish to floor finish. The depth allowed for this finish must be carefully examined as the sizes of the steelwork may vary from the drawings. A plumb line is dropped from the top riser position to the floor, a rod cut to this length, and equally divided up to form the riser heights. This vertical line also gives the position for measuring the going. The landing position is then set out full-size to give the width of the soffit as shown in Fig. 14 A.

In the detail shown in Fig. 14 A the quarter-space landing would be fixed first, then the stringers to support the bearers, and the boarding filled in. The bearers overhang in order to enable the stair strings to be squared. Strings composed of one or more boards are battened together, set out and cut to shape. The portions cut off are nailed to a 4 in. by 3 in. timber which rests over the risers to support the middle (Fig. 15). Risers are nailed to 3 in. by 1½ in. battens which are secured to the strings.

Inverted Strings

The stringers are supported in the centre by a strut whose foot butts against the posts. This has a straining beam behind taken to the nearest wall or steel. Posts should always rest on a solid plate and have adequate bearing, with fish plates at the top to hold runners and stringers in position. If the stairs are over 3 ft. wide, 1½ in. boards are used for risers, and an inverted string strutted at the foot is fixed in the centre. This prevents curved lines on riser edges.

Figs. 16 and 17 show the

methods used for shuttering walls. These generally consist of two shutters made with horizontal boards having vertical bearers spaced 2 ft. to $2\frac{1}{2}$ ft. apart. These in turn are stiffened with horizontal waling pieces which are strutted back to the ground. A nib is formed on the foundation (Fig. 16 A) to give the ground position and to serve as a guide for the shutters. Cement distance-pieces are inserted between the shutters, which are pulled tight either by bolts, straining wires, or $\frac{1}{4}$ in. steel pencil-rods. The latter have clamps which hold the rod by means of a hardened $\frac{5}{16}$ in. Allan screw or set screw, having preferably a B.S.F. thread.

Fixing the Pencil Rods

The inset Fig. 16 B gives a detail showing how the clamp holds the pencil rods. The screw is tightened and bites into the rod, holding it securely. If this latter method is used it is only necessary

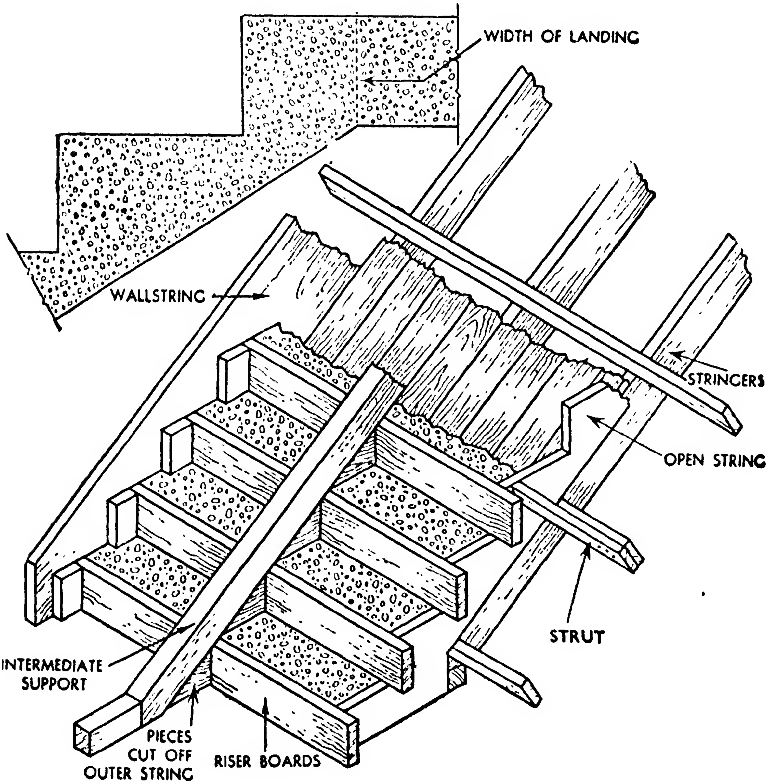


Fig. 15. Sketch of shuttering for stair with open string. Riser boards are held in position by cleats nailed to the wall string at one end, and the open string is formed by allowing the risers to extend over the face of the open string. For wide stairs an intermediate support is necessary to prevent the risers becoming bowed. Pieces cut off the outer string are nailed to the middle support.

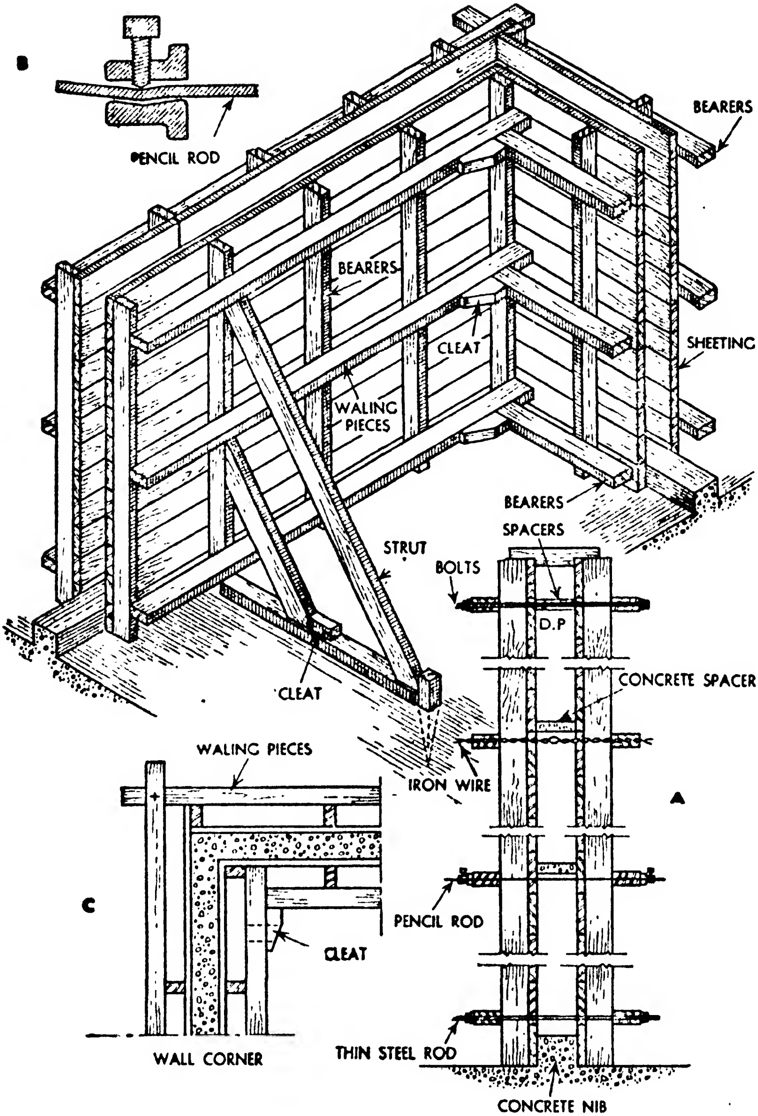


Fig. 16. Vertical shuttering for walls and panels. *A*. Various methods of holding the shutters together ; bolts with 2 in. by 2 in. washers, double-strand of 10-gauge iron wire, ½ in. mild steel pencil rod with clamped ends, and thin rods with threaded ends. To maintain an equal distance throughout, spacers are used such as the tube distance pieces ; concrete spacers ; and a concrete nib ; *B*. enlarged detail of the clamp at the end of a pencil rod ; *C*. how the corner is constructed and the method by which the struts support the straight lengths of shuttering.

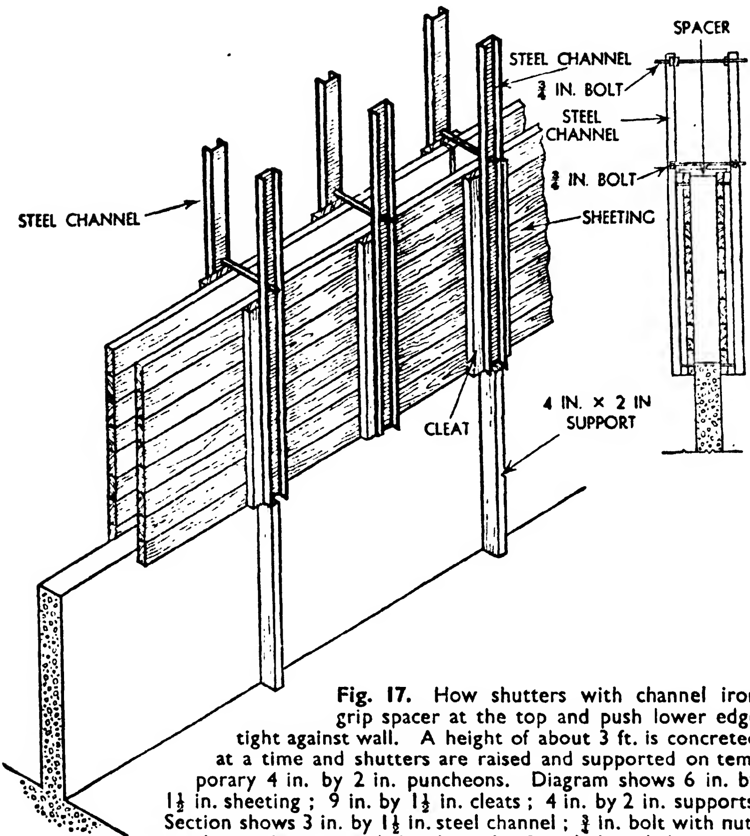


Fig. 17. How shutters with channel iron grip spacer at the top and push lower edge tight against wall. A height of about 3 ft. is concreted at a time and shutters are raised and supported on temporary 4 in. by 2 in. puncheons. Diagram shows 6 in. by 1½ in. sheeting ; 9 in. by 1½ in. cleats ; 4 in. by 2 in. supports. Section shows 3 in. by 1½ in. steel channel ; ¾ in. bolt with nuts on the inside to spread the channel ; ¾ in. bolt and the spacer.

to strut the top of the shutters plumb.

Tube distance-pieces, as shown in Fig. 16 A, can be used with bolts to make withdrawal easy. Where they are omitted the bolts should be eased after the first 24 hours and then re-tightened. This is to break the hold of the concrete on the bolt surface. When the shutters are struck after seven days, they are easily removed. One bolt only must be eased out at a time and then re-tightened until the whole surface has been covered. The holes are filled up on striking the shuttering. Where wires or pencil-rods are used, as in Fig. 16 A, the ends are cut to strike the shutters and subsequently cut flush to the wall surface. Bolts or wires are arranged in rows at a pitch of 2½ ft. and are staggered.

A wall corner is shown in Fig. 16 C. The shuttering is braced back to the ground every 8 ft. of length from the corner, which is self supporting. Bolts and straining wires pass through the horizontal walings on both sides of the wall. While this gives a rigid structure, it requires a lot of timber, consequently walings are often omitted except at the top.

Walings are not part of the actual shutter but form a continuous strengthening band to stiffen up several standard length shutters which butt joint together to produce a long run of wall.

To aid filling between the shutters, a splayed hopper is constructed about 3 ft. to 4 ft. long and is moved along the wall length as required.

An arrangement for concreting a wall without having bolts or wires through the concrete is shown in Fig. 17. A long steel channel section is bolted to a shutter which is 4 ft. high and 8 to 14 ft. long. This channel is 2 ft. higher than the shutter and acts as a pressure bar. It is bolted with a distance piece at the top of the shutter and adjusted with a bolt at the top of the bar. This gives a leverage which exerts a thrust against the bottom edge of the shutter and forces it tightly against the wall. These bars may be spaced at 3 ft. intervals, and give a satisfactory job provided that not more than 4 ft. of wall height is concreted with each lift.

Patent Cramps

A number of patent cramps are in use, based on a lever action, and these should be carefully examined when met with. Much time in bracing and tightening wires can be saved by these cramps, which hold the bottom edge of a shutter tight to the wall. In all cases a certain amount of bracing must be carried out to keep the sides plumb. A method of this type is particularly useful where the concrete has to be waterproof.

Internal walls and partitions to have a plastered finish can be erected by using a permanent shuttering of wall board. This must be the strong type of reconstructed board, and can be supported in two ways. The first method is to line the wood shutters with the wall board, and secure with a few nails, and the second method is to use the sheeting without a covering of boards. In this case it would be supported by a continuous member along the top and bottom edges, together with bearers and walings having straining wires on bolts to hold them in place. The bearers should be from 15 in. to 2 ft. apart. If carefully carried out this gives a good flat surface ready for decoration or plastering.

Circular Walls

The method of preparing a circular wall is shown in Fig. 18. The striking point is first found and a 2 in. by 2 in. peg driven in the ground or fixed on the floor. A nail is put in the centre and a steel tape hooked over it. The inside and outside wall curves are then set out and a new row of stakes driven in the ground at 18 in. centres spaced 1 in. back from the wall finish. A secondary row of pegs is then inserted 2 to 3 ft. away, keeping all the pegs on a radial line.

The boards to form the curve are made up in laminations varying from $\frac{1}{4}$ to $\frac{1}{2}$ in. thick, well wetted, bent round the curve, and nailed to the stakes with clout nails. A thickness of 1 in. is built up in this way, and held together and strutted in exactly the same manner as the straight wall.

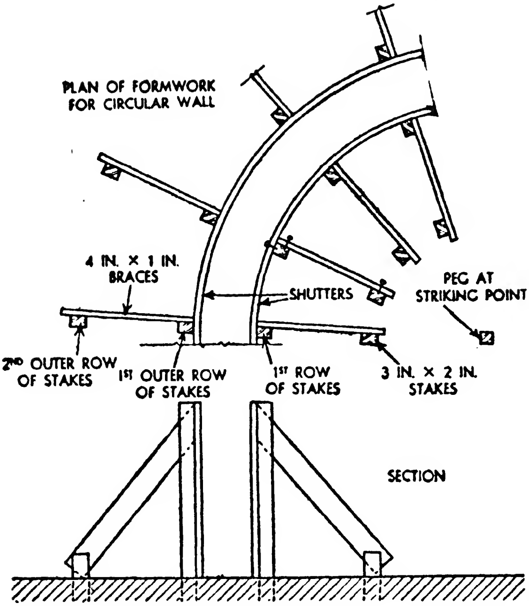


Fig. 18. Formwork for a circular wall. Includes 2 in. by 2 in. peg at striking point; 2nd row of 3 in. by 2 in. stakes driven 12 in. into ground; 1st row of stakes; shutters or separate laminations; 1st outer row of stakes; 2nd outer row of stakes; 4 in. by 1 in. braces.

It is essential to ram the concrete especially at the edges, otherwise surplus water will seep through and settle in any voids, forming a pitted surface. To help eliminate this, the front surfaces of deep faces are tapped with a hammer. The vibration thus set up packs the concrete.

Where special clamps are used for waterproof walls, and only 4 ft. of height is concreted at once, the sides are stripped after 24 hours and the work kept continuously moving. Concrete will only make a sound joint to concrete which has been set less than 24 hours, and provided that the joint surface is washed with clean water or cement grout before adding the new concrete. Any making good or adding to must be carried out while the concrete is green. After this there is little adhesion, and sudden shock will break the joint.

It is better if the whole of a floor or wall is carried out at once, especially if required to be waterproof. Concrete starts to set 20 mins. after water has been added to the cement. This is known as the "initial" set, and material which has been mixed and allowed to stand should not be used as the strength is inferior.

It is necessary to continue the built-up boards past the springing line of the curve in order to avoid a distortion at this point. If the concrete is well punned in, a first-class finish can be obtained by rubbing down the surface immediately on striking, and then giving it a cement wash to the desired texture or colour with a spray gun. If a support is not available for the pegs, it becomes necessary to use walings shaped to the curve with vertical bearers and boards bent around. Alternatively, for a large area, say the sides of a silo, 9 in. by 3 in. timbers are used instead of boards. These are shaped, covered with zinc and braced as before.

CHAPTER 17

FLOORS AND PARTITIONS

SINGLE AND DOUBLE FLOORS. GROUND FLOORS. VENTILATION. DAMP-PROOF COURSES. TIMBER SIZES. HERRING-BONE STRUTTING. HEARTHS AND LANDINGS. NOTCHING FOR FITTINGS. METHODS OF SUPPORT. INSULATING MATERIAL. FLOOR CRAMPS. CONCRETE AND WOOD-BLOCK FLOORS. PARQUET COVERING. PLYWOOD SQUARES. TYPES OF PARTITIONS. BUILDING BOARDS. METHODS OF FIXING.

FLOORS of timber construction consist of beams called *joists*, which support the floor covering. When the joists are in one continuous length and span from wall to wall they are termed single joists, and the floors are known as *single floors*. Such floors are generally used in domestic buildings.

The maximum economic span for a single floor is 16 ft. This length may require joists of about 10 in. to 11 in. in depth and from 2½ in. to 3 in. in thickness, according to the load the floor has to carry. A floor of this span is, however, subject to deflection likely to cause cracking in the plastered ceiling. Therefore it is necessary to insert intermediate supports to the joists in floors with a span over 16 ft. For this purpose, heavy timber or steel beams—called *binders*—are used at intervals of 8 ft. to 12 ft. When these binders span from wall to wall and the joists are fitted to or across them, the construction is termed a *double floor*.

Binders rarely exceed 20 ft. in length, and floors of greater span are constructed as *framed floors*, using a heavier beam section called a girder to support the binders, which in turn support the floor and ceiling joists. As framed floors are of large area,

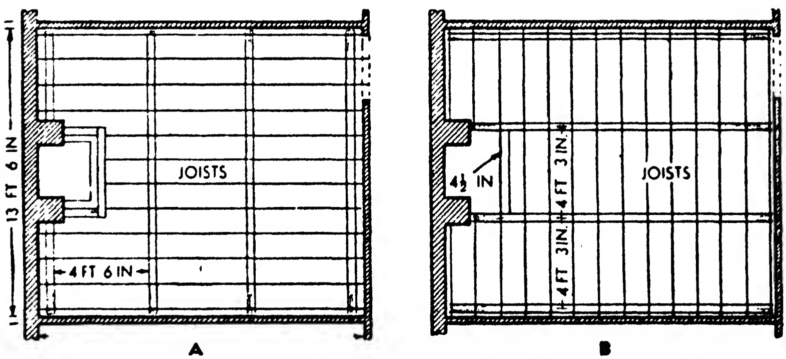


Fig. 1. Alternative arrangements of floor joists to a ground floor. At A the joists are parallel with length of room, while at B the joists are parallel with the fireplace opening. They are supported by brick walls or piers.

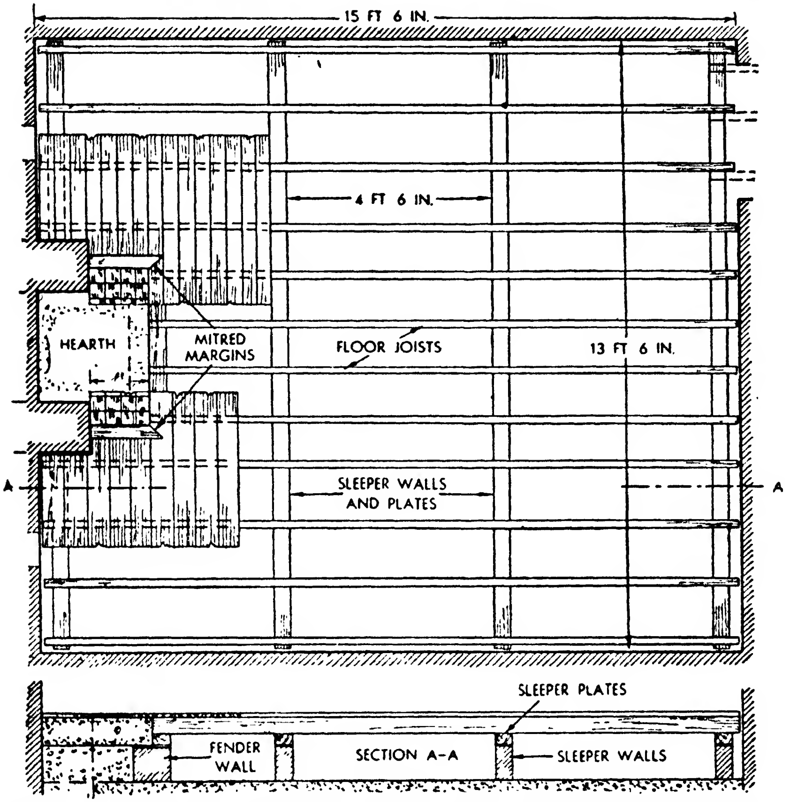


Fig. 2. Ground floor construction. 4 in. by 2 in. floor joists, spaced at 15 in. centres, are supported by sleeper walls 4 ft. 6 in. apart. Note the alternative arrangement of the mitred margins around the hearth,

they are almost entirely used in commercial buildings, where the construction must be of steel and concrete to avoid fire risks. Hence, timber framed floors are seldom used. Floor coverings to solid floors or to steel and concrete floors may be of either wood blocks or boards.

Figs. 1 A and B show alternative arrangements of the joists to a ground floor room. The joists are supported at their ends and intermediately by brick walls or piers. Joists may run in either direction, according to the circumstances of the job in hand.

Where the appearance of the finished floor is important, as in oak floors, the boards should run in the direction of the length of the room, and in a square room they should run from the doorway opening. In such particular cases, the boards decide the direction of the joists.

Ground floor joists are merely cut and nailed direct to the wall plates. Wall plates are jointed where necessary by halving them either longitudinally or at right angles to each other. The method is shown in Fig. 3 F.

In Fig. 2 the spacing of the joists varies to allow full length joists to be placed at the sides of the chimney breast. An alternative method is to space the joists at equal centres and to insert short joists on a brick offset or corbel to carry the ends of the boards.

The positions of the joists and boards near the fireplace need careful consideration. No timber must be placed nearer than 6 in. from the side of the fireplace opening, or nearer than 16 in. in front of the brickwork jambs.

A ground floor is supported on $4\frac{1}{2}$ in. sleeper walls and on a 9 in. or $4\frac{1}{2}$ in. fender wall at the hearth. Sleeper walls are built in ' honeycomb ' bond with vents to allow air to pass freely under the floor.

The plan and section of the floor shown in Fig. 2 have four honeycombed sleeper walls, two to carry the ends of the joists and two spaced equally across the plan to give intermediate support to the joists. These walls give a clear span of 4 ft. 6 in. and enable 4 in. by 2 in. joists to be used.

The maximum span for a 4 in. by 2 in. joist is 5 ft.; above this size deeper joists are necessary. A rough guide for determining the sizes of floor joists is to take half the span, calling feet inches, and add $1\frac{1}{2}$ in.; for example, a floor of 6 ft. span would require $\frac{6}{2} + 1\frac{1}{2} = 4\frac{1}{2}$ in. joists 2 in. thick.

End joists should be kept at least 2 in. away from the walls, while the ends of all joists should be at least 1 in. away from the walls. Boarding should also finish 1 in. clear around the brickwork. This helps to keep the timber dry and allows for $\frac{3}{4}$ in. plaster to clear the floor, the gap between the floor and the wall being covered with the skirting board.

Finishing the Floor

Provision has to be made round the hearth for finishing the floor.

In Fig. 2 this has been arranged by supporting the ends of the joists on a wall plate which rests on the fender wall. On each side of the hearth the joists are arranged to take the ends of the boarding and a mitred margin.

Two finishes are shown in Fig. 2, a 3 in. margin mitred into the board next to the hearth, and a separate margin which may be rebated or tongued to the ends and edges of the adjacent boards. Separate margins are usually of hardwood.

It is essential that ground floors composed of joists are well ventilated underneath. Condensation on the surface concrete, and moisture rising from the ground must be allowed to dry. For this purpose the external walls are provided with 9 in. by 3 in. air bricks built into the brickwork under the floor.

Air bricks are made in standard sizes of 9 in. by 3 in. in multiples of 3 in. up to 12 in. by 12 in. Cast-iron gratings (Fig. 3 B) have approximately double the ventilating area of terra-cotta, as shown at C. Opening frets in each case are about $\frac{1}{2}$ in. square. Air vents should be spaced so that the space under the floor has a through current of air without pockets of stale air in any corner.

To complete the protection of the timbers from rising moisture, and to ensure a dry building, all

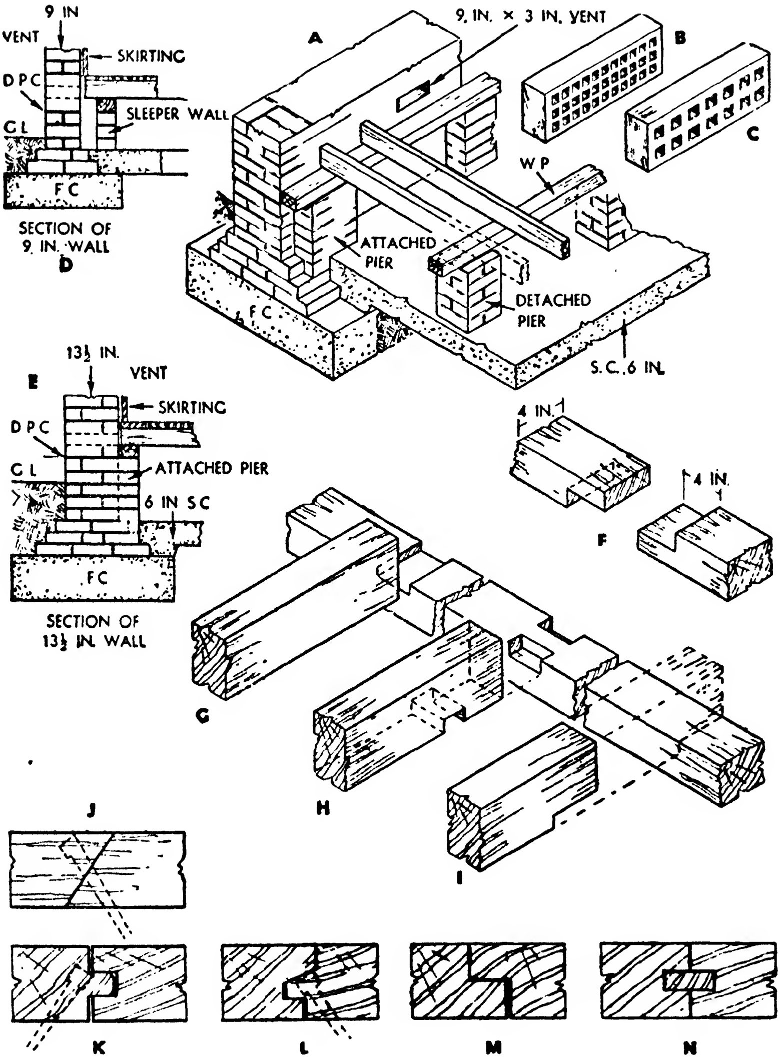


Fig. 3. Details of ground floor construction. *A.* Wall plates supported by isolated or detached piers and attached piers, spaced from 2 ft. 6 in. to 2 ft. 9 in. apart ; *B.* how a 9 in. by 3 in. cast-iron air grating has greater ventilating area than a terra-cotta air brick of the same size (*C*) ; *D.* section of a wall with a sleeper wall, and *E.* a section with an attached pier. In both cases the D.P.C. must be at least 6 in. above the ground level ; *F.* a joint between wall plates ; *G, H* and *I.* show types of joints between joists and plate. Joints to floor boards may be tongued and grooved, *K* ; special shaped tongues for secret nailing, *L* ; rebated as at *M*; or fitted with a loose tongue as at *N.* The joint in the length of the board *J* is known as a splayed heading joint.

walls or partitions which make contact with the ground, either by way of footings or site concrete, must be isolated from the ground moisture by means of an impervious *damp-proof course* (D.P.C.). Slate, bituminous felt, asphalt, or metal, to conform to the specification of the British Standards Institution, must be laid over the complete thickness of the wall at a height of not less than 6 in. above the ground level.

Earth, flower beds or similar matter must not be built up so that they cover the D.P.C. and so allow moisture to be transmitted from the ground to the brickwork above the D.P.C.

Joists supported on piers, as shown in Fig. 3 A may be used instead of sleeper walls. Attached piers of 4½ in. by 13½ in. bonded to the external walls are used to support the end plates, with 9 in. by 9 in. isolated or detached piers for the intermediate support. Distance between piers should not exceed 3 ft. for 3 in. by 4 in. plates. When piers are used, the outer wall plates are in contact with the external wall, and should therefore be impregnated with a preservative as a safeguard against decay.

Fig. 3 D shows a section through the footings and foundation of a brick wall with a separate sleeper wall. Where joints are used in wall plates and joist fixings, they should be kept as simple as possible, as shown in Fig. 3 at G, H and I.

Boards used for flooring are of two main types, plain edge (P.E.) and tongued and grooved (T. & G.) Plain edge boards are nailed through the face side with two nails to each joist, and boards which require jointing in their length are cut to finish on the centre of a joist with a splayed heading joint as shown in Fig. 3 J.

Tongued and grooved boards with straight tongues are nailed as P.E. boards or through the tongue as shown at K. Tongued and grooved boards with special shaped tongues, as shown at L, are arranged for secret nailing. M is a section through the joint of a rebated board, and N a grooved board with a loose tongue.

Standard Sections

First and subsequent floors are different from ground floors inasmuch as the joists span the complete width of the room. The depth of the joists, therefore, must be increased accordingly. Standard sections, as shown in Table I should always be used, as non-standard sections are expensive and wasteful.

2 × 3 in.	3 × 4 in.
2 × 4 in.	3 × 4½ in.
2 × 4½ in.	3 × 5 in.
2 × 5 in.	3 × 6 in.
2 × 6 in.	3 × 7 in.
2 × 7 in.	3 × 8 in.
2 × 8 in.	3 × 9 in.
2 × 9 in.	3 × 11 in.
2 × 11 in.	4 × 5 in.
2½ × 5 in.	4 × 6 in.
2½ × 6 in	4 × 7 in.
2½ × 7 in.	4 × 8 in.
2½ × 8 in.	4 × 9 in.
2½ × 9 in.	4 × 11 in.
2½ × 11 in.	

Table I. Usual stock sizes of European redwood and whitewood. British Columbian pine often has a smaller section.

To determine the correct sizes of joists to meet all the requirements likely to be met involves the use of complicated figures and formulæ, hence Table II will be of help in obtaining the depth of joist which is necessary when the breadth and the distance between the joists are already known.

DOMESTIC DWELLING USING UNGRADED TIMBER

Spacing	Breadth of Timber		
	2 in.	2½ in.	3 in.
	Constant		
12 in. ...	20	21	22
14 in. ...	18	20	21
16 in. ...	17	19	20

SHOPS, OFFICES AND BUILDINGS NOT OF THE WAREHOUSE TYPE OR PUBLIC BUILDINGS: UNGRADED TIMBER

Spacing	Breadth of Timber		
	2 in.	2½ in.	3 in.
	Constant		
12 in. ...	15	16	17
14 in. ...	14	15	16
16 in. ...	13	13	15

Table II. Method of obtaining depths of joists of ungraded timber when the breadth and distance between the joists are already known.

The spacing referred to is the clear distance between the joists.

These constants comply with most by-laws on depth of joist and binders, but contact must be made with the local authority for permission to use the size of joist so determined.

To use the constants, the length of the joist in inches is divided by the appropriate constant to give the depth in inches.

Example 1.—To find the depth of a 2 in. joist for a domestic building: length of joist 9 ft. spaced 12 in. apart (14 in. centre to centre)—

$$\frac{\text{Length}}{\text{Constant}} = \frac{9 \times 12}{20} = 5\frac{2}{5}$$

As this is not a standard section a 6 in. joist would be used.

Example 2.—To find the depth of a 3 in. joist for a shop floor: length of joist 10 ft. spaced 14 in. (17 in. centre to centre)—

$$\frac{\text{Length}}{\text{Constant}} = \frac{10 \times 12}{16} = 7\tfrac{1}{2}$$

This again is not a standard section, and the next larger size 8 in. would be used.

The strength of timber varies with the breadth and with the square of the depth, hence the strengths of sections can be compared and it may be possible to substitute sizes of standard sections when non-stock sizes are tabulated, by comparing the values of $b \times d^2$.

In Example 2 the joist section required by the formula is 7½ in. by 3 in.; as 7½ in. is not a standard size, the nearest section is 8 in., but to use 8 in. by 3 in. joists when a 7½ in. by 3 in. would suffice is expensive. If a substitute could be used of smaller section, a saving on material would be effected.

A 3 in. by 7½ in. section timber, when multiplied breadth times its depth squared =

$$3 \times \frac{15}{2} \times \frac{15}{2} = 168\tfrac{3}{4}.$$

A 2½ in. by 8 in. section is

$$\frac{5}{2} \times \frac{8}{1} \times \frac{8}{1} = 160$$

If this section is substituted for the 8 in. by 3 in. section, a considerable saving is involved while the strength being within one-twentieth of the figure asked for, would be safe. By this means an alternative section can be substituted and a saving made in cost.

Narrow floor joists are quite strong enough for flooring purposes, but to avoid any tendency to buckle, joists are stiffened by rows of strutting. These may be of the solid type, consisting of short lengths of 1½ in. by 6 in. board fitted tightly between the joists and nailed through the edges, or it may consist of diagonal strutting as shown in Fig. 4.

Herring-bone strutting — or bridging as this diagonal strutting is commonly called—is an efficient method of stiffening floor joists. The timber used may be of 1¼ in. by 1½ in. to 1½ in. by 2 in. in section, cut and nailed diagonally between the joists. The ends of each strut are kept about ½ in. from the top and bottom edges of the joists to allow for any shrinkage that may take place in the joists. Shrinkage of the joist actually tightens the strutting.

Strutting is arranged in bays of about 7 ft. apart; for example, a 14 ft. span would need one row, while a 16 ft. span would need two rows. The strutting is set out by marking a single line across the floor joists in the position that will eventually become the centre line of the struts. A second line is then marked parallel with the first line and a distance away equal to the depth of the joists less ½ in. for the clearance previously mentioned. The diagonals of these lines give the length and bevels of each strut.

Strutting is fixed by two operatives, one of which works on a scaffold board under the joists while the other cuts the struts and fixes them from the top.

Trimming to fireplaces must conform to the local by-laws. It is usual to allow 1 ft. 4 in. in front of the chimney breasts and 6 in. on each side of the fireplace opening for the hearth. No timber must be placed nearer than 6 in. to any flue. This entails the trimmer being carried at the side of the brick jambs, while the net width of the hearth is arranged by a fillet or 'cradling' piece to receive the ends of the boarded hearth.

