CARPENTRY AND JOINERY

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BY

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PREFACE TO FIRST EDITION

In trying to keep level with the requirements of Students in Carpentry and Joinery, I have tried to explain to them in the simplest possible manner, such difficulties as I happen ot know, from a long experience, do really trouble the Student and hamper his progress. I have endeavoured to treat matters of every-day experience in a plain and practical manner, in the hope that their value will be enhanced thereby.

It is hoped that the superficial treatment of some subjects will be an enticement to fuller and more detailed a comprehension of their intricacies.

It is also hoped that the work will be of assistance generally, and be a service to the trade.

W. B. DOUGLAS.

CONTENTS

CHAPTER I

TIMBER: CHARACTERISTICS OF VARIOUS TIMBERS

THE various kinds of woods now in general use—both hard and soft—are increasingly numerous.

Since the War the great demand for timber has sent the factors farther into the forests, and particularly since the formation of the Empire Marketing Board our Colonies have been a big source of supply.

The principal softwoods, however, in general use are:

Northern Pine (*Pinus sylvestris*) is commonly known as yellow deal; it can be said of this wood, it is one of the most useful—for general purposes in building—is tough, elastic, and fairly light in weight, used for joists, flooring, roofs, window-frames and their sashes, scaffolding, &c.

It weighs about 32 lbs. per foot cube. The annual rings are distinct and it shrinks about 1/20th in the process of seasoning. Shipped from Russia, Norway and Sweden.

Spruce (*Abies excelsa*), commonly known as white deal, is used in interior work and should not be exposed to the weather. Useful for shelves, dresser-tops, &c.; liable to warp, twist and shrink; has nasty knots making it hard to work. There are several American spruces on the market, but European is the best.

Silver Spruce or Columbian spruce, being grown in that locality; very light but straight grained and elastic, nearly white in colour; has a shiny, silky surface off the plane, very distinct annual rings, which are brown in colour and thick. Useful to the joiner; being very elastic, is used in aeroplane work.

American Yellow Pine (*Pinus strobus*), introduced by Lord Weymouth, has been called Weymouth Pine. Can easily be selected by the short hair-like streaks running with the fibre. Used extensively by joiners and cabinet-makers, is not so strong as European timbers, and subject to dry rot.

Canadian Red Pine (*Pinus rubra*) is called after the colour of its bark; is suitable for internal work and fairly durable.

Kauri Pine. A splendid wood for joinery work, yellowish-white in colour, comes off the plane with a fine silky surface, has a very close grain and is a native of New Zealand.

Pitch Pine. A very useful wood, both for finishing and structural work; owing to its containing a larger amount of resinous juices is very heavy; again, this resinous matter gives the wood a handsome grain when finished. Being strong and elastic, it is much used for shoring, needling, &c. It is, however, liable to cup and heartshake (see next Chapter). An American wood principally found in Virginia.

Elm. An old-fashioned but useful wood, very durable under water; used for heavy work, such as carts, agricultural implements, piles, &c.

Larch. Another old but useful wood, rather coarse in texture, but our ability to obtain firs, pines and spruces, has relegated its uses to scaffold poles, railway sleepers, posts, railings, &c.; where exposed to weather it wears well.

Teak. Grown in India, Burmah, Malay Peninsula and Siam, and according to these districts so the colour varies from dark brown to deep yellow. As the white ant is a native of India it follows that nature has provided this fine wood to resist the attacks of that scourge. It is also the best-known wood for fire-resisting purposes, and is therefore mentioned in our By-laws for use in public buildings, factories, &c. It possesses a resinous aromatic substance, pungent to the smell, but this juice crystallizes in seasoning and the grain becomes filled with this hard matter, which makes it difficult to plane to a high finish. Very suitable for hard-wearing surfaces, such as sills, stair-treads, &c.; and is used for doors, windows, shop-fronts, &c. Very durable under water.

Jarrah. An Australian timber sometimes called Australian mahogany; a very useful wood, dark red in colour, heavy and durable and when finished leaves a good surface; can be used for both exterior and interior work.

Ash. A wood noted for its toughness as well as elasticity and is used in work that is subject to sudden shock or strain; heavy and close grained, is of light brown-colour with hardly any sapwood. Principally used in boat-building, agricultural implements and tools.

Beech. Not used much in general work nowadays, but is much sought after in the making of planes for joiners, cabinet-makers, &c.; reddish brown, with very close texture, shows a very distinct 'silver' grain in cross-section.

Birch. Similar to beech, but although useful to the cabinet-maker, and the chair-making industry, is not much used in building.

Walnut. The various kinds give a varying colour of brown, and is used in superior joinery, but not for constructional work. Italian walnut shows the best grain and is therefore much in demand for veneers.

Mahogany. Spanish or Cuban is the best of several varieties which are imported from the West Indies, Central America or Africa; as stated, the best is imported from Cuba, Trinidad, and Jamaica. A rich reddish brown colour, its fibre contains a white chalky substance which dulls the edge of the plane, making it difficult to work.

Honduras mahogany from the island of that name and Central America is a coarser variety, and softer, but is brittle. It polishes with a handsome richness and is therefore seen in display work and high-class fittings which demand a high polish. Mahogany is now to be got from the west coast of Africa, but the quality is distinctly inferior and is supposed not to be a true mahogany.

Indian Silver Grey. A modern wood from Indian districts, highly suitable for internal joinery; shows a good marking in the grain, being streaky in dark brown and yellowish grey; takes polish well, but is of no use for outside work.

Oak. *For ordinary building purposes, oak is one of the most durable and is amongst the strongest woods known,* at any rate in this climate. It shrinks little, about 1/30th of its width in seasoning. The medullary rays are fairly distinct, and the balk shows a large proportion of heart-wood to that of sapwood. The wood is used for practically all purposes and is taken as the standard in strength and quality in engineering tests. Weighs about 48 lbs. per foot cube. Austrian, American and English oak all have their own characteristics, e.g.: Austrian is probably the softest, but is the most beautifully marked, and is extensively used in internal joinery, being called Wainscot oak (this is a trade term, not a species). American oak is the best of foreign oaks, of which mention can be made of Japanese and African oak. English oak is the most durable and the strongest.

CHAPTER II

TIMBER (*continued*):
GROWTH, SEASONING, CONVERSION

As the work of this trade is principally confined to timber, although in modern times rolled steel joists or girders have taken the place of the wooden beam, it is necessary to consider the growth, felling, seasoning and marketing of this important product of nature.

When we speak of timber we mean a part of a tree that has gone through a process of drying, and sawing to a given size, in preparation for being worked to a finished article or part of a fitting.

Trees of the various species already mentioned and many others are outward growers, that is, they put on a layer of woody fibre each year, these layers being soft and watery on the outer layers, but becoming harder and denser and therefore more durable as successive layers grow through the years. These layers form the annual rings one sees when a piece is cut across the end section; in softwoods they are more pronounced as they are more fibrous and not being pressed so hard towards the centre as in the case of hardwoods, are more visible.

What happens is this: after the tree, as in all growth, has been dormant through the winter, the earth's moisture, assisted by the warmth from the sun, begins to rise in the tree from the roots upwards until buds can be seen, leaves grow which in their turn absorb a certain amount of moisture from the air, and life is recommenced throughout the tree. Towards the autumn the summer's growth of another band of woody substance is complete, being assisted by the extraction of mineral salts from the earth, and each tree according to its own nature turning these foods into starches, sugars or resins. Towards the approach of winter, when the sap is descending, this outer zone becomes harder and denser than in the earlier part of the year. The harder portion around the centre of the tree is known as the heartwood, or Duramen, meaning durability, and is that part of the tree to be used by the carpenter and joiner in his work. The outer zones of the tree are called sapwood which is lighter in colour than the heartwood and is therefore given the name Alburnum, and as this portion is immature, in fact has not had the opportunity to solidify and harden, is therefore weak and would soon decay, and should be avoided for building purposes. Fig. 1 shows a section of a tree stem. This process continues in the growth of the tree from 50 to 120 years according to the species of tree. When the tree has reached its maturity it is ready for felling, and in our climate

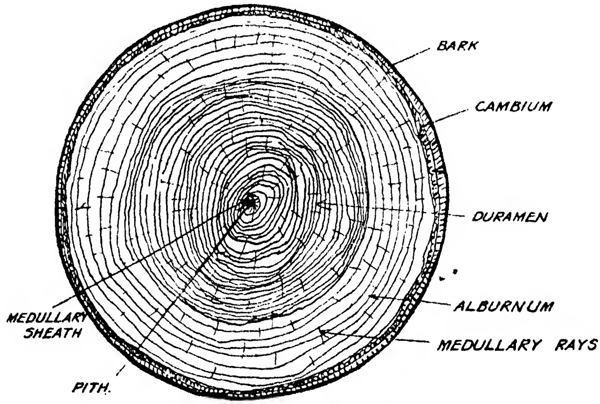


Fig. 1.—Section of Tree Stem.

should be in the winter, when growth is latent, and in tropical countries in the dry season, again when growth is latent.

Structure. The woody fibre before mentioned is actually made up of very small hollow tubes, very compact, and overlapping each other around which the sap circulates. Lying amongst these tubes are groups of cells which radiate from the centre of the tree; these convey the descending sap from the centre of the tree, and give strength and solidity to the weaker tissues, and are the medullary rays one sees in oak and beech and which we call the 'silver grain'. This function operates in all trees, but the pronounced 'silver grain' cannot be detected so easily in the softer woods, although they are still there (see Fig. 1).

When the tree has been felled, the branches are 'lopped', the bark removed, and should be hewn square without delay. They should also be removed from the site as soon as possible, to avoid contamination with harmful diseases so apparent to fallen timber.

The log is then ready for seasoning, and in modern times various methods are used.

Natural Seasoning. The enormous demands for timber have forced the dealer to invent quick methods of seasoning, although the best is to stack the logs under long sheds with overhanging roofs without sides or ends to enable the wind to play around them without being 'drawn' by the sun, and then to be cut into planks or battens and again stacked in the builder's yard. The process is really to dry up the moisture in the fibres of the plank and to enable the natural secretions to harden, as, for instance, the crystal-like matter so plainly seen in teak and well known to every joiner for the way in which it dulls the plane. To follow nature's requirements is the best rule in this, as in other matters, and what is known as natural seasoning is by far the best process. This has just been described, but the time occupied in so doing is too long, requiring from two to five years according to the size of the log, and we have to revert to artificial means. In the natural process only the sap is extracted, whilst in the artificial process, much of the natural juices, starches, resins, &c., are lost, being drawn along with the sap.

Artificial Seasoning. In this method the log is placed in running water, with the butts or root-ends towards the flow, and is left for a period of from fourteen to twenty-one days, according to the size of the timber, but it is calculated that this weakens the strength of the log for reasons already given. The wood is then placed in closed chambers of dry heated air passing swiftly through; this absorbs the moisture, and a temperature of about 200° Fahr. is kept up for about three days. This process gives the wood a bleached appearance and tends to make the timber brittle; it also reduces its tensile strength. The log is then sawn into planks, or, to use a general term, into scantlings; this gives an opportunity for finally drying out the interior parts now exposed, and is known as second seasoning.

Defects and Diseases. In making any purchase the buyer has to be aware of certain faults or failings in the commodity with which he is dealing. In timber many faults arise, some apparent, others only to be discerned by the practised eye.

Over-maturity. Some trees are healthy up to 50 years, others to 100 or 120 years. After this they begin to decay from the centre and from the bottom upwards, leaving often just the sapwood; this being moist enables leaves and buds to form in the usual way, although the heartwood has gone.

Wet Rot is a disease of growing trees, as for example a branch is broken off in a storm, leaving an open wound which becomes filled with water. It cannot circulate in the sap and therefore becomes stagnant but penetrates downwards and when the tree is felled and seasoned one sees a long, deep furrow of greyish brown powdery remains.

Foxiness is a disease found in some woods, which is really the indication of over-maturity and is seen to be reddish brown stains signifying the commencement of decay.

Druxiness. The appearance of this fault is in light-coloured spots or streaks and soft, caused by the action of fungus germs in a part affected by wet rot; in development they set up decomposition and dry out as stated.

Dry Rot. This disease is found after the tree is felled; it may commence as the log is lying ready for removal or it may, and does often, commence when the wood is made up into the finished article and fixed.

There are many kinds of fungoid growth, but the most prevalent to the builder is Merulius Lachrymans, or weeping fungus. It attacks timber in unventilated, humid conditions; in fact, it thrives in a remarkable manner in this state, but will utterly fail in dry, well-ventilated places. Enclosed areas such as the space beneath floors, backs of skirtings, dados, &c., are the most troublesome to the builder. In appearance it forms a white woolly mass on the surface of the timber, and spreads its tendrils all over the surface of the affected part in search of the life-giving properties of the wood which it absorbs, leaving just a mass of perished tubes which crumble away. It can usually be detected by a musty smell, and shows up in brown spots or patches on the surface of the timber. The attack of fungus can be arrested, but we have no cure to kill it outright. Creosote is the best preventive, coupled with fresh air, and there are other corrosive sublimates which will come under the heading of 'Preservatives'.

Heartshakes are caused by the interior of the tree beginning to shrink from the centre first and radiating outwards. They are the first approaches of decay in an over-matured

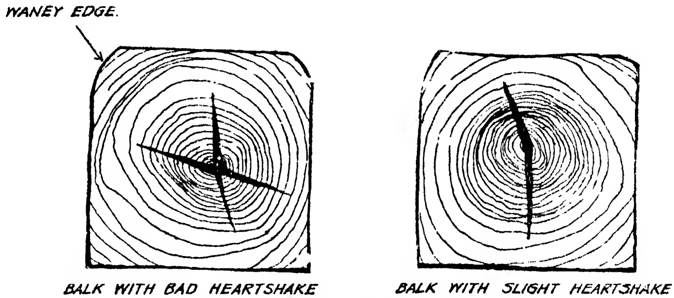


Fig. 2.—Balks showing Heartshakes.

tree, but may be found in a tree which has lain some time after felling and decomposition has set up owing to the bark, which has been allowed to remain, having held the sap on the outside and the log has begun to dry from the centre (Fig. 2).

Starshakes—the opposite to the heartshakes—begin on

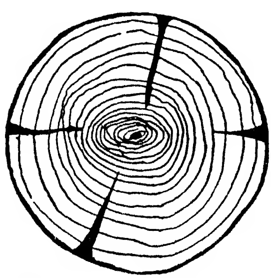


Fig. 3.—Log with Starshakes.

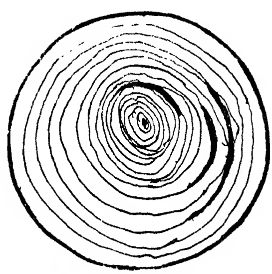


Fig. 4.—Log with Cupshakes.

the outside and radiate to the centre. This defect is not a sign of disease but can be caused from two sources. Excessive heat in the summer may dry the outside in an abnormal manner, or frost freezing the sap may burst the fibres (Fig. 3).

Cupshakes occur between the annual rings, showing unequal growth. This is more to be found in timber from the tropics where the monsoons causing suddenly increased moisture to be afforded to the roots, rapid and unequal growths are the result (Fig. 4).

Radialshakes, like starshakes, are seen to be small clefts from the outside running inwards, due to the outer layers shrinking rapidly, as, for instance, when a log is allowed to lie in the sun. These do not penetrate into the log as deep as the starshakes and are much finer.

Durability of Timber. Everybody must have seen, at some time or other, timber that has arrived at that stage when it can be said to be useless or fit only for the fire, but probably before it has arrived at this stage it has given years of service. Timber is almost indestructible given even conditions. By that we mean, it will not last long under alternating conditions such as wet and then dry in turns, but with fair and even treatment timber is almost everlasting. Many instances could be given, such as piles taken up from our rivers when bridges are being replaced, or bressummers from inside the walls of some ancient building; and of course we need hardly say that in the first instance these pieces were properly seasoned before use.

Preservation of Timber. The life of timber can be greatly lengthened by treating it with a preservative to enable it to withstand the attacks of the elements; the methods adopted are various, some are chemicals to impregnate the volume of material, others covering the surface with an oily skin or sometimes a hard shellac covering as in french polish. In the first case, appearance of the outside is a secondary consideration and, as already mentioned, creosote —oil of tar—is by far the best preservative, but we never think of treating our exterior joinery, such as windows and doors, with this excellent material, on account of the dirty appearance it leaves, and coupled with the colourful possibilities of paint we use this form of covering for joinery work. The chemical preparations are, to enumerate a few, saccharine in solution, chloride of zinc, bichloride of mercury, &c. Painting covers the material with a waterproof skin composed of white lead, linseed oil and turpentine, with colouring added to get the required shade or colour. This method is not permanent, and calls for frequent replenishment. Varnish is a similar process, but being transparent the wood is able to show its grain, being previously 'sized' and 'filled'. French polish too is transparent, and beautiful finishes can be got by this process. It is made of shellac mixed in methylated spirit.

Conversion of Timber. The student should know how to convert a log into the various scantlings and at the same

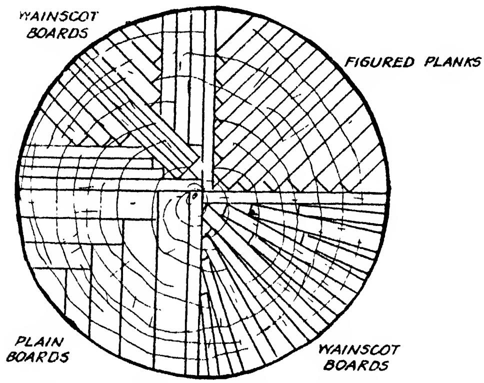


Fig. 5.—Method of cutting Quartered Logs.

time make the best use of the stuff at his disposal; for instance, he may have to cut the piece for strength, or sometimes to get the best grain showing on the face and always

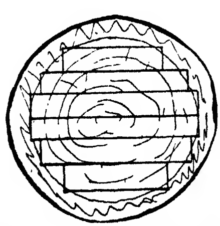


Fig. 6.—Sketch showing cutting of Battens.

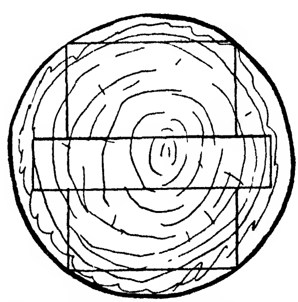


Fig. 7.—Wainscot Plank and Oak Beams.

of course be economical in his work, bringing waste to a minimum. Figs. 5 to 10 are explanatory in themselves, but a word might be said about wainscot boards; this is a term used for the method of cutting to show the beautiful 'silver grain' as in oak. Look at a fixture in oak, the framing has usually a straight grain without any 'silver grain', whilst in the panels they become a feature in themselves by the very presence of the 'silver grain'; these boards are always cut radially from the centre of the log, as shown in Fig. 5.

Ordinary boards are cut straight off the log. The sapwood

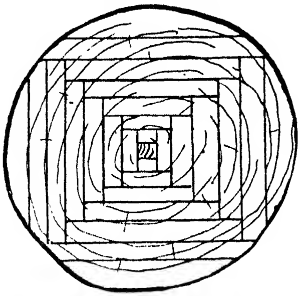


Fig. 8.—Method of producing Figured Pitch Pine Planks.

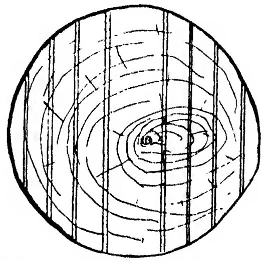


Fig. 9.—A Pine Log cut into Boards.

being on the outside and containing more moisture than the heartwood and not being compressed like the heartwood, shrinks more than the heartwood, so that the effect of boards when shrunk, which always happens, is given in Fig. 10.

Timber is divided into two classes, hardwood and softwood. Oak, Teak, &c., is usually purchased by the cube foot, whilst softwoods, such as Pines, Firs and Spruces are

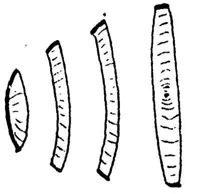


Fig. 10.—Sketch to show how Boards shrink.

bought by the standard, the commonest being the Petrograd Standard of 165 cube feet, but as these are purchased in scantlings of 9″ × 3″ or 4″ × 3″ or 4″ × 2″ etc., it is useful to know how to convert a standard of deals to running feet, so that one may know quickly how many lineal feet one should expect to receive in a standard. The simple rule is, divide 23,760 by the area of cross-section of scantling required, and the result is lineal feet for that particular scantling in a standard,

e.g. say 9 × 3, this equals 27. 23,760 ÷ 27 = 880 lin. feet,
or ,, 4 × 2, ,, ,, 8. 23,760 ÷ 8 = 2,970 lin. feet.

The following list gives market forms of timber:

A Log—a tree trunk felled and lopped.
A Balk—the log squared.
A Plank—9″ or 10″ wide and 2″ or 1¾″ thick.
A Deal—10″ wide and over 2¼″ thick
A Batten—9″ wide and 1½″ thick.
A Board—6″ wide and 2″ thick.
Die square stuff—from 9″ × 9″ to 5″ × 5″.
Quartered stuff—Planks cut radially from the centre to get the figured face.
Scantlings—A miscellaneous term.
A square—of floor boards, &c., 100 feet super.

Timber is graded according to its quality, and it is usual to obtain Firsts, Seconds or Thirds.

At the present time there are so many brands on the market that only an experienced buyer would be able to successfully designate the country of origin, but the following is a fairly good guide to the quality or port of shipment of European timbers. Again, it should be pointed out that marks and brands are constantly changing and the buyer generally decides by inspection, and the following signs are what they go by.

Column A—Russian marks used at the Port of Riga; these are stamped.
,, B—Port of Memel } These are scribed with gouge-shaped tools on sides of balks and ends of deals.
,, C—Port of Stettin }

1st or Prime Quality.
2nd or Second Quality.
3rd or Third Quality.

Swedish deals are stencilled on their ends with red or black pencil.
Norwegian deals are stencilled with blue paint.

K & Co

American timber is either hammer or chalk marked in red on side.
Russian deals have clean machine-sawn ends.
Swedish and Norwegian are rougher cut.
Russian are net size or under reputed size.

QUESTIONS ON CHAPTER II

1. What do you understand by the terms Duramen and Alburnum?
2. How do you distinguish between the two, and which should be used in the trade?
3. How do you convert oak boards, pitch pine boards, and pine logs?
4. What is the chief disease in timber after it has been converted? Give two of the most satisfactory preventives.
5. What would you be expected to avoid in purchasing a balk?
6. For what kind of work would you use the following woods: Spruce, Northern Pine, Pitch Pine, Oak, Mahogany, Teak?

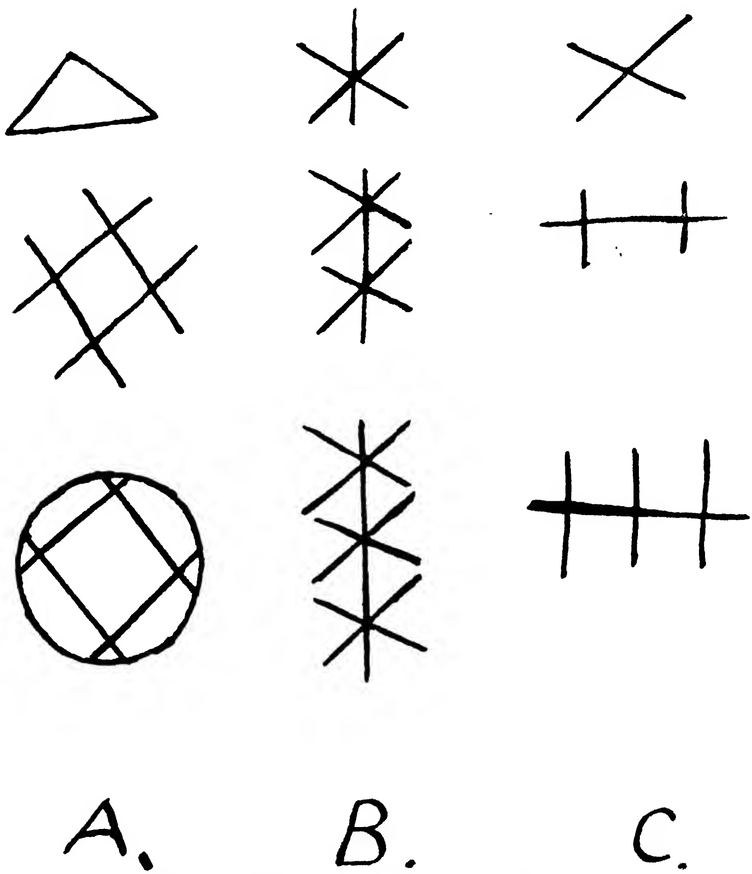


Fig. 11.—Sketch showing Markings of Quality.

CHAPTER III

TOOLS

In this age of machinery the student is tempted to think lightly of the tools he uses and should take a delight in.

The woodworker's tools are still and always will be in demand. The joiner requires a bench which should be strong and firm, the top surface level and even and not only sound in construction but the wood well seasoned, standing about 2 feet 9 inches from the ground and being about 2 feet in width, whilst the length is governed by the space available. A bench screw or vice is fitted at the head or left-hand end and is better if of the instantaneous grip type.

The saw is probably the first tool used by the craftsman, and although so much sawing is now done by machinery hardly any job can be executed without its use.

The **Rip Saw** is used for cutting wood in the direction of its fibres. The blade is about 28 inches in length and has about 8 teeth to every 3 inches.

The **Half Rip** is similar though not quite so heavy and has about 9 teeth to every 3 inches.

The **Hand Saw** for cutting against the fibres is about 24 inches in length with 4 or 5 teeth to the inch. The inclination of these teeth is made a shade more upright than the Rip Saw. The Hand Saw is set about 80° and the Rip Saw about 70°.

The **Panel Saw** has a thin blade with about 6 teeth to the inch, which are finely set.

The **Tenon Saw** is about 14 inches long in the blade with 9 or 10 teeth to the inch. The blade is stiffened on its upper edge with a band of brass, and the function of the tenon saw is to cut across the grain such as in the shoulders of a tenon, &c.

The **Dovetail Saw** like the Tenon Saw is brass-backed but smaller and more finely set. It has a 9-inch blade with 15 teeth to the inch.

The **Compass Saw** has a narrow blade tapering from 1 inch at the handle to ¼ inch at the end and is used for circular work.

The **Keyhole Saw** is similar to the Compass Saw but smaller in every respect and is used in small circular work.

The **Frame** or **Bow Saw** has a fine thin ribbon saw and is placed in severe tension which can be increased or diminished at will by twisting the slip of wood in the twine. As the blade is easily detachable the saw is useful in 'fretting' a design in wood.

Of the planes used by the carpenter and joiner perhaps the **Jack Plane** is the most useful and most called for. It is chiefly used for taking off a rough surface, and is about 15 inches long and 3 inches in width. The cutting iron is ground slightly round to facilitate increase in set, whilst this gives an uneven finish. The timber is set 'true' by means of the Trying Plane which is longer than the Jack Plane, is greater in girth, has a wider cutter and as near straight as possible to leave a flat surface on the work in hand. The iron is set much finer and therefore takes off a much finer shaving. The work is finished off with the **Smoothing Plane.** This is shorter and has a straight cutting edge. It is about 8 inches in length and about 3 inches in width and its purpose is to finally finish off the work.

The **Rebate Plane** is arranged to cut into the corner of a rebate. This is done by the cutter projecting to the sides of the stock, the width of the plane varying from ½ inch to about 1½ inches.

The Sash Fillister, Compass Plane, Plough, Bull Nose, Snipe Bill, Router, Match Plane, Moulding Planes are often in use but need not worry the student at this stage, but are worth mentioning whilst the work covered by these planes is largely accomplished by the machine.

Chisels. These can be subdivided into classes—Paring Chisels, Firmer Chisels, Mortise Chisels, whilst the Gouge is a curved chisel being ground internally or externally and the Spokeshave may be said to be a two-handed chisel with a small fence to run along curved edges.

The *Paring Chisel* is not so heavy and more finely ground than the Firmer Chisel which is used for heavy work with a mallet, the Paring Chisel being pushed across the grain with the hand.

The *Mortise Chisel* is stoutly made and is used with the mallet for 'punching out' mortises.

The **Brace and Bit** is a most useful tool. The brace has a rotating motion whilst the bits in common use are very varied, but principally we use the Centre Bit, Twist Bit, Countersink Bit and occasionally the Expansion Bit, Taper Bit, Screwdriver Bit, &c.

The **Square** is a steel blade fitted into a wooden stock for marking at right angles from the edge of the wood, whilst the **Bevel** is a similar tool but has an adjustable blade to set to any inclination. Care should be exercised to see that the movable blade is tightly screwed up when in use.

The **Gauge** is a useful tool to the woodworker. It marks off parallel lines in the work from the edge of the wood and is made up of a sliding rod moving in a wooden stock which by a screw can be set to the required distance. At the end of the sliding rod is driven a steel point to scratch the surface of the work, leaving its mark at the distance to which the slide has been set.

The *Mortise Gauge* is similar in design, but has two adjustable steel points to mark off both sides of a mortise.

The *Cutting Gauge* is arranged on the same principle but has a thin steel plate instead of a point and is used for cutting with or against the grain. The other tools in ordinary use such as the Screw-driver, Hammer, Bradawl, &c., do not require any definition.

The **Oilstone.** There are various types of oilstones. The Washita is a natural stone and is very fine in texture. Composition stones such as Carborundum of varying grades of fineness, the India stone, &c. Oilstones should be kept in a wooden box with a close-fitting lid, to keep it clean and free from dust and grit. A clean thin oil should always be used.

The **Gouge** is a curved chisel and may be ground on the inside or the outside. The inside ground gouge is used for scribing joints in moulded work.

All tools should be kept clean and sharp. The old adage of a workman being known by his tools is as true to-day as ever it was. Planes should be soaked in linseed oil and an occasional rub over will keep them in perfect order. Steel work should be oiled frequently.

QUESTIONS ON CHAPTER III

1. What wood makes the best planes and why?
2. Describe the action of sharpening cutting tools and the result.

CHAPTER IV

JOINTS USED IN CARPENTRY AND JOINERY

It will be readily understood that in framing any structure the correct method of jointing the various parts should be understood. For instance, the stout 'fished' and 'bolted' joint the carpenter would use in building a derrick tower would never do for the jointing up of a church door the joiner may be making, and vice versa, yet each has its important function to perform.

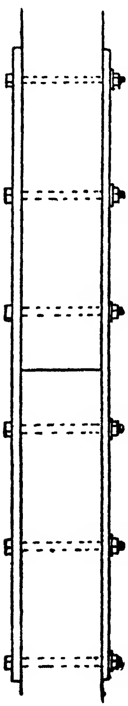


Fig. 12.—Fished Butt

A word here as to the work of the carpenter and the joiner may be useful. The carpenter makes the permanent structure of the building, such as the roof, partition walls, floors, &c., whilst the joiner makes the permanent fixtures such as the windows, doors, cupboards, &c., although in modern times the two are now linked as one. There are, however, still those who as joiners always remain in the shop and others as carpenters prefer to remain on the structural work of a building.

The strength of work executed by the carpenter relies chiefly on the careful disposition or laying out of the various parts. In the arranging of joints thought must be given to the possibility of shrinkage across the grain, which is considerable, particularly in the softwoods; allowance must therefore be made.

Heat causes metal to expand and cold will make it contract, the opposite being the case with wood. The reason is, the sap is condensed by the cold. The dovetail joint is an instance where the shrinkage of the dovetail tends to make the joints fit more tightly together.

Carpentry Joints. Fig. 12 shows a *Fished Butt* joint. This is a compressional joint as in posts, struts.

Fig. 18 shows a *Halved Scarf* stiffened with bolts, is a compressional joint and with the aid of plates can be made tensional.

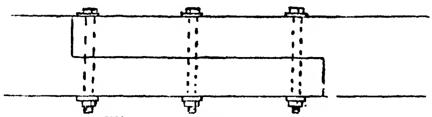


Fig. 13.—Halved Scarf.

The *Splayed Scarf* (Fig. 14) is a very useful joint to lengthen a beam. The top half is in compression, therefore a square abutment is made; the lower being in tension is stiffened

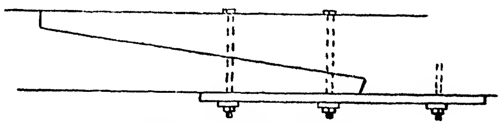


Fig. 14.—Splayed Scarf.

by a fish-plate, and the lower joint is undercut about 1/16th of the depth

Fig. 15 shows a *Splayed Indent Scarf.* Is used in extending

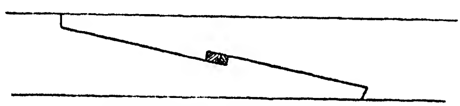


Fig. 15.—Splayed Indent.

a ridge in a roof, &c. Hardwood fox wedges are introduced, which, when driven home, force the two parts tightly together at the joints.

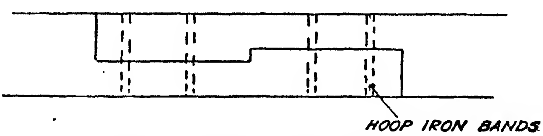


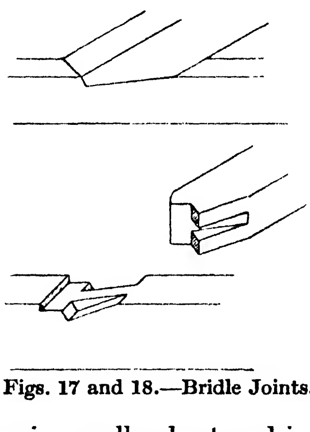
Fig. 16.—Tabled or Indented Scarf.

The *Tabled or Indented Scarf* is very useful in extending such members as tie beams where tensional stress operates (Fig. 16).

Note.—When joints are in compression they should have a square abutment; in other words, the line of the joint should be at right angles to the direction of the pressure.

Fixing Joints. The notched and cogged joints are used for connecting joists to wall-plates. Plain and dovetailed halving is used for lengthening wall-plates. The *Tusk Tenon* joint is used chiefly in joining up floor joists to a trimmer round a fireplace, the well hole of a stair, a trap-door in a warehouse floor, &c. The lower side of the tenon should lie in the neutral axis, or middle of the beam, as it would weaken the beam to allow a mortise in the lower half where the fibres are in tension. The tenon is in thickness 1/6th the depth of the beam or 1/3rd of the upper half as a tenon should always be 1/3rd the thickness of the member. In this case we can only consider the upper half, the tusk is half the depth of the lower portion or a quarter the total depth of the beam and the length about $\frac{1}{2}$ inch or $\frac{3}{4}$ inch. The student is recommended to be fully conversant with the setting out of this important point. Chase mortises are used for fixing ceiling joists between binders; the lip runs half-way across the binder.

Framing Joints. The *Bridle* joint at the foot of a principal rafter connecting with the tie beam is commonly used.



Figs. 17 and 18.—Bridle Joints.

The abutment here is usually short and in practice generally made square to the back of the rafter, but theoretically it should be square with the seating. Figs. 17 and 18 show different methods of arranging the Bridle joint.

Joinery Joints. A *Ploughed and Tongued* joint is shown in Fig. 19. The *Tongue and Groove* joint may be secured by nailing or glueing (Fig. 20).

A *Return Bead and Rebate* joint used chiefly in connecting pieces of framing at angles (see Fig. 21).