Fig. 5 shows a pictorial sketch of a first-floor plan and clearly illustrates

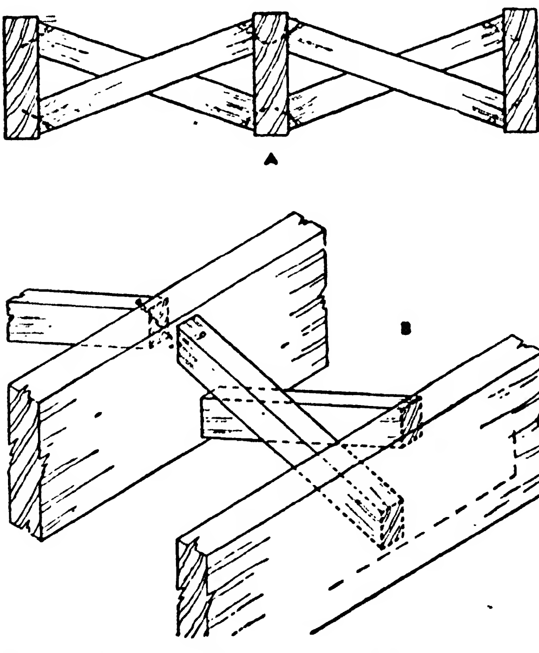


Fig. 4. Detail of herring-bone strutting is shown at A and a pictorial view at B. Note how the struts are kept ½ in. from the edges of the joists.

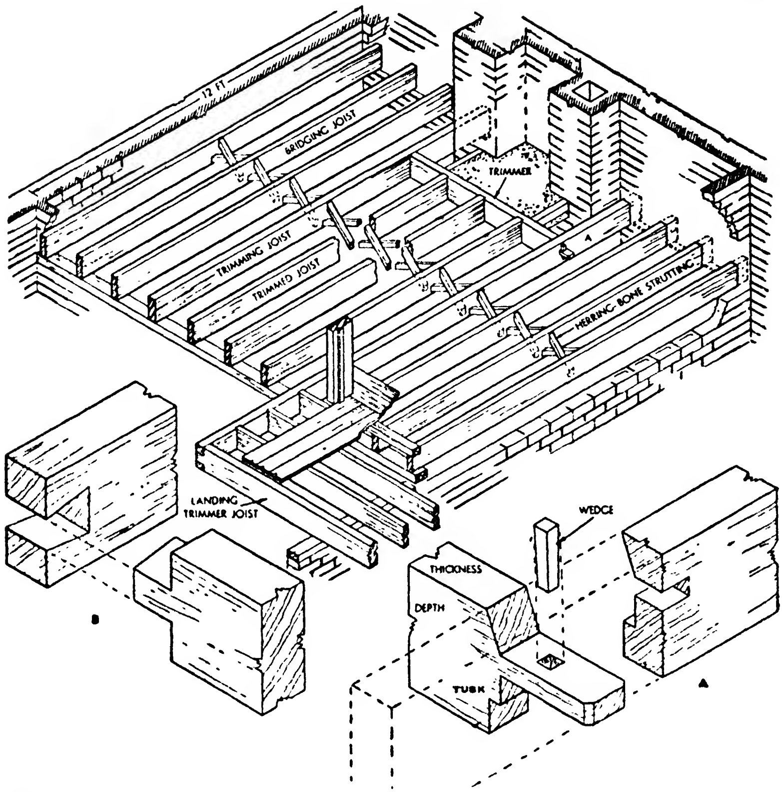


Fig. 5. Pictorial view of floor of a first-floor, with 2 in. by 8 in. bridging joists, 3 in. by 8 in. trimmer, trimming joist, and 2 in. by 8 in. trimmed joists. A. Tusk tenon joint between the trimmer and the trimming joist; *B*. trimming joist cantilevered to form the landing. The landing trimmer joist is dovetailed to the trimming joist as shown on an enlarged scale at *B*.

2 in. by 8 in. bridging joists supported on a wall plate on the $4\frac{1}{2}$ in. brick wall, and on a $\frac{3}{8}$ in. by $2\frac{1}{2}$ in. wrought iron bearing bar on the external wall. The use of a bearing bar is to assist in tying the wall throughout its length and also to distribute the bearing of each individual joist over a greater bearing area. Joists that rest directly on the brickwork are liable to scale the face of the brick supporting them and in so doing will crack the finished plaster on the walls. Joists built in walls should be creosoted or impregnated with a toxic solution to assist in resisting decay.

Hearth Trimming

Hearth trimming is arranged by framing the timbers surrounding the hearth. In Fig. 5 the trimmer is 'tusk tenoned' into the trimming joists at A, the proportion of which is shown in the larger scale sketch.

As the landing outside the room has to be self supporting, the trimming joist on the right-hand side of the fireplace is arranged to cantilever over the 4½ in. brick wall and so provide extra support for the corner of the landing. This corner joist is dovetailed as shown in the larger sketch. Where, owing to different joist section or different joist arrangement, this is not possible, the landing trimmer is carried across the wall and tusk tenoned into the first or second joist of the room.

Often joists have to change direction from landings to rooms, and, consequently, the flooring will also run in different directions. As it is not desirable to alter the direction of the floor in a room, the change is made as shown in Fig. 5 immediately under the centre of the doorway. A batten of 1½ in. by 2 in. or 2 in. by 2 in. section is notched into the ends of the room joists to carry the tail ends of the boards from the landing.

Bearings and Supports

Local by-laws determine the sizes of bearings and supports for floor joists. The minimum support required is usually a 4 in. brick or portland cement concrete wall, or timber stud partition, or a R.S.J. of suitable section with a length of bearing of from 2 in. to 2½ in. minimum.

In the case of a supported hearth the reinforced concrete hearth relies upon the trimmer for support. The weight to be supported is not great if the hearth is cast *in situ*, with the rear portion or 'back hearth' cantilevered. With a hearth of this description it is usual to form the concrete on shuttering which is supported by a bearer fixed to the trimmer and a bearer fixed to the wall. The wall bearer eventually receives the laths for the plastered ceiling formed underneath the joists. Owing to the weight of wet concrete, the vibration caused in pouring the concrete, and the weight of workmen adjacent to the hearth, it is advisable to give additional temporary support in the form of a wall bracket. The strut is birds-mouthed over the bearer and butts against a wall piece. All nail heads should be left protruding in the formwork for easy 'striking.'

A batten is placed in position when the concrete is cast and is held by two twisted wires or similar metal cramps.

Alternative arrangements are to cast the hearth wider than would normally be required and to bed dovetailed flooring fillets in place, or to notch a short joist section into the trimmer and to carry its wall end on a brick or metal corbel pin.

Metal sheeting, either flat or corrugated, is a good substitute for boarding and will often obviate the need for reinforcement. Except where it is necessary to have the maximum of strength, and the tusk tenon joint is used, joints in floor framing should be kept simple. In each case additional rigidity is obtained by nailing with either 4 in. or 6 in. nails.

Notching Joists

Care should be taken in notching floor joists for plumbing and electrical work. All notchings should be on the top edge of the joists and as near to the point of support as possible. Where two or more pipes have to be inserted across the joists the larger diameter pipes should be near the point of support and the other pipes at intervals of 3 ft. with the smallest pipe farthest away from the wall. More than one pipe should not be inserted into one notch as the amount of material cut away from the joist will make it difficult to fix the flooring.

Wherever possible traps should be left in floors for the inspection of vital service junctions. Traps should be at least one joist spacing in width and if the trap is likely to be frequently used, it should be clearly marked and screwed down using cups for the screw heads. Additional bearers may be required for the

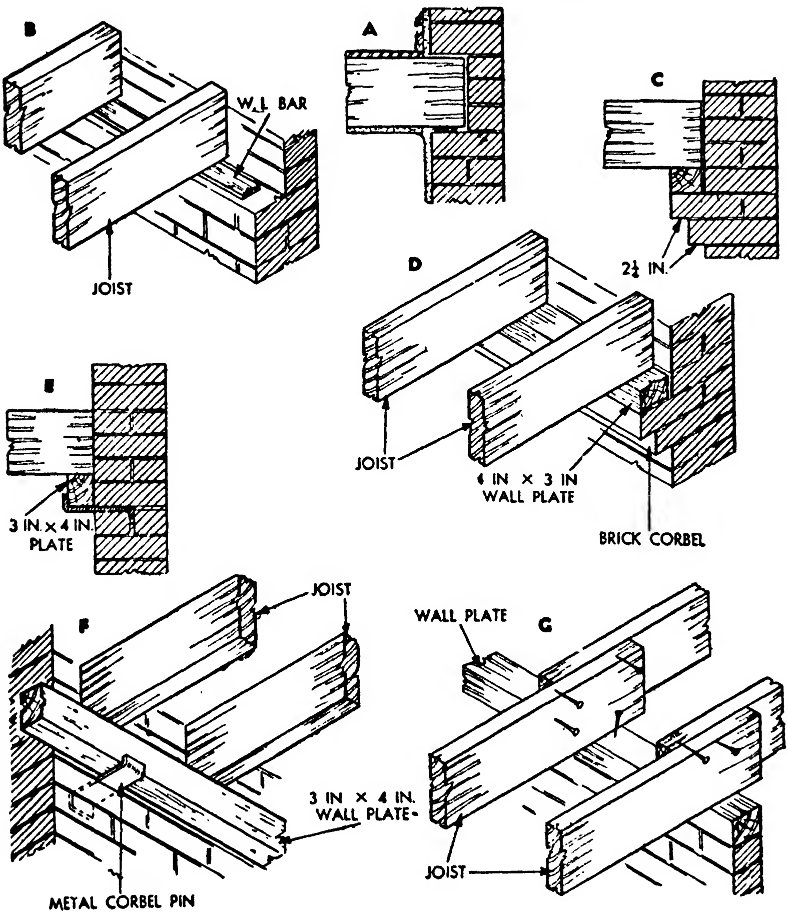


Fig. 6. Methods of supporting first floor joists. *A* and *B*. Joists built into the wall and resting on W.I. bearing bar; *C* and *D*. brick corbelling used to support the wall plate; *E* and *F*. metal corbel pins built into the brickwork; *G*. intermediate support where the joists can be nailed together.

making of a good fixing. Pipes that run in the same direction as the joists should be securely clipped to the side of the joist and preferably be supported on a batten. Flexible cables liable to damage by floor nails should be supported half way down the depth of the joist and when crossing at right angles should be threaded through one inch holes bored through the centre lines of the joists. A joist is only as strong as the timber left in the section after all notchings have been made, so care must be taken to avoid undue weakening by thoughtless cutting.

Brick Corbelling

Fig. 6 shows the methods of supporting joists in domestic floor construction. A is a section and B a sketch of the floor joists built 4 in. into a 9 in. wall and supported on a W.I. bearing bar as previously described. Where by-laws will not permit the timbers to be built into a party wall, a method known as brick corbelling is used, as shown at C and D.

E and F show an alternative form of corbelling which is often used. Metal corbel pins 7½ in. long are built into the wall to a depth of 4½ in. Both ends of the pin are cranked to support the joist and for building into the brickwork. The distance between the corbels should be 3 ft. for a 3 in. by 4 in. flat wall plate, and 4 ft. apart for a wall plate on edge as shown.

Joists should not be butted over a wall plate but should run alongside each other as shown at G. These joists when nailed together form a continuous joist and stiffen the floor considerably.

As a floor may also be arranged with a bay window, provision must be made for supporting the joists by cantilevering them across the brickwork opening and into the bay. Joists are not permitted to take a main bearing off the head of a bay window because of fire risk to the bay and the danger of the collapse of the floor.

Where the sizes of a floor require joists exceeding 16 ft. in length, intermediate support in the form of heavy wooden beam or R.S.J. is necessary. The joists may run the complete length of the room and be notched over this support, or housed into it.

With large section R.S.J. it is usual to secure the joists by notching over the flange at the top, while with smaller section R.S.J., such as the beam over the bay window shown in Fig. 7 A, the joists rest on the top.

Methods of supporting timber joists are various, and largely depend upon the load the floor has to carry. Floors subject to heavy loads have deeper R.S.J.s and should have a 2½ in. by 2 in. angle iron riveted along the web of the girder, as shown at Fig. 7 C and D to support the joists either directly or by the inclusion of a wood plate D.

In floors of domestic construction smaller section steel beams are usually employed. The support for the wooden joists is obtained by securely fastening a 2 in. by 2½ in. wall plate to the web of the beam with bolts; the floor joists are then notched over the top flange.

The portion of the beam which protrudes below the ceiling may be treated in several ways. It may be plastered, covered with

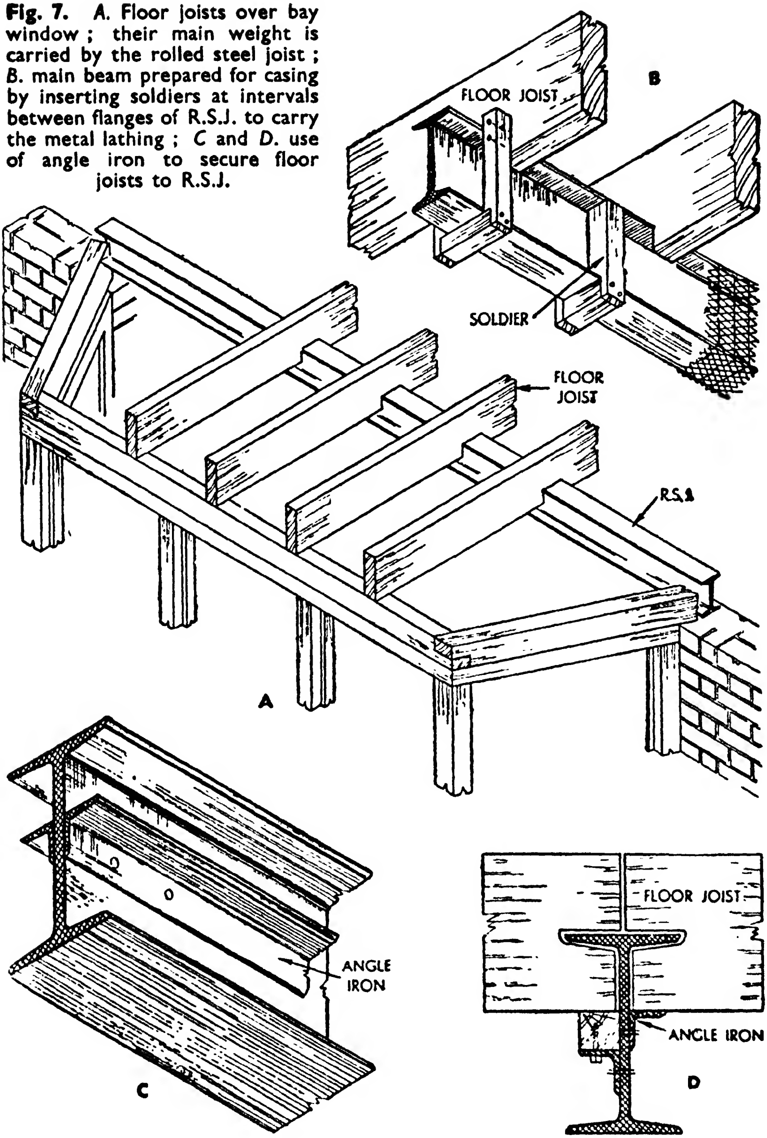


Fig. 7. *A*. Floor joists over bay window; their main weight is carried by the rolled steel joist; *B*. main beam prepared for casing by inserting soldiers at intervals between flanges of R.S.J. to carry the metal lathing; *C* and *D*. use of angle iron to secure floor joists to R.S.J.

fibre board or panelled. Fixing is obtained either by driving members called *soldiers* between the flanges of the beam, or by fixing noggings and bearers to form a cradling B to carry the wood or metal lathing and to support the soffit of the panelling.

Sometimes a level ceiling is desirable, in which case members called ceiling joists are used to carry the ceiling covering, as shown in Fig. 8 A. The joists are notched over the bottom flange of the beam with enough material above the flange to carry the weight of the ceiling, and enough material below the flange to maintain a level surface for the ceiling.

Separate ceiling joists are a great help in arranging sound proofing. Owing to the depth of the beams double floors are particularly suitable as shown at B.

Insulating material such as quilted fabric or specially prepared insulating board is fixed directly above the ceiling joists to provide two separate air spaces to absorb the noise. C shows a section of a single floor arranged for sound resisting. Battens are fixed to the sides of the joists to take the insulating material about half way down its depth, while the flooring is again insulated by a material placed directly on the top edges of the joists and counter-battened above when ceiled. This provides three air spaces and the whole of the floor is insulated from the ceiling below.

Further insulation is afforded by insulating the bearing of the main joists and beams. Owing to the weight which binders have to carry, they must be supported on concrete or stone pads sufficiently large enough to distribute the weight they transmit over a large area of supporting wall or pier.

As a large measure of noise may be transmitted along the beams it is usual to bed them on a lead or other kind of insulating pad to arrest noises that would otherwise be transmitted

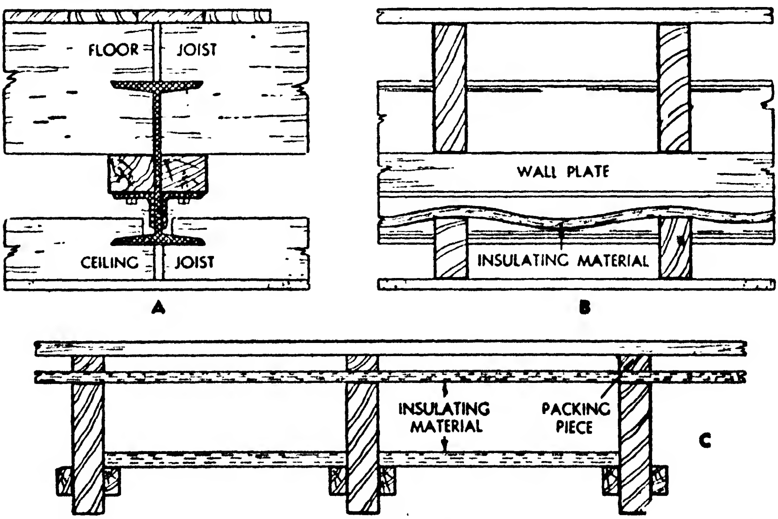


Fig. 8. Methods of making floors sound proof. A. Section through R.S.J. with the floor joists and ceiling joists notched over the flanges ; B. elevation showing insulating material laid over the ceiling joists ; C. single floor made sound-resisting by inserting insulating material half-way down the depth of the floor joists and on top of the floor joists ; the packing piece insulates the floor boards.

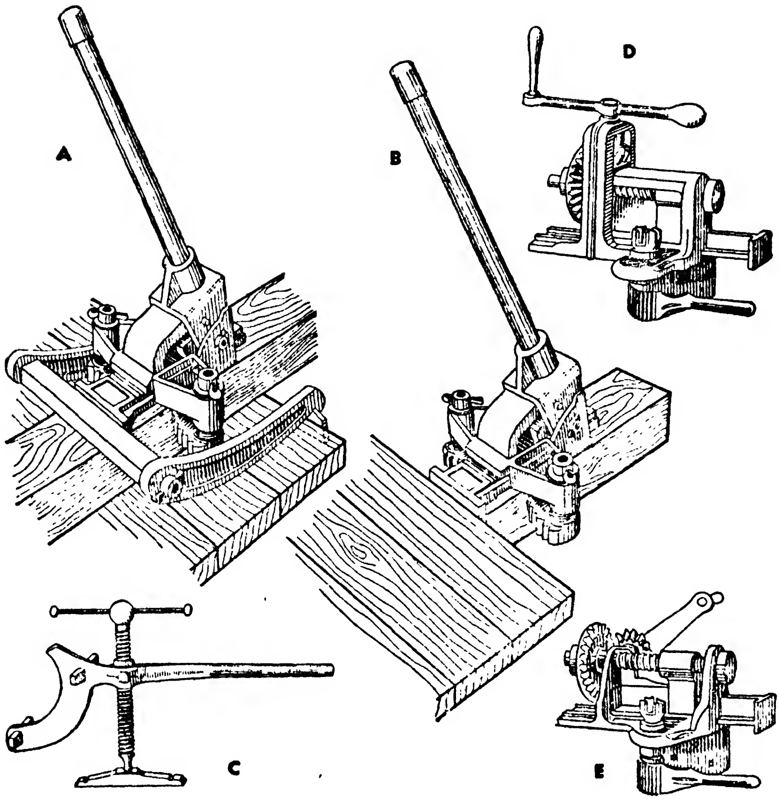


Fig. 9. Various types of floor clamps. *A.* Lever action cramp which will cramp up boards close to a wall·; *B.* lever action cramp on joist. *C.* simple type of screw action cramp ; *D.* top-action screw cramp ; *E.* side-action screw cramp.

from floor to wall of the structure.

Consideration should be given to the methods of laying floors. Floor boards are fixed by nailing either through their faces, or if secret nailed, through their edges into the joists or battens underneath. To assist in making tight joints, flooring should be kiln dried to the moisture content of the finished building, and no flooring should be laid in a building until all glazing is completed and preferably until the heating is installed, especially if the weather is damp or cold. It is just as important to ensure that kiln dried boards are put into a dried building as it is for the boards to be kiln dried at all.

With correctly seasoned boards and efficient cramps it is possible to cramp up six boards at a time. Cramps should be placed at least one to every third joist which makes four cramps necessary for the length of an average room. When cramps are scarce, half the floor is cramped up at a time, but care must be taken to keep the boards in a perfectly straight line.

Boards to be secret nailed are laid singly, and when they are of narrow strip formation cramping is often necessary. All boarding should be as narrow as possible, as wide boards leave wide shrinkage joints and often warp, giving the effect of a series of waves over the surface of the floor.

Various types of floor cramps are shown in Fig. 9. These generally act on the thickness of the joist with either a lever action or screw action to provide the necessary pressure on the boards. Cramps should be left on until all the boards are nailed. Tongued and grooved boards are laid with the groove facing the cramp, and the last board of each cramped section should only have one nail to each joist to allow for the easy fitting of the tongue in the next section. The remaining nail should be driven when the next section is cramped up.

Floor boards are frequently used to cover solid concrete floors.

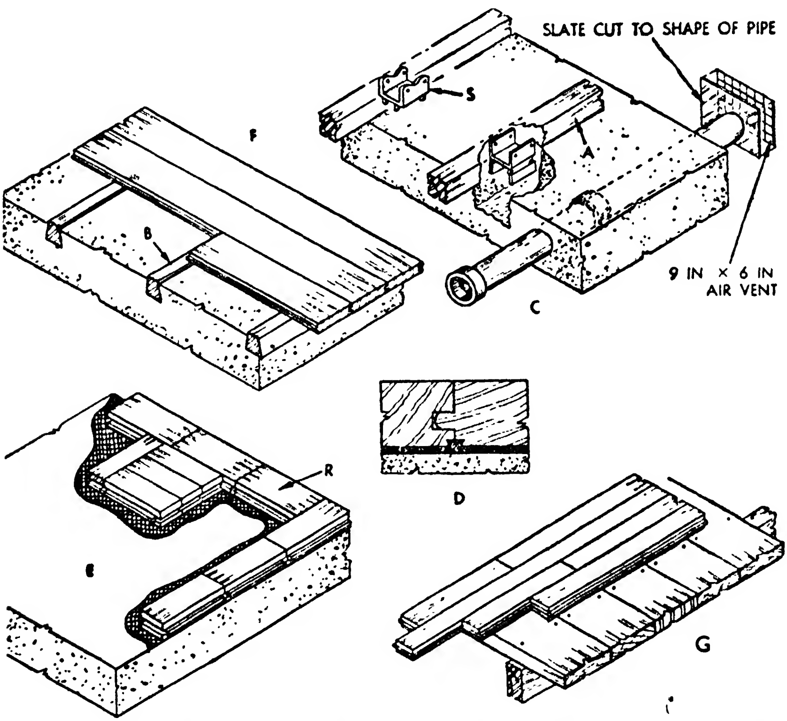


Fig. 10. Coverings to solid floors. *A.* Joists rest on the concrete and are held by clips which are bedded in the concrete ; *B.* joists are bedded in the concrete and are slightly dovetailed to obtain a better grip ; *C.* drain pipes bedded in the solid floor to allow passage of air to adjacent hollow floor ; *D.* section through the joint of solid wood flooring blocks ; *E.* start in laying the blocks with a single border *R* ; *F.* boards shown must be carefully cut to the exact length to fit over a joist, but if the ends are tongued and grooved as at G they may be laid to any length ; *S.* joist fixed in a cradle or saddle which is resting on concrete.

Fig. 10 shows how fixings are arranged for this type of floor. At B a series of 2 in. by 2½ in. joists, slightly dovetailed in section, are bedded in the concrete itself. Wherever joists are buried in concrete or where adequate ventilation is not provided, the joists must be impregnated with creosote or rot-preventing solution before they are placed in position.

It is an advantage to arrange the joists so that they project above the face of the concrete; not only does it facilitate the laying of the floor, but it provides the vital ventilation so necessary for wooden floors. Fig. 10 shows two forms of joist carriers: S rests upon the concrete while A is embedded in the concrete during casting.

It is often necessary to have solid floors adjacent to hollow floors. As provision has to be made for ventilating the hollow floor a 4 in. earthenware drain pipe laid in the concrete, as at C, communicating with an external air brick will allow fresh air to pass through the solid floor to the hollow floor adjoining.

All floor boards laid upon or adjacent to a solid floor should be creosoted on the underside before laying and the concrete should be covered with a damp-proof mastic compound.

Wood Block Floors

Wood block floors, as shown at D and E are laid on a concrete floor which has been brought to a smooth and level bed by a screeding of cement and sand. The screeding should be painted with creosote before the blocks are laid. Bituminous mastic is then heated in a bath and the blocks dipped to a depth of half their thickness. In laying the blocks it is usual to start from the centre of the room for herring-bone pattern, with what is known as the crown row, but for patterns that are composed of straight lines or squares, the floor can be started directly the border is laid. The border may be formed of a single or double row, as shown at R.

Blocks should be laid at least half an inch away from the walls to allow for expansion. On no account should the skirting be nailed to the floor as it will prevent the blocks moving in the event of the floor swelling.

Levelling Off

All flooring blocks should be dovetailed on their bottom edges to form a key for the mastic, as shown at D. An improvement on this is to tongue and groove the sides and ends with an interlocking joint. When the floor is completed, the surface is levelled off with a plane or mechanical sander. If the floor is of hardwood and is to be polished, a scraper is applied after planing. Floors of this nature can be waxed or French polished, any blemishes being stopped up and papered before the final finish is applied.

Parquet flooring is a thinner type of covering usually in oak or walnut, and is laid on top of an existing floor covering. The sub-floor must be planed down level, and all nails well punched below the surface, as any defect or movement will show on the finished parquet. The actual laying is done by fitting the blocks dry and loosely pinning with panel pins. After one row has been fitted, the pieces are lifted, laid in hot, strong glue, and finally pinned down. When the floor is laid all pins are punched $\frac{1}{8}$ in. below the surface and the whole cleaned off, stopped and finished as a block floor.

Plywood flooring squares are sometimes used as a finish, and when not subjected to excessive wear they afford plenty of scope for decorative treatment. Special plywood is obtainable which has a thicker veneer on the face.

Strip Flooring

Strip flooring of the American type is generally of $\frac{3}{8}$ in. oak tongued and grooved together, and is laid across existing boards by nailing through the tongues (Fig. 10 G). Some manufactured 1 in. nominal flooring has square butt ends against the American type which has tongued and grooved ends. In the former case the flooring strips must be selected so that the ends of the floor boards joint over the centres of the joists, otherwise the ends must be cut to the correct length, as in Fig. 10 F. With tongued and grooved ends this cutting is avoided, as the matched ends support each other and the boards can be used in random lengths.

Partitions

Partitions are vertical walls or panels used to divide rooms or portions of a building. They can be constructed in various materials, but where lightness combined with strength is required, timber and associate materials are mostly used.

There are three main types of timber partition; these are (1) the *stud* or *quartered* partition, (2) the *braced* partition, and (3) the *trussed* or *framed* partition. The first type is invaluable in dividing an existing building. The entire weight is supported by the floor, hence the need of a light structure which can be treated in the same finish as the existing walls. The second type is a variation of the stud partition, but a large portion of the weight is transmitted to the structural supports of the building. The third type is capable of carrying loads in addition to its own weight, but is rarely used nowadays.

Stud partitions, as shown in Fig. 11, consist of vertical members called studs. These are of 2 in. by 2 in. to 2 in. by 4 in. in section and are connected to horizontal members called a head and a sill. The timbers are covered with laths and plaster or a suitable building board. Temporary partitions are sometimes covered with canvas and papered or painted with very pleasing results.

Nogging Pieces

The adjoining sketch in Fig. 11 shows the component parts of a partition. Horizontal members between the studs, as shown at B and C, are necessary to stiffen the partition in the same way that strutting stiffens the joists to a floor. Nogging pieces, as these stiffeners are called, may be level or inclined as shown. In both cases the noggings are staggered to enable them to be fixed by nails driven through the studs.

It is usual to make a partition

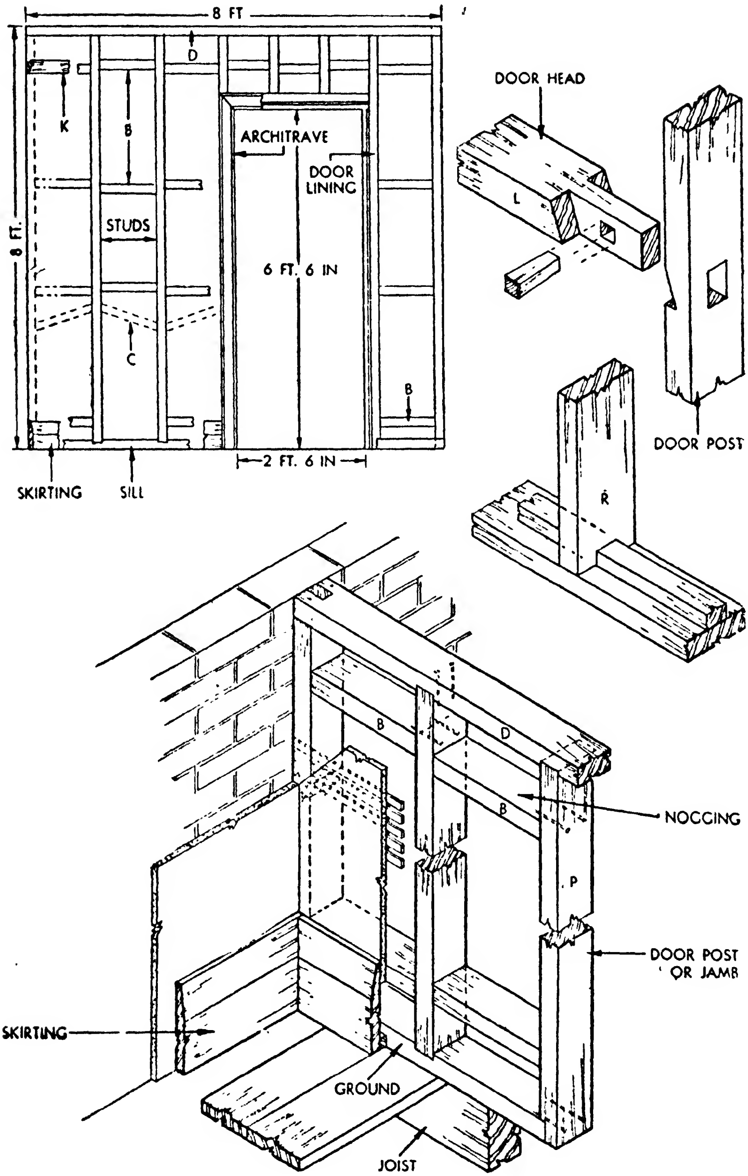


Fig. 11. Detail of stud partition. *B* and *C*. Nogging pieces used to stiffen the studs and to provide fixings for members such as picture rail *K*, and skirting ; *D*. head ; *P*. door post ; *R*. method of forking a stud over the sill ; *L*. door-head tenoned to the door post. Architrave and door lining are also shown.

slightly smaller than the space in which it is to be fitted. A light partition can be assembled on the floor and then erected and fixed. Joints are of a very simple type, but all outer members should be framed together, that is, the wall posts should be tenoned into the head and sill. Interior members can be tenoned or housed or even cut square and fitted with a butt joint, as in the case of the noggings.

Noggings also provide additional fixing for the joinery. Skirtings, picture rails and panelling must be catered for, and noggings should be arranged to give the best fixing for these members.

Studs can be forked over at the head and sill by means of a forking fillet fixed to those members. The door head should always be tenoned to the door posts and the shoulders of the tenons housed into the posts to carry the weight of the partition above the head. Sometimes the door head is termed a lintel.

This type of partition is not self supporting, and unless it rests on a beam or floor, it may tend to take the shape shown in Fig. 12 A. Various means of supporting stud partitions are employed to prevent them becoming distorted.

When studding is used for return partitions, or where one partition is fixed at an angle to another, the junctions must be arranged to provide adequate fixing for the laths or lathing, as shown in Fig. 12 G or similar to the fixing shown at E.

Studding is also used to augment other building materials as shown at Fig. 13 A. This type of partition is known as a *brick nogged* partition, and is formed of courses of bricks placed on edge with 3 in. by 2 in. vertical studs at approximately 2 ft. centres and rows of noggings, approximately 3 ft. apart, to give greater stability to the structure. Although not as rigid as a stud partition, the fire-proof quality is much higher.

Breeze blocks and 'pot' walls of hollow tiles often rely upon timber framing for additional rigidity. For this purpose, door frames are prepared for fixing to other components. In Fig. 13 B the door jamb is carried up the full height of the room and fixed to the ceiling joists, while the door head is continued across the opening and built into the wall. If the frame is to be fixed in the centre of the partition, both jambs should be continuous and fixed to the joists above. The back of the frame is grooved to receive the partition blocks. Partition blocks should be bedded on a stout timber sill to distribute the weight more evenly.

Breeze Block Partitions

Breeze or similar block partitions, like stud partitions, are carried entirely by the floor, hence their use on an existing floor must be accompanied with additional floor supports.

To make a partition self-supporting, braces or struts are inserted.