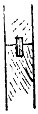


Fig. 19.—Ploughed and Tongued.

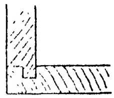


Fig. 20.—Tongue and Groove.

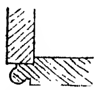


Fig. 21.—Return Bead and Rebate.

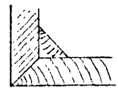


Fig. 22.—Plain Mitre.

The plain mitre (Fig. 22) is secured by nailing or, where the internal angle is unseen, may be blocked whilst the tongued mitre is an improvement on the last (Fig. 23).

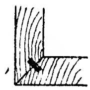


Fig. 23.—Tongued Mitre.

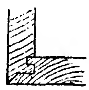


Fig. 24.—Lipped Mitre.

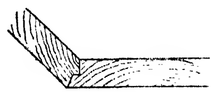


Fig. 25.—Rebated Mitre.

A Lipped mitre is used in superior work and forms a strong joint. A tongue is sometimes added as shown and this increases the strength (Fig. 24).

A *Rebated Mitre* joint is used for framing which is not at right angles (Fig. 25).

Dovetailing. For common dovetailing for packing-cases, cisterns, &c., the pins should equal in width the distance between the sockets.

The *Lap Dovetail* for drawer fronts enables the end grain of the wood to be hidden from view when the drawer is closed, while the *Mitre* or *Secret Dovetail* hides the pins altogether, and for joinery purposes is used in the salient angles on polished skirtings, &c. (Fig. 26).

The *Mortise and Tenon* joint is proportioned as follows: Thickness—one-third the substance. Width—one-half the width of the rail, less any sinkings as shown in Fig. 110.

The *Double Tenon* is chiefly used in lock rails and the haunching should, in this case, be taken out the full width of the tenons. The space between the tenons should equal the thickness of the lock, usually $\frac{5}{8}$ inch, and the thickness of the tenons half the remaining substance, a drawing of which appears in the section dealing with doors. Fig. 111.

A *Fox wedged, or Foxtail* joint is an ordinary *stub tenon with saw cuts made in it, in which several small wedges* are inserted. These are driven home in the 'cramping up' and the tenon spreads out in the form of a dovetail. The

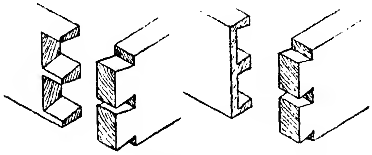


Fig. 26.—
Common Dovetail. Lap Dovetail.

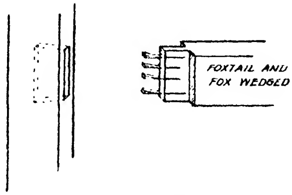


Fig. 27.

joint is employed in work where the end of the tenon showing through would be objectionable (Fig. 27).

The *Hammer Headed Tenon* is sometimes used for connecting the head of shaped work to the jambs; small oak wedges are driven in to draw the joint close up. A variation of this joint is made with both ends being made alike; this is inserted separately into two pieces to be joined together as in the crown of a frame and is known as a hammer-headed key (Fig. 28).

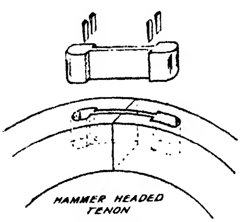


Fig. 28.

Paint, not glue, should be used for carpentry joints and tenons should be fixed with pins or straps, but not wedges.

Glue is employed in drawing up joints in joinery. The joint is of a different type to the carpenter's in that it is not clean off the saw but is carefully fitted together and cannot be pinned or strapped.

Wedges dipped in glue and driven between the edge of the tenon and the abutment of the mortise makes a very sound joint.

QUESTIONS ON CHAPTER IV

1. What are the main characteristics of a carpentry joint and a joinery joint?
2. What proportions should be used in setting out for a mortise and tenon joint?
3. What methods are adopted in securing carpentry joints and joinery joints?
4. Under what circumstances should the haunched tenon be used?

CHAPTER V

INTRODUCTION TO GEOMETRY

It is of the highest importance that the student should be able to draw with the aid of instruments with the greatest possible accuracy and neatness. The following are essential to every beginner:

Drawing Board—with a perfectly level surface, with corners a true right angle; half imperial size is very convenient.
T Square—used for drawing parallel lines, the blade should be of mahogany and bevelled. It is screwed to the head which slides along the edge of the board.
Two Set Squares—45° and 60° set squares are to obtain perpendicular lines from the T square, parallels and angles at the same angle of the set square.
Scale Rule—a wooden ruler marked off in various scales, to enable measurements to be taken from drawings or be made on to a drawing.
Compasses—These need not be of an expensive pattern, but most institutions nowadays have a bureau where all instruments can be purchased at a minimum price. Compasses with needle-points are preferable, also fitted with movable pen and pencil legs. A pair of Dividers for measuring and a Mathematical Pen for ruling lines in ink.
Protractor—This enables the user to mark off any angle he may desire.
Paper and Pencil—Use ordinary cartridge paper for pencil work, although a better quality would be needed for inking-in a drawing. H.H. pencils are the best for drawing in constructional lines, and H for finishing or darkening the finished drawing.

It is not customary to make drawings the same size as the objects they represent, obviously they would be too big, but a drawing made to a scale can be made to accurately represent the object. The craftsman must be able to read a drawing; he should also be able to prepare one. Every inch on a drawing is made to represent say 1 foot or 1 yard. Therefore as each inch is really 1 foot or 1 yard a representative fraction is made such as 1 inch = 1 foot = 1/12th full size or 1 inch = 1 yard = 1/36th full size. This shows the ratio of each line on the drawing to the real object. The scale of a drawing can be given in words as 1 inch to 1 yard.

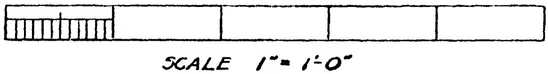


Fig. 29.

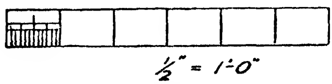


Fig. 30.

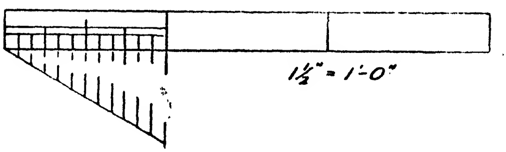


Fig. 31.

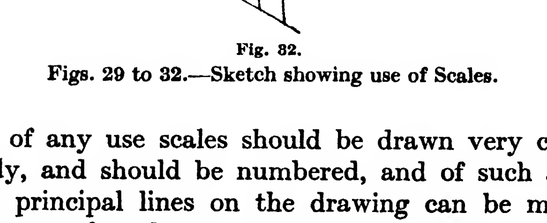


Fig. 32.

Figs. 29 to 32.—Sketch showing use of Scales.

To be of any use scales should be drawn very carefully, accurately, and should be numbered, and of such a length that the principal lines on the drawing can be measured. Figs. 29 to 32 show how to construct scales having different denominations.

Diagonal scales give a greater degree of accuracy than the plain scale. Fig. 33 shows a line 3 inches long divided so as to be able to read to 1/144th part of an inch. The base line is divided in three equal parts, while the left-hand space is subdivided into 1/12ths. By erecting perpendiculars from each division and equally spaced lines parallel to the base we have subdivisions each 1/12th part of 1 inch and by drawing diagonals across each section as 0 on the base to 1 at the top and 1 on the base to 2 at the top and so on,

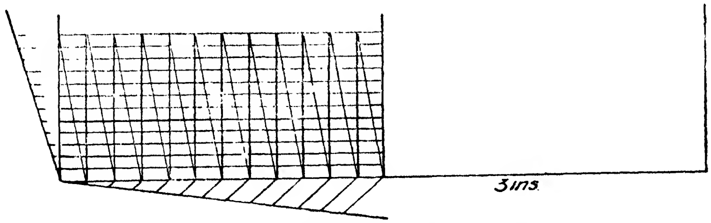


Fig. 33.—Sketch showing Diagonal Scale.

we are able to measure one space on the base which is 1/12th part, and by moving the dividers along the perpendicular to the first parallel to the base we find the inclined line has increased by 1/144th part of 1 inch.

Practice in reading scales is very necessary, and is recommended.

Enlarging Drawings by means of a Proportional Scale. It is sometimes necessary to be able to enlarge a drawing, and the procedure is as follows:

Take a four-panelled door (Fig. 34), draw out the small size and, having determined the new and larger size, make a proportional scale by making the base line of the scale equal to the height of the door and step off the intermediate heights. Next draw a line a^1b^1 to any angle to the base line and join up bb^1. Draw parallels to bb^1 and the new proportions are determined. The same procedure is followed for the width as for the height.

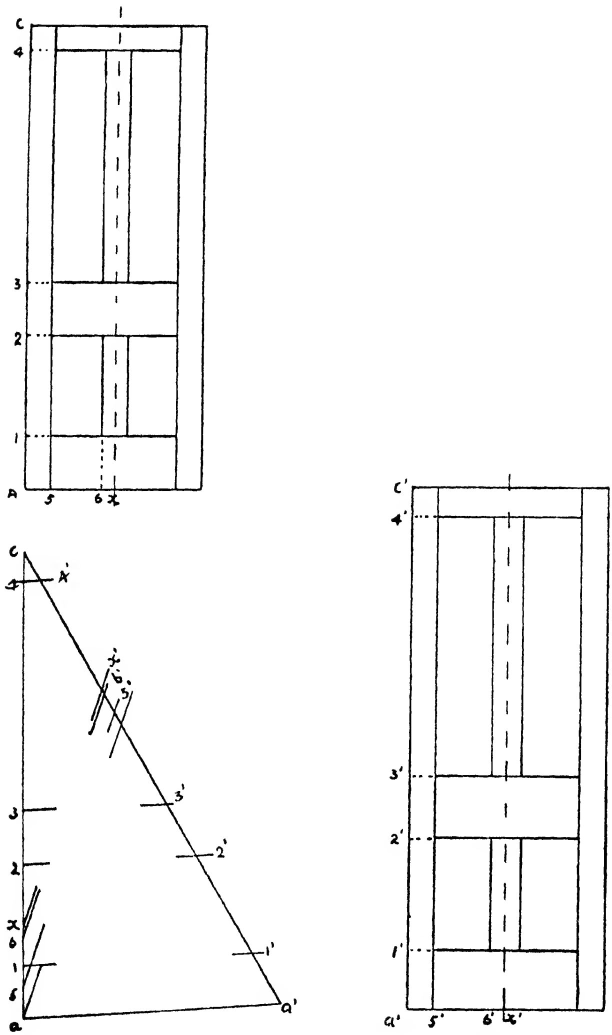


Fig. 34.—Sketch showing a Proportional Scale.

CHAPTER VI

CENTRING, SHORING AND SCAFFOLDING

IN forming brick or stone arches it is first necessary to make temporary centres which when fixed in position have the arches built upon them. The centres are removed when the structure has 'set'.

Centres are classified as Turning Pieces, Rib Centres, Laminated or Built-up, Framed and Trussed, Close Lagged and sundry special varieties in connexion with the purpose for which they are used.

Centres being purely temporary should be made so as to injure the material as little as possible, chiefly to enable it to be used over again. This sometimes means the use of larger material than is necessary for the load to be carried, but is a wise policy.

The stresses in the members should be directed towards the points of support. The centres are supported on uprights and should be so constructed that their shape will not be changed through the superincumbent weight.

The centres should be placed in position in such a way that they can be easily 'struck' or lowered. This operation should be gradual to give the arch above an opportunity for evenly setting. The centre is actually rested on pairs of folding wedges; these are driven parallel with the opening, not towards it. It is useful to have them black-leaded and should be placed at the top of the uprights, not the bottom, as in the latter position the wedges may get knocked out of place as the work is going on.

Lagging is the process of nailing across the centre strips of wood which are fixed at intervals of 1-inch spaces for rough brickwork, and 'close lagged' for gauged brickwork, but in the case of stone arches one lag comes under each end of a voussoir or arch stone. The lags are usually nailed into position on the ribs, but in large centres should be notched.

Turning Pieces are the smallest and simplest forms of centres. They are used for small arches of 4½-inch brick-

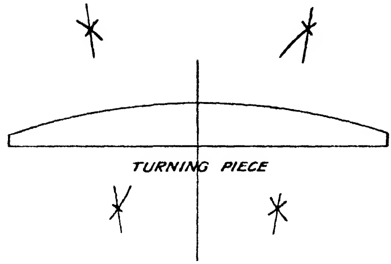


Fig. 35.

work. The method of finding the centre for the arc is also shown.

The Rib Centre is suitable for arches of 4 or 5 feet span and about 9 inches rise.

Built-up centres are used for larger openings up to 12 feet or 14 feet. The braces should radiate from the middle of the span in the case of circular arches, and normal

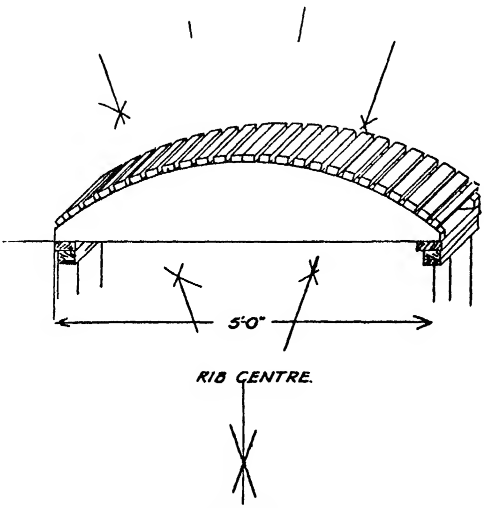


Fig. 36.

to the curve in elliptic and parabolic arches. The ribs lap over each other and are nailed together and therefore in two thicknesses.

A Trussed Centre is of economical construction, being made of a frame of quartering to support the ribs. This kind of centre requires to be supported in the middle and is used for large spans up to 30 feet.

In setting out a centre the actual span should be chalked out on the floor by a rod measured to the radius required and a bradawl, piercing the rod at the radius point, is stuck into the floor and the circle described. A template is 'struck' to the same radius and carefully sawn round and prepared. From this any number of pieces can be marked for the particular span in question. Blocks of wood are placed between the ribs according to the thickness of the centre.

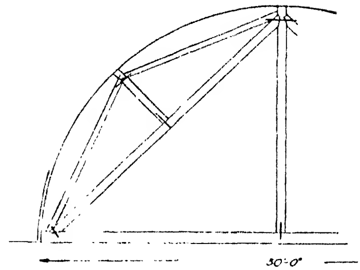


Fig. 37.—Trussed Centre

A Framed Centre with details is shown in Fig. 38.

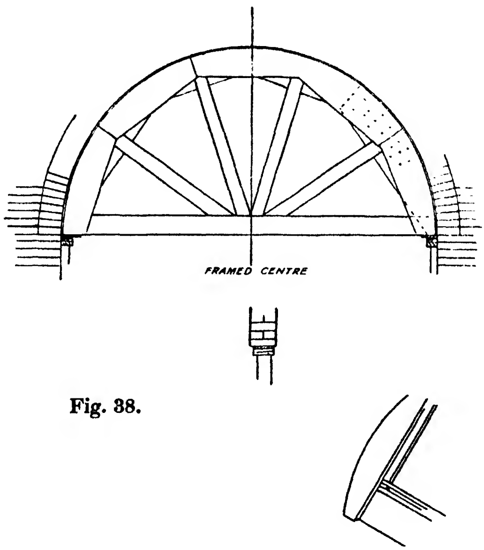


Fig. 38.

An Elliptic Rib may be set out by trammelling. 'Shoot' the edge of a board forming the major axis and draw a line at right angles in the middle; continue this line below the major axis. Next take a lath and on it mark the rise and half of the span or semi-minor and semi-major axes. Keeping these points work-

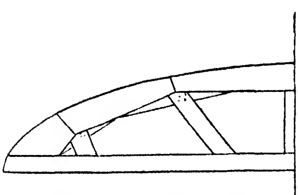


Fig. 39.—Elliptic Rib.

ing along the base line, and the lower part of the vertical line, slide the lath round, marking the end on the object to be drawn upon and the ellipse will be formed.

Scaffolding. A scaffold is a temporary platform used to accommodate workmen and permit the movement of materials for the work in progress. It may be built up from the ground, or suspended. For the purpose of this treatise we are confined to bricklayer's scaffolds, mason's scaffolds and builder's stages.

A bricklayer's scaffold is built up from a number of fir poles placed in an upright position fixed in holes in the ground or let into a barrel filled with earth. The poles vary in length according to the nature of the work, but can be got up to 35 feet in length and are placed about 10 feet apart at a distance of from 4 to 5 feet from the building.

Poles are also bound across the uprights in a horizontal position and are called 'Ledgers'; they are spaced about 5 feet apart and usually are placed into position as the work goes up in 'lifts'. Resting on these ledgers at one end and on the brickwork at the other are putlogs placed at intervals of 4 or 5 feet, two being placed at each heading-joint of the boards they support. The putlogs are out of 3″ × 3″ birch, 6 feet in length and are 'cleft', that is, roughly dressed by the adze and are not sawn, because the result of straight sawing would be to cut through certain fibres of wood which would weaken the piece where the grain is not quite straight. Scaffold boards are usually out of spruce and can be got in various lengths up to 15 feet and are 9″ × 1½″; the ends should be bound or strapped with hoop iron to prevent the end grain splitting. Wire ropes are the commonest form of binding now in use. The scaffold is stiffened by lashing diagonal poles across the front.

The mason's scaffold is really a repetition of the last, but is double, having uprights on both sides of the wall and tied across, passing through any aperture in the wall, therefore not dependent on the wall for support and for this reason is sometimes called an independent scaffold. The timbers are often stronger than the bricklayer's scaffold according to the nature of the work; the putlogs, being longer, are stouter and may be bolted or coach-screwed to the uprights.