All the main timbers should be tenoned or housed together, and well nailed, because unless every member is securely fixed in its proper position, undue loads may be wrongly transmitted to other parts of the partition. The studs

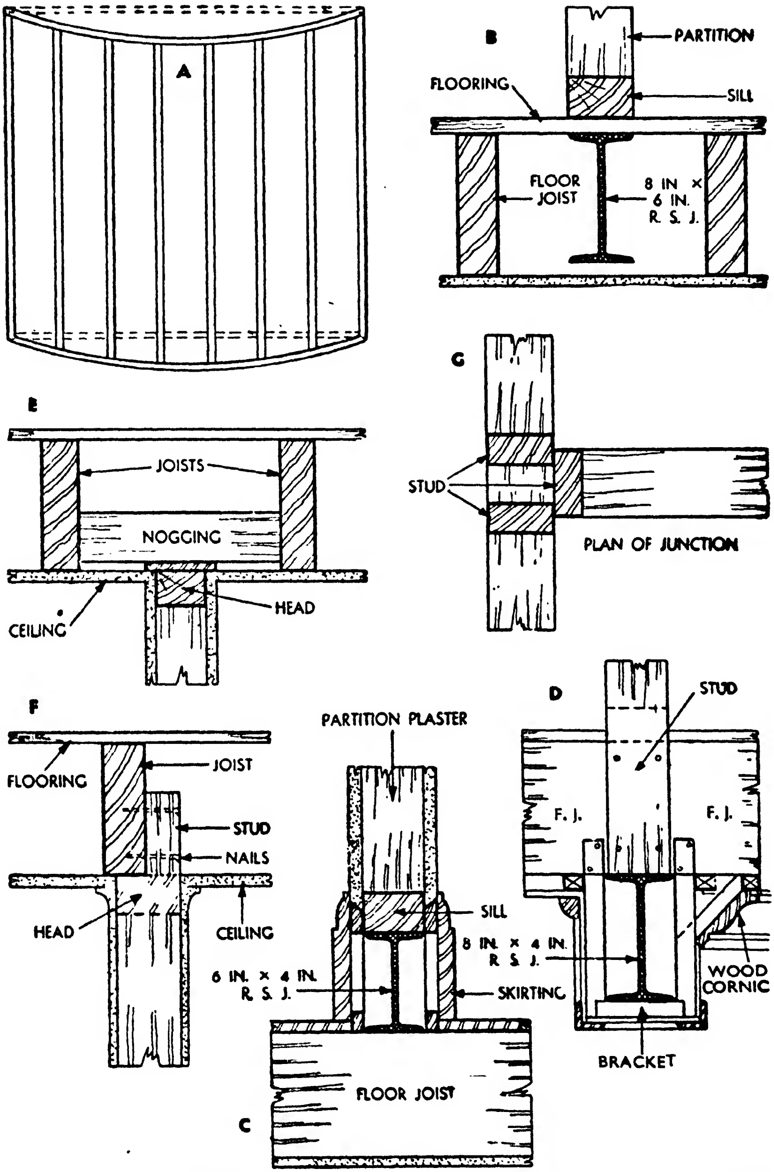


Fig. 12. Further details of stud partition. *A*. Effect of loading on an unbraced partition ; *B*. section through R.S.J. supporting a partition when floor joists are parallel with the partition. When the floor joists are at right angles the R.S.J. can be placed above the floor as at *C* or under as at *D* ; *E* and *F*. methods of securing the head of a partition ; *G*. plan of junction.

over the door head can be arranged to form a pair of braces.

Door linings used in conjunction with wood partitions should be wedged down over the jambs, and where the linings are thin, for example, $1\frac{1}{4}$ in. or less in thickness, fixing blocks should be arranged at intervals along the jambs to provide adequate fixing for the hinges.

Building boards, or as they are often called, *compo boards*, are used extensively on new and old buildings as a covering for timber studs and ceiling joists. The three main categories are :—(1) *Hardboards*, (2) *general wall boards* or *millboards*, and (3) *acoustic or insulating boards*. These three types have a very wide range of uses, the most popular being as substitute for lath and plaster on walls, ceilings and partitions.

Setting out rough grounds for wall boards should be carefully done. Expense in fixing the boards is only a small proportion of the cost, as the major work is in the fixing of grounds, studs and backings. In partitions to be covered with wall board the studs should be arranged to suit the sizes of the boards, and any difference in the spacing of the

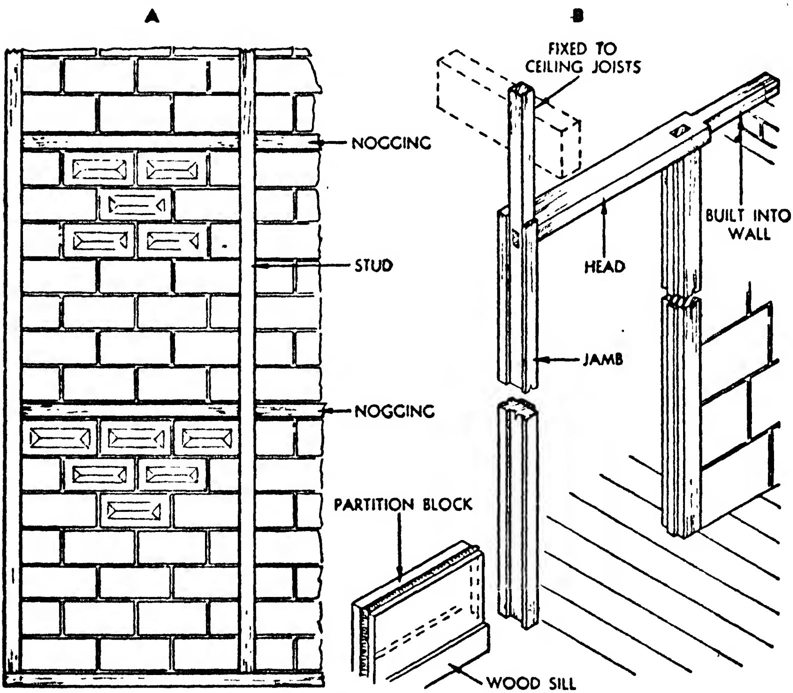


Fig. 13. A. Brick-nogged partition with bricks on edge stiffened by studs and nogging pieces ; B. door-frame prepared for partition blocks. Back of the jamb is grooved for the blocks, and the end extends to the ceiling joists for further security. End of door head is built into the wall at one end and tenoned into door jamb at the other. Both partitions rest on a sill.

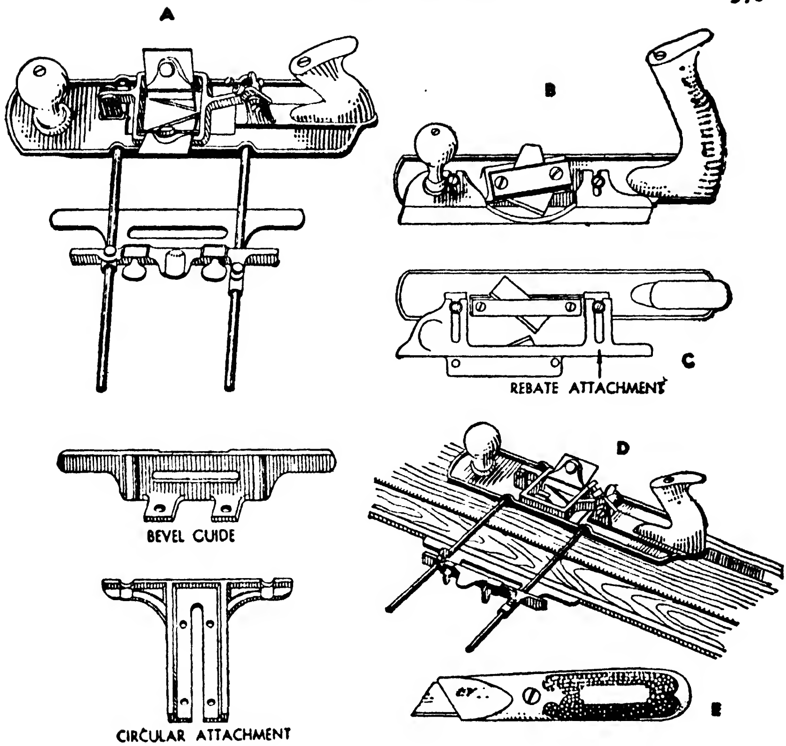


Fig. 14. Building board cutters. *A.* Plane for cutting and shaping wall boards, with bevel guide, and circular attachment ; *B.* plane for edge bevelling and rebating hardboards ; *C.* plane showing rebate attachment ; *D.* plane in use cutting a vee groove ; *E.* type of knife commonly used.

studs should be left at the end so that only one sheet need be cut.

Tools for cutting and finishing hard and insulating boards are various. Hardboards are from $\frac{1}{8}$ in. to $\frac{1}{4}$ in. in thickness and are very dense. Insulating boards and other similar soft textured boards are from $\frac{3}{8}$ in. to $\frac{5}{8}$ in. in thickness. Hence the latter, being softer in structure than hardboards, lend themselves to a wider range of treatment.

Fig. 14 A shows a Stanley fibre board cutter which is specially made for vee cutting, slitting and rebating wall boards. B shows a Stanley hardboard beveller with a stronger cutter than that used for softer boards. An attachment can be fitted to this plane as shown in the plan at C which enables it to be used for rebating. D shows the fibre board plane in use. Without a special plane, boards may be sawn and treated as a softwood; certain hardboards can even be trimmed on their edges with a smoothing plane.

E shows a knife which is suitable for fibre boards. In every case cutters should be as thin as possible in order to facilitate cutting.

CHAPTER 18

ROOF CONSTRUCTION

SLATES AND TILES. MINIMUM SLOPES. ROOF TERMS. DOUBLE ROOFS. VALLEY RAFTERS. PURLINS. HIPPED ROOFS. CEILING JOISTS. TYPES OF EAVES. MARKING OUT RAFTERS. SIZES OF ROOF MEMBERS. TRUSSED ROOFS. GUTTERS. DORMER WINDOWS.

APART from the main purpose of keeping rain, wind, and other climatic effects out of the building, a roof should be so designed and constructed as to give ample stability to an entire structure.

Roofs vary considerably, both in design and general utility, ranging from a flat to a very steep slope. To a large extent the material used for the covering decides the inclination of the roof surface. Tiles and slates are the most generally used covering material. Tiles are small units held in place by nails, and, as the wind is liable to lift them and allow the rain to drive underneath, a steep slope is necessary.

Slates are larger than tiles and are more even on their surfaces, hence they offer more resistance to wind and driving rain. Because of this, slates may be laid to a lesser slope than tiles.

Minimum Roof Slopes

A fair guide to the minimum slopes which should be used is as follows :—

$\frac{1}{4}$ pitch or 26 degrees. Large slates, interlocking tiles.

$\frac{1}{3}$ pitch or 33 degrees. Small slates.

$\frac{1}{2}$ pitch or 45 degrees. Small tiles.

Lead, zinc, copper and ruberoid are used for flat roofs, and they should be laid to a minimum fall of $1\frac{1}{2}$ in. in 10 ft.

Although it is usual to design a roof with the minimum slope for obvious economic reasons, architects often make a special feature of the roof to give added character to the building. In such cases, a much steeper slope than is structurally necessary is used to give a bolder appearance.

While the term *roof* is generally applied to the whole structure of the covering and its support, in carpentry a roof is taken to mean the framework which supports the roof covering.

The distance between the supporting walls is called the *clear span.* For calculation purposes the span is taken from the points where the centre lines of the bearings intersect the walls. This is known as the *effective span.*

The *rise* of a roof is the distance measured vertically from the bottom edge of the sloping surface to the apex of the roof. This term rise has a different meaning when used with the steel square, and reference should be made to Chapter 20.

The slope of a roof is known as the *pitch*, and is the angle at which the roof slope makes with the horizontal. Architects sometimes give this angle in degrees, but the usual practice in the trade is to express the pitch as a ratio between the span and rise.

The pitch is determined by dividing the rise by the span; for example, pitch = rise/span.

A roof with a span of 20 ft. and a rise of 10 ft. would be called a *half-pitch* roof, while a roof with a span of 30 ft. and a rise of 10 ft. would be described as a *third-pitch*. When expressing the pitch as a ratio, the span is taken over the net width of the roof including any overhanging portion.

Common rafters or *spars* are the timbers forming the slope. These span from the ridge to the wall plate. They are called common because, if all the slopes of the roof are made to the same inclination, all the rafters are made to one common length.

A *wall plate* is the horizontal member to which the feet of the rafters are fixed. The plate, usually 4 in. by 3 in., transmits the thrust of the roof to the wall and spreads it evenly over its length.

The *ridge piece* is a board placed at the highest edge where the sloping roof surfaces meet, and to which the heads of the rafters are nailed.

A *valley rafter* is the inclined member at the internal angle where the roof surfaces meet.

A *hip rafter* is the inclined member placed at the intersection between two roof surfaces which form an external angle.

Jack rafters are rafters reduced in length to intersect the hip or valley rafters. Where they intersect both the hip and the valley rafters they are sometimes called *cripples*.

The *eaves* form the lowest edge of a roof surface whether the roof

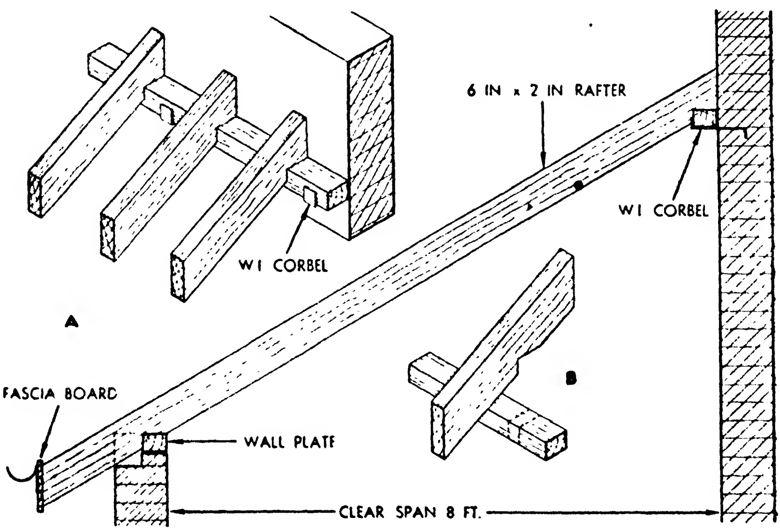


Fig. 1. Lean-to roof suitable for spans up to 8 ft. Both ends of the rafters are supported by wall plates. A. Plate carried by 2 in. by $\frac{3}{16}$ in. wrought-iron corbels built into the wall. As shown at B. the feet of the rafters are notched over the wall plate, which is levelled and bedded in cement mortar.

is flat or pitched. Eaves may be closed or open as shown in Fig. 6 A and B.

A *sprocket* is a member or firring piece fixed to the rafter feet to break the main pitch and cause the tiles or slates to bed tightly at their ends or tails. A *tilting fillet* is used for a similar purpose.

A *purlin* is a stout member whose purpose is to support the common rafters at intermediate points along their lengths. The purlins are in turn supported by cross walls or by struts from partitions. If these supports are not available, the purlin is braced and strutted, and is known as a *trussed purlin.*

Single roofs consist of sloping surfaces formed by rafters supported at the head and feet only with no intermediate support. The simplest example is that of a *lean-to* roof as shown in Fig. 1. When it is desired to roof a shed or out-building against a main wall, and the span does not exceed 8 ft., the usual method is to form a single slope, pitched to suit the covering, and made to lean against the wall. The wall plate on the lower wall is levelled and bedded in cement mortar, while the plate at the higher main wall rests on iron corbels, as shown at A.

A good way of supporting the top plate is to add an extra $4\frac{1}{2}$ in. of brickwork to the main wall in the form of an offset as shown in Fig. 2 A. Alternatively, the plate may be supported by corbelling the brickwork as shown at Fig. 2 B. The rafters are notched over the plates and well nailed. This notching is termed *bird's-mouth*, and is used throughout roofing practice as the standard wall plate joint. The depth of the notching should be one-third the depth of the rafter, as shown in Fig. 3.

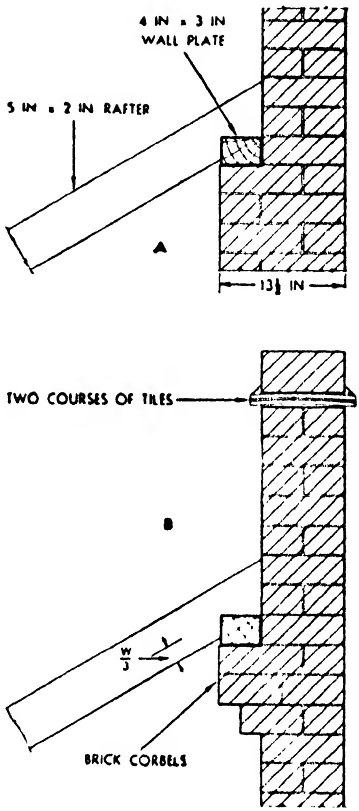


Fig. 2. Alternative methods of supporting top wall plate in a lean-to roof. A. Plate is supported on an offset; B. plate rests on brick corbels which project from the main wall.

The type of roof known as a *couple roof*, is formed by a series of rafters arranged in pairs or couples, and spaced at 12 in. to 16 in. centres. As described in Chapter 7, any weight on this inverted vee tends to spread the

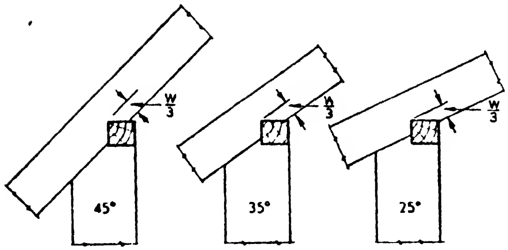


Fig. 3. Bird's-mouth joint between rafters and wall plate. Diagram shows proportion of notching in three different pitches. In all cases the notch is made in the rafter to one-third its depth.

feet of the rafters. Consequently, the rafter feet must be well secured as a considerable outward thrust is exerted. This limits the span to about 10 ft.

To obviate the tendency of the rafter feet to spread outwards, the rafters are tied together. This type of roof is known as a *close couple*. Details are similar to the couple roof, but with the addition of an extra member called a *tie*. Its purpose is to tie the rafters together in a triangulated frame. By this means spans can be increased to 14 ft.

The joints are all as previously stated; rafters are notched over the plates and well nailed; at the head, the rafters are butted against the ridge board to which they are well nailed.

As the ties are to prevent the rafters spreading, their greatest stress is tensional, and the joints

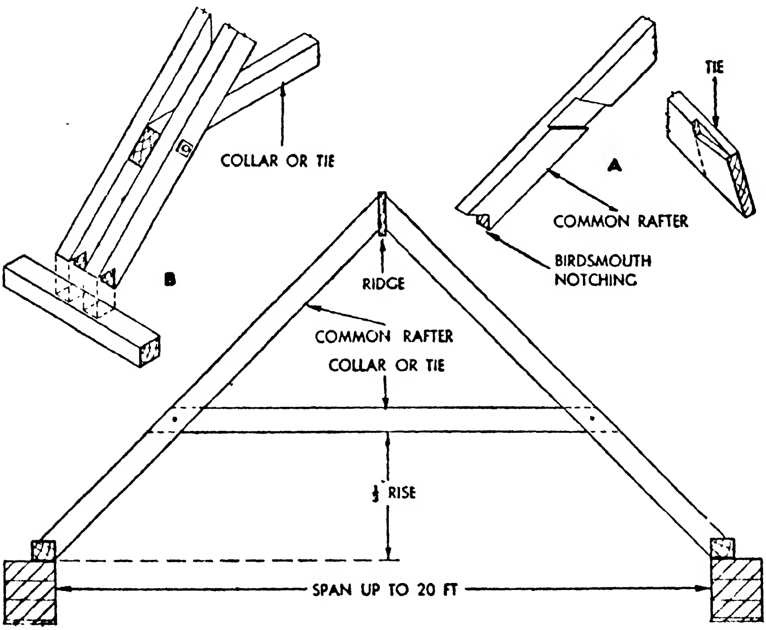


Fig. 4. Collar roof for spans up to 20 ft. Rafters are tied together with a collar or tie spaced one-third up the roof. Alternative methods of jointing the collar to the rafters are given. A. The usual dovetail halving-joint; B. the collar bolted between double rafters with a bolt of ½ in. diameter and 2 in. by 2 in. washers.

between the ties and rafters must be carefully made. A strong tension joint is difficult to make in timber. A good solution to this problem is to use double rafters and use one tie between, with a half-inch bolt through all three members (Fig. 4 B). It is always better to use bolts than to rely solely upon nails. The double rafters with its tie need only be used at every third rafter.

A *collar roof* (Fig. 4) is similar to a close couple, but the tie, known as a *collar*, is placed above the level of the wall plate. It is sound practice to place the collar about one-third up the rise to prevent excessive bending stress in the rafters. Because there is no tie at the wall level, the length of rafter from the wall plate to the collar tends to spread outwards, at the same time subjecting the collar joint to severe bending stress.

As previously stated, a collar or tie should be bolted between two rafters, as shown at Fig. 4 B. This gives an ideal job, and is far superior to the usual method of dovetail housing shown at Fig. 4A. The rafters depend upon this dovetail to prevent spreading, but the shrinkage of the timbers nearly always loosens the joint. At the same time the rafters are weakened by the housing in the position subjected to the greatest stress. Coach screws may be used instead of bolts.

The advantage of the collar is that it ties together the rafters, and by combining a couple for the lower half and a closed couple for the top, spans can be increased to 20 ft.

This system is often used in church halls and schools where a ceiling is not required. When timbers are exposed to view, it is considered that rafters of almost square section give a better appearance. Such members are usually dressed or wrought. This word is sometimes written as *wrot*, and means that the timbers are to be planed.

So far, single roof slopes, supported at the ends only, have been dealt with, but it will be obvious that larger spans will require heavier timbers in proportion. It is not wise or economical to use large size timbers, hence other means are employed to enable stock sizes to be used for all types and spans of roofs.

Use of Purlins

For a large span, intermediate members called *purlins* are used to give additional support to the rafters every 7 to 8 ft. The use of purlins to a lean-to roof enables 4 in. by 2 in. rafters to be used for a span of 16 ft. In this case the purlins rest on the gable end and the party wall, and the rafters span from the main wall to the wall plate.

To maintain economic timber sizes, the cross walls or partitions which support the purlins should not be more than 10 to 12 ft. apart. A roof with purlins to support the rafters is known as a *double roof*. Such roofs are widely used for domestic purposes, and Fig. 5 clearly illustrates the general arrangement of a typical house roof.

The clear span, as shown, is 21 ft. and the pitch is a half pitch or 45 deg. This gives a rafter length of 15 ft. 6 in., which means that if the rafters span

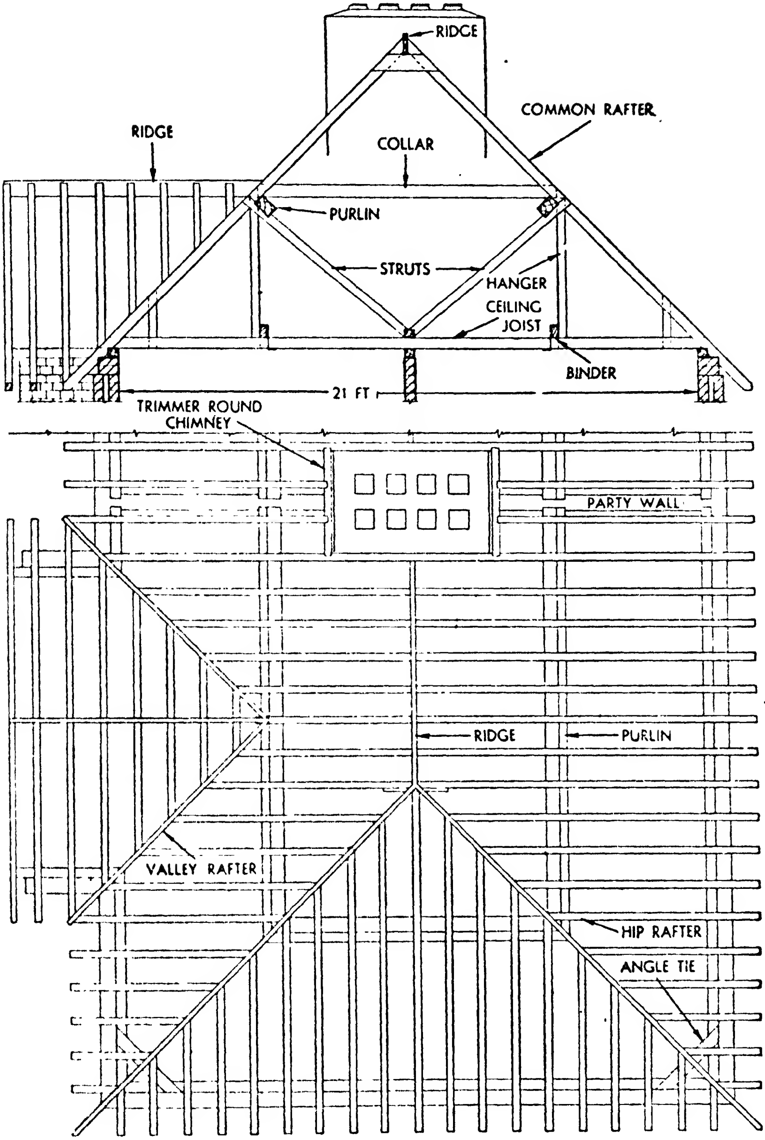


Fig. 5. Suitable sizes for this roof are: Ridge piece, 7 in. by 1½ in.; common rafters, 4 in. by 2 in.; ceiling joists, 4 in. by 2 in.; collars, every fourth rafter, 6 in. by 2 in.; purlins, 8 in. by 5 in.; struts, at 6 ft. centres, 3 in. by 3½ in.; hangers, every third rafter, 3 in. by 2 in.; binders to support the ceiling joists, 4 in. by 2 in., with 1 in. by ⅛ in. W.I. straps; valley rafter, 7 in. by 2 in.; hip rafter, 9 in. by 1½ in.; angle tie, 4 in. by 2 in.; trimmer round chimney, 5 in. by 2 in. Note the 4½ in. space between the timbers on the party wall.

from the wall plate to the ridge without an intermediate support, they would have to be of 8 in. by 2 in. material. By using a purlin to support the centre of each rafter, the rafter sections can be reduced to 4 in. by 2 in. spaced 13 in. apart.

The distances between the rafters can be up to 18 in., but as the ceiling joists are attached to the rafters, it is usual to space them at 12 in. or 15 in. centre to centre, to accommodate the laths for the ceiling.

Again, if the rafters are more than 14 in. apart, stronger battens must be used to support the slates or tiles.

In the cross section of the roof in Fig. 5 is shown a projection from the main building. This extra portion of the roof is called a *gablet*, and introduces valley

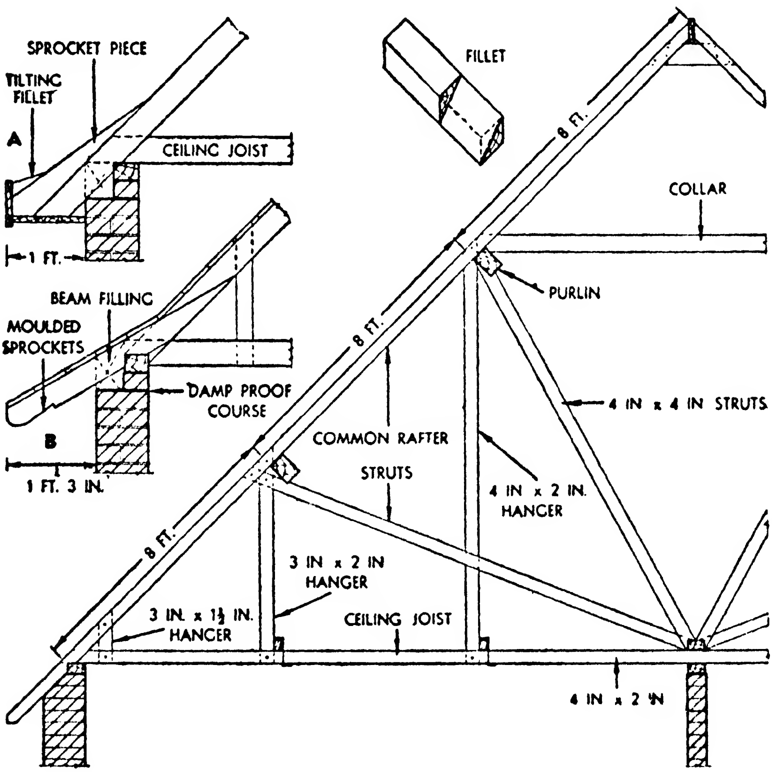


Fig. 6. House roof suitable for span of 33 ft. 4 in. by 4 in. struts are spaced at 6 ft. centres ; hangers every third rafter ; collars are spaced at 6 ft. centres. The 4 in. by 2 in. ceiling joists are fixed to the 4 in. by 2 in. binders with iron straps at every joint. The rafters are spaced at 14 in. centres. A. Detail of a roof with closed eaves, with a sprocket piece nailed to the edge of the rafter ; B. detail of a roof with open eaves with moulded sprockets nailed or bolted to the side of the rafter. Dotted lines indicate the beam filling.

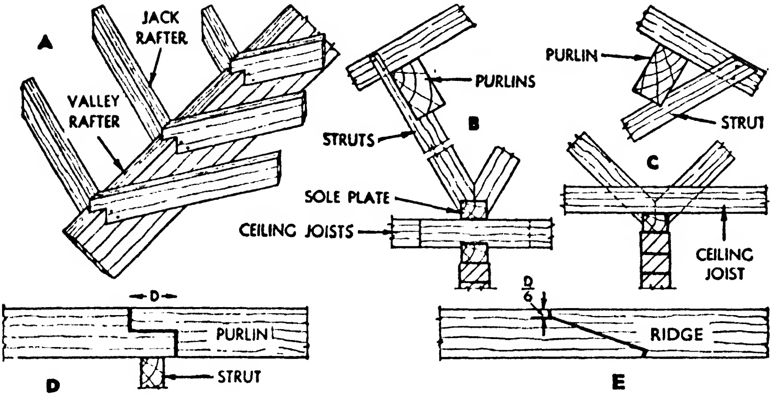


Fig. 7. Details of the joints used in a house roof. *A.* Valley rafter set low so that jack rafters can obtain a good bearing ; *B.* how purlins are strutted from a sole plate. Ceiling joists can be jointed together by notching over the partition plate, but their ends must project at least 6 in. on either side of the bearing ; *C.* alternative arrangement of joints between purlin and struts ; *D.* scarfed joint suitable for a purlin supported by a strut ; *E.* scarf joint suitable for ridge, hip or valley rafter. The top cut is vertical and bottom cut perpendicular to scarf pitch.

rafters. On the drawing, the common rafters are shown bird's-mouthed over the valley rafter, but a more usual way with a small gablet is to continue the rafters of the main roof down to the wall plate, and to nail a 7 in. by 1 in. valley board across the slope to receive the feet of the jack rafters.

Fig. 6 shows the construction of a roof for a span of 33 ft. This requires identical sizes to those used in the roof shown in Fig. 5, except that the struts should be stouter because of their extra length. Two purlins are shown, but with 6 in. by 2 in. rafters, one purlin only need be used, but it would have to be of 11 in. by 4 in.

Purlins are heavily loaded beams which support the whole weight of the rafters. Their ends, therefore, should have a sound bearing. Where a purlin butts against a hip or valley rafter it should be well strutted.

Joints made in the length of a purlin should be halved together with a strut under the joint as shown in Fig. 7 D. A purlin should be set at right-angles to the rafters with its edge against them, and struts supporting the purlins should be inclined at right-angles to the pitch of the roof.

Position of Struts

The struts at the top should be notched to receive the purlin, and continued to the rafters and well nailed, as shown in Fig. 7 C. It is important to make the centre line of the strut as near as possible to the centre line of the purlin. The bottom of the strut should be bird's-mouthed over a sole piece resting on a partition or party wall.

Struts are subject to compression, and not only must they have a firm base, but they should be stiff enough to take loads without buckling. For this reason struts should be square in section.

If partitions are not available to support a purlin, it should be fixed vertically and strutted off the wall with the rafters notched over the corner of the purlin. Where there are no partitions from which to strut the purlins, and where the party walls are wide apart, *trussed purlins* may be used. Where trussed purlins are employed distances of 20 to 30 ft. can be spanned.

A valley rafter is a form of beam which supports considerable weight due to the downward thrust of the jack rafters. It is better to set the valley below the face of the rafters and to bird's-mouth the jack rafters over it as shown in Fig. 7 A than merely to nail the jack rafters flush with the valley edge.

If necessary, hips and valleys may be jointed with a simple scarf as shown in Fig. 7 D, provided that a strut is placed under the joint. Valleys should be 2 in. thick and twice the depth of the common rafter.

The ridge piece is usually 7 in. by 1¼ in. or 1½ in. As it does not support weight, but only serves as a fixing for the rafters, lengths may be jointed together with a scarf. The method of jointing is shown in Fig. 7 E.

Hip Sizes

Hips are similar to ridge boards and serve to anchor the jack rafters which thrust against each other. If the purlins are strutted, hip sizes should be 1½ in. by twice the depth of the rafters. For pitches greater than 40 deg. an extra inch should be added to the depth.

The weakness of a hipped roof is at the corner of the wall plate where the thrust caused by the weight of the purlins down the hip tends to push the wall plates out. This point should be

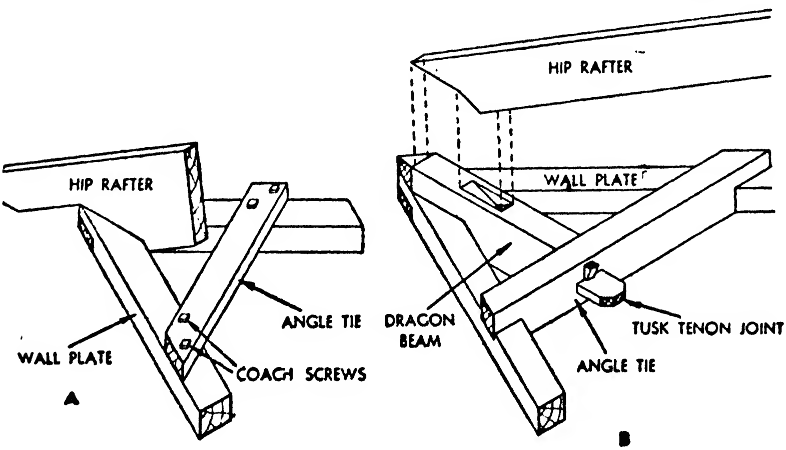


Fig. 8. Methods of holding the corner of a roof against the thrust of the hip. *A*. 4 in. by 2 in. angle tie fixed with coach screws to the wall plate ; *B*. 6 in. by 3 in. angle tie is halved into the wall plate to a depth of ¾ in. A 6 in. by 3 in. dragon beam to carry the foot of the hip rafter is jointed by a tusk tenon to the angle tie.

strengthened, and the method frequently adopted is to dovetail-halve a 4 in. by 3 in. *angle tie* across the corner, in a similar manner to that shown in Fig. 8 A. This member often shows in the ceiling below and forms an awkward angle for the plasterer.

To overcome this difficulty. ceiling joists should be notched over the wall plates up to one-third their depth. Alternatively, a 4 in. by 2 in. angle tie, coach-screwed to the wall plates, may be used to enclose all members within the ceiling depth. Ceiling joists may then be notched over the tie.

Where two purlins are used on a large hipped roof, considerable pressure is exerted on the corner of the building, and nailing the members together is not sufficient. A stronger tie should be used to secure the wall plates, and a *dragon beam* framed into it to support the hip, as shown in Fig. 8 B. The strength of this construction is given by the angle tie being housed into the wall plates.

Ceiling joists are important members of a roof, because they tie the feet of the rafters together and prevent them spreading. In addition, they must be strong enough to carry the weight of the ceiling and any loads in the roof space without danger of cracking the ceiling surface. The joints of the ceiling joists at the eaves must be carefully made, and particular attention should be given to ensure a strong tie to the rafters. This joint is often badly made by merely nailing the members together. Better methods are shown in Fig. 9.

At Fig. 9 A the ceiling joists are notched over the wall plate, and any tensile stress is resisted by the bearing area of the notching. Each joist is continued well beyond the notch to resist shear along the end fibres. This projection may be used as a fixing for the soffit boards, but a sprocket piece must be used for the purpose

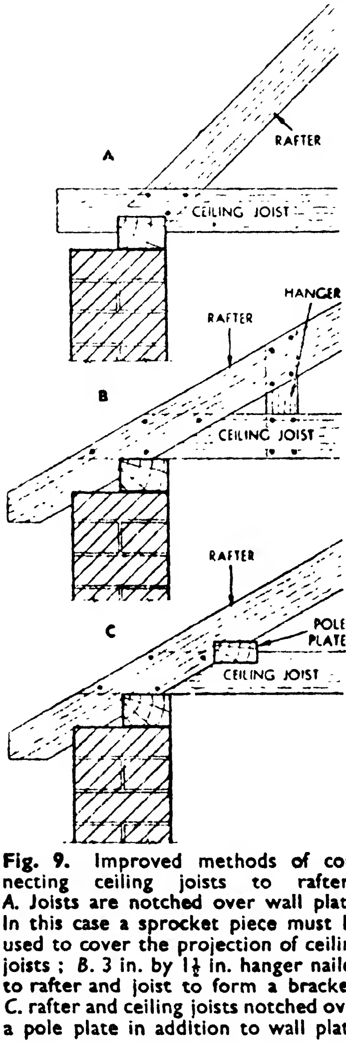


Fig. 9. Improved methods of connecting ceiling joists to rafters. A. Joists are notched over wall plate. In this case a sprocket piece must be used to cover the projection of ceiling joists ; B. 3 in. by 1½ in. hanger nailed to rafter and joist to form a bracket; C. rafter and ceiling joists notched over a pole plate in addition to wall plate.

of covering the projecting ends.

Alternatively, the rafters may be bird's-mouthed over a *pole plate* in addition to the wall plate, as shown in Fig. 9 C. If these methods are not used, short hangers should be nailed to the rafters and the joists, as shown in Fig. 9 B.

The usual method of erection is to nail the rafters to ridge and plate first, and then fix the ceiling joists. In the methods shown in Fig. 9 A and C, it is necessary to reverse the procedure and fix the ceiling joists first and the rafters last.

The sizes of ceiling joists for a clear span of 8 ft. are 4 in. by 2 in. spaced at 13 in. centres. If the span were 16 ft. then 8 in. by 2 in. joists would be required. To enable lighter joists to be used for a large span, members called *binders* are used to give intermediate support in a similar manner as a purlin supports the rafters.

But there is one important difference; a purlin is always fixed under the rafters which bear upon it, while a binder is invariably fixed on top of the ceiling joists which hang to it.

Because of the difficulty experienced in making a joint, it is necessary to make some allowance in the size of the joist for the connections.

Safety Measures

It is no longer possible in the London area to use joists of 4 in. by 2 in. for spans of 14 to 15 ft., even when a binder is employed, if nails are the only means of jointing. Ceiling joists must be properly secured by means of joints or bolts and wrought-iron straps.

Ties are the members which do not carry a ceiling, but which span the roof between the purlins. They should be notched over the purlin and well nailed to the side of the rafter. One tie to every fourth or fifth rafter is sufficient.

The character of a whole building can be completely altered by making a feature of the eaves. By using a large overhang, much can be added to the appearance of an otherwise plain and uninteresting building.

Eaves may be divided into three main classes, all of which can be used with any type of building or roof design.

Main Types of Eaves

(1) *Closed Eaves.* Fig. 6 A. When the rafters overhanging a wall face are completely hidden from view by using horizontal and vertical boarding, they are known as closed eaves. The horizontal board, called a *soffit lining*, consists of either wide boards tongued and grooved together, or vee-jointed matching. The soffit is fixed to bearers which are nailed to the feet of the rafters to form a bracket. The vertical board, which is known as *fascia*, is grooved to receive a tongue on the soffit and projects one inch below the underneath soffit level thus forming a drip.

This form of eaves treatment is a structural asset. If the overhang is large, considerable extra weight is added to the feet of the rafters. This strengthens and stiffens the rafters by counterbalancing the load about the point of support, namely, the wall plates. It is of special use with a couple or collar roof, as it helps to counteract the tendency of the rafters to spread. An overhanging roof also keeps rain off the walls and forms a protection to windows underneath by preventing rain blowing in at the top.

(2) *Open Eaves* (Fig. 6 B) consist of projecting rafters without the soffit and fascia. In this case, the exposed feet are usually wrought and moulded. If the whole roof is not boarded, it is advisable to board the eaves, as this portion can be seen from underneath. This type used with a bold sprocket gives a pleasing pagoda effect when the covering is of pan tiles.

(3) *Flush Eaves.* When property is built along a boundary line, no part of the building must be allowed to project over the line. It is necessary, therefore, to arrange the gutters flush with the wall. This is bad construction, as the slightest leak in the gutter or eaves covering will penetrate into the wall.

Fig. 10 gives the general arrangement of closed eaves con-

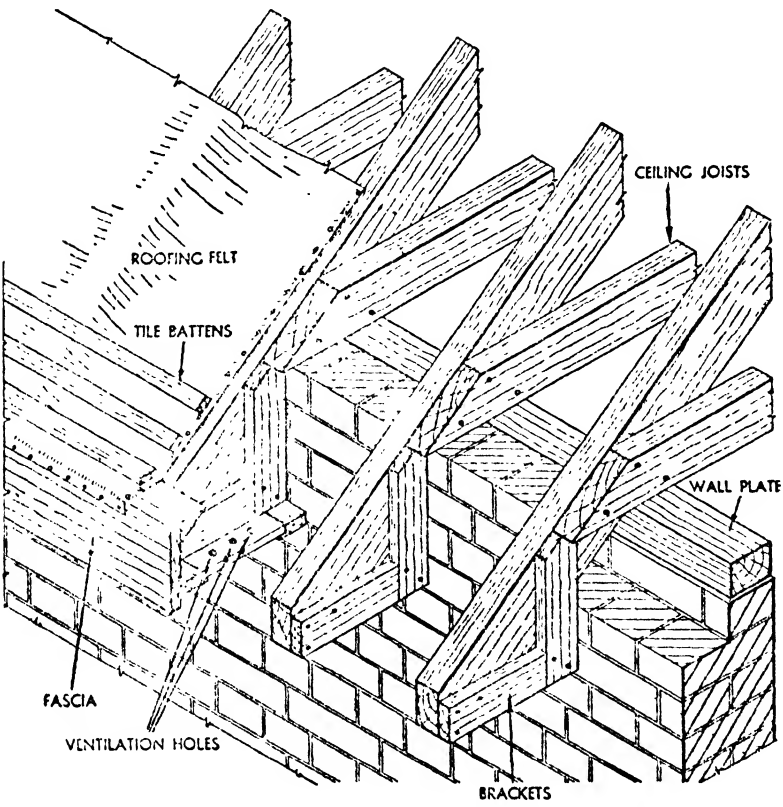


Fig. 10. Isometric view of eaves construction showing brackets of 3 in. by $1\frac{1}{2}$ in. halved together and nailed to rafter feet. Note the ventilation holes in the soffit board, and the roofing felt nailed over the edge of the fascia.

struction and shows the preparation for soffit and fascia. Ventilation should be provided by drilling a row of $\frac{3}{4}$ in. holes at 6 to 8 ft. centres across the width of the soffit. If cost prohibits full boarding and felting, the overhanging portion should have one 3 ft. width of roofing felt secured to the rafters with the edge turned over 1 in. on the fascia, and close nailed with non-corrosive clout nails. This is necessary in order to prevent leakages at the eaves from penetrating to the soffit and brackets. The usual ventilation arrangements about this portion of a roof do not allow timbers to dry out and a saturated member in a closed space will soon decay.

Sizes of roof timbers should be selected with care in order that the strengths of members, joints, and fastenings are balanced. It is no use having strong purlins and weak rafters on flimsy struts; due regard must be paid to the proper spacing which controls the scantling required.

When marking out rafters for cutting, the hollow side should be placed upwards. The reason for this is to enable the tiles or slates to bed more firmly at their tails. This concave surface is encouraged by the use of sprockets and tilting fillets. On the contrary, ceiling joists are placed hollow side down to prevent the appearance of a sagging ceiling.

Where a roof span exceeds 20 ft., and partitions or cross walls are not available, a strong timber frame called a *truss* is used to support the purlins. The main types of trusses in common use are shown in diagrams in Fig. 11.

As previously stated in double roofs, all members should be supported every 8 to 10 ft. to maintain economic sizes, and in selecting or designing any roof truss, particular attention should be given to this important factor.

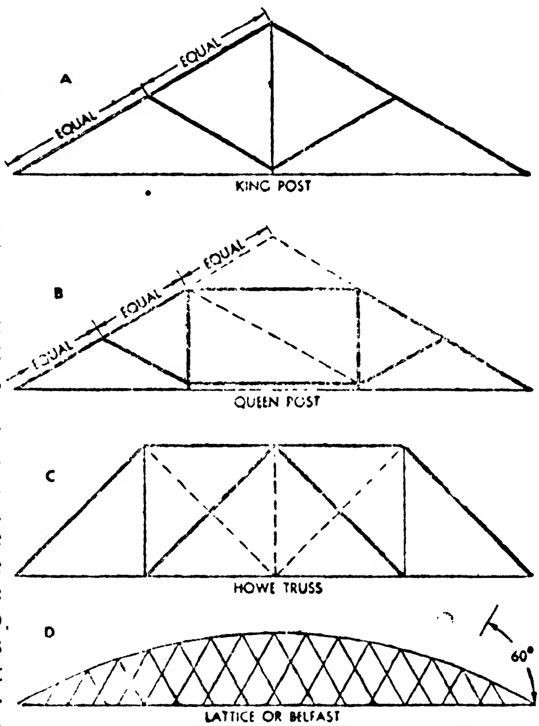


Fig. 11. Main types of common roof trusses. A. King-post roof truss; B. Queen-post roof truss to support two purlins; C. Howe truss. For a large span, extra braces shown dotted, should be used; D. lattice or Belfast truss. Double lines indicate compression, single lines, tension.

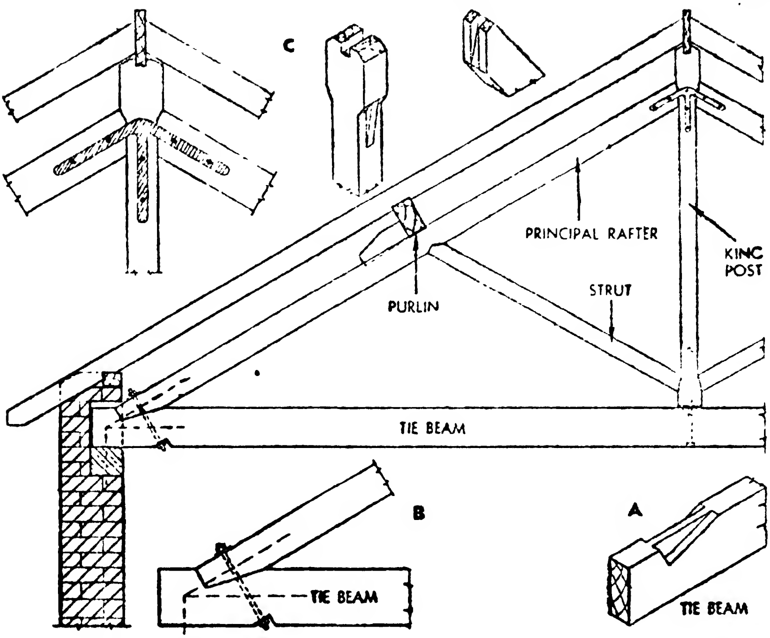


Fig. 12. Part elevation of king-post roof truss for span of 20 ft. Principal rafter is framed into the tie beam by a bridle joint shown at *A* or by an oblique mortise and tenon joint. The principal rafter is connected to the king-post in a similar manner as shown at *C* and is held by a three-ways strap.

A truss should adequately support the purlins of a roof, and transmit their weight to the walls.

Except possibly for church work, timber trusses are not used to a great extent to-day. Their place has been taken by steel trusses, which are much cheaper in first cost and are quicker to make. Over a period of years, however, timber trusses are definitely more economical, as metal requires regular wire brushing and painting to preserve it from rust, while timber needs very little attention.

The most suitable and commonly used truss for spans of 20 to 30 ft. is the *king-post roof truss*, as shown in Fig. 12. The truss consists of a triangular frame with two main or *principal* rafters, with a tie-beam to hold the feet from spreading, and a centre post to tie the whole frame together. The principal rafters have additional support at the point where the purlins are fixed by inclined struts, which are fixed to the foot of the king-post.

The distance from the joint of the strut to the end of the post, should not be less than 6 in., so that enough timber is provided to resist shear along the grain. Fig. 13 B shows how the joint is made. The principal rafter is framed into the tie beam up to one-third its depth, and a tongue is formed on the beam or a tenon on the rafter. This tongue or tenon prevents any lateral move-

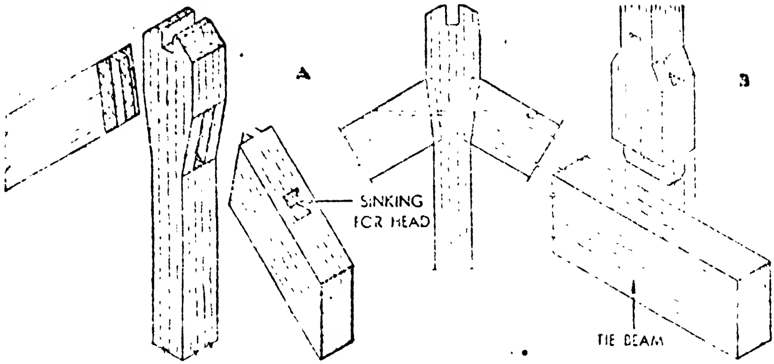


Fig. 13. Details of joints to king-post roof truss. A. Principal rafters tenoned into post. In this case a bolt holds them together instead of a strap. Note the sinking for the head ; B. joint between the tie beam and the foot of the king-post.

ment. The former method is known as a *bridle joint*, and is shown in Fig. 12 A.

When the tenon is on the rafter the shape of the notching is the same, that is, square to the pitch. These bridle joints are conventional ones, but a ¾-in. bolt through a notching which is merely butted will serve the same purpose to prevent slipping. This is shown in Fig. 12 B.

At the top of the truss, the principal rafter is notched into the post in a similar manner, and here again the tongue or tenon could be omitted if a bolt passes through the members, as shown in Fig. 13 A. The foot of the post is made about ½ in. short, so that when the bolt or strap to the tie beam is tightened, all the joints will close and at the same time produce a camber to the beam. This is necessary to allow for any movement which would allow the beam to sag.

Trusses may be assembled in the shop, or on the site and are hoisted by the appliances shown in Chapter 15. A rope is lashed under the principal rafters, and the whole truss is swung into place. Joints, therefore, must be able to withstand any side thrusts.

Alternative Method

An alternative method to support the purlins in a roof of from 20 to 30 ft. span is to use a *king-bolt truss*, as shown in Fig. 14, with a wrought-iron or steel bolt as a substitute for the post. A vee-shaped strap is used to hold the joint at the top of the rafters and a large steel plate is inserted under the tie beam.

The principal rafters butt together at the apex with a short strap on each side, as shown in the details. If the bolt is a fair fit, the straps will prevent any side movement. In addition, the vee strap is coach-screwed to the rafters.

It is emphasised that trusses are only used to support the purlins. Usually they are spaced at 8 to 10 ft. centres, and where a hipped end is required, the centre of the end purlin should always be firmly supported on a half truss bolted to the king-post.

It should be noted that all joints are designed about a centre line, and that the centre lines of all members meet at the same point. Particular attention should be paid to this, as the balance of the truss and the joints depends upon it.

First set out the line diagram of the truss and then on each side of the lines mark the width of the timber.

The bearing of any truss should rest on the wall at least 6 in., and a template should be used to distribute the weight of the roof over the wall.

A *queen-post truss* is suitable for spans up to 40 ft. The two posts support the tie beam and the struts to purlins. The truss is not so well triangulated as the king-post, and cross-braces may be inserted in the centre portion of the truss, as clearly indicated by the dotted lines in Fig. 11 B.

If a flat roof is not objected to, a truss similar to a trussed purlin will allow spans of 60 ft. or more. With a span of this size, braces should be inserted, as shown in Fig. 11 C. The main beams in this truss should be constructed with a camber of ½ in. in 20 ft. to allow for any settlement in the numerous joints when the truss is loaded.

As it is usually rather difficult to obtain timber in lengths over 20 ft., the joints in the tie beams should be spliced with a steel plate bolted to the under side.

Large spans can also be covered by using the *Belfast* or *bow string* truss. This is similar in form to a large center and the finished construction forms a strong lattice girder. The radius for the curve is determined by taking ⅛th of the span for the rise.

There are several methods of dealing with the lattices. The

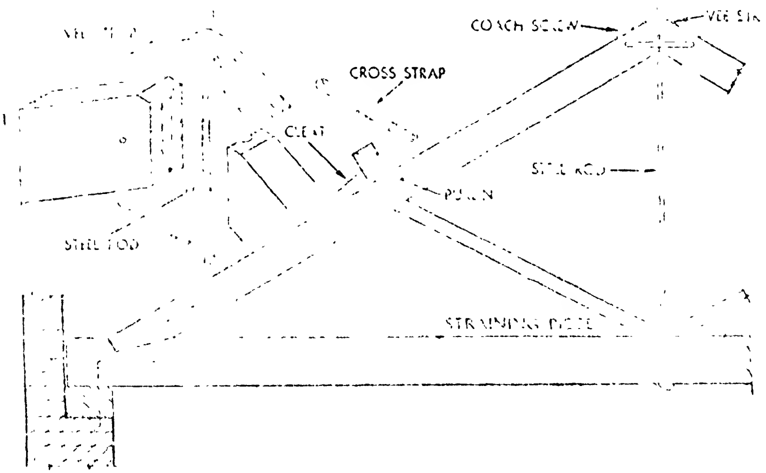


Fig. 14. King-bolt truss for spans from 20 to 30 feet. This truss is a good alternative to the king-post truss. The purlin rests on the principal rafter which is held at the top by a vee strap and the cross strap. The steel rod passes through the truss and is well bolted at both ends.

illustration of the truss in Fig. 11 D shows the lattices inclined at 60 deg. to the horizontal, while Fig. 15 shows the lattices set-out radial with half the span as centre. The curved bows and tie beam are both double, while the lattices cross each other and are nailed between them. The gaps at the ends are filled with packing pieces having the grain vertical. These are continued up to the first purlin and bind the bow and tie beam together. A steel strap with a connecting plate and washer is fixed to each end to complete the joint.

The lattice bars are carried through the truss sufficiently to form a seating for the purlins which are of 4 in. by 2 in. spaced at 2 ft. centres.

The bow is bent round the curve. Where the depth exceeds 3 inches, the member is laminated in two or more thicknesses as shown in Fig. 15 B.

Bending the Bow

No difficulty will be experienced in bending the bow provided that the radius of the curve has not more than $\frac{1}{8}$th of the span as the rise.

These trusses are spaced at 8 to 10 ft. centres and have two runners that span the length of the building, well nailed at the

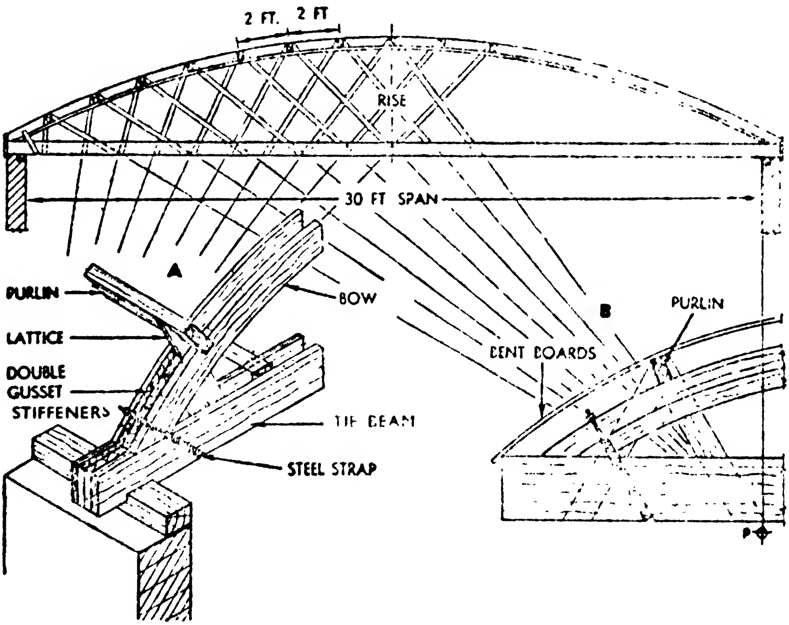


Fig. 15. Bow string or Belfast roof truss. The rise is equal to one-eighth the span and the lattices are set out radially from a point *P* equal to half the span. Purlins are spaced at 2 ft. centres and trusses 8 feet apart. A. Detail at the bearing, with bow tie beam, steel strap, purlin, lattice and double gusset stiffeners; *B*. how the bow is laminated when over 3 in. deep. The boards are bent round and nailed to the purlins, and the tie beam is in two pieces.

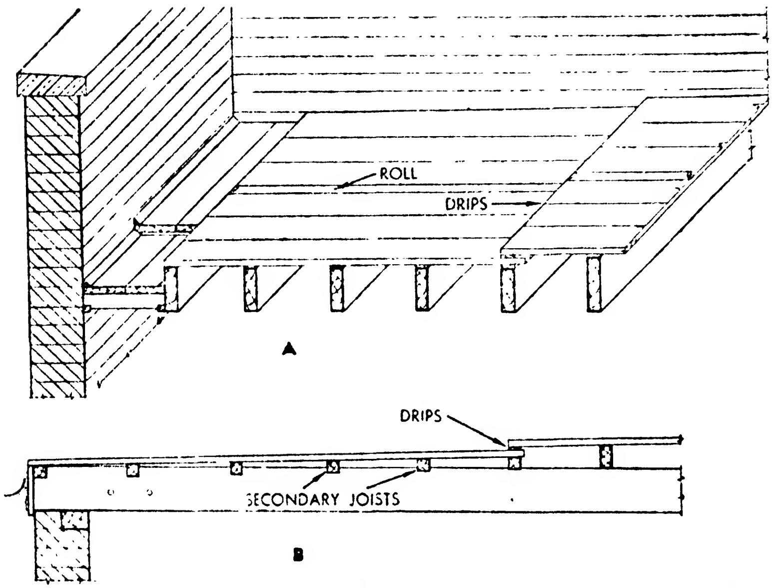


Fig. 16. Lead flat details. A. General arrangement with drips to form length joint of lead, and rolls to form width joint. Fall is obtained by packing or firring each joist ; B. joists are laid in the direction of fall, and secondary joists, which are nailed across the top for the boards, give the fall.

sole of each truss to prevent side movement, with a row of cross bracing between each pair of trusses secured to the top of the bow to tie the whole together and enable the building to resist wind pressure without distortion. Runners and braces are 4 by 2 in.

To cover in the roof, $\frac{3}{4}$-in. boards are nailed to the purlins with a finish of three thicknesses of roofing felt. This makes a sound, durable job which can be erected at speed as the joints are all nailed. For the large spans, tie beams and bows could not

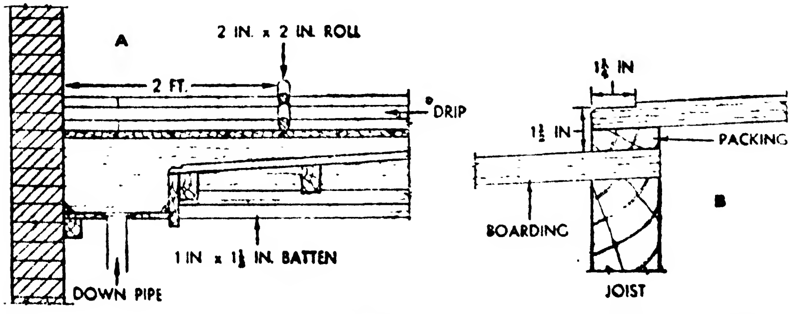


Fig. 17. A. Section through a cesspool at the end of the trough gutter behind a parapet wall ; B. shows a drip. Drips should be arranged at intervals of 9 ft.

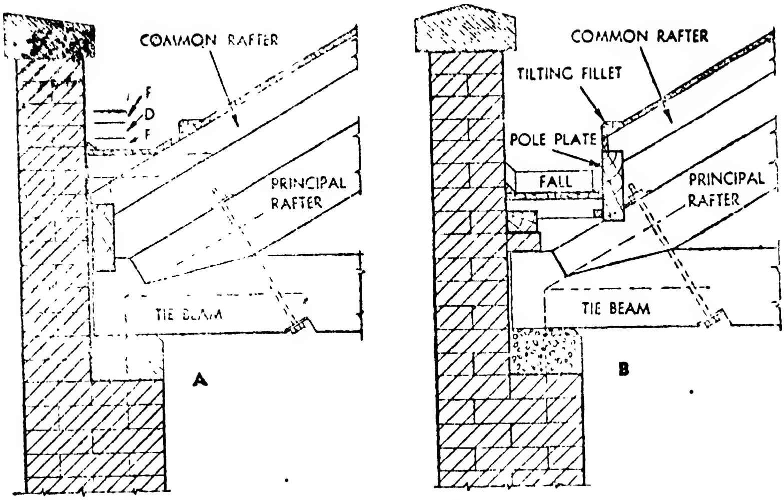


Fig. 13. Arrangement of gutters to parapet walls in pitched roofs. A. Tapering gutter formed by the gutter board intersecting the sloping roof surface at a higher point at the top than the bottom, *F* is the amount of fall, and *D* indicates a drip ; *B*. parallel gutter formed as a trough. The gutter boards are firmly fixed to bearers which are secured to the side of the pole plate and the wall plate. The minimum width of gutters is 12 in.

be obtained in one piece. The bows should be halved together and bolted with the tie beams built up of several thicknesses or butt jointed with fish plates nailed to the sides having a lap of 2 ft. each side of the joint. It is important that the joints are staggered and not all opposite to one another.

Roofs with an inclination of less than 20 deg. are called *flat*. No roof is made dead level in all directions, but always has a *fall* of not less than 1½ in. to every 10 ft., in order that rain and melted snow can be collected at given points. Coverings may be of sheet lead, zinc, copper, three thicknesses of roofing felt or asphalt.

The covering decides the nature of the construction. Metals need special arrangements for jointing the sheets together. Due to the expansion and contraction, fixing can only be made at one end, and steps across the fall, called *drips*, must be arranged every 9 ft., as shown in Figs. 16 and 17 B. To join the widths of the metal, a 2 in. by 2 in. roll is fixed in the direction of the fall at 2 ft. centres.

The structure of a flat roof is similar to a floor, inasmuch as the joists which form the main timbers are fixed level when a ceiling is required to the underneath side. If the ceiling is not important, the joists can be built on wall plates set at different levels in order to give the necessary fall.

When the joists are level, the fall is arranged with *firrings*, which may be of 2 in. timber tapering to the fall, and nailed to the joists. Owing to the fact that boards shrink and curl, the covering tends to assume the shape of a series of waves across the roof which are liable to damage and may interfere with the fall. For these reasons, the boards are better if laid in the direction of the fall.

A simple way to arrange this is shown in Fig. 16 A where the joists run across the fall, and different thicknesses of 2 in. wide strips are nailed to the tops to fir up an even slope. Another method is to fix joists in the direction of the fall and to notch secondary joists across the top for the boards, as at Fig. 16 B.

Water is collected by a trough gutter behind a parapet wall as shown in Fig. 17 A.

Because of the work involved, and the extra cost of the covering, a flat roof does not effect a big saving in cost over a pitched roof.

Gutters in common use are usually in the form of an open trough of cast iron or asbestos. Some types of roof construction do not lend themselves to an easy solution of this type. In these cases, a trough is formed of timber and lined with lead, zinc or three thicknesses of roofing felt.

A building with imposing lines often has the main wall carried up to a higher level than the eaves. This walling is described as a *parapet*. Fig. 18 B shows a cross section through the construction of a *box* gutter. The trough is framed between the pole plate on which the rafters rest, and bearers supported on a plate plugged to the wall, or on a wall plate bedded to an offset from the main wall. To allow easy flow of water, the trough

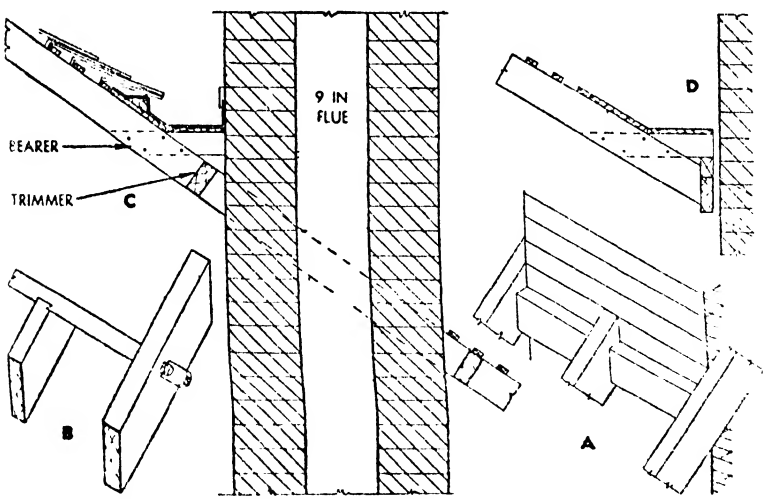


Fig. 19. Trimming roof rafters round a chimney stack. A. Trimming to a small stack, the rafters being nailed together ; B. the rafters are framed together with tusk tenon and dovetail housing joints. Section at C shows the trimmer square to the roof pitch, while at D the trimmer is vertical. Note that no timber must be allowed to touch the stack.

bottom is given a fall of not less than 1½ in. in 10 ft. If lead or zinc covered, arrangements are made for this to be jointed in lengths up to 9 ft. Where a joint is required, a drip of not less than 1½ inches deep is constructed across the width. Details are shown in Fig. 17 A. The water is collected at the ends into a box called a *cesspool*, having a down pipe leading out at the bottom.

Tapering Gutters

A similar arrangement may be formed without the deep trough as Fig. 18 A which shows a *tapering* gutter.

This is formed by securing 3 in. by 2 in. bearers to the top edge of the rafter, with the other end either supported on a wall plate as in the detail or halved to a short post which rests on the plate. These bearers should not be built in the wall, and it is better to cut the ends to rest on top of the rafter in preference to nailing to the sides, although the latter method is the easiest. All lined gutters have a fall of not less than 1½ in. in 10 ft. The taper with this type is obtained by the fall cutting the pitch at a higher position at the top than at the bottom.

Generally, there would not be more than three falls and two drips in one complete length of gutter. If the length is over 25 ft., it is made to fall away from the centre in two directions with a roll at the highest point to form the joint in the covering.

Two methods of framing the rafters round a roof stack are shown in Fig. 19. If the opening is not more than 3 ft. wide a simple dovetail housed joint is sufficient with the trimmer at right angles to the pitch. Should the stack be wide, then the opening must be properly trimmed with sound joints. In every case the trimmers and trimming rafters should have at least a half-inch space around the stack to prevent the damp brick work coming into contact with roof timbers. If the opening is over 4 ft. wide, increase all the trimming members by either 1 inch in depth or width.

In cases where it is desired to build a room in a pitched roof, a *dormer* window is necessary to give light and ventilation. The timber framework must be adequately tied to the roof structure and all joints notched together where possible. As a rule, the opening in the roof is first trimmed to size and the dormer framing assembled to suit.

Where the opening is over 6 ft. wide, the trimmer would be increased in depth and fixed vertically with the dormer ceiling flush to the underside. The trimming rafter would also require to be 1 inch wider and the joint between this and the trimmer notched and drift bolted.

Arrangement of Dormers

Dormers can be arranged with a flat roof for lead or other covering, or as a hipped roof for tiles. When lead is used, the sides, called *cheeks*, are boarded and the top is in the form of a flat roof usually having a fall towards the front edge where the rain water is collected in a gutter and transferred to the sides which discharge on the roof surface.