A builder's staging is a heavier type of mason's scaffold.

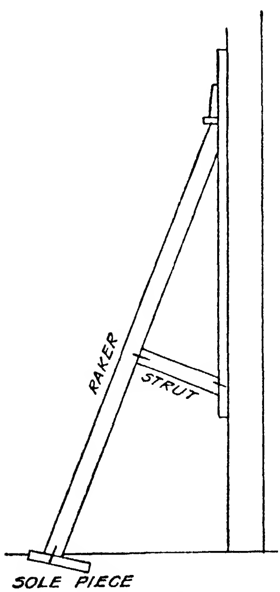
It goes up in floors or stories, each floor resting on a double row of standards, placed on sleepers and carrying longitudinal heads, which in turn support the transverse footing plates of the tier above. The height of each system depends on the size of timbers used, but usually is about 10 feet. The parts may be secured with 'dogs' or mortises and tenons.

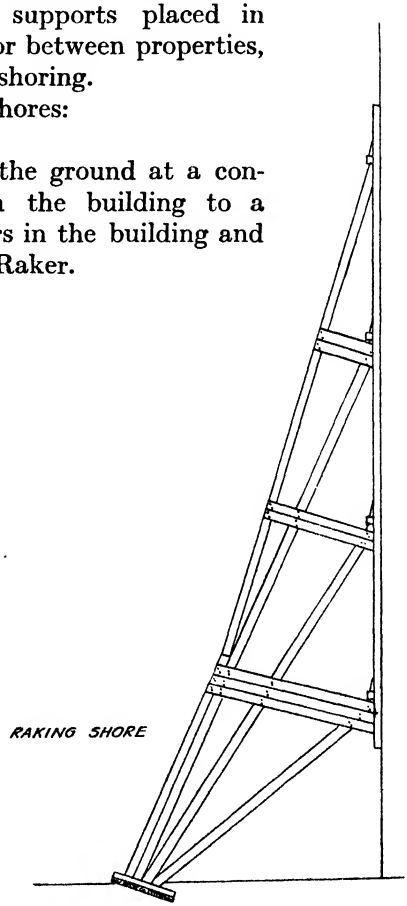
The 'working stage' of all scaffolds in the Metropolitan area must be guarded at the ends and sides 'not less than 7 inches in height', but usually two 9-inch boards are nailed into position.

Shoring. Alterations to adjoining property or the failure of a wall often requires supports placed in position either on the front or between properties, and this work is known as shoring.

There are three kinds of shores:

Raking Shores run from the ground at a convenient distance from the building to a floor or number of floors in the building and each shore is called a Raker.





Figs. 40 and 41.—Types of Rakers in Shoring.

Horizontal Shores are placed between the walls of buildings where a space intervenes. The bearing surface is increased by the introduction of struts.

Dead Shores are upright posts carrying Needles which project through the wall of a building and support the superstructure. This is necessary where the lower portion has to be taken away.

Shoring calls for great care in erection. The building may be insecure and therefore the process of propping must be

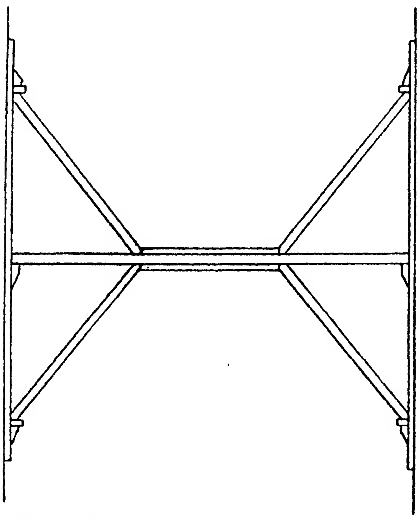


Fig. 42.—Horizontal or Flying Shores.

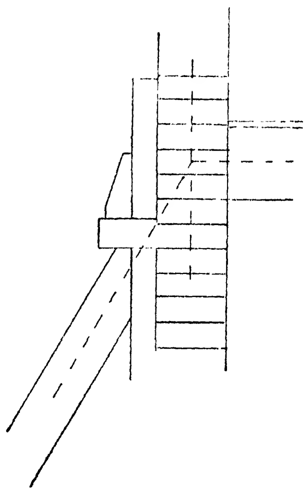


Fig. 43.—Position of Raker taking Thrust from Floor.

carefully and skilfully carried out. The rakers are of stout material from 6″ × 6″ to 9″ × 9″, usually pitch pine as it is procured in long lengths, and is fairly straight in the grain and free from large knots.

The position of the raker is determined by the width of the strut and the requirements of the local authority, but usually about 60° pitch or less is permissible where the building has three or four floors. Each raker must be placed in such a position that it is supporting the thrust due to the floor.

At the head of each raker a 'needle' is let into the wall where a brick has previously been removed. The wall-piece is mortised and the needle passing through this is stiffened by a cleat and takes the thrust of the raker.

The same principle is adopted in flying shores. Underpinning a building requires vertical posts or dead shores on which rest a stout beam to take the weight above. It is usual to place the uprights as near the wall as can be,

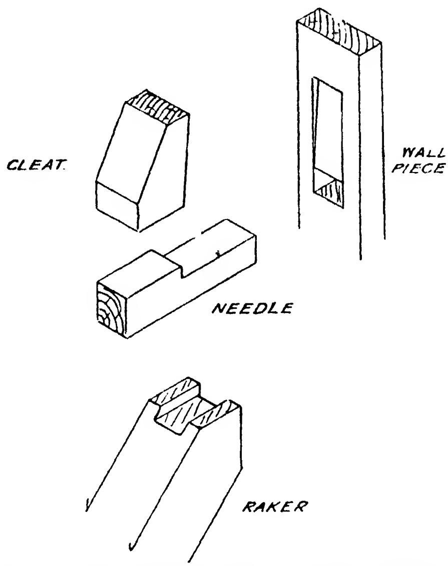


Fig. 44.—Detail showing Parts at Head of Shore.

both on the inside and outside. This enables the needle to be short in length which increases its supporting capacity.

It will be obvious that all shoring must have a firm base. If the ground is loose a platform of two or three layers of sleepers should be laid down crossing each other, the rakers being tightened up with a crow-bar and the needles with fox wedges.

CHAPTER VII

TIMBERING FOR TRENCHES

THE timbering of trenches, although not usually done by the carpenter, should be fully understood by him, if only for the reason that the majority of foremen are carpenters and have to ensure the safety of others in their charge. Usually there are three kinds of earth to contend with—firm ground, moderately loose earth and very soft earth.

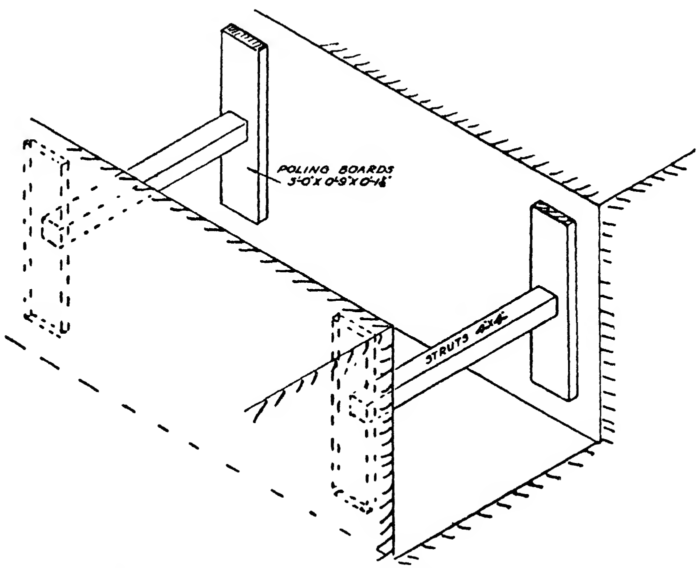


Fig. 45.—Timbering for Trenches in Firm Ground.

These are explained in Figs. 45, 46, 47, the first being the placing of Poling boards at intervals of 6 feet secured on each side of the trench by a strut wedged between. In the second method the same principle is adopted, but the poling boards are held in position by a waling piece which enables the poling boards to be drawn closer together, whilst the struts remain at intervals of about 6 feet. In very soft earth the trench requires careful preparation on the part

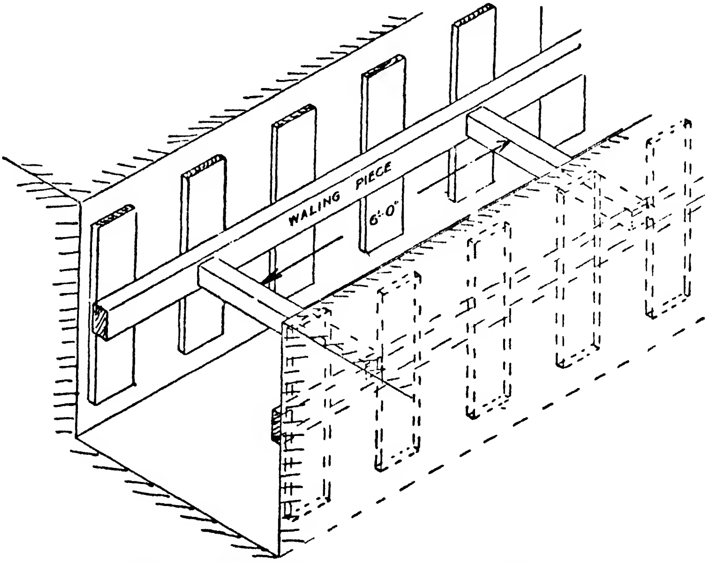


Fig. 46.—Timbering for Trenches in Doubtful Ground.

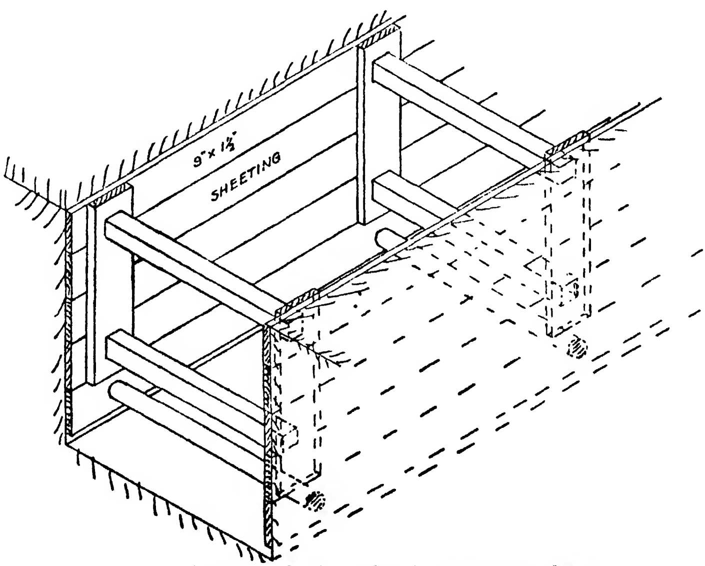


Fig. 47.—Timbering for Trenches in Dangerous Ground.

of the person supervising the work. The whole surface of the trench side is enclosed with sheeting and the bottom board is temporarily placed in position whilst another excavation is made one board in depth, the strutting going on in easy stages.

The excavation and timbering for a deep trench is shown in Fig. 48.

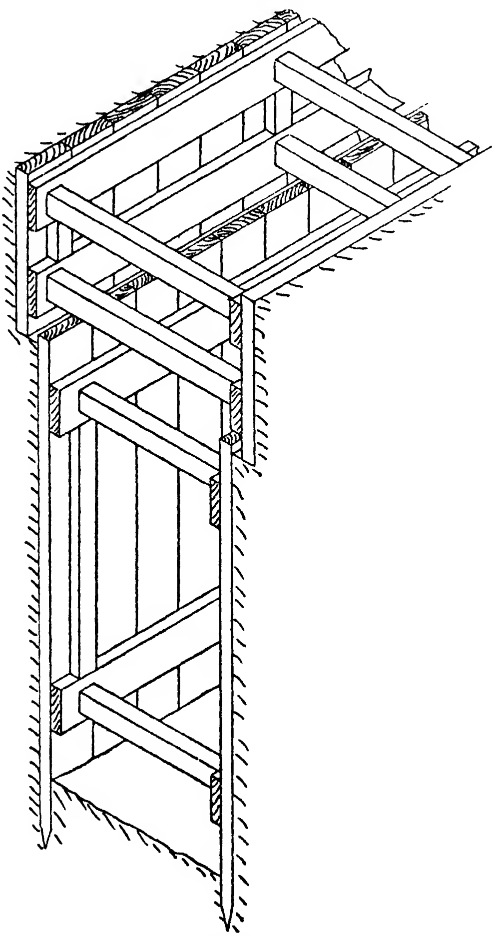


Fig. 48.—Timbering for a Deep Trench.

CHAPTER VIII

SHUTTERING FOR CONCRETE WORK

SHUTTERING is the general term we use for temporary work in connexion with moulding plastic concrete either alone or with reinforcement until it has hardened. Usually all straight casing-in is called shuttering, Fig. 49, to distinguish it from centring as being reserved for curved forms. A further classification is also necessary; large flat surfaces made up of numerous boards nailed together by ledgers for floors,

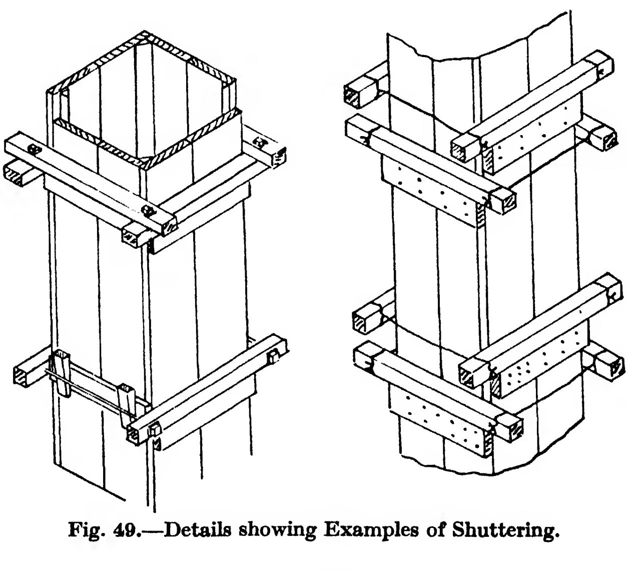


Fig. 49.—Details showing Examples of Shuttering.

walls, &c., is called Sheeting, Fig. 50, while open troughs or boxes which are formed in the casting of piers, columns, floor beams, &c., are called Forms, Fig. 51. There are certain regulations we have to observe in successfully carrying out this work. The work is of necessity temporary, therefore it must be fixed so as to be easily 'struck'. Being temporary it must be economical, but at the same time strong enough to remain rigid when the concrete is poured, being a heavy material, and has to be well 'punned' into position and then must remain for some time in 'setting'. It will be obvious that the concrete being wet, the timber shuttering will swell, which means that the work must not be fixed too tightly, otherwise a buckling will occur, possibly causing fracture or rupture in the concrete. It must be arranged also to allow the 'striking' to be done easily and in stages, thus

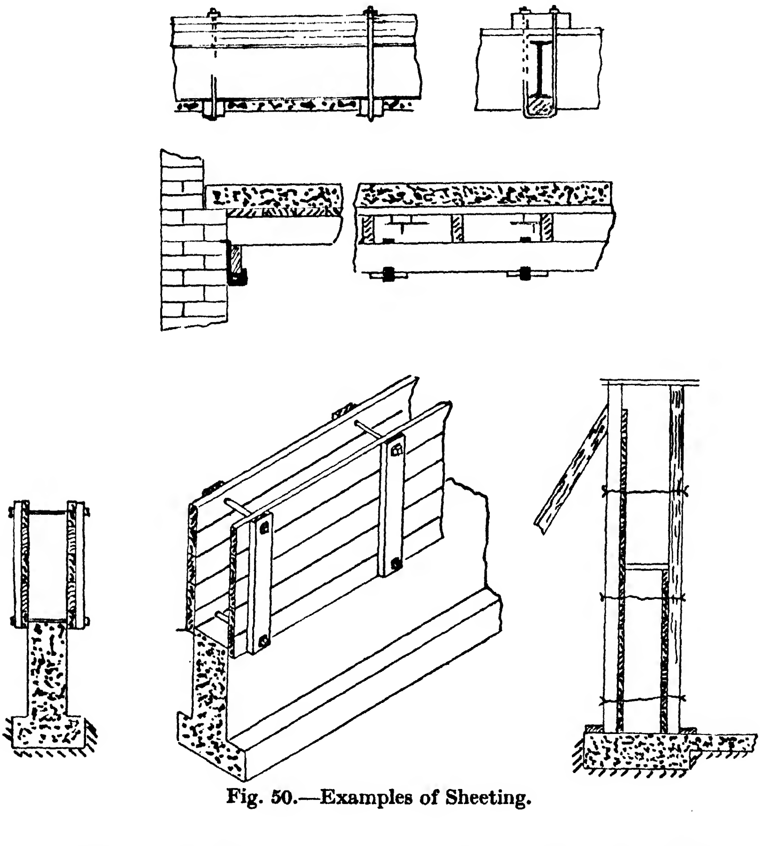


Fig. 50.—Examples of Sheeting.

avoiding any 'jarring' of the finished work. The salient angles of piers, beams, &c., should be rounded off to avoid the sharp edge being so easily damaged. This is accomplished by fixing angle fillets in the corners, Fig. 52. The timber used in shuttering should be smooth and true; large defects in the wood should be carefully avoided as the appearance of the board is always repeated on the surface of the concrete.