Should the flat roof be long,

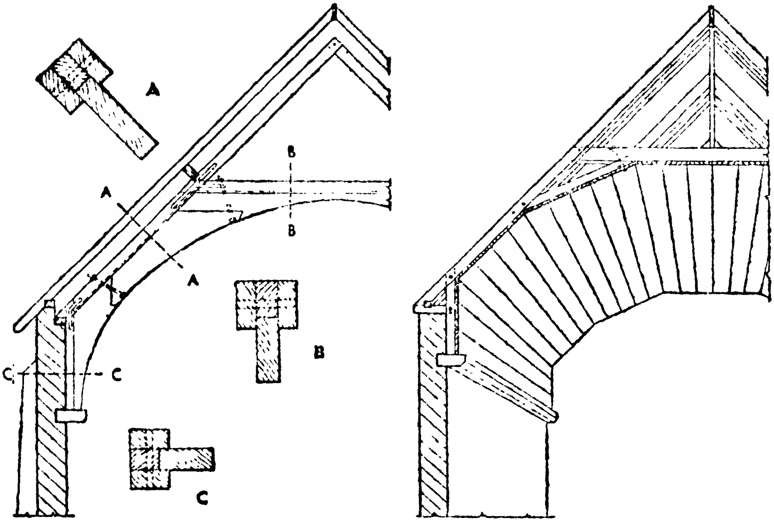


Fig. 20. Section through an open roof. A B and C are sections of the curved rib and double rafters. Because no tie is used, thicker walls are necessary.

the covering can slope away from the centre for collection at the sides. Sometimes it is arranged to fall inwards with a flat gutter at the junction with the main pitched roof. This is not good practice as a heavy fall of snow may allow moisture to creep through the joints of the tiles or slates and in to the roof timbers. If this method is used, the end of the lead must be at least 6 inches higher than the surface of the flat roof.

Fig. 20 shows a section through an open roof, *i.e.*, one that has no tie beam. This system is often carried out in small churches. The purlins rest in the centre of the principal rafters.

As previously stated, a collar roof exerts considerable bending stress on the main rafters. In the example given, this is overcome by bolting a curved brace to the rafter and taking this down the wall to form a bracket which spreads the outward thrust over a large area of wall. The truss itself consists of double principal rafters with a collar dovetail halved and bolted between, and a packing member also bolted to the rafters, the same thickness as the gap. This packing is not as deep as the rafter and forms a $1\frac{1}{2}$ in. deep rebate into which the curved brace fits.

The trusses are spaced at 8 ft. centres with boarding on the underside of the common rafters of V-jointed matching. The truss and purlins are prepared with the edges stop chamfered. The whole of the interior would be varnished.

It is exceedingly important that no sap wood be used on any part of the interior as this turns black when varnished. All interior wood-work should be carried out in carefully graded timber.

CHAPTER 19

DETERMINING BEVELS

GENERAL METHODS. CALCULATIONS. PURLINS AND WALL PLATES. RABATMENTS. GEOMETRICAL DETERMINATION OF BEVELS. RAFTER BEVELS. DEVELOPMENT OF OGEE TURRET. CUTS AT FEET OF RAFTERS.

THE accurate determination of the bevels to be worked on the various members of a roof, in order that the roof may be soundly constructed, is of paramount importance. It is essential that each member should take full bearing at its head and foot, otherwise there will be excessive strain on part of the member, while other parts will be doing nothing to help to support the roof, and this may result in the failure of members and the collapse of the roof.

General Methods

The various methods used in ascertaining the bevels of roofing members may be classified under five heads: (1) Rule of thumb; (2) trial and error; (3) geometrical; (4) steel square, and (5) calculation. Of these methods the first two may be ignored by craftsmen who desire to become really efficient in all classes of roofing work.

The Rule of Thumb method depends on a long and varied experience in all classes of roofing work, and therefore, while not wishing to depreciate the rapidity and skill with which rule of thumb methods are applied by older craftsmen, this method can hardly be considered as sound, in spite of the fact that most rule of thumb methods are the result of confidence arising out of experience.

Trial and Error cannot be considered to be a method, as it consists of cutting bevels by guesswork and trying the member in position. Here again a craftsman with a long experience can, in a good many cases, cut the more common bevels with fair accuracy, but trouble invariably arises as soon as anything unusual is encountered.

The *Geometrical* method is dealt with later in this chapter and is the foundation upon which the steel square is based. From a practical point of view the amount of drawing to be done may be reckoned as a defect when it is considered that the work has to be done by the craftsman on the job; but with practice and a sound knowledge of the principles involved, the bevels can be quickly determined.

The *Steel Square* method is widely used to-day. It is based upon sound geometrical principles, and in skilled hands can be made to give the most complicated bevel in a very short time. The steel square itself is fully dealt with in Chapter 20.

The part of this chapter which relates to methods of ascertaining bevels generally, deals in the first place with the geometrical method of obtaining bevels using

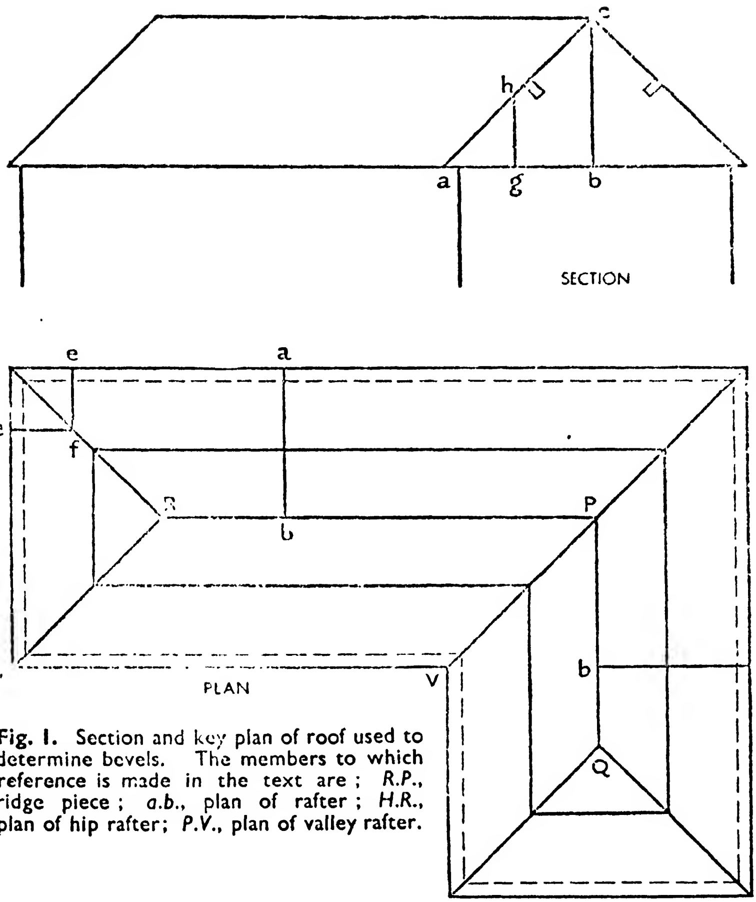


Fig. 1. Section and key plan of roof used to determine bevels. The members to which reference is made in the text are; *R.P.*, ridge piece; *a.b.*, plan of rafter; *H.R.*, plan of hip rafter; *P.V.*, plan of valley rafter.

full-size sections, elevations and plans of the members, while later in the same section the methods of obtaining the various bevels using scale drawings are given.

The former method is perhaps more satisfactory, as any slight inaccuracy is not magnified as it is by applying bevels obtained from scale drawings to full-size materials. Against this must be placed the fact that the scale drawing method is simpler and more rapidly done.

The *calculation* of the lengths of the various members of a roof requires a thorough knowledge of the properties of the right-angled triangle (see Chapters 5 and 21). Given this knowledge, the calculations are not too complicated.

Fig. 1 shows the roof plan and section of a house. The lengths of the various members are obtained as follows, care being taken not to forget the overhang of the eaves:—

The lengths of the ridge pieces, being parallel to the horizontal plane, can be measured direct from the roof plan.

The length of the rafters may be obtained by calculation. The square root of the sum of the distance a b squared and the distance b c squared being the true length of the rafter. The distance a b on the plan and section is the horizontal run of the rafter from the outside edge of the eaves to the line of the ridge. The distance b c on the section is the vertical rise of the rafter.

Jack Rafters

The lengths of jack rafters are calculated in the same manner as the lengths of ordinary rafters, but in this case a separate calculation is necessary for each jack rafter that is not the same distance from the foot of the hip or valley as a jack rafter of known length.

The lengths of the hip and valley rafters are similarly obtained. The 'runs' of the rafters are taken from the plan (H R and V P), and the 'rise' is equal to the 'rise' of the ordinary rafters.

The lengths of purlins and wall plates, being parallel to the horizontal plane, can be measured direct from the roof plan, but care should be taken to add 4 in. in length for each lap joint in the length of the wall plate and also 4 in. for each right-angle junction.

Calculations are useful for taking off quantities and checking lengths, but are not used on the site. The actual dimensions invariably differ from those intended, and are quite sufficient to render this method valueless.

As stated in Chapter 5, the simple plan and elevation of a line or plane very often does not express the true length or form of that line or plane. This is very true of the lines and planes met with in roofing work, as the slope of the roof is inclined to the plane of plan of the building (horizontal plane) and, therefore, the true dimensions cannot be measured on the plan or elevation.

The true dimensions of roofing lines and planes are obtained by rabatment, that is by turning the inclined plane down so that it lies parallel to the plane to which it was originally inclined.

Fig. 2 shows the plan and a section of a roof of the type commonly met with in domestic work. A B C D represents the plan of the roof, and R P the plan of the ridge piece. A R, B R, C P and D P then represent the plans of the hip rafters. In the section, a r b represents the section of the roof and the distance h the 'rise' of the roof.

Rabatment of Planes

To rabat the planes of the roof, at P erect a perpendicular to P C and make P h′ equal to the rise of the roof h. Join C h′, which will be the true length of the hip rafter C P. From P drop a perpendicular on to C D and produce. With centre C and radius equal to C h′, describe an arc cutting the perpendicular from P in H. Join D H and C H. Then the triangle C D H will be the rabatment of the hipped end of the roof whose plan is represented by the triangle C D P.

The longer slopes of the roof are rabatted by dropping the perpendiculars from P and R

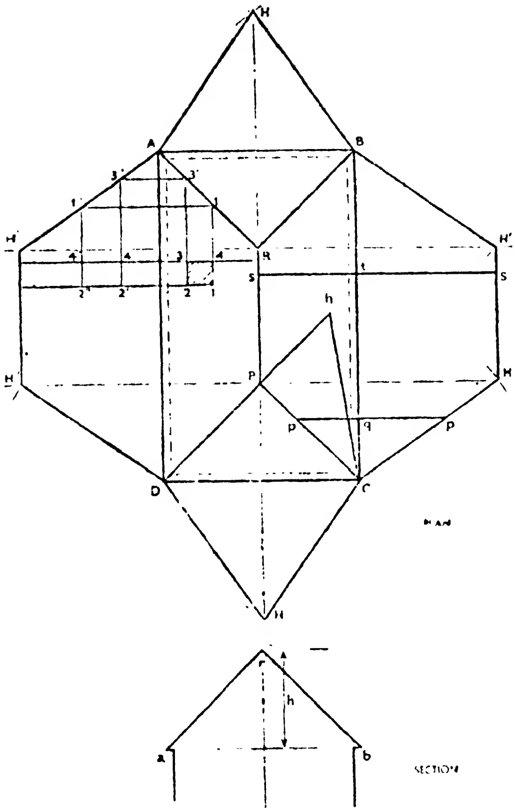


Fig. 2. Plan and section of roof showing development of surfaces to obtain true lengths and bevels for roof members. The inclined roof surfaces are folded down to the horizontal plane. Any member which lies on the inclined plane has its true shape and length given on the developed surface.

on to B C and both produced beyond B C. With centres B and C and radius equal to C h′, describe arcs cutting the perpendiculars from R and P in H′ and H″ respectively. Join B H′, C H″ and H′ H″. Then the figure B H′ H″ C is the rabatment of the side of the roof whose plan is represented by the figure B C P R.

Having rabatted the roof slopes the lengths of the rafters can be graphically ascertained by drawing in the individual rafters on the plan and producing beyond the eaves till they cut the upper edge of the rabatment area. Thus, if p q is the plan of a jack rafter, then if p q be produced till it cuts C H″ in p′, then q p′ will be the true length of the jack rafter. In the same way, t s′ is the true length of the common rafter s t.

If in the roof being dealt with a chimney stack 1, 2, 3, 4 pierces the roof slope, the lengths of the trimmed rafters above and below the stack are ascertained as follows:

Produce 1 4 and 2 3 parallel to A D, and cutting the plan of the hip rafter A R in 1′ and 3′ respectively. Through 1′ and 3′ draw perpendiculars to A D and cutting A H′, the true length of the hip rafter in 1″ and 3″ respectively. Through 1″ and 3″ draw parallels to A D. Produce 1 2 and 4 3 perpendicular to A D and cutting the parallels to A D from 1″ and 3″ in 2′ and 2″ and 4′ in 4″ respectively.

The perpendicular distance from A D to 2′ will then be the true length of the trimmed rafters rising from the eaves to the stack. and the perpendicular distance from 2″ to H′ H″ will be the true length of the trimmed rafters rising from the stack to the ridge.

The geometrical determination of the bevels of the various members of a roof depends upon the rabatment of lines and planes as dealt with in the previous section.

Fig. 3 shows the plan of a typical roof, and it is now proposed to deal with the method of obtaining the bevels of each member. The roof illustrated is pitched at 35 degs, and members are shown as follows :—10 in. by $1\frac{1}{2}$ in. ridge piece; 7 in. by 3 in. hip rafters; 7 in. by 3 in. valley rafter; 5 in. by 2 in. common rafters; 5 in. by 2 in. jack rafters; and 7 in. by 4 in. purlins.

Bevels at head of common rafters are the simplest bevels to ascertain, the angle of the side cuts always being 90 degs. minus the angle at which the roof is pitched—so in this case the angle of the bevel is 90 degs. − 35 degs., which equals 55 degs.

This can be ascertained geometrically by drawing the section of the ridge piece and the side elevation of a common rafter rising from the horizontal at 35 degs. (see Fig. 4); then the angle A B C will be the required bevel, which, being the third angle of the right-angled triangle C D E, will equal 180 degs. minus the sum of the other two angles C E D (35 degs.) and C D E (90 degs.) = 180 degs. − 125 deg. = 55 degs.

This bevel also gives the cut for the head of jack rafters rising from the valley rafter to the ridge piece, and for the foot of common rafters and jack rafters rising to hip rafters where it is required that the eaves should have a vertical fascia.

As these members meet the

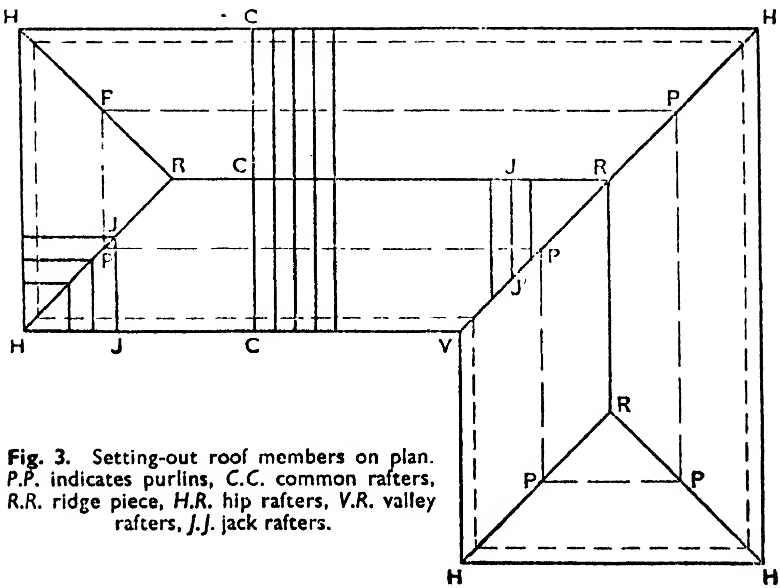


Fig. 3. Setting-out roof members on plan. *P.P.* indicates purlins, *C.C.* common rafters, *R.R.* ridge piece, *H.R.* hip rafters, *V.R.* valley rafters, *J.J.* jack rafters.

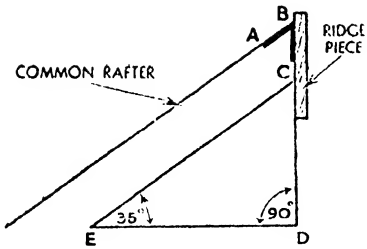


Fig. 4. How the pitch of roof determines the side bevel of the common rafters. The vertical cut is equal to 90 deg. minus the pitch of the roof.

ridge piece at right angles, the top and bottom cuts are right angles.

Bevels at head of Jack Rafters. To find these bevels, draw the plan of the intersection as shown in Fig. 5, and project vertically the foot o the jack rafter J to J′ on a line parallel with the run of the jack rafter. From J′ draw J′ K inclined at the same angle to the horizontal as the pitch of the roof (i.e., 35 degs.). Project vertically the points S and T (where the jack rafter intersects the hip rafter) to S′ and T′ in the line J′ K. Draw the line L M parallel to J′ K so that the perpendicular distance between the two lines equals the depth of the jack rafter.

Let this line cut S S′ in N. Then the angle J′ S′ N will be the angle for the vertical cuts, and is the same angle as the bevel at the head of the common rafter, but in this case the head cannot be cut square due to the splay of the hip rafter.

In order to obtain this second angle a new plan of the jack rafter is drawn projected from the elevation J′ S′ T′ and parallel thereto. This is shown at j k k′ j′. (Note the distance j j′ equals the thickness of the rafter.) Project S′ perpendicular to J′ K to S″ in j′ k′ and from T′ to T″ in j k. Join S″ T″. Then the angle j′ S″ T″ is true bevel for the upper and lower cuts.

These angles, of course, will be the same for the head of any number of parallel jack rafters which are intersecting the same hip rafter.

Bevels at foot of Valley Jack Rafters. The bevel at the foot of a jack rafter rising from a valley rafter to the ridge piece is very similar to the bevel at the head of an ordinary jack rafter. Indeed, the piece cut off in forming the head bevel of the ordinary jack rafter is correctly bevelled for the foot of a jack rafter rising from a valley rafter. This fact is very

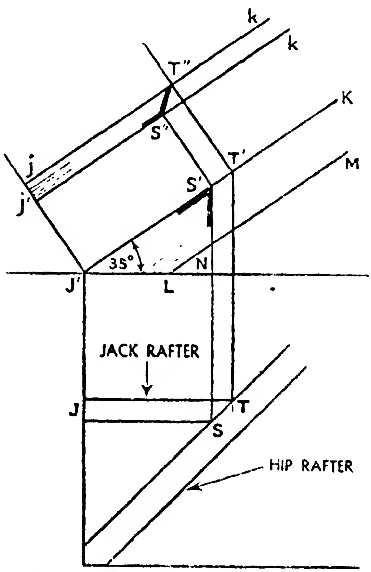


Fig. 5. Bevels for jack rafters at the intersection of the hip rafter. Angle j′. s.″ t.″ is the edge cut, and angle J.′ S.′ N. is the side-cut.

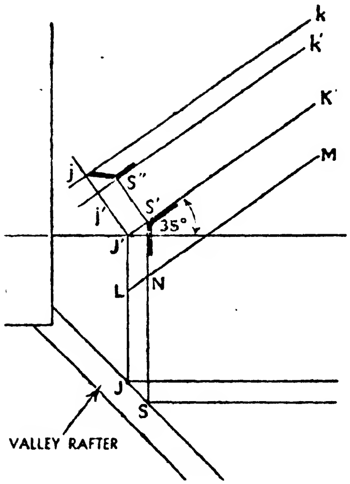


Fig. 6. Bevels for jack rafters at intersection of valley rafter. Angle *k' S." j.* is the edge cut, and angle *K.' S.' N.* is the side cut.

frequently made use of in cutting the bevels for rafters to roofs that have both hips and valleys, the two bevels always being cut together from a length of timber of suitable length.

Fig. 6 shows the geometrical determination of these bevels. Draw the intersection as shown in the diagram and project vertically the point J (the lowest point where the jack rafter intersects the valley rafter) to J′ on a line parallel with the run of the jack rafter. From J′ draw J′ K′ inclined at the same angle to the horizontal as the pitch of the roof (i.e., 35 degs.). Also project vertically from the point S (the highest point where the foot of the jack rafter intersects the valley rafter) to S′ in the line J′ K′.

Draw the line L M parallel to J′ K′ so that the perpendicular distance between the two lines equals the depth of the jack rafter. Let this line cut S S′ in N. Then the angle K′ S′ N will be the angle for the vertical cuts and is the supplement of the angle obtained for the vertical cut in the case of an ordinary jack rafter.

In order to obtain the second angle, proceed as before and draw a new plan of the rafter projected from and parallel to the elevation J′ S′ K′. This is shown at j k k′ j′, the distance j j′ again equalling the thickness of the jack rafter. Project J′ perpendicular from J′ K′, cutting j k in j, and from S cutting j′ k′ in S″. Join j S″. Then the angle j S″ k′ is, therefore, the required true bevel for the upper and the lower cuts.

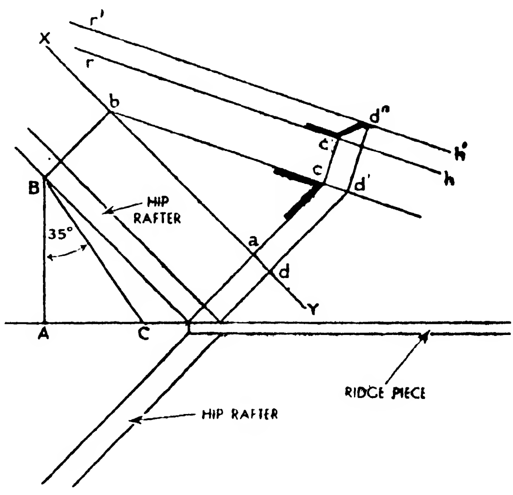


Fig. 7. Hip bevels at the intersection of the ridge piece. Angle *b.c.a.* is the side cut of the hip and angle, *r.c.' d."* is the edge cut of hip.

Bevels at head of Hip Rafters. To find the bevels at the intersection of the hip rafters and the ridge piece draw the plan of the intersection as shown in Fig. 7. Produce the line of one side of the plan of the ridge piece and at any point A in this line erect a perpendicular cutting the line of the hip rafter on that side of the ridge piece in the point B.

At B draw the line B C, making an angle equal to the pitch of the roof (in this case 35 degs.), with the perpendicular A B. Draw X Y parallel to the hip rafter, and at B and the two points of intersection of the hip rafter with the ridge piece, erect perpendiculars to X Y, and cutting X Y in b, a and d. Produce the perpendiculars through a and d beyond X Y. From a set up the distance a c along the perpendicular, making a c equal to A C. Join b c and produce cutting the perpendicular through d in d′.

The angle a b c then gives the true inclination of the hip rafter to the horizontal, and the angle a c b gives the bevel for the vertical or side cuts. The top and bottom bevels are obtained by drawing the auxiliary plan r h h′ r′ of the hip rafter parallel to b c, the distance between the two sides of the rafter r h and r′ h′ being the thickness of the hip rafter. At c erect a perpendicular to b c, cutting r h in c′, and at d′ erect a similar perpendicular cutting r′ h′ in d″. Join c′ d″. Then the angle r c′ d″ gives the required top and bottom bevels for the head of hip rafters.

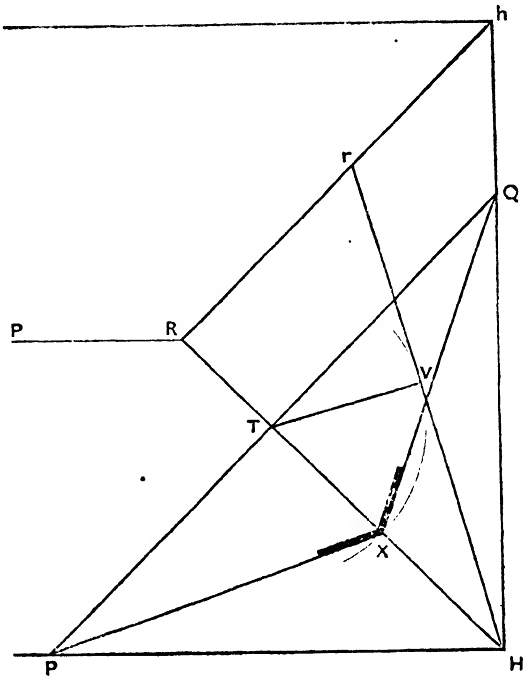


Fig. 8. Method of finding dihedral angle or backing-level to hip rafter. This bevel is the true angle o the intersection of the roof slopes measured perpendicular to their line of intersection. The bevel is the angle Q.X.P. Half this angle is the bevel required to mitre boarding at hips.

The Dihedral Bevel of Hips is the true angle formed by the intersection of the two roof slopes at the hip when measured at right angles to the slope of the hip. The upper surface of the rafter is thus bevelled when the roof is to be boarded so as to give a good finish over the hip. Half this angle also gives the angle for the mitre of the roof boarding over the hip rafters.

To find the bevel, draw the plan of the hipped end of the roof as in Fig. 8, in which H R and h R represent the two hips and R P the ridge piece. R H, therefore, represents the run of one of the hip rafters, and by setting up the rise of the hip R r from R perpendicular to R H, the true length of the hip is given by joining r H. Draw P Q (any line at right angles to R H—the plan of the hip rafter).

Let this line cut the plan of the hip in the point T and the eaves in the points P and Q. From T draw T V perpendicular to r H (the projected true length of the hip rafter) and cutting this in V. With centre T and radius T V, describe an arc cutting R H in the point X. Join P X and Q X. Then the angle P X Q is the required dihedral bevel and the angle P X T is the bevel for mitre of the roof boarding.

Bevels at head of Valley Rafter. The angles of this bevel are exactly the same as the angles of the bevel at the head of the hip rafter, but the splay of the top and bottom cuts is reversed, due to the rafters rising to the ridge piece from a direction at right angles to the direction to which a hip valley would rise.

Fig. 9 shows how these bevels are obtained, and can easily be followed by comparison with Fig. 7, showing the bevels at the head of the hip rafter. It will be seen that the angle a c b will be the side cuts and the angle r c′ d″ the top and bottom cuts.

Purlin Bevels

Bevels for the end of Purlin intersecting a Hip Rafter. Fig. 10 shows the method of ascertaining these bevels. Draw the section of the purlin a b c d with the side elevation of the hip rafter H R. Through the topmost point a of the section of the purlin, draw a horizontal line X Y, and rabat the sides of the purlin a d and a b into this horizontal plane by taking centre a and radius a d and cutting a X in D′ and radius a b and cutting a Y in B′.

Now draw the plan of the hip rafter and purlin, taking care that the hip rafter H′ R′ is inclined at the proper angle,

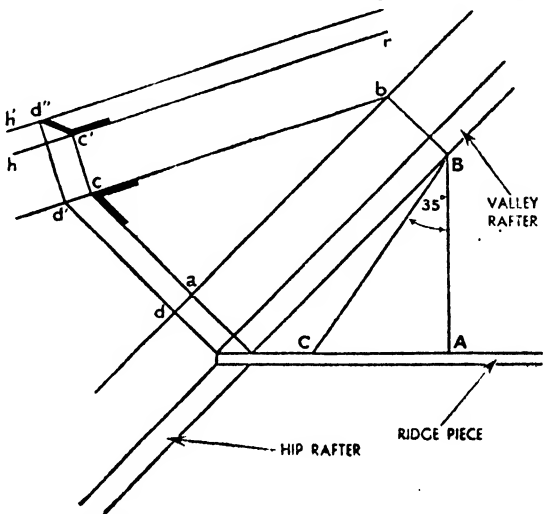


Fig. 9. Method of obtaining bevels at head of valley rafter. Bevels for valley rafter at intersection with ridge piece. *r.′ c.′ d.″* is the edge cut, and *a.c.b.* is the side cut,

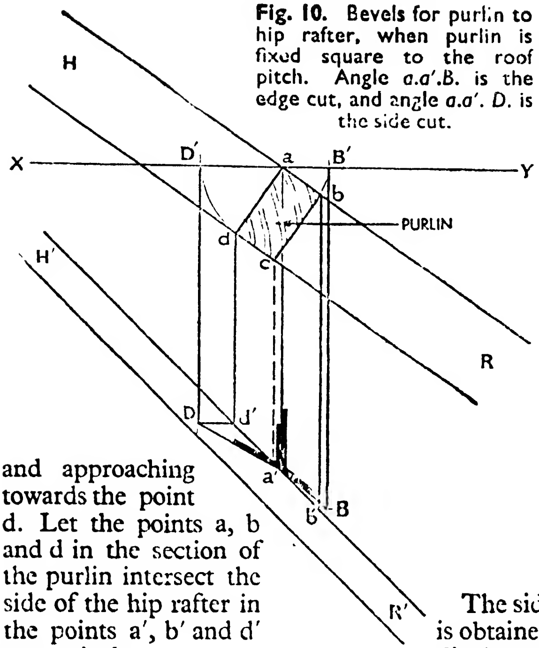


Fig. 10. Bevels for purlin to hip rafter, when purlin is fixed square to the roof pitch. Angle *a.a'.B.* is the edge cut, and angle *a.a'. D.* is the side cut.

and approaching towards the point d. Let the points a, b and d in the section of the purlin intersect the side of the hip rafter in the points a′, b′ and d′ respectively.

From d′ draw d′ D horizontally and intersecting a perpendicular from D′ in D. Join D a′. Then the angle D a′ a will be the bevel for the side cuts. Similarly, by drawing a horizontal from b′ cutting a perpendicular from B′ in B, and joining B a′, the angle B a′ a is obtained, which will be the bevel for the top and bottom cuts.

Alternate method of obtaining Rafter and Hip Bevels. The rafter and hip bevels can also be obtained from a plan and section of the complete roof as shown in Fig. 11. Draw the plan of the roof in which A B, B C, C D and D A are the eaves lines: A R, B P, C P, and D R are hip rafters; and R P the ridge piece. Draw X Y parallel to A B and erect perpendiculars from A and B to cut X Y in a′ and b′ respectively. Transfer B to b on the X Y line. From P drop a perpendicular on to B C and cutting same in P′. Transfer P′ to X Y in p and at p erect a perpendicular. At b set up the angle p b p″ (equal to the pitch of the roof—in this case 35 degs.).

Let the line b p″ cut the perpendicular from p in p″. Now transfer C to c on X Y line, making b.p.c. equal to B.P′C. Join c p″. Then the triangle b c p″ will be the end elevation of the roof.

The side elevation of the roof is obtained by erecting perpendiculars to X Y at R and P and producing to cut a line drawn parallel to X Y through p″ in r′ and p′ respectively. Join a′ r′ and b′ p′. Then the figure a′ r′ p′ b′ is the side elevation.

If at any convenient point e in a′ r′ a line be dropped perpendicular to X Y so as to cut X Y in e′, the angle a′ e e′ will be the side bevel of the jack rafters and also the bevel at the head of the common rafters. To find the edge bevels of the jack rafters, with centre a′ and radius a′ r′ describe an arc cutting a′ b′ in r″, and from this point drop a perpendicular to the plan of the ridge R P and cutting the same in the point r. Join D r.

Any line drawn parallel to the X Y line and cutting D r in E and the plan of the eaves A D in E′ gives the angle E′ E D, which will be the required edge bevel

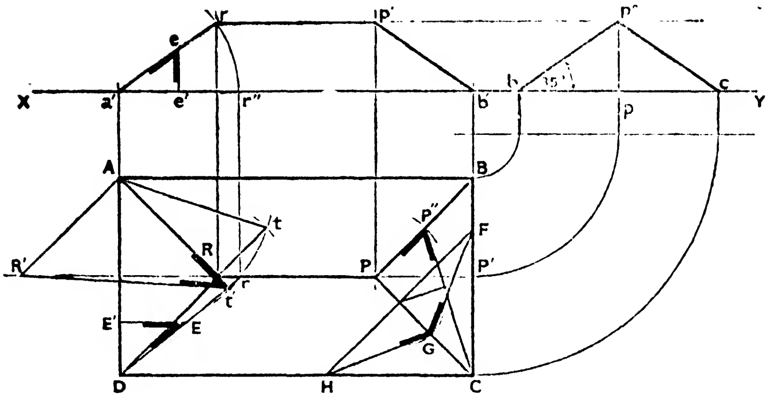


Fig. 11. Roof bevels determined by scale drawings. The roof members with the required bevels are : Common rafter, side bevel, angle *a'.e.e'* ; jack rafter, side bevel, angle *a'.e.e.'*, edge bevel, angle *E'. E.D.* ; hip rafters, side bevel, angle *P.P."C.*, and/or angle *A.t.R.*, edge bevel, angle *A.t'. R'*. Backing for hip rafter, angle *F.G.H.* Lengths of members are : Ridge piece, *R.P.* ; common rafter, *b.p"*. ; hip rafters, *P"C* and/or *A.t*. Jack rafters vary according to their spacing, but are parallel to *E'.E* ; *a' r' p' b'* shows the side elevation of the roof.

for the jack rafters in this case.

To find the hip bevels, set up the distance P P″ equal to p p″ perpendicular to P C. Join P″ C which is the true length of the hip rafters, and the angle P P″ C will be the side cuts or bevels of the hip rafters.

To find the edge bevels for the hip rafter, set up R t perpendicular to A R. Join A t, which will again be the true length of the hip rafter. With centre A and radius A t, describe an arc cutting A R produced in t′. At A set up a perpendicular to A R cutting P R produced beyond R in R′. Join R′ t′. Then the angle A t′ R′ will be the required edge bevel of the hip rafter.

The dihedral angle of the hip F G H can also be obtained as described previously.

The accuracy of the above bevels can easily be checked by redrawing on stout paper the above roof plan and the bevels obtained, and so make a model of the roof in the following manner (Fig. 12).

Rabat the slope of the roof D R P C by producing the perpendiculars through R and P beyond D C. With centres D and C and radius equal to P″ C (the true length of the hip rafter), describe arcs cutting the perpendiculars from R and P in S and T respectively. Join D S, S T and T C.

Then the figure D C T S will be the required rabatment. If the paper or card be now carefully cut along the lines D S, S T and T C, and folded upwards along the line D C this roof slope can be folded into its true position over the plan.

If a line J K be drawn parallel to E′ E and a reasonable distance therefrom and cutting A D in J and D r in K, and cuts are made along the lines J K, K E and E E′ and folded upwards along E′ J it will be seen that the mitre E K will exactly fit the hip line D S when both are folded into position.

If cuts be made along the lines P P″ and P″ C and the card be folded upwards along the line P C, it will be seen that P″ C intersects exactly with the hip line T C.

The side bevel of the rafters cannot be shown directly on this new plan, but can be illustrated as follows:—Draw any line N O perpendicular to A B and equal in length to the true length of the common rafter b p″ in Fig. 11, and through O draw O V parallel to R P. At N draw N Q, making the angle O N Q equal to the pitch of the roof

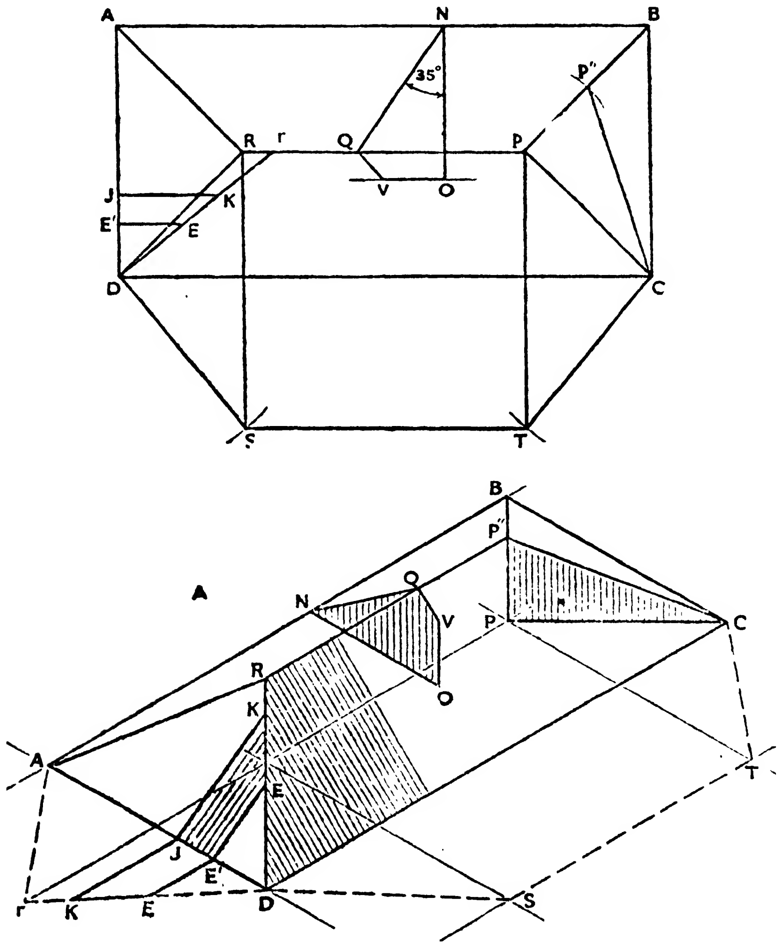


Fig. 12. Construction of a model roof from cardboard in order to check the accuracy of bevels. The geometrical setting-out is that shown in Fig. 11. A. is an isometric drawing to show how the various surfaces fit together.

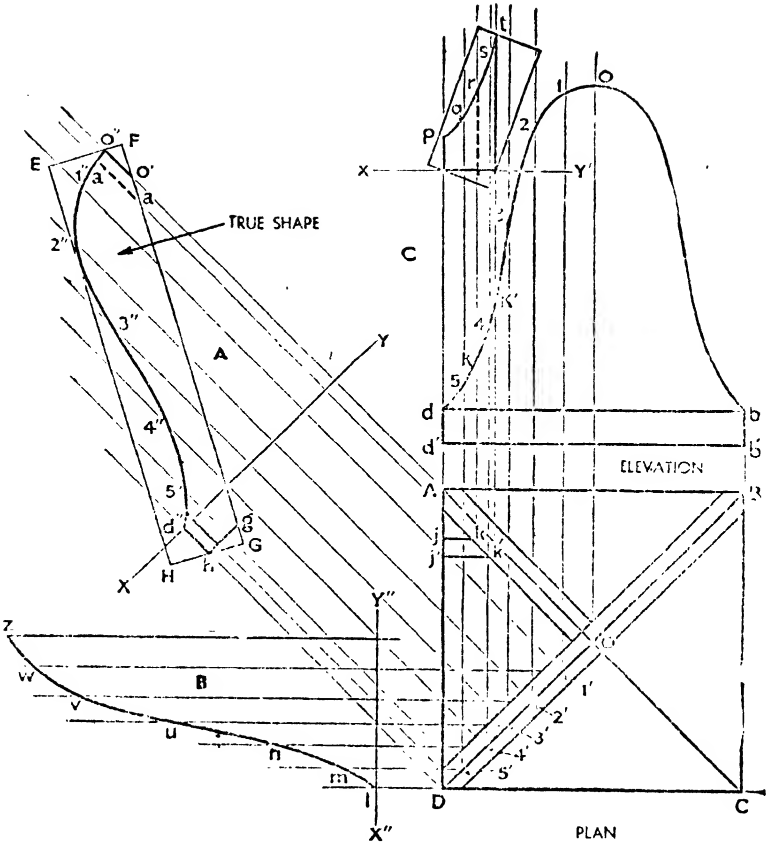


Fig. 13. Development of ogee turret. A. True shape of hip rafter ; B. development of true shape of boarding ; C. true shape of common rafter. The curved shape is the shape of the elevation. The vertical height of any point is always the same in any elevation, while the plan gives the true length of any line which is parallel to the horizontal plane.

(35 degs.) and let N Q cut R P in Q. At Q draw Q V so as to make the angle V Q P equal to N Q P, and these angles will also equal the angle of the side bevel, a′ e e′ as obtained before. If the lines N Q, Q V and V O be cut and folded up along N O it will be seen that Q V will fit exactly with the roof slope D C T S when folded into position.

If this model be made and each portion folded into position and fixed with gummed paper to the rabatment of the roof slope, it will be seen that each fits exactly and will provide a permanent record of typical bevels used in roofing.

Development of an Ogee Turret. Let A B C D represent the plan of the turret and the diagonals A C and B D intersecting at O the centre lines of the hip rafters, and let d d′ b′ b o be the elevation of the turret. (Fig. 13.)

Take any points 1, 2, 3, 4 and 5 on the curve d o in the elevation, and from each point drop perpendiculars intersecting the centre line of the hip rafter O D in 1′, 2′, 3′, 4′ and 5′.

At these latter points and the points D and O, erect perpendiculars to D O, and at any convenient point cut these projectors at right-angles with the line X Y, and on each projector above X Y set up the distances to o″, 1″, 2″, 3″, 4″ and 5″, making the height of each point above X Y the same distance as the respective points o, 1, 2, 3, 4 and 5 above d b.

The points o″, 1″, 2″, 3″, 4″ 5″ and d″, when joined with a curve, will give the true shape of the hip rafter. The rectangle E F G H represents the size of timber from which the hip rafter would be cut, and the figure h g o′ o″ 1″ 2″ 3″ 4″ 5″ d″ represents the true shape of the rafter.

The hip rafter O B will be the same as the hip rafter O D as obtained above, but, if a finial is not used, the hip rafters O A and O C will be shorter, as these will butt against the hip rafters O D and O B. The amount by which these hip rafters are shorter can be obtained by projecting the side of the rafter A O at right-angles to D O so as to cut 1″, o″ and o′ g in a′ and a. The true shape of the hip rafters O A and O C is then given by the figure h g a a′ 1″ 2″ 3″ 4″ 5″ d″.

The true shape of a common rafter is given by the elevation; to find its exact shape draw in its plan j k j′ k′. Project vertically the points j, k and k′ cutting the curve of the elevation in d, K and K′, and at any point above the elevation of the turret cut these projectors at right-angles with a line X′ Y′.

Also produce the lines 5′, 5, 4′, 4, etc., that lie between the perpendiculars from j and k′, and on each projector above X′ Y′ set up the distances p, q, r, s and t, making the height of each point equal to the distances of the respective points d, 5, K, 4 and K′ above d, b.

The points p, q, r, s and t, when joined with a curve, will give the true shape of the back of the rafter. The perpendicular from k above X′ Y′ to r should be dotted in to indicate the vertical cut of the side of the rafter j k.

To obtain the development of the roof boarding, draw perpendiculars to A D from the points o, 1′, 2′, 3′, 4′, 5′ and D in the plan and produce beyond A D, and at any convenient point draw X″ Y″ parallel to A D.

Set up the distances l, m, n, u, v, w and z above X″ Y″, making the vertical height of each equal to the distance of the respective points d, 5, 4, 3, 2, 1 and o in the elevation measured along the curved outline of the turret, i.e., the vertical heights of the points m, n, etc., equals the length of the curve from d to 5, 4, etc. These distances are best measured with a flexible rule.

The points l, m, n, u, v, w and z, when joined with a curve, represent the development of half the area of one roof slope to be covered with boarding.

Cuts at Feet of Rafters. Fig. 14 shows the method of finding the true shape of the foot of a common rafter. Draw the section of the

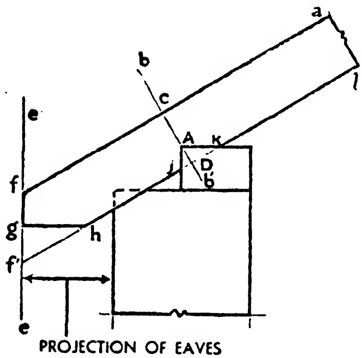


Fig. 14. Foot-cuts to a common rafter with overhanging eaves.

wall and wall plate and through the angle A of the wall plate draw the line b b′ normal to the slope of the rafter (i.e., at an angle of 90 deg. minus the pitch of the roof—in this case 90 deg. − 35 deg. = 55 deg.).

From the point A towards b is set up a distance A C equal to two-thirds the depth of the common rafter, and one-third the depth is set down the line A b′, so that the distance C D equals the depth of the common rafter.

Draw e e′, parallel to the outside face of the wall in section and at a distance therefrom equal to the projection of the eaves.

Through the points C and D draw parallels inclined to the horizontal at an angle equal to the pitch of the roof (i.e., 35 deg.), and cutting e e′ in f and f′ respectively, and let the parallel through D cut the side of the wall plate in j and the upper surface of the wall plate in k.

The depth of the required surface f g is then set down f f′ from f, and through g is drawn a horizontal line cutting D f′ in h, thus completing the foot of the common rafter, whose true shape is given by the figure a C f g h j A k l.

To find the true shape of the foot of a hip rafter draw the plan of the rafter resting on the wall plate as shown in Fig. 15, in which H R represents the plan of the hip rafter, from which the side elevation is projected, inclined to the plan of the rafter at the angle of the hip rafter's true inclination to the horizontal.

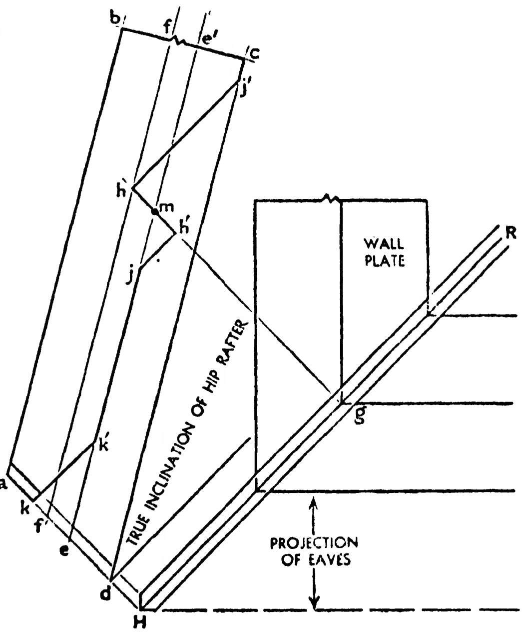


Fig. 15. True shape of foot of hip rafter with overhanging eaves is given by figure *b a k k′ j h′ h j′ c*.

Let this side elevation be represented by a b c d in which a b is the upper edge, and let the distance between the upper and lower surfaces, a b and c d, equal the depth of the hip rafter. From a along a d mark the distances a k equal to f g in Fig. 14, and a e′ equal to f f′ in Fig. 14. Through k draw k k′ parallel to H R to complete the foot of the rafter.

Draw e′ e parallel to a b, and from g the point where the angle of the wall plate cuts the centre line of the hip rafter, erect a perpendicular to H R cutting e′ e in m. From m along h g set off the distance m h equal to the distance A j in Fig. 14 and mark h h′ equal to the depth of the wall plate (generally 3 in.). From h draw h j′ parallel to H R and cutting c d in j′, and similarly draw a parallel to H R through h′ and cutting e e′ in j. This completes the foot of the hip rafter, whose true shape is given by the figure b a k k′ j h′ h j′ c.

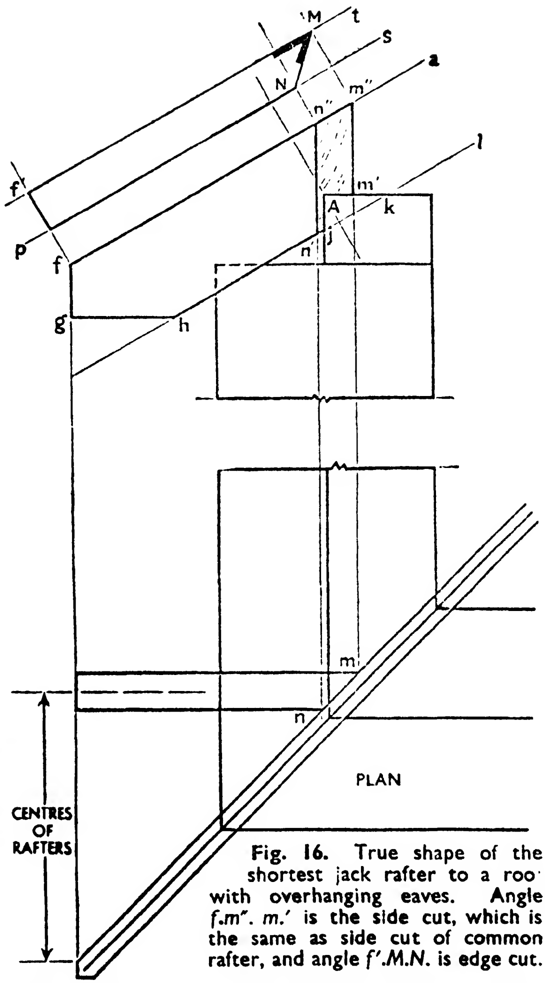


Fig. 16. True shape of the shortest jack rafter to a roo with overhanging eaves. Angle *f.m″. m.′* is the side cut, which is the same as side cut of common rafter, and angle *f′.M.N.* is edge cut.

To find the true shape of the foot of a jack rafter, draw the plan of the hip rafter and jack rafter as shown in Fig. 16, and obtain the side elevation of a common rafter a f g h j A k l, as was done in Fig. 14. If the points n and m (where the sides of the jack rafter meet the hip rafter) are projected perpendicularly to cut a f in n″ and m″ respectively, these two perpendiculars cut h j in n′ and A k in m′ respectively, thus giving the required true shape of the jack rafter m″ n″ f g h n′ j A m′.

CHAPTER 20

USES OF THE STEEL SQUARE

STANDARD MARKINGS. SETTING OUT AN OCTAGON. ESSEX BOARD MEASURE. RAFTER AND PURLIN BEVELS. RISE PER FOOT RUN. RAFTER FRAMING TABLES. PITCH LENGTHS. MANSARD ROOFS. FLOOR BRIDGING. STAIR PLANNING. LANTERN LIGHTS. RISE FIGURES FOR DEGREES.

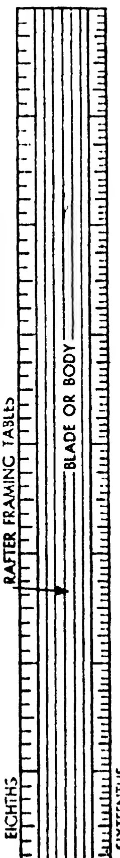
FOREMOST advantage of the steel square method of determining bevels and true lengths lies in the simplicity and directness of application. An intelligent carpenter can become proficient in setting out bevels by observing the rules described in this chapter, especially if he has given some study to the geometry of the subject.

Briefly, the fundamental principles of the steel square as applied to bevels may be summed up as: given the lengths, or the proportions of the lengths of two sides of any right-angled triangle, the length and inclination of the third side can automatically be found.

The square itself (Figs. 1 and 2) is of steel plate stamped from one sheet or welded together at the corner. It is obtainable in various finishes, polished, blued with white markings, coppered, enamelled, galvanised; it is also made in aluminium and stainless steel.

The square has two arms in the form of a letter L; the larger arm, called the body or blade, is 24 in. long by 2 in. wide, while the other arm, called the tongue, is either 16 in. or 18 in. long by 1½ in. wide. The arms form a right-angle, that is, 90 deg. at the heel. Both arms taper in thickness from the heel outwards to give balance and lightness, and the whole is accurately machined, and the corners hardened.

The arms are calibrated with standard markings on both sides, as shown in the diagrams. The face of a square is found by holding the blade in the left hand with



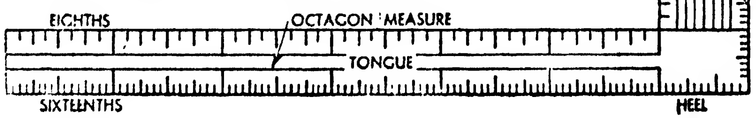


Fig. 1. Face of the steel square. The longer arm is 2 in. wide and 24 in. long, and is known as the blade or body, while the shorter arm, called the tongue, is 1½ in. wide by 16 or 18 in. long. In the centre of the tongue is an octagon measure, and, on an R square, rafter framing tables are stamped on the blade.

the heel pointing outwards; usually the maker's name is stamped on the face. The outer edge of the face is divided into sixteenths of an inch and the inner edge into eighths. The outer edge of the back is divided into twelfths, the inner edge of the tongue into tenths, and the inner edge of the blade into thirty-secondths. In addition, various scales are marked on the square as shown.

On the face of the blade (in an R square) are rafter framing tables, and on the face of the tongue is an octagon measure. On the back of the blade is a board measure, and on the back of the tongue is a brace measure.

For convenience in carrying, a square of the TD (take-down) type may be used. This has a cam-locking device whereby the tongue is detachable and is drawn into place by the turn of a screw. Any possible wear on the joint is allowed for, and the square is always true. The heel of a take-down square is shown in Fig. 3.

The eight square or octagon measure consists of a series of dots stamped along the centre of the face of the tongue, as shown in Fig. 4 A. These dots are used to determine the sides of any octagon. A number of spaces is taken which corresponds with the number of inches in the sides of the square, and these spaces set out on each side of a centre line, as shown at B.

A quicker and more accurate way to set out an octagon is to lay the square across the timber to be marked out so that the heel touches one edge and the 12 in. mark the opposite edge. Marks made at 3½ in. and 8½ in. give the points required, as shown at C.

The brace measure is given along the centre of the back of the tongue, and is in the nature of a ready reckoner with the actual lengths of struts or braces clearly indicated. For example, if both the vertical and horizontal distances of a brace were 27 in. long, the brace measure would be referred to, which reads—

$$\frac{27}{27}\,38.19$$

the last figure being the length required, as shown in Fig. 5 A.

The brace measure given on the square covers only certain standard sizes which may not suit a particular length; therefore, it is better to set the lengths on the arms of the square to determine the brace length, as shown

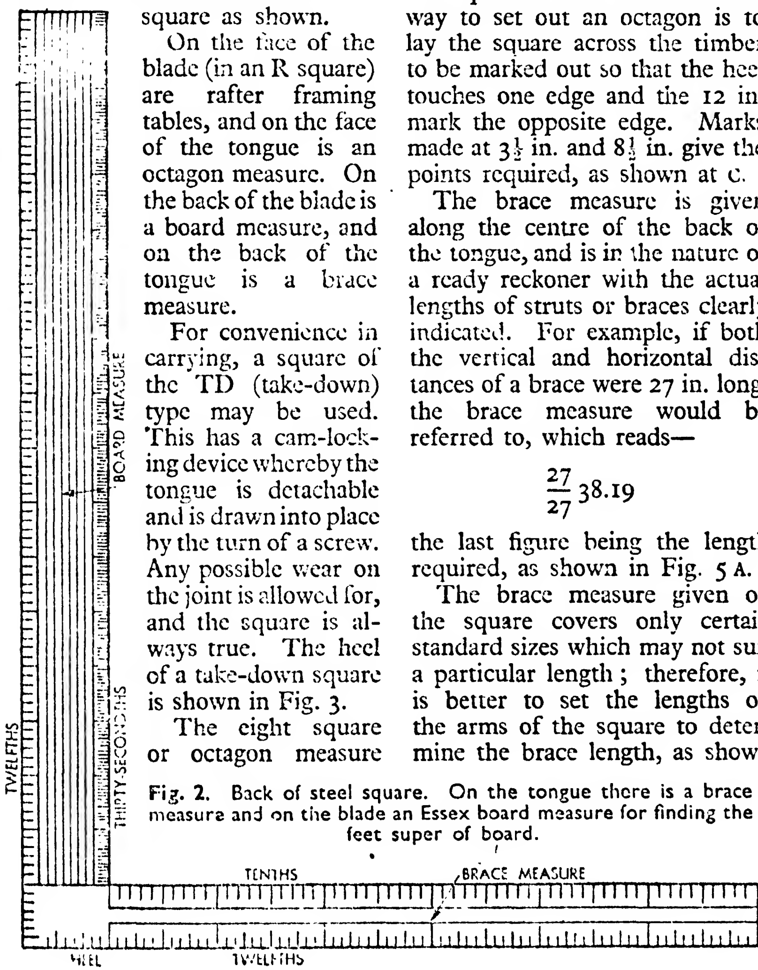


Fig. 2. Back of steel square. On the tongue there is a brace measure and on the blade an Essex board measure for finding the feet super of board.

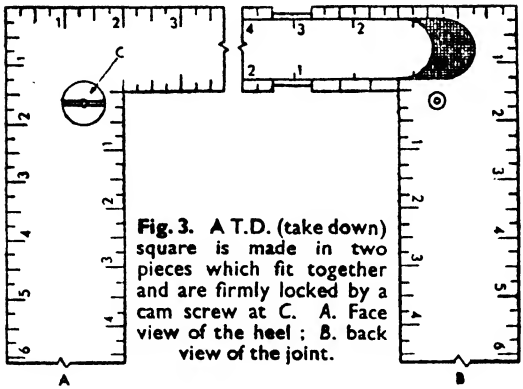


Fig. 3. A T.D. (take down) square is made in two pieces which fit together and are firmly locked by a cam screw at *C*. *A*. Face view of the heel ; *B*. back view of the joint.

at C. This set-up of the square may be to either full-size, half, quarter or twelfth scale, whichever is most appropriate.

On the back of the blade are stamped 23 columns known as the Essex board measure. These give the feet super or contents of a board in square feet and inches. As they are based on one inch thickness, the number of feet super in boards of other thicknesses is found by dividing or multiplying by the thickness of the particular board.

To find the amount of feet super in any board, find the length of the board in the column under the 12 in. mark, as shown at Fig. 6 A. Then follow the row of figures along the square until the vertical column headed by the width of the board (reading feet as inches) is reached. Under the length figure is given the total number of feet super in the board.

An alternative way is to set the width of the board on one arm of

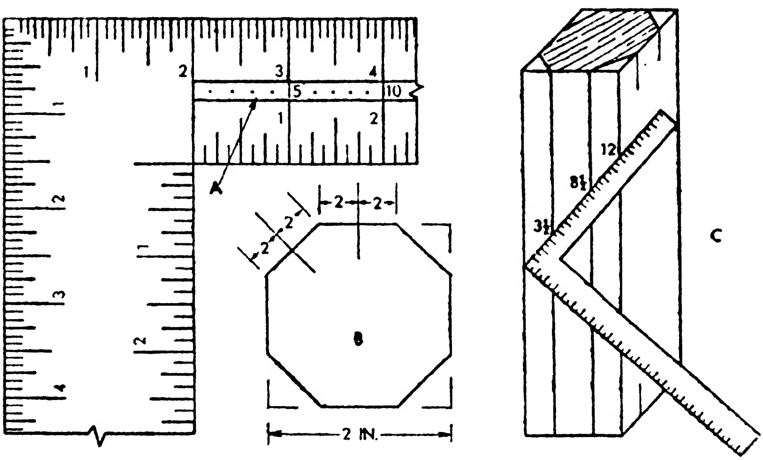


Fig. 4. Octagon measure on face of tongue. The spaces shown at *A* are taken, which correspond with the number of inches in the side of the square. These spaces are set out on each side of a centre line as shown at *B*. *C*. method of setting out an octagon without the aid of the measure. The square is placed diagonally with the heel touching one edge of the material and the 12 in. mark on the other edge. Marks at 3½ in. and 8½ in. give the width of the side.

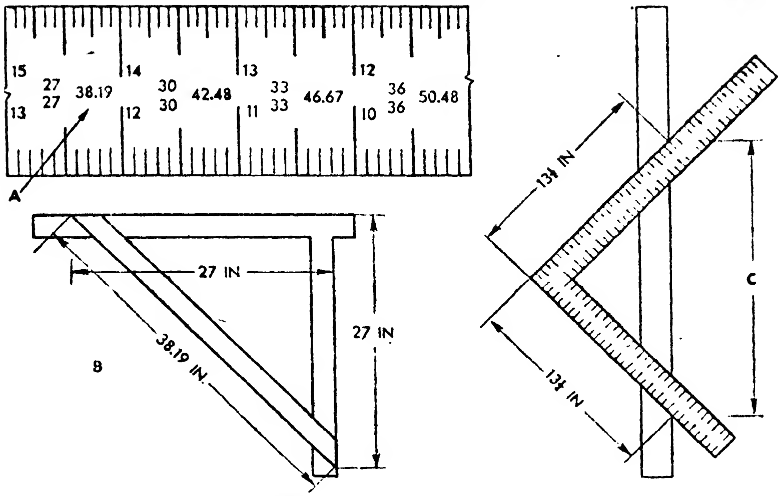


Fig. 5. Brace measure is given on the back of the tongue, and gives the length of common braces. The figure is taken from the tables, as at *A*, to mark out a brace, as shown at *B*. *C*. a more satisfactory manner of setting up the figures on the square and measuring the diagonal.

the square, 12 in. on the other arm and then slide the square until the length figure (again counting inches as feet) reads in its place. The number of feet super (reading inches as feet and fractions of inches as fractions of feet) is given on the first arm, as shown at B.

Sliding the Square

This method of sliding the square in order to obtain proportional figures or amounts, is an important feature of steel square work. Fig. 7 shows how the square is manipulated in this operation. The square is set to the figures concerned, and a straightedge or rule is held against one arm to allow the square to be adjusted without altering the angles. By this method of sliding the square comparative figures are given on the arms, and the measurement between these new figures gives the relative pitch length.

All roof bevels are composed of a series of right-angled triangles and thus are particularly suitable for steel square methods. Fig 8 shows the complete geometrical setting out for roof bevels, and should be carefully considered in relation to the methods described in Chapter 19. Drawings of this kind are not necessary for steel square work, but they are included to illustrate the importance of the right-angled triangle and to allow comparison of the methods. It is the sorting out and the complete understanding of these triangles which makes the use of a steel square a perfectly simple matter.

Note how each bevel can be determined when the base, or run, and the rise are known, or when one length and one angle (other than the right-angle) are already known.

The drawings show the plan

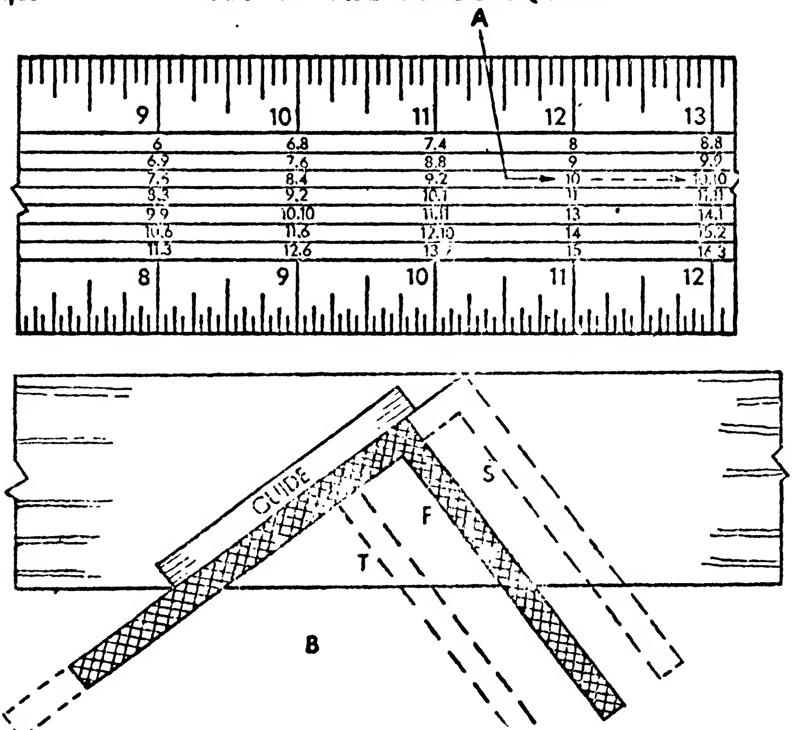


Fig. 6. Essex board measure is given on the back of the blade, as shown at A. To use the measure, find the length of the board under the 12 in. mark on the outer edge of the square, for example 10 ft. On the outer edge of the square find the width of the board, say 13 in. Then follow the line on which the length is marked until the column under the width is reached. The figure 10 ft. 10 in. is the number of feet super in the board. Another way is to set the width of the board on the blade and the 12 in. mark on the tongue, as shown at B. Slide the square until the length of the board reads on the tongue, as shown at T or S. Counting inches as feet the number of feet super then reads on the blade.

and sectional elevation of the essential members of a hipped roof with the position of the steel square indicated. Four different diagrams are shown in order to avoid a great number of confusing lines, but all the right-angled triangles are closely related to each other.

At A the sizes given are the run of the common rafter (RR) and the rise of the rafter (R). To obtain the length and bevels of the common rafter, the run is set on one arm of the square and the rise on the other. The diagonal or hypotenuse of the right-angled triangle thus formed gives the length of the common rafter, the plumb bevel (1) and the seat bevel (2).

To find the length and bevels of the hip rafter, the length of the hip run must first be determined. This is obtained by setting the side run of the roof (SR) on one arm and the run of the rafter (RR) on the other arm as shown. In a roof square in plan, the run of the hip is always taken to be 17 in.

This figure is correct to within about three hundredth parts of an inch.

Hip Bevels

Hip bevels and length are shown at B. The rise (R) is set on one arm and the hip run (HR) on the other to give the bevels for the plumb cut (3) and the seat cut (4). The edge bevel for the hip rafter splay, birds' mouth or mitre, to fit against the ridge, is readily determined by first finding the traces of a plane which contains the edge of the hip.

In a roof square in plan the horizontal trace of this plane is of the same length as the run of the hip. Hence, the length of the hip rafter set up on one arm and the run of the hip rafter on the other arm gives the edge bevel (5). This development is clearly shown in section C of the sketch.

Jack Rafters

Jack rafter bevels are found by developing the true shape of the roof slope containing the edge of the rafters, as shown at C. The side run of the roof (SR) is set on one arm and the rafter length

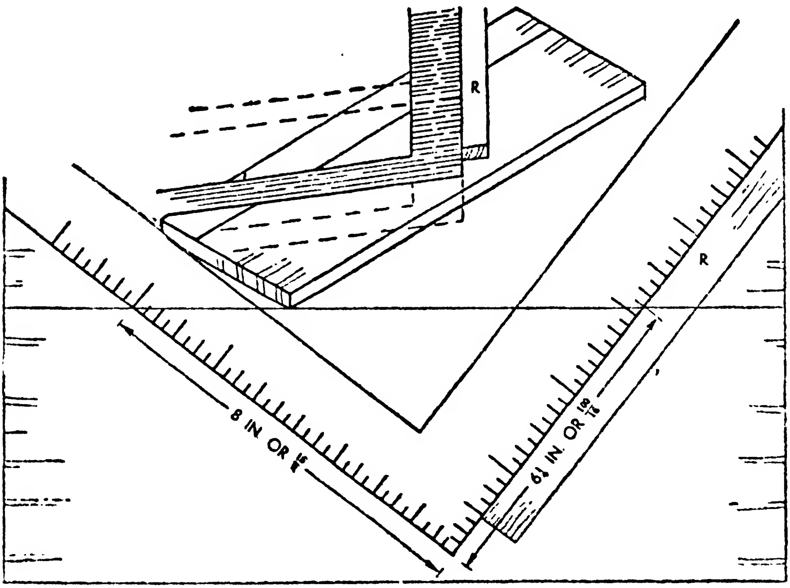


Fig. 7. How a steel square is used to obtain proportional figures or amounts by sliding. The square is set up to the required pitch with a rule or straightedge against one arm ; by moving the square backwards or forwards the proportions are increased or decreased. The example shows how tenths of an inch can be converted into sixteenths. The blade is set to 100 parts (100 sixteenths) and the tongue is set to 16 parts (16 half inches). When the square is moved to read any figure on the blade the tongue gives the proportional figure.