Precise dimensions cannot be given as each job is governed by its own circumstances. Large sections of concreting should never be attempted at one time, thus avoiding dis-

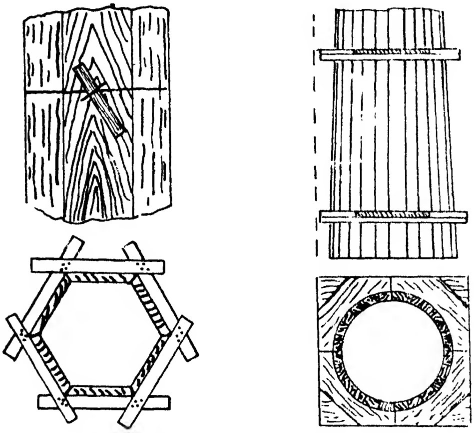


Fig. 51.—Examples of Formwork.

placement of the reinforcement and the danger of forming voids; also the large pieces of the aggregate sink to the bottom instead of remaining dispersed amongst the mass. This means that shuttering should be erected in stages of

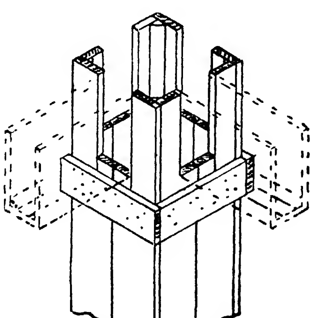


Fig. 52.—Example showing Treatment of Internal Angles.

2 feet or 3 feet in height, and for walls the ledgers on the sheeting should lip over the succeeding sheets and thus keep the surfaces in alignment. In striking, the boards want to come away as freely as can be, therefore a minimum of nailing is recommended. In the case of sides for beams, these

should be independent of the bottoms so that they may be taken down, leaving the sides of the concrete beam to dry,

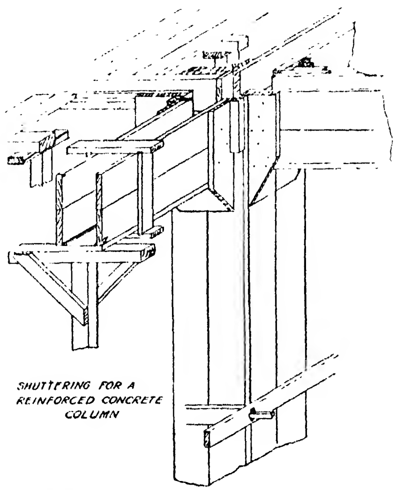


Fig. 53.—Composite Drawing of Beams, Floors and Column.

and the bottom is still in position to take the main weight until the concrete has matured.

How long the sheeting and forms remain in position after

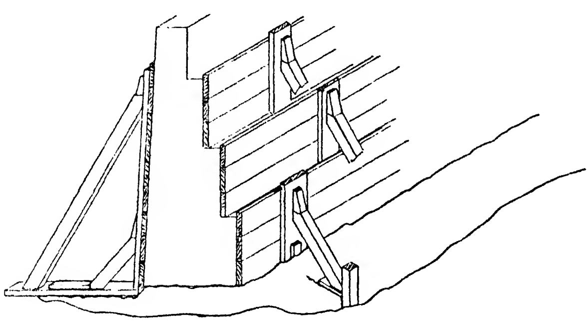


Fig. 54.—Typical Example of a Sea Wall.

pouring the concrete is controversial, depending on the time of the year, the amount of water used in mixing, and the system of concreting used. Soffits of floor slabs of 4 feet span could be removed after eight days, with soffits of beams and floors of greater span at fourteen days, but with modern quick-setting cements it is now possible to reduce these periods of time. Should a frost occur during the setting, then the time frost lasts should not be included in the above periods. Various sketches are shown which are explanatory in themselves. Building paper is sometimes used over the sheeting where a smooth finish is required.

The sides of troughs and columns should be lime-washed or oiled to prevent the boards adhering to the concrete.

Figs. 53 and 54 give details of typical examples of shuttering.

QUESTIONS ON CHAPTER VIII

1. As timbering is a temporary measure, what main principles should be observed in erections?
2. How would you prepare for external angles?
3. What is the difference between forms and sheeting?
4. How would you prevent the boards sticking to the concrete?

CHAPTER IX

FLOORS

FLOORS are distinguished from floor coverings in that the floor is a construction whilst the covering is one of many methods employed which is laid over the construction.

The placing together, therefore, of the various parts of a floor makes it into a naked floor. Wood floors are of three composite types, with each its own variation in construction according to requirements. These are the Single, Double and Framed floors.

There are other types, such as Fire-resisting and Composite floors.

The Single floor (Fig. 55) is the common method adopted

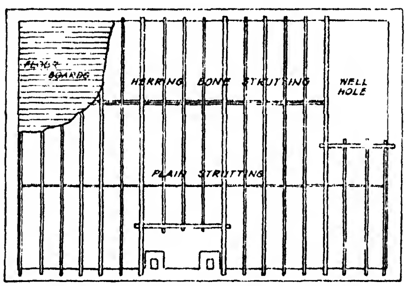


Fig. 55.—Plan of a Single Floor.

in forming a 'naked floor' for a small house or ordinary building with a clear span of about 16 feet. Any greater span would require an increased depth. The single floor is formed of a series of common or bridging joists and are thin and deep rather than thick and narrow, the former making for stiffness in the floor. These joists should not be less than 2 inches in thickness, as it is found that a thinner joist will split when the process of floor-laying is commenced. It need hardly be said that these joists are set on edge, not flat, and spaced about 12 inches to 15 inches apart, centre to centre. The ends, of course, rest upon the wall-plate and nailed to it, or in some cases may be on corbels built out from the wall.

For ground floors the span is decreased by introducing intermediate walls and consequently the depths of the common joists are correspondingly reduced.

In cases where flues, fireplaces, or staircase openings occur they impede the continuous common joist, and in consequence trimmers are introduced. which in turn support the trimming joists. In all cases the joint employed being the tusk tenon, Fig. 56. These trimming joists and trimmers, having to support the extra portion of floor, must necessarily be constructed of stronger materials. We usually add 1 inch in thickness to each of the joists, although

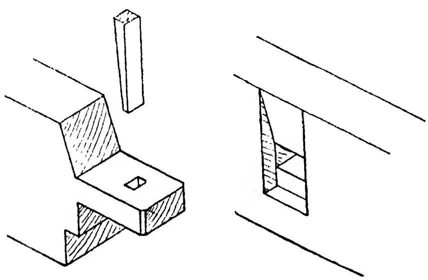


Fig. 56.—Isometric View of Tusk Tenon Joint.

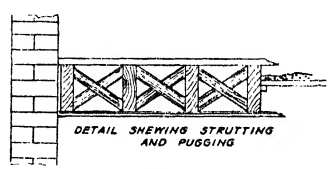


Fig. 57.

Tredgold's rule of $\frac{1}{8}$ inch for each intermediate trimming joist is theoretically correct.

To prevent twist and also make the floor rigid, strutting is used. These struts are brought into use when the span exceeds 8 feet and an extra row of struts for every 4 feet of span over and above 8 feet, i.e. 2 rows for 12 feet, &c. There are two kinds of strutting in actual practice; one is solid, being boards about $1\frac{1}{2}$ inches thick of the same depth as the joists; frequently short ends of the joists themselves are made to do; the other is herring-bone strutting, a much better method, and this is done by crossing two pieces of $2'' \times 1\frac{1}{2}''$ side by side and secured to opposite edges of the joists, Fig. 57. A convenient method of marking off these struts is shown in Fig. 58.

The hollow space between the top of the joists where the boards are laid and the bottom where the ceiling is suspended is unfortunately a conductor of sound, and this is often inconvenient to the occupier of the building. To make floors sound-proof, 'pugging' is often resorted to. This is done by nailing fillets to the sides of the joist (see Fig. 59) and resting thereon pieces of rough boarding. This forms a channel for rough plaster or, better still, slag wool (silicate of cotton) or coconut fibre, cedar felt or Cabot's quilt (a preparation of seaweed), which is very effective as a non-conductor of sound and is fireproof and vermin proof. The present tendency to concrete floors has supplanted this method very largely, but it is still in operation.

Double floors are brought into use where the span exceeds 15 or 16 feet and a Binder is introduced across the room at right angles to the span just mentioned, thus reducing the span and taking a certain amount of weight. It will be plain to the student that care should be taken in fixing the

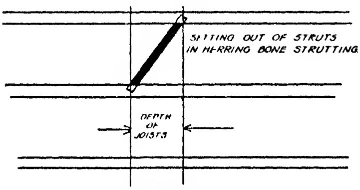


Fig. 58.

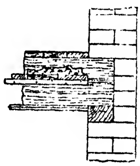


Fig. 59.—Method of Sound-proofing a Floor.

position of these binders. For instance, a binder should not be built into a chimney breast near flues, neither should it be placed over an opening such as a doorway, but should be laid upon the piers intervening. The old-fashioned wooden binder has now departed for the rolled steel joist, and the method of arrangement and ceiling suspension is shown in Fig. 60. The ends of the binders rest upon stout stone templates; the ends should be either quite clear of the brickwork with a cover stone placed above, or be built into a pocket having an air brick through the wall, and a clear space of 1 inch all around the joist. The bridging joists are cogged down on the binders and the ceiling joists are either lipped over fillets or placed in position by sliding them sideways into chase mortises (see Fig. 61).

Framed floors are used for spans of even larger dimensions. The binders and bridging joists of the foregoing are laid upon stout girders at intervals of about 10 feet or such distances as conveniently meet the case (see Fig. 62). Many of our modern buildings are constructed on these lines and the student should have no difficulty in seeing this work actually in practice.

This type of floor is usually to be found in the warehouse class of building when the shortest span is over 20 feet.

The requisite sizes of common joists are arrived at by common rules and their efficiency has been proved.

One common rule is ½ span in feet + 2 = depth in inches

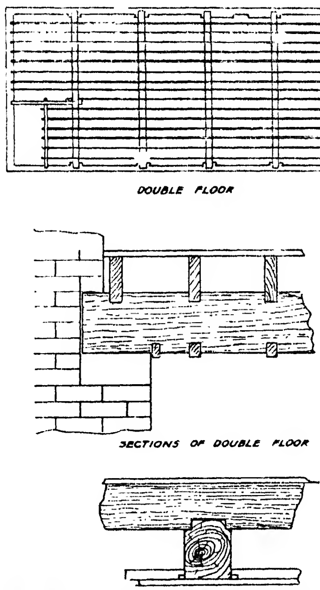


Fig. 60.—Details of Double Floor.

and 1/3rd depth equals the thickness thus: take 14 feet span $= \frac{14}{2} + 2 = 9$ inches deep and $\frac{9}{3} = 3$ inches thick.

A simple formula for the strength of a fir beam is: Allowing a factor of safety of $7 = W = \frac{b.d^2}{L}$ where W = safe load in cwts. distributed, b = breadth in inches, d = depth in inches, L = span in feet. Then 9″ × 3″ joist over 14 feet span $= \frac{b.d^2}{L} = \frac{3 \times 9^2}{14} = 17{\cdot}3$ cwts. distributed. Assuming the joists were 12 inches apart, i.e. 15 inches centre to centre, this will give a safe load of $\frac{14 \times 1{\cdot}25}{17{\cdot}3}$ = say 1 cwt. per foot super. Another rule is $\frac{6}{10}$ span in feet = depth in inches, 1/6th span = thickness in inches, e.g.

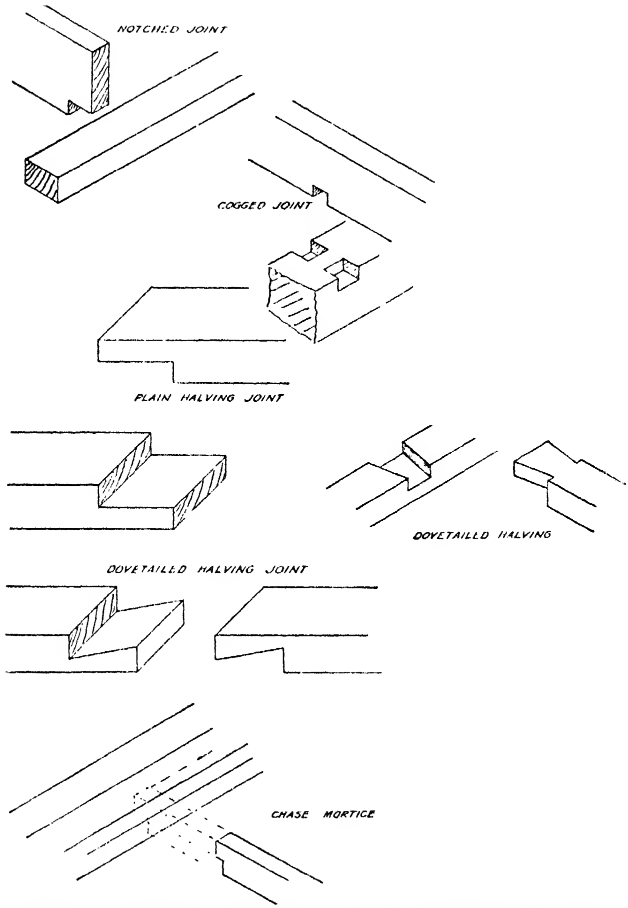


Fig. 61.—Details showing Joints used in Binders and Joists.

14 feet span $\frac{14 \times 6}{10}$ = 8·4 inches deep, 14 × $\frac{1}{6}$ = $2\frac{1}{3}$ inches thickness. Another rule is $\frac{1}{2}$ inch deep for every foot of span, thickness 1/3rd depth, e.g. $\frac{1}{2}$ × 14 = 7 inches deep, $\frac{1}{3}$ × 7 = $2\frac{1}{3}$ inches thick, but this is light for ordinary use.

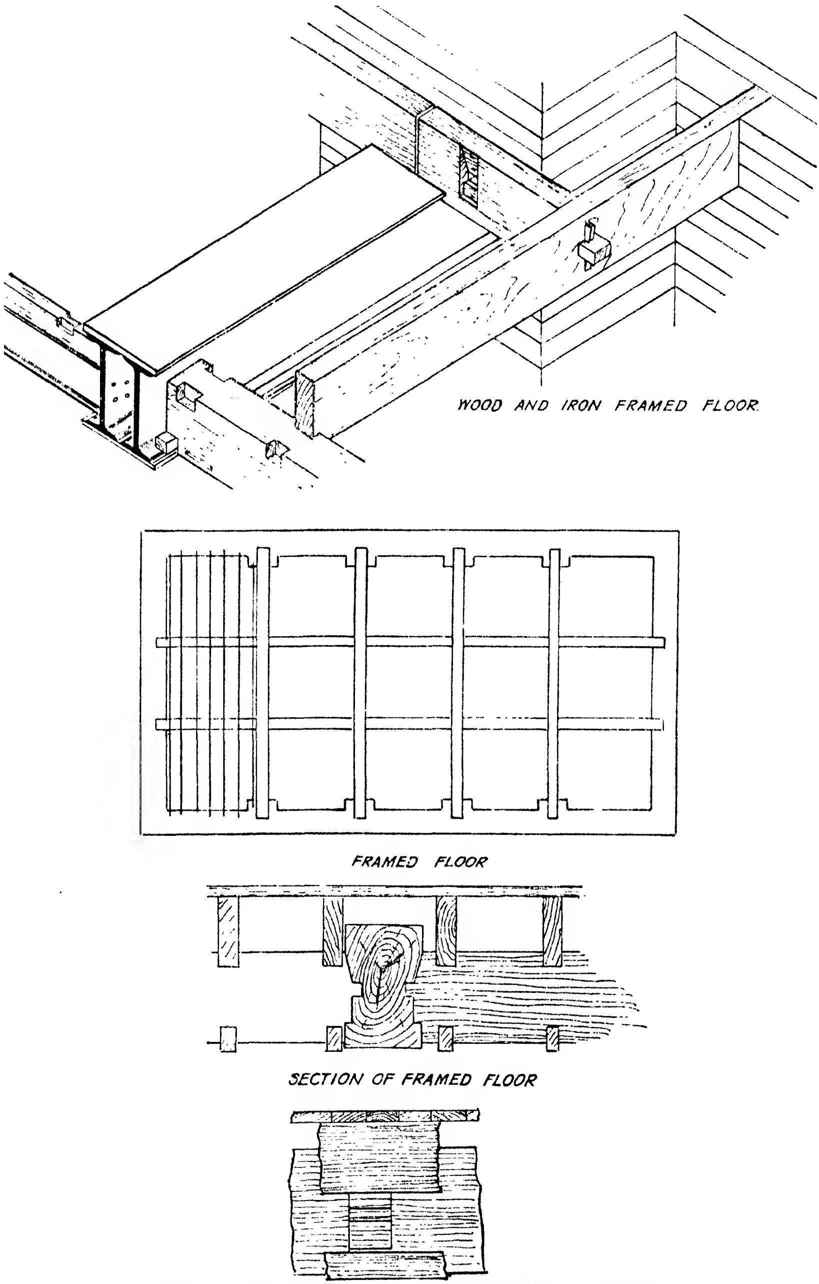
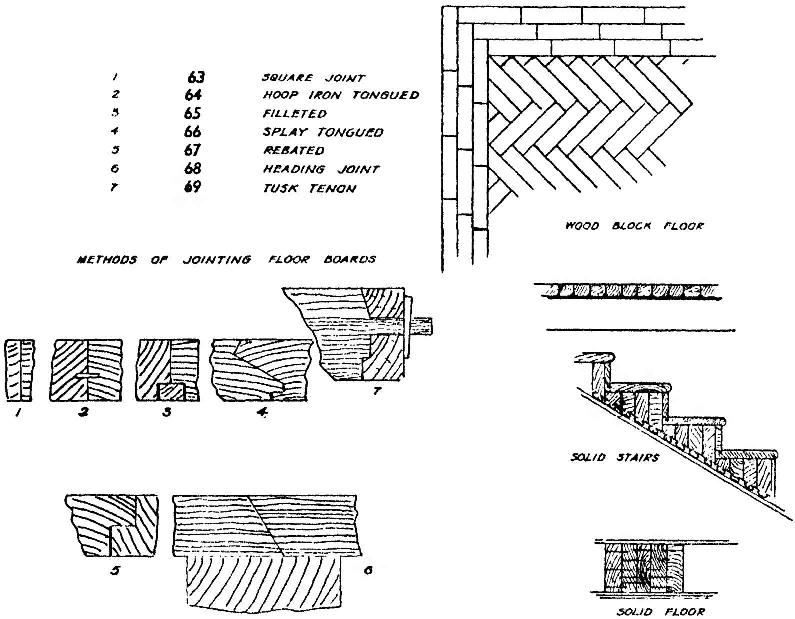


Fig. 62.—Showing Methods of arranging 'framed' Floors.