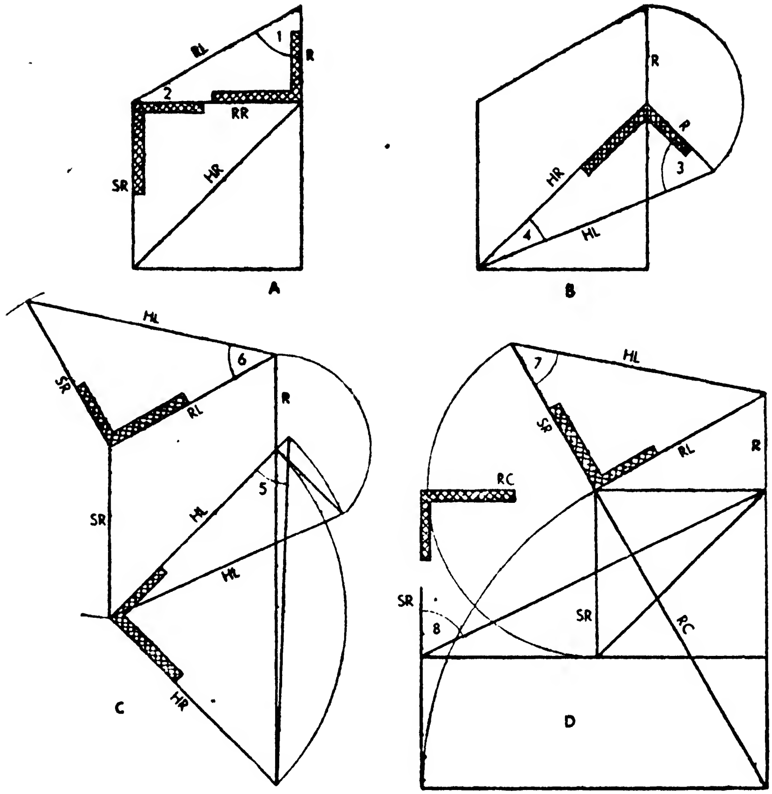


Fig. 8. Right-angled triangles in roof work. A. Rafter run and rafter rise set up on the square to give rafter length and bevels (1) and (2). The run of the hip is obtained by setting the rafter run on one arm and the side run on the other; B. how the length of the hip is obtained by setting the hip run on one arm and the rise on the other to give the bevels (3) and (4); C. edge bevel for hip rafter. The trace of the plane containing the edge of the hip is of equal length to the run of the hip, therefore hip run is set on one arm and hip length on the other to give bevel (5). The edge bevel for jack rafters is found by setting the rafter length on one arm and the side run on the other. Purlin bevels are shown at D. The edge bevel is found by setting the side run on one arm and the rafter length on the other to give bevel (7). Side bevel (8) is found by setting the co-pitch on one arm and the side run on the other.

(RL) on the other to give the required bevel (6).

Purlin bevels are often considered difficult to obtain with a steel square, but a little thought will make them quite clear. A purlin fixed upright only requires a mitre to the hip, while those which are fixed square to the slope of the roof require at least two bevels.

The edge bevel lies on a sloping plane parallel to the slope of the roof surface. This has already been obtained by the set up of the square for the jack rafter edge bevel. The setting is merely reversed to read length of common rafter (RL) on one arm and the side run (SR) on the other arm to give the bevel (7) illustrated at D.

The side bevel for a purlin requires further explanation. One arm of the square lies on the edge of the purlin parallel to the eaves, while the other arm lies in a plane perpendicular to the roof slope. The width of this plane (RC) is set up on one arm and the side run of the roof (SR) on the other to give the side bevel (8).

Alternative Methods

In the above examples the actual lengths themselves cannot be set up on the square, therefore one of two methods is used. The first consists of setting up the dimensions to a scale of one inch to one foot, and the second consists of using a proportional rise for one foot of rafter run. This second way is known as the rise per foot run method, and is used extensively by all experienced steel square users. It has definite standards and is far simpler; fewer figures are needed which are easier to obtain and apply.

Measuring an Angle

Before dealing with this method the correct manner of measuring an angle must be clearly understood. A bevel or angle is defined as 'the inclination of two straight lines which meet,' as shown in Fig. 9 A. When this angle is measured with a protractor the lines show that they enclose an angle of 37 deg. In measuring the angle with the steel square, one arm is placed along one line with the 12 in. mark at the point of intersection, as shown at A, and the distance between the inclined lines where they cross the other arm is measured. This distance is known as the rise. In the example given, the distance measures 9.04 in. and is the rise for an angle of 37 deg. with a base of 12 in. A 12 in. base is always taken and is the accepted

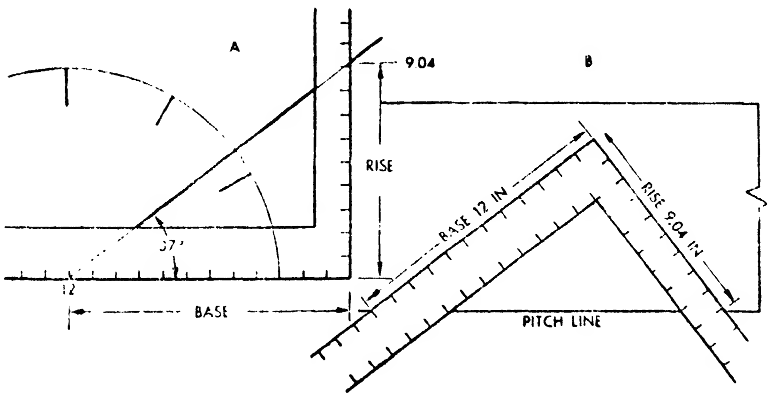


Fig. 9. How an angle is measured with the steel square. The 12 in. mark is placed where the two lines forming the angle meet, then the other arm reads the rise for 1 ft. run, as shown at A. A 12 in. base is the standard measurement for all angles. B. method of marking an angle when the square is set to rise and run.

standard measurement for all angles which are set out with the steel square.

The angle made with the base is the angle of pitch, and may be indicated by degrees; or the rise may be stated in inches and fractions of an inch. When the rise is given, the pitch may be determined by placing the square on a board with the 12 in. mark and rise mark (in this case the rise mark is 9.04 in.) to the edge of the board, as illustrated in Fig. 9, section B. A mark along the base arm will give the pitch required, while the other arm gives an angle known as the co-pitch. Both angles added together equal 90 deg., the right-angle, therefore if the pitch is 37 deg. the other angle must be 53 deg.

Marking the Angle

Since two angles are always given when the steel square is set up, a definite rule of marking the angle by the first-named figure must be followed to avoid confusion or doubt as to which angle to mark. For example, base/rise, whose lengths may be 12 in./9 in., gives the level or

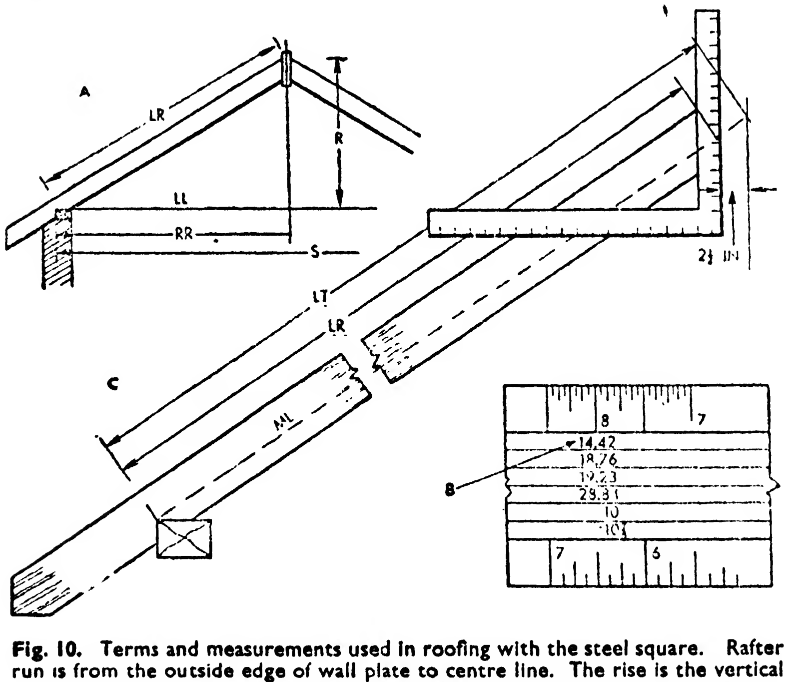


Fig. 10. Terms and measurements used in roofing with the steel square. Rafter run is from the outside edge of wall plate to centre line. The rise is the vertical distance from a level line over the wall plates to the top of the ridge, as shown at *A*. *B*. portion of the rafter framing tables on the face of the blade. The length per foot run of common rafter is taken from the first line under the appropriate rise figure—in the example, 8 in. rise per foot run; *C*. various measuring lines. *ML* is the theoretical measuring line, but in practice *LT* on the edge of the roof is used. For odd number of inches in rafter run, an even number of feet is always taken, for example, a roof of 11 ft. 9½ in. run would be taken as 12 ft. and the odd 2½ in. would be deducted by sliding the square as shown at *C*.

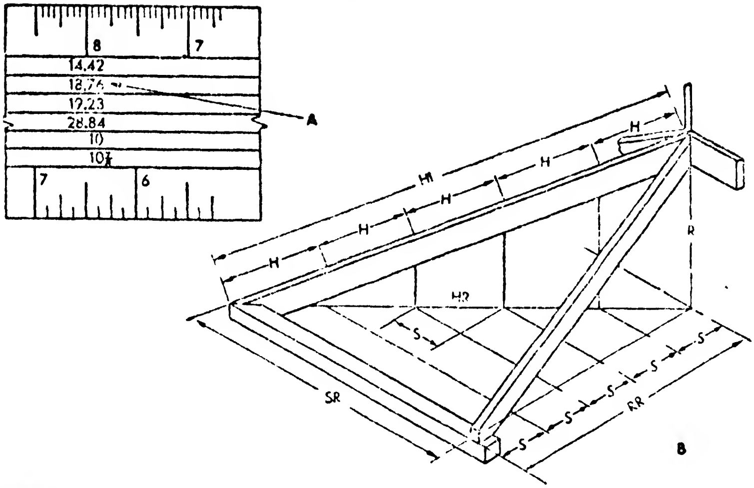


Fig. 11. Hip lengths from rafter framing tables on face of blade. The second line under the appropriate rise per ft. run figure gives the length of hip as shown at *A*. This is for 1 ft. run of common rafter. *B*. How the length is computed. *RR* is rafter run ; *R* rise ; *HL* is hip length and *S* 1 ft. ; *H* hip-length for 1 ft. of common rafter. The length of the hip is found by multiplying the length taken from the tables by the number of feet in the common rafter run.

pitch bevel, while if the figures were reversed as rise/base, it would give the co-pitch or plumb bevel.

Rafter run, or the run of a roof, is a level line measured from the top external edge of the wall plate to the centre line of the roof, or half the span measured from the outside edges of the wall plates. The rise is the length or height of the centre line above the level line, that is, the plumb height from the level of the wall plates to the top of the ridge piece. These terms are illustrated in Fig. 10 A.

On a R square, rafter framing tables are given on the face of the blade. These give :—

(1) The length of common rafter for one foot run.
(2) The length of hip or valley rafter for one foot run.
(3) The length of the first jack rafter spaced at 16 in. centres.
(4) The length of the first jack rafter spaced at 2 ft. centres.
(5) The side or edge cuts of the jack rafters.
(6) The side or edge cuts for hip or valley rafter.

To use the tables, procedure is to find the rise per foot run of the common rafter, then under that figure on the upper edge of the square read the appropriate length for whatever member is required.

The rise per foot run of a common rafter is found by taking the rise of the roof in inches, and dividing it by the number of feet in the run.

Fig. 10 B illustrates a portion of the square with the various tables. The first four tables on the square give lengths and the last two give setting figures for bevels.

In cases where the run of the rafter measures feet and odd inches, the nearest foot length is taken and the odd inches are deducted or added when the rafter is set out. For example, a rafter run of 11 ft. 9½ in. would be taken as 12 ft. and the extra 2½ in. deducted by sliding the square as shown in Fig. 10 C.

To find the length of the common rafter, the figure taken from the tables is multiplied by the number of feet in the run. All lengths are taken as single lines, and a deduction must be made for half the thickness of the ridge. A good plan is to deduct half the thickness of the ridge from the run.

The second column on the rafter framing tables (Fig. 11 A) gives the length of hip or valley rafter for a 12 in. run of common rafter. Therefore the length given on the square is multiplied by the number of feet in the common rafter run. The third and fourth tables give the difference in length of the jack rafters, thus the length of any rafter can be found by multiplying the figure given by the place number of the rafter.

The tables given on the square are, of course, only suitable for even inches of rise, from 2 in. to 17 in.; they are not interchangeable, and are not as useful as degree tables. The method which is introduced herein gives all the figures required for any bevel, and furthermore, may be automatically adjusted to conform with any variation of pitch or shape in plan. The method is based on the properties of congruent triangles; thus additional figures such as co-rafter length, co-hip length, co-side run and co-rise are necessary. But all these figures are given on the simple set-up of the square, and they do not require a special or intricate setting up. These lengths are shown as congruent triangles in Figs. 12 and 13.

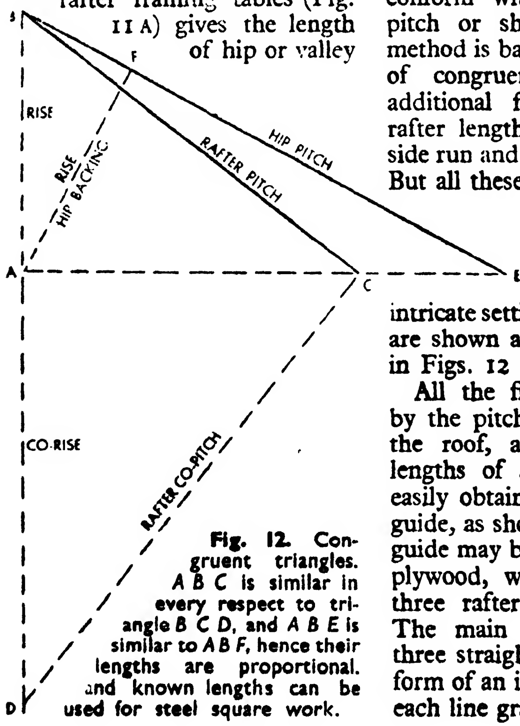


Fig. 12. Congruent triangles. A B C is similar in every respect to triangle B C D, and A B E is similar to A B F, hence their lengths are proportional. and known lengths can be used for steel square work.

All the figures are controlled by the pitch, that is, the rise of the roof, and the proportional lengths of all members can be easily obtained by using a figure guide, as shown in Fig. 14. This guide may be drawn on a sheet of plywood, wallboard or even on three rafters laid side by side. The main markings consist of three straight lines set out in the form of an inverted letter T, with each line graduated in inches and

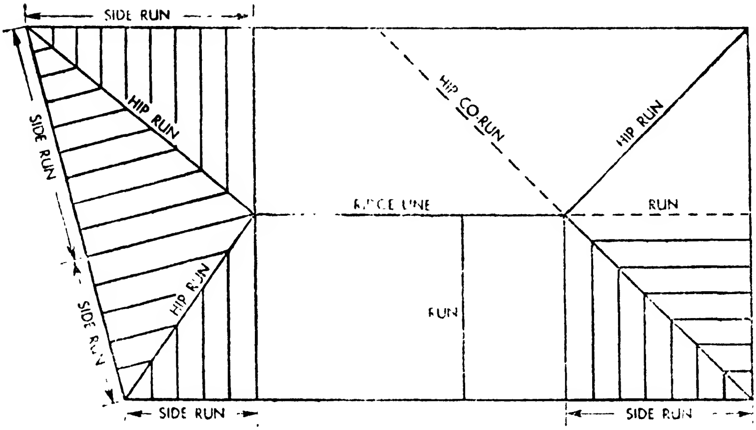


Fig. 13. From the lengths given in this diagram and in Fig. 12 all roof bevels can be found. Note how side runs for the splayed hipped end are determined.

fractions of an inch to read outwards from their point of intersection.

On the vertical line marked A is set out the rafter run of 12 in. and on the right-hand line is marked the rise, say 10½ in. The square is then laid on the figure guide with the heel to the 12 in. mark on the line A, and with the tongue crossing the line B at the 10½ in. mark. The tongue then gives the rafter or pitch length, the blade gives the co-pitch length, and on line C is given the co-rise length. These figures should be recorded for further reference. Next, mark on the line B the length of the side run, say 12 in., then when the heel of the square is placed on the mark on line A, the tongue gives the length of the hip run, and the blade gives the length of the hip co-run. Both these settings are shown in Fig. 14 at 1 and 2 respectively.

On a roof with a square plan and a rafter pitch of 45 deg., both the rise and the side run are 12 in.; while the rafter length and the co-length, as well as the hip run and co-run are all 17 in. In such a case there is no need to find the figures on the guide, but if the rise or the side run is different from 12 in., then all other figures are different.

The lengths obtained by this figure guide will mark all the bevels necessary for any ordinary roof, and it can also be used to obtain more complex bevels.

The set-up of the steel square, and the bevels they mark on roof members, are as follows :—

Rafter run	/ rise	= rafter level.
Rise	/ rafter run	= rafter plumb.
Hip run	/ rise	= hip level.
Rise	/ hip run	= hip plumb.
Rafter length	/ side run	= jack splay.
Side run	/ rafter length	= edge of inclined purlin.
Side run	/ co-rafter length	= side of inclined purlin.
Hip length	/ hip co-run	= hip splay.
Hip reduced length	/ hip co-run	= hip backing bevel.

These arrangements hold good for every form of roof without

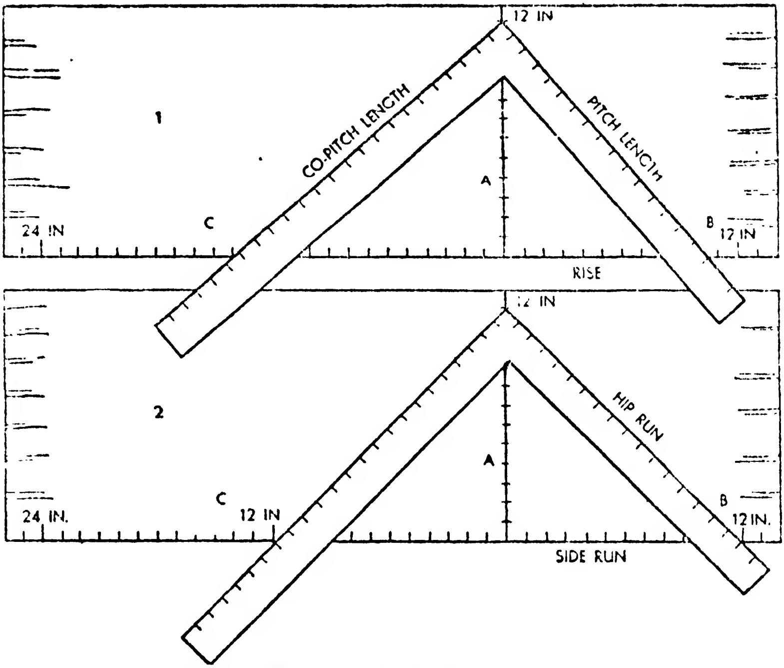


Fig. 14. Figure guide to determine all necessary figures for bevel work. This guide can be used for any pitch of roof of any shape. Heel of the square is set to the 12 in. mark on line *A* and the tongue to the rise on line *B*. The tongue then gives pitch length and the blade gives the co-pitch length, as shown at 1. At 2 the square gives the hip run and co-run.

modification. Some of the terms which are given are on the plan of the roof, and some are on the elevation.

To obtain the difference in length of the jack rafter, set up the square to the figures given, that is, rafter length/side run of roof, then slide the square until the blade reads to the spacing. The difference in length is given on the tongue. Fig. 15 shows the relation of the square to the spacing and the jack rafter diminish.

Shaped rafters and brackets usually have the bevels set out from the straight back or on a line which is struck on their sides.

Regular polygons, of which the most frequently used is the octagon, have different side runs, *e.g.*, a triangle or three-sided figure has a side run of 20.78 in. per foot run, while a dodecagon or twelve-sided figure has a side run of only 3.22 in.

The hip run of any polygon is the diagonal of the run and side run, and is less than 17 in. This makes the hip co-run of greater length, which automatically adjusts all the bevels accordingly, but there is no alteration in the rules and methods previously stated.

A building with one side longer than the other, as in Fig. 13,

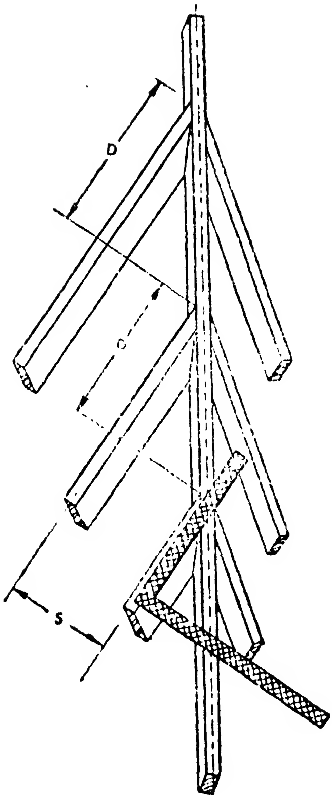


Fig. 15. To illustrate the relation between jack rafter diminish and rafter spacing. When the square is set to jack rafter bevel and moved until the spacing reads on the blade, the tongue will give the amount of diminish for each jack rafter.

has one corner greater than 90 deg. and one corner less than 90 deg. Except that the side runs are not so apparent, the method of treatment is similar to that described for polygons. From the building sizes it can be found that the end is ' out of square ' by, say, 3 in. per foot run; as the diagonal of 12 in. and 3 in. is 12⅜ in., 3 in. is added to this for the acute corner, and subtracted for the obtuse angled corner to give side runs of 15⅜ in. and 9⅜ in. respectively. The bevels are then determined by the rules previously stated. It will be found that each hip run is the co-run to the opposite hip run.

For reasons of appearance, a flat deck may form part of the roof structure, as shown in section at Fig. 16 A. To obtain the bevels for the pitched members deduct the width over the curb from the span over the wall plates and divide by two to give the run of the pitched rafter. If the rafter pitch is fixed, the run of the rafter may be found by sliding the square, set to the rafter pitch, until the rise reads on one arm. The other arm then gives the run. Twice the run deducted from the span will give the size of the curb.

Mansard Roofs

The sizes of a mansard roof, that is, a roof with a double pitch, can be obtained in a similar manner. When once the run and the rise are determined, any bevel and length can be found by the rules previously stated.

Joist bridging or strutting presents a slight variation in working, as shown in Fig. 16 C. The depth of the joists is set up on one arm and the spacing of the joists on the other arm, the plumb cut and the length of the strut are marked, then the square is moved along the strut to mark the second plumb cut.

Stair planning can be simplified by using the square to calculate the number of risers, as shown at Fig. 17 A. Assuming a total height of 11 ft. 1½ in. from floor to floor, and 18 steps, set up the

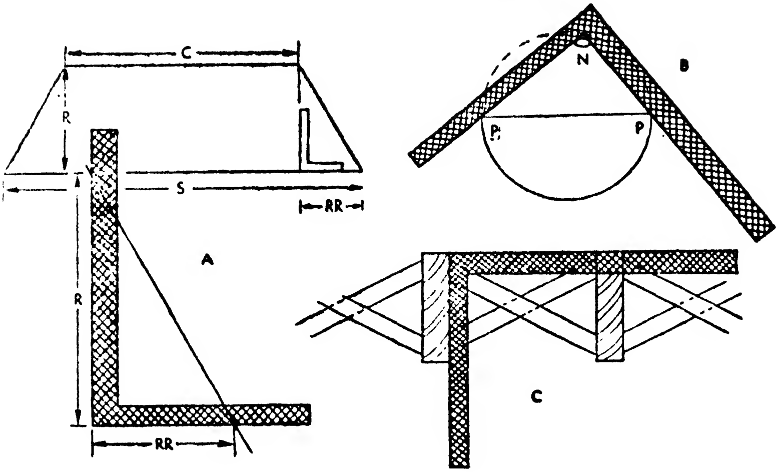


Fig. 16. A. Flat deck to a pitched roof ; B. marking out a circle with the aid of a square ; C. square used to obtain bevels for herringbone strutting.

square as shown at A. On the blade set up 18 in. (equal to the number of steps) and on the tongue set up the height to scale. Slide the square until the blade reads 12 in., the tongue then gives the rise in inches.

Fig. 17 B shows how the square is used as a pitchboard to mark out the housings on a string. For this purpose a fence is a great asset. A fence may consist of a pair of metal gauges, or may be made from two parallel strips of hardwood screwed together, as shown in the diagram.

Lantern lights, gabled or hipped, call for no more knowledge than ordinary steel square roofing, and the same remarks apply to greenhouses, conservatories, ventilators or other structures. Splayed sided hoppers or bins also employ the usual rules and methods, and can be easily marked out with the guidance of the rise figure.

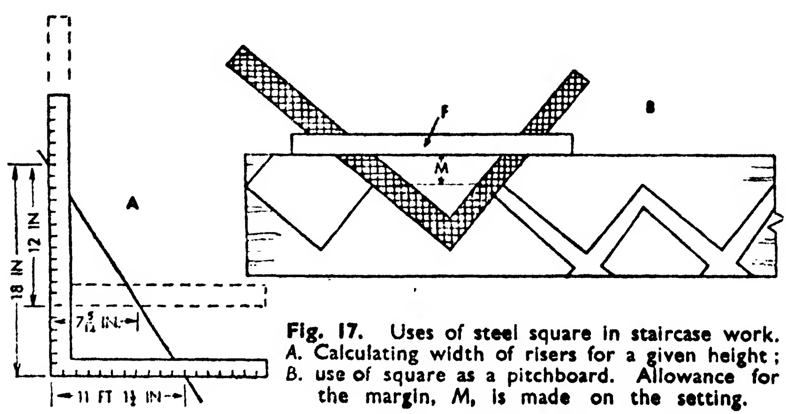


Fig. 17. Uses of steel square in staircase work. A. Calculating width of risers for a given height ; B. use of square as a pitchboard. Allowance for the margin, M, is made on the setting.

CHAPTER 21

USEFUL CALCULATIONS

MATHEMATICAL ABBREVIATIONS. VULGAR FRACTIONS. UNITS OF MEASURE. DECIMALS AND DUODECIMALS. AVERAGES. RATE AND RATIO. PROPORTION AND PERCENTAGE. ALGEBRA. INDICES: SQUARING AND SQUARE ROOTS. EQUATIONS AND FORMULÆ. MENSURATION.

FIGURES are as common in everyday usage as the language. They are used for the computing of lengths, areas, volumes, weight, amounts of money, speed, census, the forecasting of the weather and a host of other things. Apart from simple numerals, units are used such as inches, miles, acres, quarts, pence, pounds, knots, etc.

In addition, the following abbreviations are used in calculations :—

$+$	signifies	addition	$\because$	signifies	because
$-$	,,	subtraction	$>$	,,	greater than
$\times$	,,	multiplication	$<$	,,	less than
$\div$	,,	division	Δ	,,	triangle
$=$	,,	equality	$\pm$	,,	plus or minus
$\therefore$	,,	therefore	$\sqrt{}$	,,	square root

Calculations are seldom confined to the use of whole numbers. Parts of whole numbers have to be used and these are termed fractions. These may occur as vulgar or decimal fractions.

It is as well to examine the process used in the addition of fractions in everyday life. If we add $\frac{1}{4}$d. to $\frac{1}{2}$d. we call the answer three-farthings, or $\frac{1}{4}$ in. and $\frac{1}{2}$ in. as three-quarters of an inch. That is, the sum is expressed in a term common to both.

This process is followed in the addition and subtraction of vulgar fractions generally.

$\frac{3}{4} = \frac{\text{numerator}}{\text{denominator}}$ which shows that the unit is divided into the number of equal parts indicated by the denominator (4) and the numerator shows how many parts are used (3).

Example—Reduce $\frac{10}{16}$ to its lowest terms.

$$\frac{\cancel{10}}{\cancel{16}} = \frac{5}{8}, \text{ cancelling by 2.}$$

Cancelling means the division of both numerator and denominator by the same number or numbers until the lowest stage is reached.

Example—Express as a mixed number in its lowest form $\frac{45}{12}$

$$\frac{\cancel{45}}{\cancel{12}} = \frac{15}{4} = 3\tfrac{3}{4}.$$

(i) Cancel by 3. (ii) Divide 15 by 4. The quotient (= the number of times it "goes") is 3 and the remainder is 3. Conversely, $3\frac{3}{4}$ may be expressed as an "improper" fraction by multiplying 3 by 4 and adding 3—*i.e.*, finding the number of "quarters" in $3\frac{3}{4}$, which is 15.

When one number is contained in another an exact number of times it is a *factor*, *e.g.*, 7 and 9 are factors of 63, since $7 \times 9 = 63$. A prime number is one which has no factors, *e.g.*, 1, 2, 3, 5, 7, 11, 13, 17, etc., are all prime numbers.

Example—Split 63 into prime factors.

$$\begin{array}{l} 3\,/\underline{63} \\ 3\,/\underline{21} \\ \quad 7 \end{array} \quad \therefore 63 = 3 \times 3 \times 7.$$

The least common multiple (L.C.M.) of a series of numbers is the least number which contains each number as a factor.

Example—Find the L.C.M. of 12, 10 and 16.

$$\begin{array}{r} 2\,/\underline{12} \\ 2\,/\underline{\ 6} \\ 3 \end{array} \qquad \begin{array}{r} 2\,/\underline{10} \\ 5 \end{array} \qquad \begin{array}{r} 2\,/\underline{16} \\ 2\,/\underline{\ 8} \\ 2\,/\underline{\ 4} \\ 2 \end{array}$$

$\therefore 12 = 2 \times 2 \times 3$ $\quad\therefore 10 = 2 \times 5$ $\quad\therefore 16 = 2 \times 2 \times 2 \times 2$

The L.C.M. is the *least* product of prime factors which contains each of the products $2 \times 2 \times 3$, 2×5, and $2 \times 2 \times 2 \times 2$.

The L.C.M. of 12, 10 and 16 $= 2 \times 2 \times 3 \times 5 \times 2 \times 2 = 240$.

That is, 240 is the smallest number exactly divisible by 12, 10 and 16.

The latter is used in order to arrive at the multiple common to denominators when adding or subtracting vulgar fractions.

Example—Simplify $\frac{5}{12} + \frac{9}{10} - \frac{7}{16}$

The L.C.M. of 12, 10 and 16 is 240.

$$\therefore \frac{5}{12} + \frac{9}{10} - \frac{7}{16} = \frac{100}{240} + \frac{216}{240} - \frac{105}{240} = \frac{316 - 105}{240} \quad \frac{211}{240}$$

Where mixed numbers occur, *e.g.*, $13\frac{4}{5}$ and $3\frac{2}{7}$ are mixed numbers, the whole numbers may be added first, the fractions afterwards, and the sum of both additions is the answer—

$$\text{i.e.,}\quad 13\frac{4}{5} + 3\frac{2}{7} = 16 + \frac{28 + 10}{35} = 16 + \frac{38}{35} = 16 + 1\frac{3}{35} = 17\frac{3}{35}$$

$$\text{Also}\quad 14\frac{1}{6} - 3\frac{5}{8} = 11\frac{4 - 15}{24} = 11\frac{-11}{24} = 10\frac{13}{24}$$

To multiply two fractions, multiply the two numerators to make the numerator of the product and the two denominators to form the denominator of the product.

Example—Find the product of $\frac{4}{5}$ and $\frac{1}{7} = \frac{4}{5} \times \frac{1}{7} = \frac{4}{35}$

In multiplication mixed numbers must be expressed as improper fractions. Any numerator and denominator may be cancelled whether they occur in the same fraction or not. This may be reasoned from the preceding notes.

Example—The area of a circle is given as $3\frac{1}{7} \times r \times r$. What is the area when $r = \frac{7''}{8}$?

$$\text{Area} = \frac{\cancel{22}^{11}}{\cancel{7}_{1}} \times \frac{\cancel{7}^{1}}{\cancel{8}_{4}} \times \frac{7}{8} = \frac{77}{32} = 2\frac{13}{32} \text{ sq. ins.}$$

Explanation: (*a*) Convert $3\frac{1}{7}$ to an improper fraction $= \frac{22}{7}$. (*b*) Cancel common factors top and bottom, *i.e.*, cancel by 7 and by 2. (*c*) Multiply numerators for new numerator and denominators for new denominator. (*d*) Reduce to mixed number.

It should be emphasised that the reader would benefit by selecting examples for practice, particularly should he be uncertain of the work.

To divide by a fraction, multiply by the fraction turned upside down, *i.e.*, to divide a fraction by 6 multiply by $\frac{1}{6}$.

Example—How many pieces of board $6\frac{7}{8}$ in. long may be cut from a length of 11 ft. (ignoring saw-cuts)?

$$11 \text{ ft} \div 6\tfrac{7}{8} \text{ in.} = 132 \div 6\tfrac{7}{8} = \frac{132}{1} \div \frac{55}{8} = \frac{\cancel{132}^{12}}{1} \times \frac{8}{\cancel{55}_{5}} = \frac{96}{5} = 19\frac{1}{5}$$

or 19 pieces and $\frac{1}{5}$ of a piece over.

A compound fraction such as $\frac{1\frac{1}{2}}{\frac{3}{4}}$ means $1\frac{1}{2} \div \frac{3}{4} = \frac{\cancel{3}}{\cancel{2}} \times \frac{\cancel{4}^{2}}{\cancel{3}} = 2.$

When several fractions (or any other numbers) are connected by the signs of addition, subtraction, multiplication and division, the operations denoted by $\times$ and $\div$ must be done first.

The word "of" between two fractions means "multiply by" ($\times$).

If "of" and "$\times$" are in the same expression, the "of" is done first, *i.e.*—

$$8 \div \tfrac{3}{4} \text{ of } 12, \text{ or } 8 \div (\tfrac{3}{4} \times 12) = 8 \div 9.$$

whereas—

$$8 \div \tfrac{3}{4} \times 12 = 8 \times \tfrac{4}{3} \times 12.$$

When two or more numbers are enclosed in brackets their value must be found first, whatever the signs.

Example—Simplify $2\frac{1}{3} \times (1\frac{1}{2} - \frac{1}{4})$.

$$1\frac{1}{2} - \frac{1}{4} = \frac{3}{2} - \frac{1}{4} = \frac{6}{4} - \frac{1}{4} = \frac{5}{4} \;:\; 2\frac{1}{3} \times \frac{5}{4} = \frac{7}{3} \times \frac{5}{4} = \frac{35}{12} = 2\frac{11}{12}$$

We will now refer back to the question of units mentioned on the first page of this chapter. Those used most commonly by the carpenter and joiner are :—

(1) Units of length, or linear measure.

(2) Units of area, or square measure.

(3) Units of volume, or cubic measure.

(1) The measurement of length is obviously familiar to every craftsman and consists of the number of linear units in any given length. The unit table is as follows :—

12 inches	=	1 foot
3 feet	=	1 yard
$5\frac{1}{2}$ yards	=	1 rod, pole or perch
220 yards	=	40 poles = 1 furlong
1,760 yards	=	8 furlongs = 1 mile
100 links	=	22 yards = 1 chain
10 chains	=	1 furlong

A familiarity with the metric system is an advantage.