Floor Coverings. In ordinary work the joists are covered with boards or battens. These vary in width according to their quality and should not be more than 6 inches, but narrower if possible. As previously explained, boards shrink across the grain and a wide board would shrink in greater ratio than two boards having half the width of the former. It is therefore desirable to use floor-boards as narrow as possible. An inspection of any floor in an important build-



Figs. 63 to 69.—Showing Methods of Jointing in Hollow Floors and Laying Blocks in Solid Floors.

ing where boards are used will prove this. (Figs. 63 to 69 show the longitudinal joints in use and also Heading joints.)

Red pine, deal and fir make good floor coverings for ordinary use, whilst teak or pitch pine is often used for hard wear, and maple is perhaps the best for dance floors, being clean in appearance, very close in texture and therefore hard-wearing, and is capable of taking polish.

Care should be exercised in sawing floor-boards. If the heart is allowed to remain uppermost the grain will lift and any board showing this should be rejected. If the board is cut with the heart downwards it may be used, but the best board and the hardest wearing is what is called 'rift sawn', i.e. at right angles to the annual rings.

QUESTIONS ON CHAPTER IX

1. Describe the following: Single floor, Double floor, Framed floor.
2. Describe two methods of stiffening floor joists and draw the sections.
3. Draw ¼ full size a tusk tenon joint.
4. What timber should be used for the following floors? A dwelling-house, a warehouse, a ballroom.
5. Show the method of marking off struts in herring-bone strutting.

CHAPTER X

PARTITIONS

In forming partitions to divide one room from another one has to remember the many fire-resisting materials of the present age that are used in place of timber for this purpose: slabs made of breeze concrete, hollow bricks, expanded metal, or iron cores, all more or less fire-resisting and useful.

The carpenter, however, may still have occasion to erect a wood partition, as part of the superstructure to receive one of the above methods of walling. In doing so care must be exercised in placing the various members; for instance, if the partition runs across the joists, the load is distributed

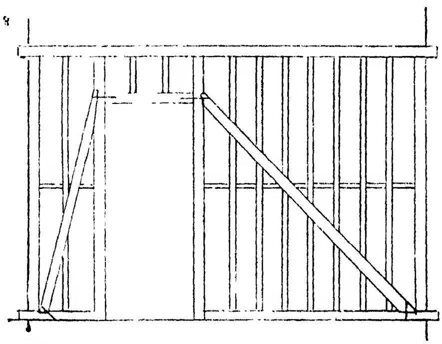


Fig. 70.—Framed or Quartered Partition.

more uniformly than if the partition ran parallel with the joists. If the partition on an upper floor is to support the roof struts, the uprights and braces must be so disposed as to take the weight off the struts.

In Fig. 70 an ordinary partition in an upper storey called a framed or quartered partition is arranged to fulfil the above requirements. The sill is built into the wall on a solid bed, whilst the head, although let into the wall, is not supported by the wall, but a space below allows for any settlement. The joints of the uprights are stub tenoned into the sill, but where the door-stile is between two joists the weight should be taken by a bridging piece between the joists. The bridle joint is used for the braces into the sill. The upright door-posts are out of $4\frac{1}{2}'' + 4''$ and the intermediate up-

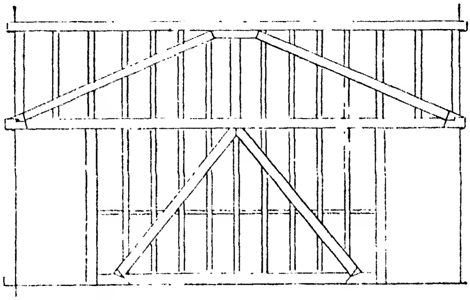
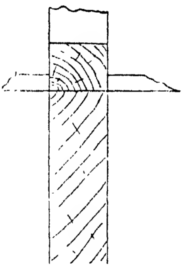


Fig. 71.—Trussed Partition.

rights of $4\frac{1}{2}'' \times 2''$ or sometimes $4'' \times 2''$, whilst the sill and head would be out of $4\frac{1}{2}'' \times 3''$.

In the event of a partition having an additional load such as a floor above, a heavier type of partition is required. The trussed partition comes into use here, and as they are very similar in construction and principle one sketch only is given (Fig. 71).



In erecting the partition care must be exercised in noting the position of the joists below. If the partition runs across the joists the weight is superimposed over the whole area. If, however, the partition runs in the direction of the joists it becomes necessary to fix 'bridging pieces' between the two joists where the partition runs, as shown in Fig. 72. These are spaced at intervals of about 2 feet. The weight in all cases should as far as possible be taken off the floor and thrust on to the walls supporting the structure.

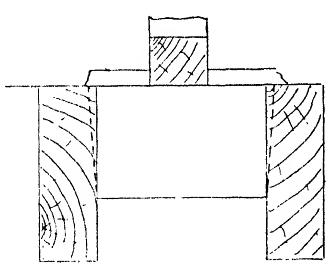


Fig. 72.—Details of supporting a Partition between the Joists.

CHAPTER XI

ROOFS

In introducing the important subject of roofs, the student has an opportunity of studying a portion of his craft giving ample scope for constructive detail coupled with theoretical principles and uniting the two to make a pleasing and artistic covering to the building. It has been said: 'There is nothing in the wide scope of architecture more worthy of distinct consideration than the Roof.'

The present use of iron and steel in roof construction has tended to govern roof design and has certainly supplanted the work at one time put into roof trusses, although much is still left to the carpenter to show his craftsmanship in the encasing of the steel trusses and finishing the ceiling.

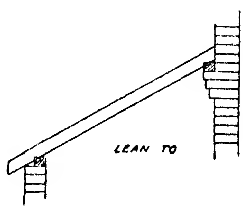


Fig. 73.

Again the flat roof, which is rapidly displacing the pitched roof, is in construction similar to a floor with 'firring' pieces secured to the joists to give the required 'fall'.

In the sloping roof, however, we control the 'pitch' by the covering of the roof, which covering is in turn determined by the climate and the surrounding country. The *Encyclopedie Methodique* has sectionalized the world's climates into sections running parallel with the Equator and giving the adequate roof covering for the particular section. The common pitch of roof used in this country varies from 25° to 45°, but 35° is a good average.

The simplest form of roof is the 'Lean-to' in which one side leans against a wall (Fig. 73).

The Couple roof is the ordinary cottage roof (Fig. 74), but the Couple Close roof is better as the feet of the rafters are tied by the ceiling joist arresting any tendency to spread at the feet. The term 'Couple' is derived from the two rafters forming a couple and the word still obtains in the North of England.

Another form of roof suitable for small spans is the 'Collar

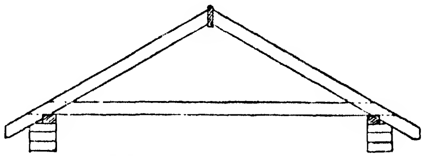


Fig. 74.—Couple Roof.

Beam' roof (Fig. 75). The advantage of this method is in the extra height gained by raising the collar, but it will be seen that the higher the collar is fixed, the more there is a tendency for the feet to spread. The collar should be kept in the lower third of the total height. The size of the rafters and ties is usually 4″ × 2″. This size is easily purchased and covers the requirements of this particular con-

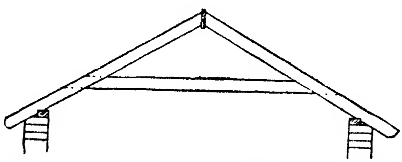


Fig. 75.—Collar Beam Roof up to 18′ 0″.

struction, whilst the wall-plates on which the roof sits are 4½″ × 3″.

The foregoing had served the purpose for small spans commencing with 10 feet and going up to 18 or 20 feet, and it is now necessary to deal with spans of greater magnitude. This is achieved by forming what is called a 'Truss' at intervals of 8 or 10 feet. This is an arrangement of tying together the various parts, the simplest being the 'King Post' truss for spans of from 25 to 30 feet. An inspection of Fig. 76 will make clear the formation of the parts and the various iron fastenings which will be further dealt with. The parts which go to make up a 'king post' truss are lettered and can be traced here:

T.	Tie Beam	6″ × 4″
P.R.	Principal Rafter	7″ × 4″
K.P.	King Post	6″ × 4″
S.	Strut	4″ × 4″
P.	Purlin	7″ × 4″
W.P.	Wall-Plate	4½″ × 3″
R.	Ridge	7″ × 1½″
C.R.	Common Rafter	4″ × 2″
K.S.	3-way King strap	3″ × ¼″
G.C.	Gib and Cotter strap	3″ × ¼″

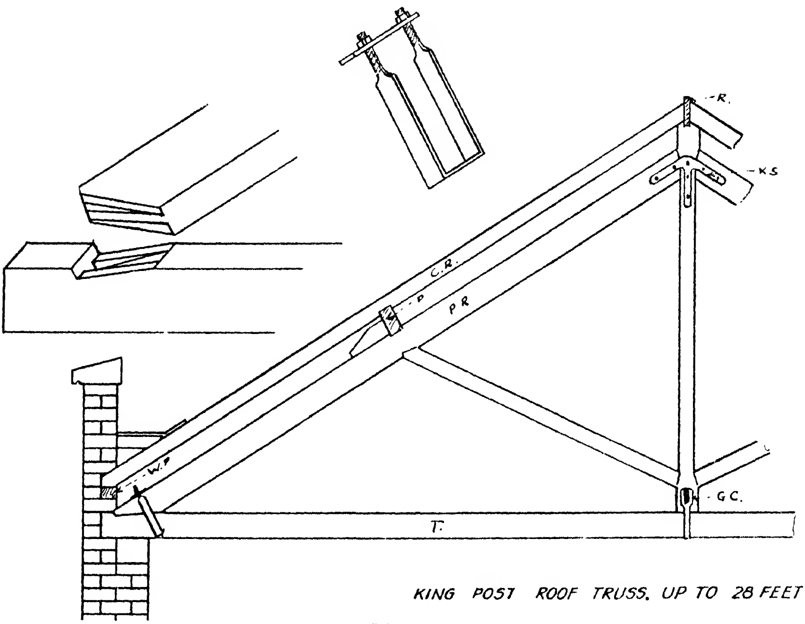


Fig. 76

The main function of the king post is to secure the centre of the tie beam whilst the top holds in position the principal rafters. The junction of the king post and tie beam has a specially arranged iron strap of ¼-inch metal and about 3 inches wide at the top, where mortises are forged to correspond with mortises through the timber; the iron wedges are driven home in such a way that the joint is drawn up tight, the shoulder of the king post having been previously cut short to give 'camber' to the tie beam; this 'camber' is about ⅛ inch to every foot of span. The action of drawing up the joint is best seen by following the sketch in Fig. 77. The tie beam may be notched or cogged to a wall-plate or may rest on a stone template. The purpose of the strut is

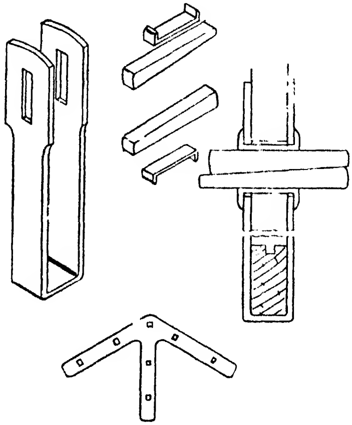


Fig. 77.—Showing Metal Parts in the Gib and Cotter Joint.

to act as a support to the principal rafter and purlin. These are in compression and it is sometimes difficult to space the strut to be immediately below the purlin, but it will be

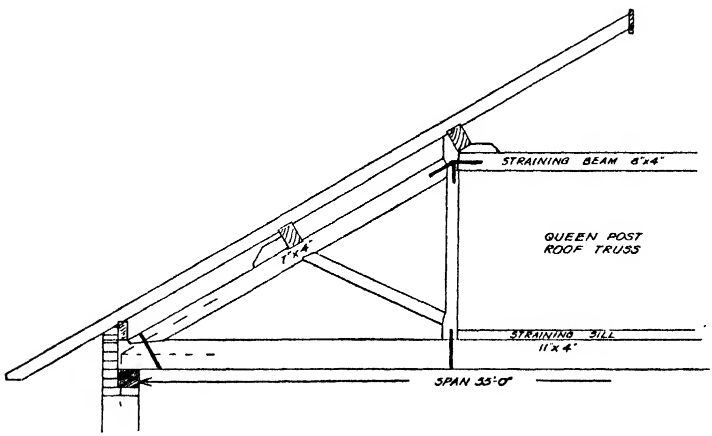


Fig. 78.

obvious that this is necessary. The purlin is notched into the principal rafter and supported by a cleat at the back.

By following the above practice the student should be able to adapt it to almost any form of roof truss which does not come under the requirements of this book, but we include

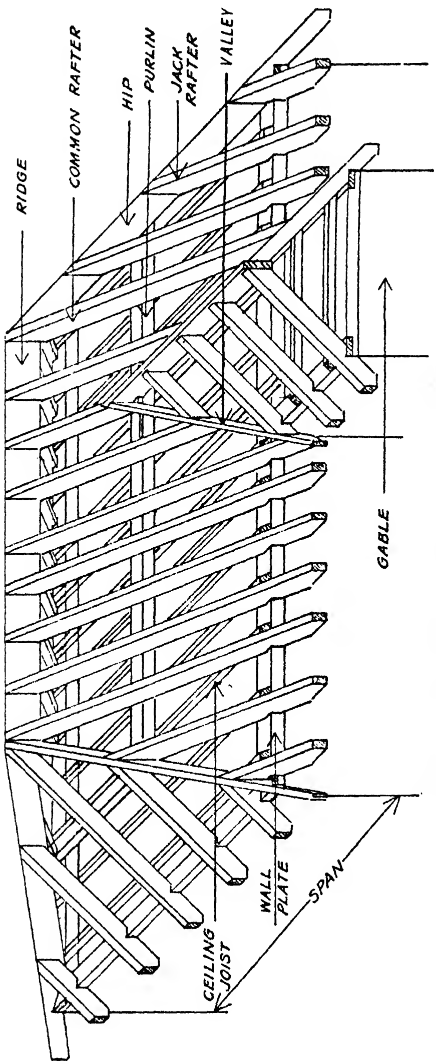


Fig. 79.—Isometric View of a Roof ready for Covering.

a sketch of a Queen Post truss for a span of 35 or 40 feet (Fig. 78).

The horizontal wind pressure usually allowed is 45 lbs. per foot, acting on only one side at a time or a normal pressure of 80 lbs. per foot for a 30° pitch and 40 lbs. per foot for a 45° pitch.

Roofs covered with 1-inch rough boarding and felt laid over make the best preparation for the permanent finish of slates or tiles.

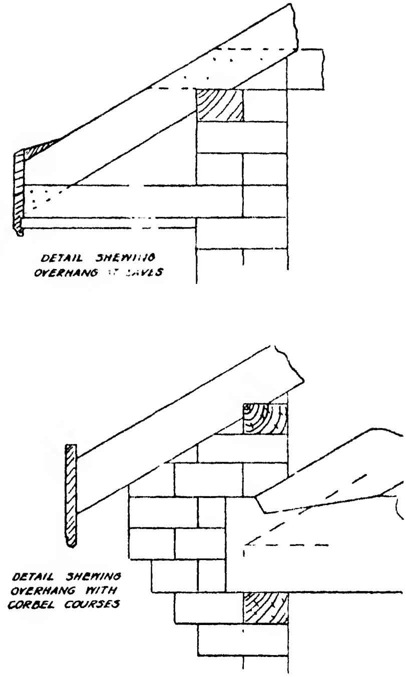


Fig. 80.

When the rafters remain in an upright position at the end of a building they form a gable end to the building, but if it is desired to continue the pitch around the end of the building, hip rafters are introduced as seen in the outline sketch. Again, any deviation from the straight, by throwing out a projection from the building, a valley is introduced as shown in the outline sketch, to return the re-entrant angle. This opens up the question of bevels, so interesting to the craftsman, but will be thoroughly dealt with later. The arrangement for fixing the rafter feet is shown in Fig. 79. The rafter has a birdsmouth cut out on the under side to sit on and be nailed to the wall-plate, on which rests the ceiling joist which is nailed to the feet of the rafter. The overhang of the rafter is formed by the projection of the rafter from the face of the wall and the cut at the end forms the line of the fascia board. This board fulfils two functions: the gutter brackets are screwed to it to the required 'falls', and the upper edge projecting beyond the rafter gives the required 'tilt' to the slates or tiles (Fig. 80). Sometimes tilting fillets are used. The lower edge of the fascia board allowing for a break of $\frac{1}{2}$ inch is grooved to receive the soffit board. It is sometimes necessary at the foot of a hip rafter to form a Dragon tie. This is to give a full seating to the heel of the hip and at the same

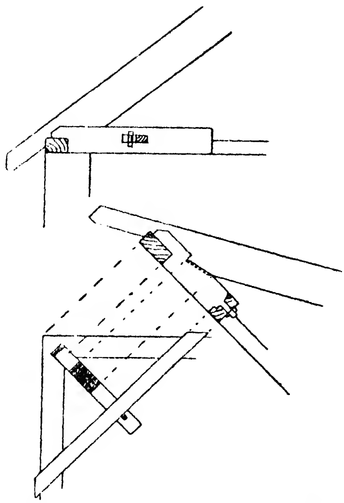


Fig. 81.—Sketch showing position of a Dragon Tie.

time ties the corner of the wall-plates at their intersection (Fig. 81).

Purlins in ordinary roofs are fixed at right angles to the pitch and where joined to a hip require special bevels (these will be dealt with in a subsequent chapter). Where division walls occur they are used as supports for the purlin struts. Lead is used in roof work to form valleys, backs of chimneys, &c., and the carpenter must needs prepare valley soles and chimney gutters. These are done by laying 1-inch boards up the valley and nailing thereon tilting fillets to receive the slates, whilst behind the chimney blocking pieces are nailed to the rafters as a seating for the board on which the lead is laid and beaten to its required shape.

Pieces of 4″ × 1½″ called hangars are nailed to the rafters and ceiling joists between the purlin and the wall-plate, to stiffen the ceiling joist in the centre of the room before it receives the weight of plaster it is destined to carry.

Too much care cannot be spent on the preparation of a roof, and a few extra pieces of timber well distributed and securely fixed can save much subsequent trouble.

It is better that a roof should be boarded with rough 1-inch boards before slating or tiling. This makes the roof absolutely rigid and by keeping out the wind, which otherwise must find its way in, ensures a warm building in the winter. In addition 'sarking felt' is sometimes used.

The space between the ceiling joists and the rafters is used to accommodate the water-storage cistern and therefore extra strength is required either by laying girders across the dividing walls or increasing the strength of the ceiling joists and hangers.

What is termed a Composite Roof is very common to-day. It is a steel frame with wood purlins and boards, &c., drawings of which are shown in Fig. 82.

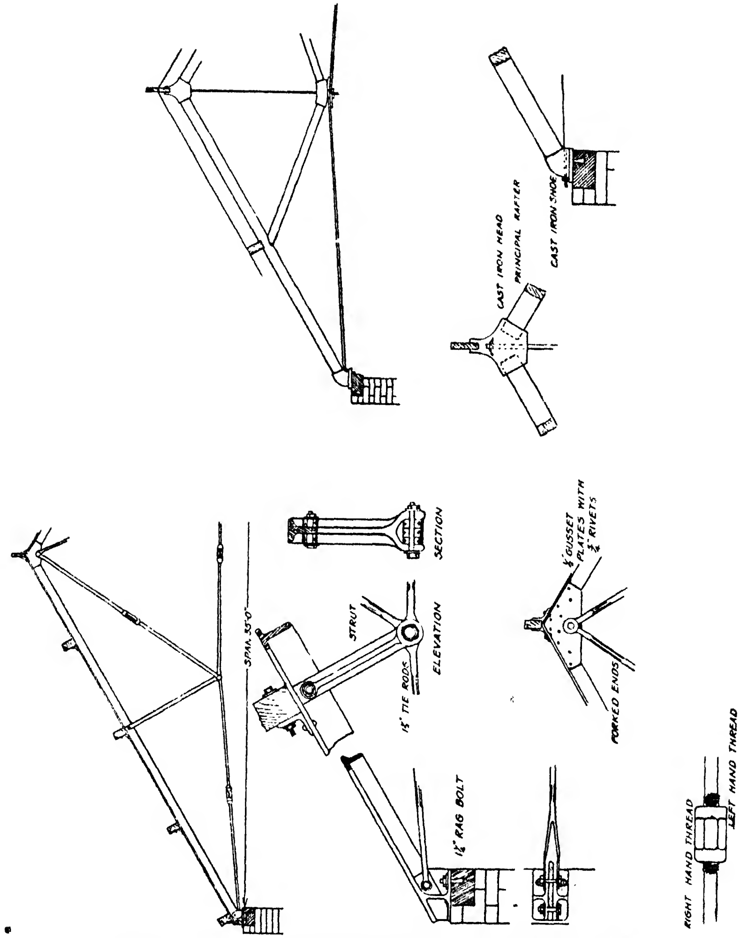


Fig. 82.—Details showing Parts of a Composite Roof.

The formation of the foot of a roof forming a boxed gutter behind a parapet wall is shown in Fig. 83. The common rafter is seated on a pole-plate which runs from truss to truss along the wall. From each rafter blocking pieces are fixed, laid to falls to take the water off the roof. When boarded and

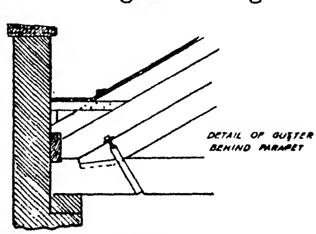


Fig. 83.

finally trimmed off, 6 lbs. lead is laid in the gutter and beaten into position.

It is a big advantage to be able to obtain light through a roof. This introduces the skylight, a drawing of which is shown in Fig. 84. The lower half of the light is the roof itself cut out and trimmed to the required size of opening.

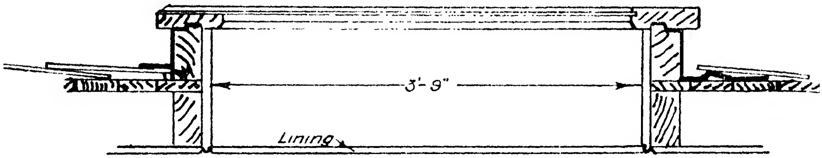


Fig. 84.—Drawing of Skylight raised above the Roof.

Around this opening a 'curb' is laid and the whole of the inside is lined out as shown. The 'lay' light sits on top of the curb, being grooved, and lead is beaten round as seen in the drawing.

Patent glazing has often to be fitted to the carpenter's work, examples are shown of bars to roof lights and the methods used to ensure them being watertight.

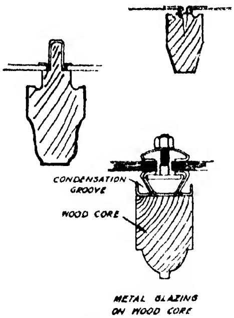


Fig. 85.

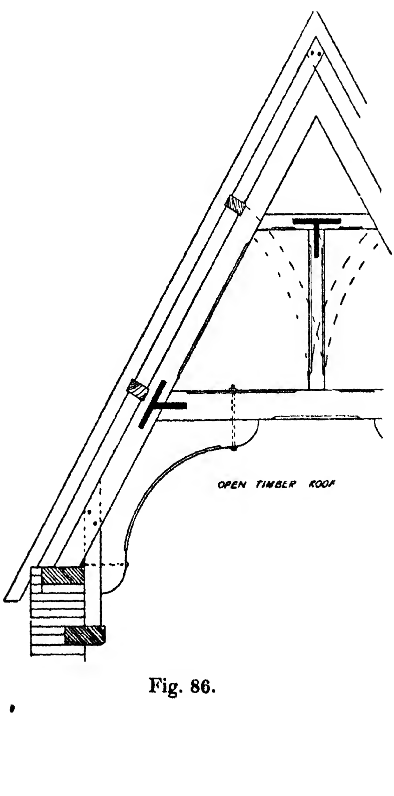


Fig. 86.

TABLE GIVING WEIGHT OF ROOF MATERIALS

	lbs. per foot super
Common Rafters and Purlins (wood trusses)	7
,, ,, ,, ,, (iron trusses)	6
One-inch deal boarding	3·33
Battens laid 8½ inches gauge 2″ × ¾″	1·32
Asphalted felt	0·5
Zinc laid with rolls 12 inches gauge	1·5
,, ,, ,, ,, 14 ,, ,,	1·7
,, ,, ,, ,, 16 ,, ,,	1·9
Lead and copper according to weight per foot adding 1/10th for seams and laps.	
Corrugated iron B.W. gauge with bolts	1·9
Slates 3-inch lap all sizes except Rags and Queens including nails	9·0
,, Rags and Queens	12·0
Tiles 10½″ × 6″ × ½″—4 inches gauge	16·0
Ceilings including joists 10 feet, bearing with lath and plaster	12·0
Snow according to climate	3 to 10

QUESTIONS ON CHAPTER XI

1. Draw rather more than half of a king post roof truss for a 25-foot span. Show clearly the position of all ironwork. Scale ½ inch to 1 inch.
2. Draw in isometric the joint at the foot of a principal rafter and the tie beam.
3. Make a sketch showing a gib and cotter joint to a king post.
4. Draw to a large scale the foot of a common rafter in position on the wall-plate. Show the fascia board and soffit.
5. Draw the section of a gutter behind a parapet wall.
6. Draw plan and elevation of a dragon tie and project the true shape.

CHAPTER XII

ROOFS (*continued*): HOW TO OBTAIN THE BEVELS

In preparing the various timbers for a roof, the student has probably been faced with the problem of assuring himself that the bevel or angle which he wishes to cut is correct.

This section is specially written for the solution of such problems.

If two inclined surfaces join, the joint is different to that shown in a plan and elevation and has to be determined. On the other hand, where an inclined surface joins either the horizontal or the vertical plane the bevel is at once assured. In Fig. 87 a bracket in a corner is showing the angle to be cut. This can be used in similar fashion to the common rafter of a roof.

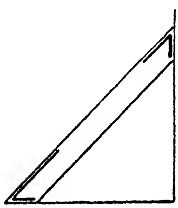


Fig. 87.—Angle Bracket representing a Roof Rafter.

The first case in roof work to be dealt with is the hip and its top and bottom bevel. Fig. 88 shows a plan and elevation of a roof. All roof work is made up of a system of triangles and the important point to remember in hips and rafters is that the height does not alter, but the base does. A study of the plan in Fig. 88 will prove that *H* and *C* stand equal in height over the ceiling, but the base of *H* is longer than *C*. Therefore place your 60° set square on the corner of your drawing-board and you have a good example of a hip to a roof. Similarly, place your 45° set square at right angles to your drawing-board and you have the position of the common rafter; although the angles of the two set squares are different, the edges would appear in elevation to be in line when placed in such a position.

Referring again to Fig. 88 the plan shows *H* and *C* as the bases of two triangles, but we know they are standing at a point equal to the height of the roof as at *B* in the elevation.

We will now proceed to get the bevels for the hip and common rafter. Place the 60° set square on the top left-hand corner of the drawing-board as before in an upright position, next turn it flat down on the drawing-board towards the left.

Standing over it you see the true shape of the set square which you could not see before. You can now say that the foot cut and head cut, as they are called, are lying in their position on the drawing-board, and by referring to Fig. 88 again we can now say that by turning *Z—X* and *Y—X* through a quarter of a circle we can see the hip and rafter in their true shape. Further, this procedure not only gives the required bevels, it gives the length of the hip and rafter, as they are found to be the hypotenuse of a triangle.

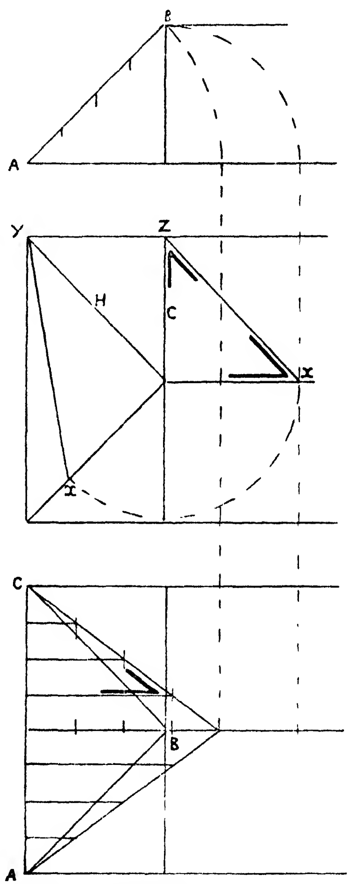


Fig. 88.—Showing Development of Surfaces for Hip and Jack Rafters.

The student is recommended to practise this procedure and master it thoroughly, because it is the fundamental of all oblique and therefore bevelled work. There are other bevels still to be found. Alongside the common rafters which are all equal in length and nailed to ridge and wall-plate, we have the jack rafters nailed to hip and wall-plate and which diminish in length as they disappear towards the corner of the building.

It will be seen in Fig. 88 that these diminish equally according to the spacing out of the rafters and the pitch of the roof, but we do not know by how much as every pitch alters the length of the jack rafters, although it is usual to space the rafters at 12 inches between each pair of rafters, or as some prefer it 14 inches centre to centre. As the jack rafters are lying in an inclined plane we cannot see the true bevel for the top edge, and we have therefore to find it. We know, however, that the vertical cut is the same for all rafters, that is as long as the same pitch is kept in the roof to be dealt with, but the moment the pitch alters so the 'down cut' is altered. Looking along the rafter *AB* in elevation Fig 88, it can be easily imagined that in this line are really several jack rafters of varying length shown by the marks on the long or centre rafter. Returning to Fig. 88 where we have a plan of this end of the roof, but like the hip we have no indication of the length of these jack rafters. If, however, we develop the triangle *ABC* in Fig. 88 by folding it down on to the drawing-board, we shall be able to see its true shape and thus get the bevels and lengths desired. Place the compass point on *A* in Fig. 88 and drop *B* down into the horizontal plane in *D* and produce the line to *E* in Plan, Fig. 88. By joining up *C—E* and *A—E* we have the true shape of the end of the hipped roof, and by continuing the lengths of the jack rafters until they cut these new lines, we have the various lengths of each jack rafter, the bevel of which is constant for all, but the lengths decrease uniformly. In setting out these points are dropped down to the centre rafter, and a saw cut on the pattern rafter enables the carpenter to mark any number of jacks from his pattern, remembering, of course, that they must be cut in pairs. A simple and practical method of getting the edge cut from any jack rafter is shown in Fig. 89. In this case the 'down cut' must first be given. Place the down cut *AB* on the timber and whatever is the thickness of the jack rafter—usually 2 inches—mark off a line the same distance away and parallel to it, at *CD* square off a line on the edge from *C* to *E* and connect *EA*. This is the required bevel for the jack rafter. The student is recommended to try the two methods on a small piece of wood using, of course, the same pitch of roof, and satisfy himself as to the accuracy of both methods. The second method does not give any guidance as to the diminish in the jack rafters, which is an advantage in the first method.

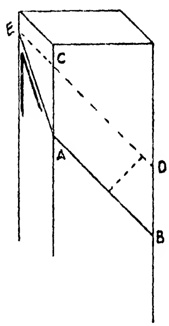


Fig. 89.—Showing how to obtain 'edge' cut to Jack Rafter.

As the valley rafters lie in the same plane as the hip rafters, the hip bevels are used for the valleys.

It is sometimes necessary to 'back' the hip, that is to give the top edge a bevel which will be in the same plane as the roof. Fig. 90 explains this. A plan of the hip would not give its true shape which is proved in Fig. 91, but by folding down into the horizontal plane as before we can again attain our object. Refer to Fig. 90, draw a line at 45° to the wall-plates *AB*. Point *C* would be standing above *A* and *B* a certain distance, again forming a triangle. Develop the hip as before, and the true section of the hip through *C* is therefore moved to *D* by squaring off a line from the developed hip from *C* to *D*. Taking the compasses and swinging round from *D* to *E* with *C* as centre, we have the top edge of the hip developed. It will be recalled we said that *C* in the first place was standing over the line *A* and *B*; it is now turned into the horizontal plane, and as the three points *ABC* were originally joined they can be now joined in the same way which shows the true connexion of the three points. This is the required bevel for the top edge of the hip.

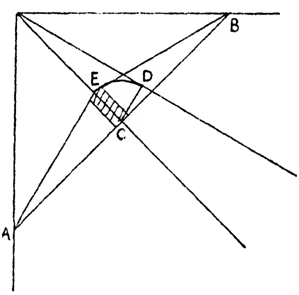


Fig. 90.—Development of Section of Hip Rafter.

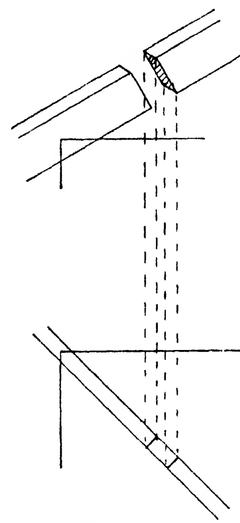


Fig. 91.—Sketch showing how the true Section of a Hip Rafter is not shown in Plan.

Sufficient has been said to prove that the only solution to these problems is to develop the surface in question; it is therefore not necessary to state any more in explanation, but proceed to give the remaining bevels for a roof. Fig. 92 shows two methods of joining the hip rafters to the ridge

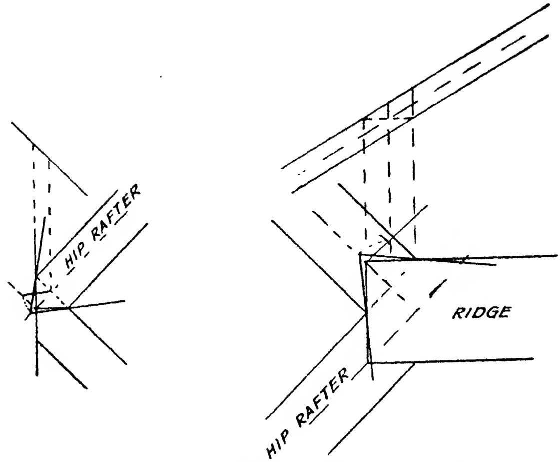


Fig. 92.—Bevels for Hip Rafter at Ridge.

with the necessary bevels; the purlin bevels are also shown. If the purlin stood in the vertical plane the joint at the hip would be a mitre. But as it is the proper procedure to fix the purlin square off the pitch of the roof, the two surfaces have to be developed to get the two bevels. See Fig. 93.