(2) The measurement of area consists of the number of square units in any given surface. For instance, the number of square inches (*i.e.*, squares of 1 in. side) in the surface of a panel 11 in. × 15 in. = 11 × 15 = 165 square inches. The unit table is as follows :—

144 square inches	=	1 square foot
9 square feet	=	1 square yard
$30\frac{1}{4}$ square yards	=	1 square pole or rod
40 square rods	=	1 rood
4 roods	=	1 acre
4,840 square yards	=	1 acre
10 square chains	=	1 acre
640 acres	=	1 square mile

(3) Measurement of volume consists of the number of cubic units in any given volume. For instance, the number of cubic inches in a block 6 in. × 2 in. × 4 in. = 6 × 2 × 4 = 48 cubic inches.

1,728 cubic inches	=	1 cubic foot
27 cubic feet	=	1 cubic yard

To return again to the subject of fractions, the alternatives to the use of vulgar fractions are decimal and duodecimal fractions.

Decimals are an extension of the practice of our ordinary notation, but in a decreasing instead of an increasing scale in units of 10 times. Thus, 01111·1110 reads one thousand, one hundred, one ten, one unit, POINT, one tenth ($\frac{1}{10}$), one hundredth ($\frac{1}{100}$), and one thousandth ($\frac{1}{1000}$). Thus, if we call 1 the basic unit the digits left and right are in ascending and descending order of tens respectively. The change to fractional values is indicated by the decimal point after the unit digit. Note that as the number of figures *after* the decimal point increases so their significant value decreases. Noughts at *each* end have no value.

Addition and subtraction are the same as for ordinary notation and in the case of multiplication and division care is needed in the placing of the decimal point. A rough check will always assist in the fixing of the decimal point.

Duodecimals.—The use of duodecimals is a system born of our measuring scale of dividing units into 12 parts, *i.e.*, 12 inches = 1 foot, etc. In this system the units and sub-units are divided into 12 instead of 10 as in the ordinary decimal system.

It follows that as the units are divided into 12 parts, two digits may occur in one unit, whereas in ordinary notation there is only one, anything above 9 carrying on to the next higher unit in the scale. This means that units and sub-units in the duodecimal system are spaced apart.

The following notation is that used in the building trade—strict duodecimal notation differs slightly.

1 foot (1′)	=	12 inches (12″)
1″	=	12 parts (12″′)
1″′ or part	=	12 thirds

In practice, anything beyond inches is ignored, always working to the nearest twelfth—sub-divisions are included here for the sake of accuracy.

The foot may be (*a*) Run (linear), (*b*) Super (area), (*c*) Cube (volume). Compare the scale set up in Fig. 1.

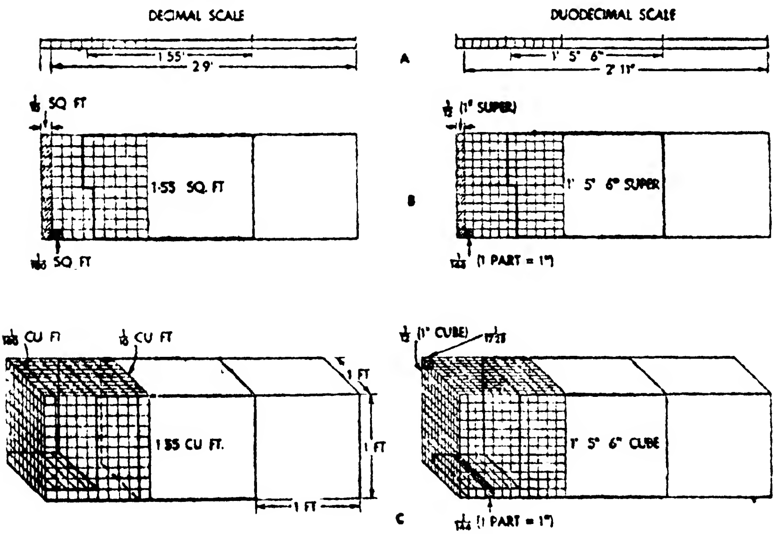


Fig. 1.—Difference between decimal system of measuring and the builders' method of measuring by duodecimals. A. Linear or length measurement, known as *feet run*; one dimension required. B. measurement of area, or *feet super*; two dimensions required. C. measurement of volume or *feet cube*; for this calculation three dimensions are required.

(*a*) RUN: (i) DECIMAL: 1·55 feet represents—

$$1 \text{ foot} + \frac{5}{10} \text{ foot} + \frac{5}{100} \text{ foot } or\ 1\frac{55}{100} \text{ feet}$$

$$= 1 \text{ foot} + \tfrac{1}{2} \text{ foot} + \frac{1}{20} \text{ foot} \left(\frac{12}{20} \text{ inch}\right)$$

$$= 1 \text{ foot } 6\frac{3}{5} \text{ inches.}$$

(ii) DUODECIMALS: 1′ 5″ 6‴ represents—

$$1 \text{ foot} + \frac{5}{12} \text{ foot} + \frac{6}{144} \text{ foot.}$$

$$= 1 \text{ foot} + 5 \text{ inches} + \frac{6}{12} \text{ inch.}$$

= 1 foot $5\frac{1}{2}$ inches run—this is quite straightforward ordinary measuring. Note that areas and volumes are divided into the *same parts* as are used in linear dimensions.

(*b*) SUPER: (i) DECIMALS: The complete vertical strips are tenths of a *square* foot and the small squares hundredths of a square foot.

1·55 square feet represent—

$$1 \text{ square foot} + \frac{5}{10} \text{ (or } \tfrac{1}{2}\text{) square foot} + \frac{5}{100} \text{ square foot.}$$

(ii) DUODECIMALS: Each complete vertical strip is $\frac{1}{12}$ square foot (called 1″ super) and each small square is $\frac{1}{144}$ square foot.

1′ 5″ 6‴ super, represents—

$$1 \text{ square foot} + \frac{5}{12} \text{ square foot} + \frac{6}{144} \text{ square foot}$$

= 1 foot $5\frac{1}{2}$ inches super.

(*c*) CUBE: (i) DECIMALS: Each complete vertical slab is $\frac{1}{10}$, each column $\frac{1}{100}$ and each small cube $\frac{1}{1000}$ square foot.

1·55 cubic feet represents—

$$1 \text{ cubic foot} + \frac{5}{10} \text{ (or } \tfrac{1}{2}\text{) cubic foot} + \frac{5}{100}\left(\frac{1}{20}\right) \text{ cubic foot.}$$

(ii) DUODECIMALS: Each complete vertical *slab* is $\frac{1}{12}$ (1″) of a cubic foot, called "1 inch cube" (*note !*), each column of $\frac{1}{144}$ cubic foot (1‴) and each small square (*i.e.*, each actual cubic inch) is $\frac{1}{1728}$ cubic foot.

1′ 5″ 6‴ cube represents—

$$1 \text{ cubic foot} + \frac{5}{12} \text{ cubic foot} + \frac{6}{144} \text{ cubic foot} = 1 \text{ foot } 5\tfrac{1}{2} \text{ inches cube.}$$

It is wise to think of these inches, parts and thirds as shown in Fig. 1. They are all twelfth parts and the quantities are added and subtracted in the same way as other weights and measures.

Example—Add—

Decimals	Duodecimals
1·43	$1'\ 4''\ 3'''$
2·71	$2'\ 7''\ 1'''$
9·6	$9'\ 6''$
13·74	$13'\ 5''\ 4'''$

Example—Subtract—

Decimals	Duodecimals
7·94	$7'\ 9''\ 4'''$
4·38	$4'\ 3''\ 8'''$
3·56	$3'\ 5''\ 8'''$

Since duodecimals are used chiefly for the measurement of lengths, areas and volumes, it follows that length by length will give area (super), and areas by length, volume (cube)—these operations involving multiplication are known as squaring and cubing. Since 1 ft. run × 1 in. = 1 in. super (Fig. 1) and 1 ft. super × 1 in. run = 1 in. cube, it follows that when either a length or an area is multiplied by one inch (1″) the answer is one step lower in the duodecimal scale; or, either a length or an area is multiplied by one foot (1′) the answer is the same step in the duodecimal scale. Therefore, commence multiplication by using the feet multiplier first to give the same relative steps as in the multiplicand.

Example—Find the area of a flat roof 17′ 7½″ × 12′ 4½″ (*a*) by decimals, (*b*) by duodecimals.

(*a*)

```
 17·625
  1·2375  × 10
 ------------
 17·625
  3·5250
   ·52875
   ·123375
   ·0088125
 ------------
 21·8109375  × 10

=   218·109375
```

For all practical purposes this is 218·1 square feet, but if ·109375 is multiplied by by 144 (square inches in a square foot) the answer will be 218 sq. ft. 15·75 (15¾) sq. ins.

(*b*)

```
 17′   7″   6‴
 12′   4″   6‴
 -------------
211′   6″   0‴     (multiplying 17′ 7″ 6‴ by 12′)
  5′  10″   6‴  0  (multiplying by 4″)
        8″  9‴  9·0 (multiplying by 6‴)
 -------------
218′   1″   3‴  9·0
```

$= 218 \text{ sq. ft.} + \frac{1}{12} + \frac{3}{144} + \frac{9}{1728}$

= 218 sq. ft. 15¾ sq. ins. This would be entered up in quantities as 218·1.

In (*a*) the multiplier has been reduced to *standard form, i.e.*, a number having the decimal point after the first significant figure. To multiply a number by a standard number put the decimal point of the standard number (the multiplier) under the decimal point of the multiplicand (the number to be multiplied) and proceed in the usual manner. The decimal point of each line of working and of the answer come in the same column. Another method of multiplication in decimals is to multiply in the ordinary way and then "count the decimal points."

Example—Find the cubic contents of fir in 15 joists 9″ × 2″ × 14′ 9″ (*a*) by vulgar fractions, (*b*) by decimals, (*c*) by duodecimals.

(*a*) $15 \times \frac{3}{4} \times \frac{1}{6} \times \frac{59}{4} = \frac{885}{32} = 27\frac{21}{32}$ cubic feet = 27 cubic feet 1,134 cubic inches.

(*b*)

14·75
1·5 × 10 (= 15)
————
14·75
7·375
————
22·125 × 10
————
= 221·25

221·25
7·5 ÷ 10 (= ·75 = ¾ = 9″)
————
1548·75
110·625
————
1659·375 ÷ 10
————
= 165·9375

165·9375
1·667 ÷ 10 (= ·166 = $\frac{1}{6}$ = 2″)
————
165·9375
99·56250
9·956250
1·1615625 (× 7 to nearest)
————
276·6178125 ÷ 10

= 27·66 to two decimal places.
= 27 cubic feet 1,140 cubic inches.

(*c*)

14′ 9″
9″
————
11′ 0″ 9″′ (14′ 9″ × 9″)
2″
————
multiply by 15: 1′ 10″ 1″′ 6″″
15
————
27′ 7″ 10″′ 6″″ =

$27 \text{ cu. ft.} + \frac{7}{12} + \frac{10}{144} + \frac{6}{1728}$:

1008 = $\frac{7}{12}$ of 1728
120 = $\frac{10}{144}$ of 1728
6 = $\frac{6}{1728}$ of 1728
————
1134 —

27 cubic feet 1,134 cubic inches.

It can safely be said that duodecimals are chiefly used for linear, superficial and cubic dimensions in building, particularly for work in quantity surveying. When ordinary division, etc., is called for, more general methods are used. The reader should work out examples for practice.

Rate and Ratio

When two quantities are of the same kind, such as 8 feet and 12 feet, the fraction which the first is of the second is $\frac{8}{12}$ ($\frac{2}{3}$), which is the ratio of the first to the second. Thus, the ratio of 8 feet to 12 feet is $\frac{2}{3}$, or,

$$8 \text{ feet} : 12 \text{ feet} = 2 : 3 \text{ or } \frac{8 \text{ ft.}}{12 \text{ ft.}} = \frac{2}{3}$$

$\frac{2}{3}$ is an abstract number, *i.e.*, it only explains a fact, it is not any *thing*.

When two quantities are of different kinds, *e.g.*, 18/– and 3 ft., the fraction now represented is a *rate*, thus the rate of 18/– to 3 ft. is 18/– divided equally among 3 ft., or 6/– to the foot.

$$i.e., \frac{18/-}{3 \text{ ft.}} = \frac{6/-}{1 \text{ ft.}} \text{ or } 6/- \text{ per foot.}$$

The *Unitary method* is useful for solving many problems.

Example—If 336 feet super of panelling cost £29 8s. od., how much would 450 feet super cost ?

$$336 \text{ feet super cost } £29 \ 8 \ 0$$

$$1 \quad ,, \quad ,, \quad ,, \quad \frac{29 \ 8 \ 0}{336}$$

$$450 \quad ,, \quad ,, \quad ,, \quad \frac{£29 \ 8 \ 0}{\cancel{336}_{56}} \times \cancel{450}\ 75$$

$$\frac{\cancel{588}^{21}}{\cancel{56}_{2}} \times 75/- = \frac{1575}{2} = 787\tfrac{1}{2}/- = £39 \ 7 \ 6$$

When two rates or ratios are equal the quantities involved are said to be in *proportion*, *e.g.*, both $\frac{14 \text{ yards}}{6 \text{ yards}}$ and $\frac{£3 \ 10 \ 0}{£1 \ 10 \ 0} = \frac{7}{3}$ and 14 yards, 6 yards, £3 10s. od. and £1 10s. od. are in proportion and may be written as 14 yds. : 6 yds. = £3 10s. od. : £1 10s. od., or $\frac{14 \text{ yards}}{6 \text{ yards}} = \frac{£3 \ 10 \ 0}{£1 \ 10 \ 0}$, or we say 14 yards is to 6 yards as £3 10s. od. is to £1 10s. od.

In any proportion the product of the inside numbers—the means—equals the product of the outside numbers—the extremes, *e.g.*, if $3:4::9:12$, then $3 \times 12 = 4 \times 9$, or if $\frac{3}{4} :: \frac{9}{12}$ then $3 \times 12 = 4 \times 9$.

Percentage is a method of stating ratio or ratios in proportion to 100, or comparison on the basis of 100 of the same kind. For example, 3d. is $\frac{1}{4}$ of 1/–, or 25 per cent. of a 1/–, *i.e.*, $\frac{25}{100} = \frac{1}{4}$; or £2 is 40 per cent. or $\frac{40}{100}$ of £5, *i.e.*, $\frac{40}{100} \times 5 = £2$.

Example—The net cost of a job is £750. What should be the estimate to allow for 10 per cent. profit ?

$$\frac{10}{100} \text{ of } £750 = £75 \text{ profit} \therefore \text{ estimate} = £750 + 75 = £825 = \text{total cost}$$

Algebra

Algebra is the use of literal symbols to express quantities, and the following facts should be noted :—A formula is a statement of the numerical relation between two or more quantities expressed by letters.

Letters (symbols), or letters (symbols) and numbers, placed against each other imply multiplication, *e.g.*, $6xy$ means $6 \times x \times y$. Generally literal amounts are dealt with in the same way as ordinary numbers, *e.g.*, $x + 4x - x + 10x = 15x - x = 14x$; note that x is the same as $1x$.

and $\frac{\cancel{4x}}{\cancel{3}} \times \frac{\cancel{9}\,3}{\cancel{8}\,2} = \frac{3x}{2}$: *and* $\frac{4x}{3} + \frac{9}{8} = \frac{59x}{24}$

Minus quantities are often met with in algebra and the reader must keep in mind that "minus" is the exact opposite to "plus." If $+$ means up, $-$ means down. Ground level is neutral and is 0. $+ x - x$ means 0 *always*. $+ 7 - 2$ means up 7 (feet) and down 2 and equals $+ 5$. $- 7 + 2$ means up 2 and down 7 and equals $- 5$.

The reader must think about what an expression such as $-(-7)$ means. Here it will help to think of minus as a "reverse" sign, *i.e.*, -7 means go down 7, but the minus outside the bracket means "go in reverse" or up, or $+ 7$.

A minus times a minus is equivalent to plus, and two minus quantities in multiplication or division give a plus:

$$e.g., \quad \frac{6}{12} = \frac{1}{2} : \frac{-6}{-12} = \frac{1}{2} : -6 \times -12 = 72$$

Note (i) $+ 7 \times + 2 = 14$: (ii) $-7 \times + 2 = -14$:
(iii) $-7 \times - 2 = + 14$.

Brackets are more common to literal than to numerical quantities. A bracket in arithmetic is treated thus $2(41 - 19) = 2 \times 22 = 44$. This treatment is not possible in algebra and in these cases each of the symbols must be multiplied separately by the number outside the bracket.

Examples—(i) $4(x + y) = 4x + 4y$
(ii) $5(2x - 3y) = 10x - 15y$
(iii) $a(2x + 3y) = 2ax + 3ay$

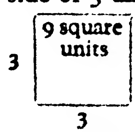
Should any expression appear difficult to follow, then check by using arithmetic in a similar case.

When the numerator of an algebraic fraction consists of several quantities connected by $+$ and $-$ signs, the *whole* numerator is treated as an entity—as if it were in a bracket.

$$e.g., \quad \frac{3a - 7}{2} = \frac{1}{2}(3a - 7) = \frac{3}{2}a - \frac{7}{2}$$

Indices: Squaring and Square Roots

If 3^2 is written down then it is stated as 3 squared or the number found by taking a square of side of 3 units, *i.e.*—



Conversely, 3 is put down as $\sqrt{9}$ or $9^{\frac{1}{2}}$ stated as the square root of 9, or the number which when multiplied by itself equals 9. The number is, of course, 3. (i) 3^2 and (ii) 3^3 represent the raising of 3 to (i) two dimensions or squared and (ii) 3 dimensions or cubed. $3^2 = 9$ and $3^3 = 27$. $\sqrt{9} = 9^{\frac{1}{2}} = 3$, and $\sqrt[3]{27} = 27^{\frac{1}{3}} = 3$.

Beyond the obvious raising of a number to a cube we speak of raising numbers to powers, *i.e.*, 4 to the fifth power $= 4^5 = 4 \times 4 \times 4 \times 4 \times 4 = 1024$ and $\sqrt[5]{1024} = 1024^{\frac{1}{5}} = 4$.

The small figure used to indicate the power to which the number is raised is called the *index*, and indices are applicable to symbols (algebra) as used in formulæ, in the same way as to figures.

Examples—

(1) $a^3 \times a^2 = a \times a \times a \times a \times a = a^{3+2} = a^5$

(2) $3^3 \times 3^2 = 3 \times 3 \times 3 \times 3 \times 3 = 3^{3+2} = 3^5 = 243$

(3) $a^4 \div a^3 = \dfrac{a \times a \times a \times a}{a \times a \times a} = a^{4-3} = a^1 = a$

(4) $3^4 \div 3^3 = \dfrac{3 \times 3 \times 3 \times 3}{3 \times 3 \times 3} = 3^{4-3} = 3^1 = 3$

(5) $(a^3)^2 = a^3 \times a^3 = a^{3\times 2} = a^6$

(6) $(3^3)^2 = 3^3 \times 3^3 = 3^{3\times 2} = 3^6 = 729$

From the above note that to *multiply* two powers of a number or symbol, *add the indices*. To *divide* one power of a number or symbol by another *subtract the index of the divisor*.

To raise a power of a symbol or number to some other power, multiply the indices, and conversely it follows that to find the square or cube root of a power of a letter or number, divide the index by 2 or 3 respectively. Notice from the previous remarks on algebra $-7 \times -7 = 49$ or $(-7)^2 = 49$, that the squares of all minus quantities are plus, or that $\sqrt{49}$ may be $+7$ or -7, usually written as ± 7. It follows that there is no real root to any negative quantity.

It is quite obvious that comparatively few numbers have a whole number as a square root—such numbers are 4, 9, 16, 25, 36, 49, etc., the roots of which are 2, 3, 4, 5, etc. It is often necessary to find the square root of a number and the method is as follows :—

Find the square root of 303·8049 17·43 = Ans.

$a \times a = 1$		3′03·80′49
		1
(2 × 1 and put down 7)	27	203
		189 = 7 × 27
(2 × 17 and put down 4)	344	1480
		1376 = 4 × 344
(2 × 174 and put down 3)	3483	10449
		10449 = 3 × 3483
		......

Method—Mark the number off in pairs either side of the decimal point as shown.

(1) The largest square which is less than 3 is 1^2. Put 1 in the answer and also on the left side. Multiply and subtract from the 3.

(2) Bring down the next *pair* of figures.

(3) Double the 1 already obtained and put down the result on the left of 203.

(4) Try 7 in the answer and the left column : it goes, enter up the 7 and multiply.

(5) Proceed similarly until an answer is obtained to the necessary number of significant figures.

To find the square root of a vulgar fraction (*a*) find the square root of the denominator and numerator separately (this is the better method when each are perfect squares), (*b*) reduce the fraction to a decimal and find the square root as above.

Equations and Formulæ

An *equation* is a statement that two quantities are equal, connected by the sign equality (=). The two parts of the equation are 'sides.'

A simple equation contains only one unknown quantity represented by a *letter*, and that only to the first degree, *e.g.*, $2x + 3(x - 1) = 9$, is a simple equation; it contains only one *letter* and there are no powers or roots of 'x.' To solve an equation is to find the value of the unknown quantity.

All simple equations can be solved by applying the first two equation laws :—

(1) Any number can be added to or subtracted from both sides of an equation without altering the equality.

(2) Both sides of an equation can be multiplied or divided by the same number without altering the equality.

Also (3) Any power or any root may be taken of both sides of an equation without altering the equality.

Obviously, both sides of an equation may be interchanged, *i.e.*, if $x = 3$, then $3 = x$. RHS and LHS will be used as abbreviations for right-hand side and left-hand side respectively.

Example—Solve the equation $4x - 5 = x + 4$

$4x - 5 = x + 4$

$4x - 5 - x = x + 4 - x$: Law 1 (in order to remove the x from the RHS)

$\therefore\ 3x - 5 = 4$

$3x - 5 + 5 = 4 + 5$ (in order to remove the -5 from the LHS)

$\therefore\ 3x = 9$

and $x = 3$ (Law 2—divide both sides by 3). *Check* $4 \times 3 - 5 = 7$ and $3 + 4 = 7$.

Formulæ are used to express, generally, areas of plane figures, volumes of solids, and particular laws, *e.g.*, the area of a rectangle is length times breadth, or $A = lb$. The volume of a cube is length times breadth times height, and since these are equal, $V = L^3$, where V is the volume and L the length of one side. $\text{Safe load (in cwts.)} = \dfrac{Wh}{8d}$ is a formula for finding the safe load in cwts. that a pile will support where W = weight of monkey in cwts., h = height fallen by monkey in inches, and d = distance driven by last blow in inches.

When W = 20 cwts.
h = 7 ft. 6 in.
d = $\frac{1}{4}$ in.

$$\text{Safe load} = \frac{20 \times 90}{8 \times \frac{1}{4}} = 900 \text{ cwts.}$$

Notice that each formula represents something—the subject of the formula—in the above (1) the subject is A, in (2) V, and in (3) Safe load. By substituting particular figures for values in the formula we get a particular case.

Example—To design a joist, the formula M = R is used where M is the bending moment and R is the resistance. If $M = \frac{WL}{4}$ and $R = \frac{fbd^2}{6}$ for a wooden joist, find the depth of the joist when W = 1,440 lbs., L = 144 inches, f = 2,000 lb. and b = 3 in.

N.B.—Since we have to find the depth 'd' the formula is needed in terms of 'd.'

$$\frac{WL}{4} = \frac{fbd^2}{6}$$

$\therefore$ $3\ WL = 2 \times fbd^2$ (multiplying both sides by 12, the L.C.M. of 4 and 6, to *clear* the fraction).

$\therefore$ $\frac{3\ WL}{2\ fb} = \frac{2 \times fbd^2}{2fb}$ (divide both sides by 2f to remove 2fb from the RHS).

$\therefore$ $\frac{3\ WL}{2\ fb} = d^2$ *or* $d^2 = \frac{3\ WL}{2\ fb}$ $\therefore$ $d = \sqrt{\frac{3\ WL}{2\ fb}}$ (Law 3).

Substituting given values :—

$$d = \sqrt{\frac{\cancel{3} \times 144\cancel{0} \times 144}{2 \times 200\cancel{0} \times \cancel{3}}} = \sqrt{\frac{144 \times 144}{20 \times 20}} = \frac{144}{20} = \underline{\underline{7.2''}} = \text{depth.}$$

N.B.—Since the unknown 'd' in the above equation is of the second power, the equation is known as a *quadratic equation*.

Mensuration

Mensuration is possibly the branch of calculations most important to the carpenter and joiner and from our point of view means the memorising of formulæ peculiar to the shape or solid concerned, and the application of the preceding notes thereto in their solution.

Areas (A in each case).

Parallelogram.—A = l × h. The same formula applies to the special parallelograms—rectangle and square.

Triangle.—A = $\frac{1}{2}$b × h *or*

$$A = \sqrt{s\ (s - a)\ (s - b)\ (s - c)}$$

where a, b and c are lengths of the sides and s = the semi perimeter of the triangle = $\frac{1}{2}$ (a + b + c).

Regular Polygons.—The area of a polygon can be found by dividing it into triangles and adding the areas of the triangles together, *or* if s = length of side. $A = s^2 \times$ multiplier (see Table on page 443).

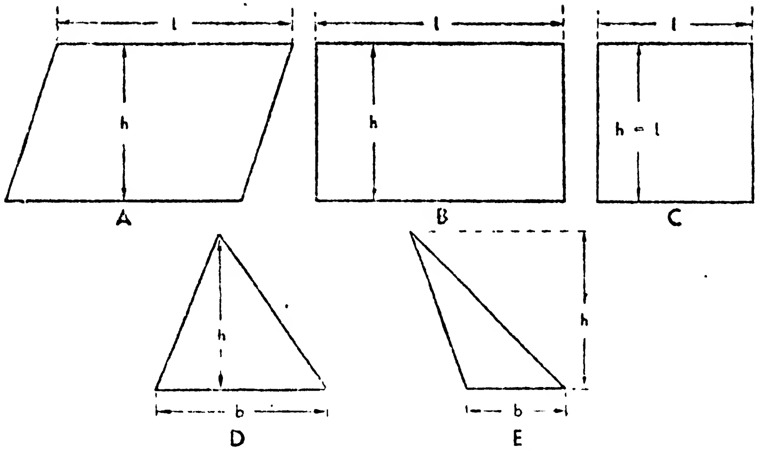


Fig. 2. Method of determining formulæ of plane figures to compute area. *A.* Rhomboid with length of side *l* and width *h*; *B.* Rectangle with length of side *l* and width *h*; *C.* square with length of side *l* and width *h* or *l*. These figures are parallelograms, area, $A = h \times l$; *D* and *E* are triangles whose area $A = \frac{b}{2} \times h$, when *b* is the length of base and *h* is the perpendicular height.

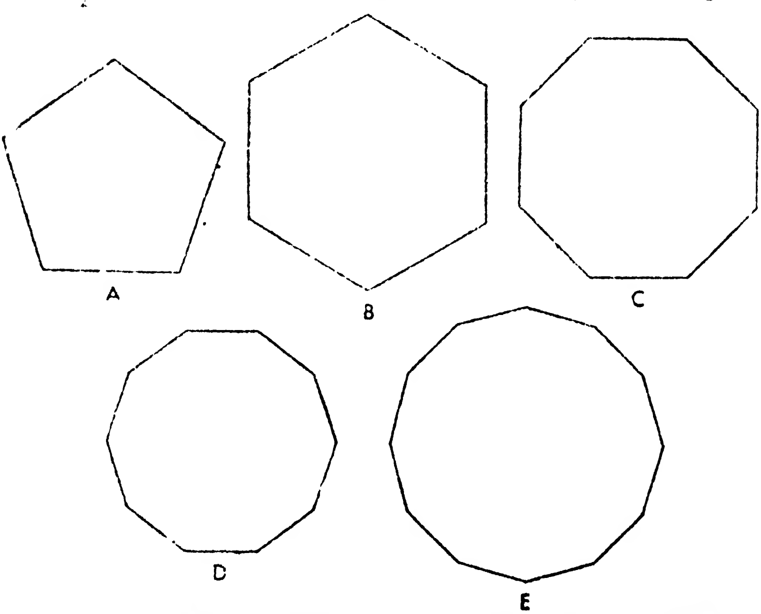


Fig. 3. Area of regular polygons can be found by dividing into triangles and adding their areas, or by using the formulæ $A = s^2 \times$ the appropriate figure from the Table on p. 443, when *s* is the length of side. *A.* Pentagon containing five triangles; *B.* hexagon of six sides and six triangles; *C.* octagon of eight sides; *D.* decagon of ten sides; *E.* duodecagon of twelve sides.

SIDES	POLYGON	MULTIPLIER
3	Triangle	·433
5	Pentagon	1·720
6	Hexagon	2·598
8	Octagon	4·828
10	Decagon	7·694
12	Duodecagon	11·196

Trapezium.—$A = h \times \left(\frac{a + b}{2}\right)$

Circles.—The ratio of the circumference of a circle to its diameter is "pi," written π, and its value is not exactly determinable. Depending upon the degree of accuracy needed the values used are $3\frac{1}{7}$, 3·14, or 3·1416. $3\frac{1}{7}$ (or $\frac{22}{7}$) is most generally used in building.

It follows that the circumference of a circle of diameter D (radius R) is given by the formula $C = \pi D$ *or* $C = 2\pi R$.

$$A = \frac{\pi d^2}{4} \text{ or } \pi r^2$$

The number of degrees at the centre of the circle is 360.

Sector.—The area of a sector of a circle with a central angle of a° is $\pi r^2 \times \frac{a}{360}$:

$$A = \pi r^2 \times \frac{a}{360}$$

Segment.—The area of a segment less than a semi-circle is the area of the sector minus the area of the triangle, enclosed by the radii. A = sector − triangle.

The area of a segment more than a semi-circle. A = sector + triangle.

Ellipse.—The area is like that of a circle, except that the two axes are unequal.

$$A = \frac{\pi}{4} Mm \qquad \begin{array}{l} M = \text{major axis} \\ m = \text{minor axis} \end{array}$$

Annulus.—$A = \pi (R^2 - r^2) = \pi (R + r)(R - r)$.

Irregular Figures.—The areas of irregular plane figures are found by Simpson's rule or the mid-ordinate method—by finding average lengths and multiplying by the base.

Surfaces and Volumes of Solids.—Prism—any solid of constant section, *e.g.*, a pencil, a length of iron piping, etc. The volume of *any solid* of constant section is area of end × length.

The area of the surface of any prism (ignoring ends) is perimeter of section × length, *e.g.*, volume of cylinder $= \frac{\pi d^2}{4} \times l$ or $\pi r^2 \times l$.

Area of curved surface of cylinder $= \pi d \times l$.

Pyramids and Cones.—The volume of any solid that slopes uniformly to a point is $\frac{1}{3}$ that of a prism on the same base and same height. The

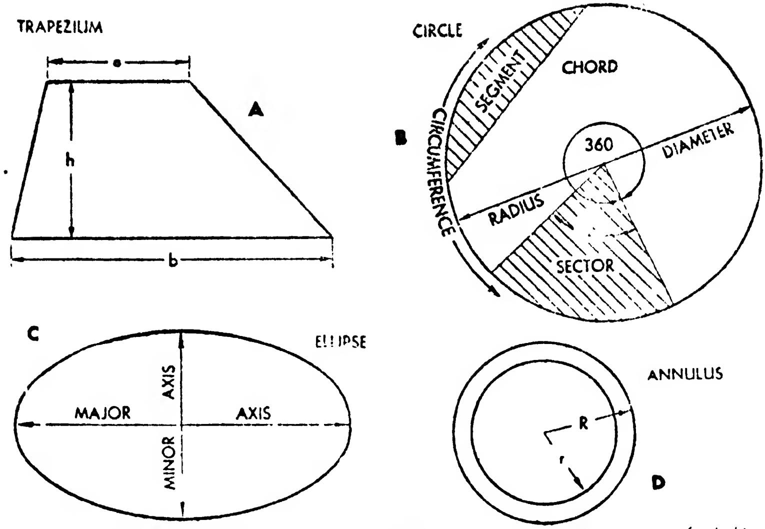


Fig. 4. Calculating areas from formulæ. *A.* Trapezium $A = h \times \left(\frac{a+b}{2}\right)$. *B.* Circle $A = \frac{\pi d^2}{4}$ or $A = 2\pi R$. Area o sector is $A = \pi r^2 \times \frac{a}{360}$. Area o segment is A = sector − triangle. *C.* Ellipse whose area is $A = \frac{\pi}{4} Mm$., where M = major axis, and m = minor axis. *D.* Annulus with area $A = \pi (R + r) (R - r)$.

base of a pyramid may be any shape, and if its area is A, then the volume (V) = $\frac{1}{3}$ AH (H = vertical height).

$$\text{For a cone, } V = \tfrac{1}{3} AH \quad : \quad A = \pi r^2$$

$$\therefore \quad V = \tfrac{1}{3} \pi r^2 H.$$

The area of the sloping surface of a pyramid or cone is $\frac{1}{2}$ perimeter of base × slant height (l).

$$\text{For cone } A = \pi r \times l.$$

Volume of the frustum of a cone or pyramid $= \frac{h}{3} (A + a + \sqrt{Aa})$.

Where A = area of base ; a = area of face parallel to base ; h = height of frustum.

Sphere or Ball.—A sphere is the solid formed by the revolution of a semi-circle about its diameter. A carefully made ball whose diameter in every direction is constant has the form of a sphere.

$$V = \frac{4}{3} \pi r^3 \quad \text{or} \quad \frac{1}{6} \pi d^3$$

$$\text{Surface area} = 4\pi r^2 \quad \text{or} \quad \pi D^2$$

Graphs.—When two quantities are so connected that a particular value of one is associated with a particular value of the other, the connection between the two can be demonstrated graphically. Squared paper divided into inches and tenths of inches is most convenient. There are various types of graphs, *e.g.*, experimental, conversion (*e.g.*, degrees Fahrenheit to Centigrade), and graphs from formulæ. Graphs can be used for many purposes including estimating intermediate values.

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T 9461 R T Printed in Great Britain by McCorquodale & Co., Ltd., St. Thomas Street, London.