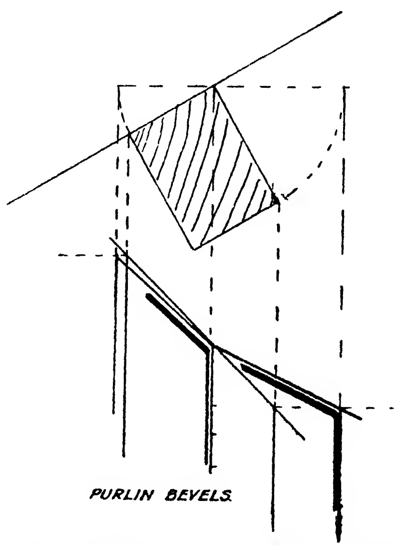


Fig. 93.—Development of Surfaces in Purlins giving Bevels.

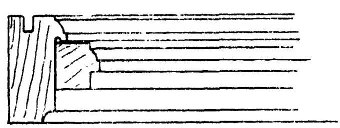
CHAPTER XIII

WINDOWS

A STUDY of windows conveniently precedes that of doors. The design of windows has altered considerably of recent years. A visit to any building scheme will prove how the architect has contrived to give his client the maximum of sunshine and daylight.

The hollow or boxed frame with sliding sashes is but little used now, although it is still the view of many that it is the most serviceable, and is dealt with here in passing but not in detail, as the student will be more concerned with solid frames, with casements and French casement windows.

The solid window-frame is arranged on the same principle as a door, being a sash or sashes



CASEMENT WINDOW
OPENING OUTWARDS

hinged to a rebated frame. It is usual to make these open outwards—an example is given in Fig. 94—although they are sometimes made to open inwards but are more difficult to arrange to resist rain penetrating the joints. The sill should be of oak and the top surface bevelled outwards to throw off the water; a metal water bar is fixed in a groove on the bottom of the sill to prevent the penetration of rain between the sill and wall. The rebates in the frame should be throated as an additional check to the weather. The admission of any water has an

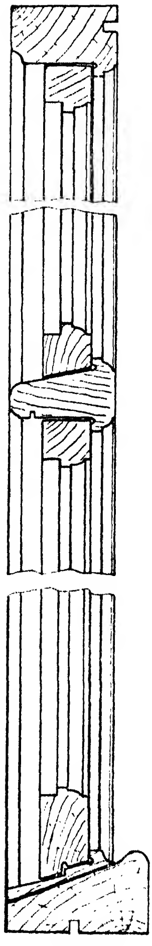


Fig. 94.

opportunity of running down this throating and out at the sill. It also arrests the passage of water drawn in by capillary attraction. The frame is grooved to allow the window-board to be tongued to the sill, and the head and stiles may also take the tongue of the linings, or if plastered back to the frame they afford a key for the plaster.

The sash (or casement) is framed up with rails and stiles, the rails being scribed to the stiles as shown. Bars throw shadows in the room and have the effect of making the window look heavy and cumbersome. If these casements are not hung on hinges but remain nailed in position they are called fixed casements.

The centre hung casement is shown in Fig. 95, and is usually placed in positions where they are not easily accessible but can be opened by means of a cord. The sash swings on metal pivots fixed in the centre, and the beads forming a rebate on both sides are fixed as shown, one half on the sash and the other to the frame.

In the case of the hollow or boxed frame (Fig. 96), the frame is in the form of a box, the inside forming a space for the sliding of the weights, the outer lining projecting beyond the pulley stile forming a rebate for the top sash, whilst the inner lining finishes flush with the pulley stile, giving entry for the sashes to be hung and then enclosed by the nailing or screwing on of a bead. The bottom bead if made wider will enable the bottom sash to open and give adequate ventilation through the meeting rails and obviate the danger of any draught at the bottom.

When the sashes have been glazed they are weighed to ascertain the required balancing weights; the weight behind the top or outer sash should be slightly over the weight of the sash to ensure keeping it in position. Similarly, the weight behind the bottom or inner sash should be slightly under that of the sash to enable it to remain in position when pulled down.

The moulding of the various members can be varied, but the usual method and by far the most satisfactory is to use the Ovolo mould. Paint should be used round all the tenons and mortises before cramping up and a good practice is to pin as well as wedge all joints. The bottom rail or sill of all sashes should be made of wider material than the remainder, as this enables a wider tenon to be used, giving greater rigidity to the sash and where possible it should be double rebated on the bottom edge, fitting the sill.

French casements are tall windows also acting as a door or a pair of doors; being 6 feet 6 inches or 7 feet in height they should be of stronger material. The ordinary sash is out of 2″ × 2″ stuff, but the French casement sashes should be got out of 2½″ × 2½″ with a bottom rail of 9″ or 7″ in

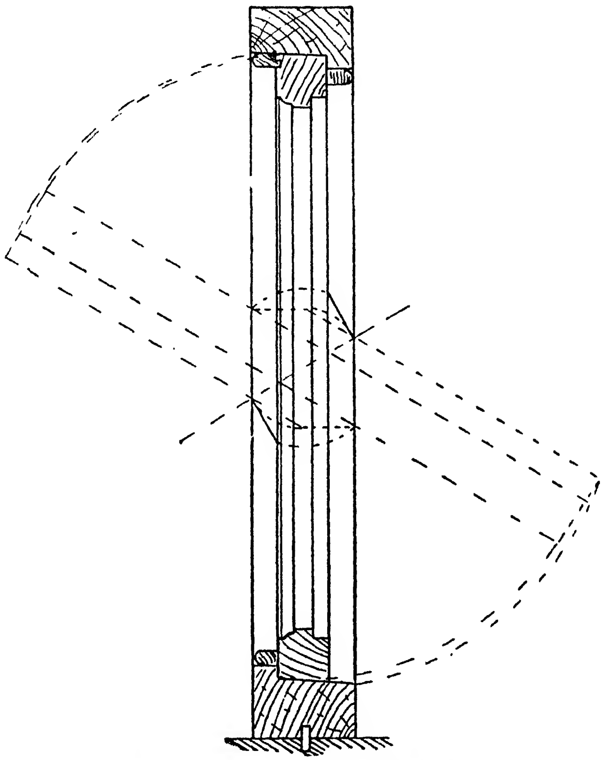


Fig. 95.—Detail of Centre Hung Sash.

width; a special 'hook joint' is made at the meeting stiles, as shown in Fig. 97.

The student may have had to deal with metal windows in wooden surrounds.

The call of modern requirements endeavours to combine efficiency with comfort and a pleasantness of appearance.

A wood surround makes for a harmonious finish between metal and masonry in a window opening. Each member of

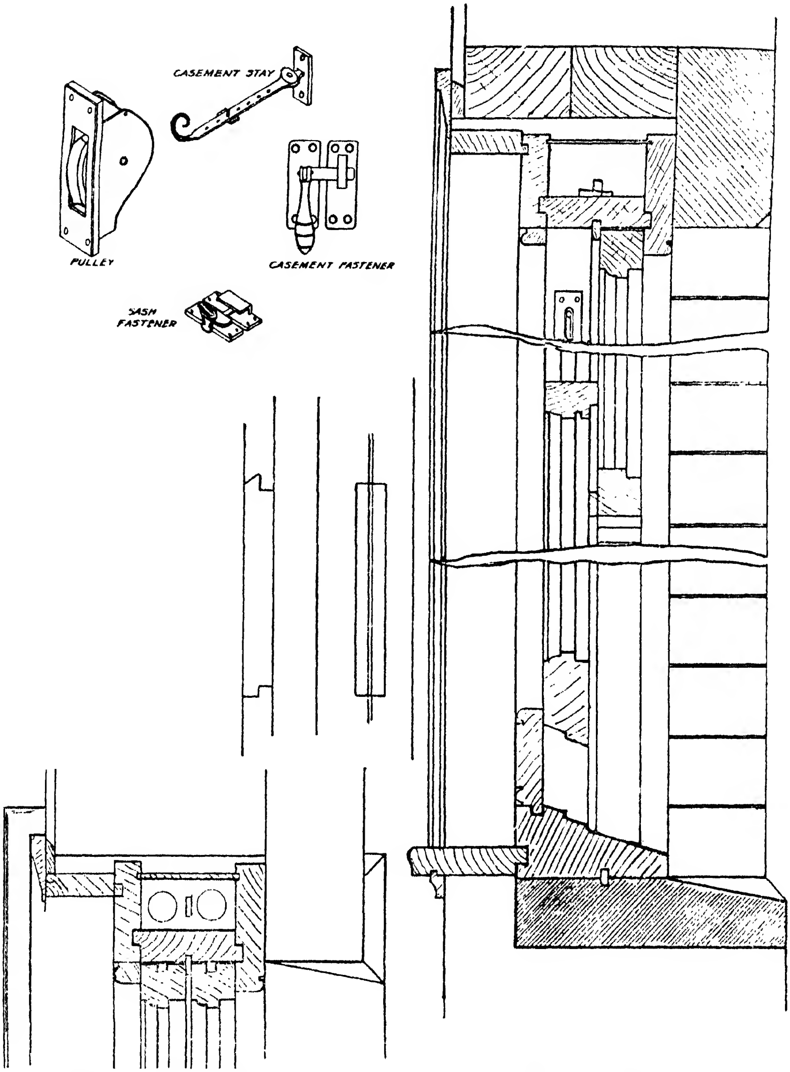


Fig. 96.—Horizontal and Vertical Sections of Boxed Sashes and Frame showing Ironmongery.

the surround is treated in exactly the same manner as the other window parts for grooves for plaster, water bars, &c. They, however, have the advantage of a double check in the rebate which receives the metal window where it is bedded into its position with a mastic cement and screwed.

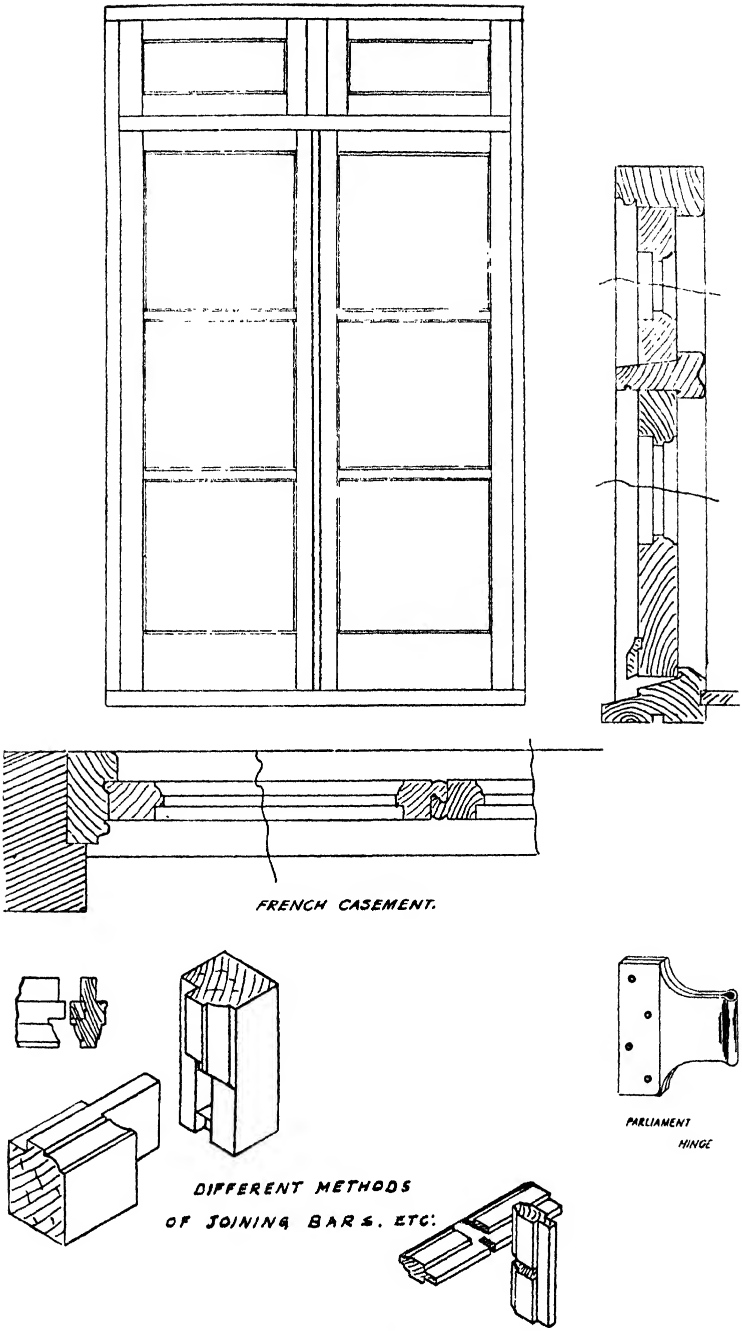

FRENCH CASEMENT.
DIFFERENT METHODS
OF JOINING BARS. ETC.
PARLIAMENT
HINGE

Fig. 97.

Figs. 98 to 102 show sections of parts. The chief advantage of this type of window is the ability to obtain in standard sizes windows of differing kinds to suit varying needs. Natural ventilation, that is from the open window, has

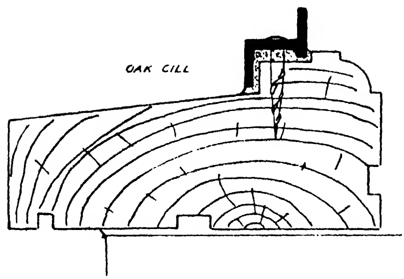


Fig. 98.

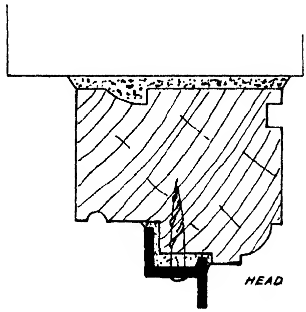


Fig. 99.

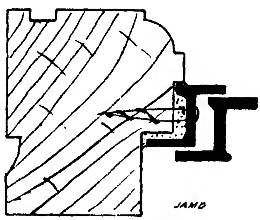


Fig. 100.

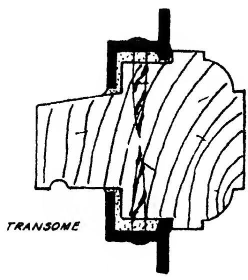


Fig. 101.

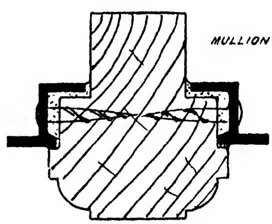


Fig. 102.

been proved to be the most satisfactory provided that the openings are properly regulated so as to avoid strong direct draughts and that there is sufficient heating in the room to enable it to have a comfortable temperature. Adequate cross ventilation can be had by arranging the 'hopper' windows on opposite sides of the room at a low level; this method is commonly adopted now in hospitals. All types of windows, whether wood or iron, can be hung on Parliament hinges; the reason is twofold: they have been called shutter hinges to enable shutters to fold close to the brickwork in the reveal and on opening to enable the shutter to fold back to the outside wall.

Another claim for the Parliament hinge is that when opened one's arm can be passed through the space caused by the wide opening of the hinge, enabling the outside of the window to be cleaned from the inside.

The writer is indebted to the Crittal Manufacturing Company, Limited, for much assistance referring to metal windows and wood surrounds.

QUESTIONS ON CHAPTER XIII

1. What precaution should be taken to prevent the penetration of rain in the joints between the frame and the sash?
2. Why is the sill bevelled?
3. How do you regulate the weights in boxed frames?
4. Where are sizes taken from in measuring for window-frames?
5. What is the best preservative to use on windows?
6. What is the advantage of a Parliament hinge?

CHAPTER XIV

DOORS AND FRAMES

In approaching the subject of doors it will be necessary to first of all deal with the frame to which the door is hung and endeavour to get a thorough understanding of making, fixing, and adopting the style of frame.

An interior door would possibly be hung to jamb linings as the most suitable frame for that particular door, but an external door would require a solid frame partly because it has to stand the weather and partly that being external the door may be of heavier make and thus require a stronger frame.

External doors are therefore usually hung in a solid frame, i.e. a frame built into reveals in the brickwork and made out of $4\frac{1}{2}'' \times 3''$ stuff; a solid rebate is cut out of the material on the inner side and some method of finishing the outer corner is adopted by making a round, chamfer, ovolo mould, &c. The size of the rebate is made to the thickness of the door and about $\frac{1}{2}$ inch in depth.

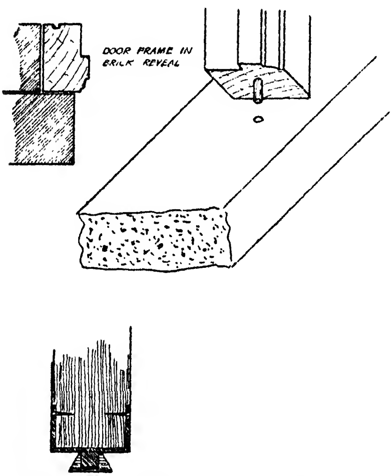


Fig. 103.—Sketch of Door Jamb in Iron Shoe.

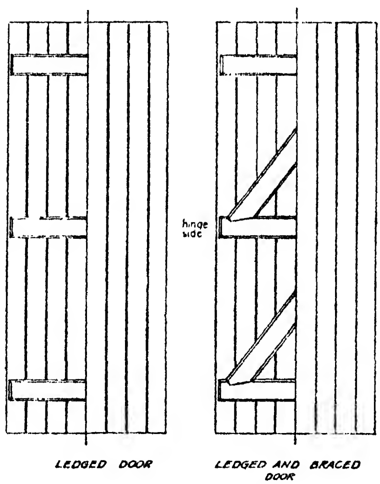
When built into reveals the frame projects from the face of the brickwork, which gives the size of the opening, or 'sight size' as it is commonly termed.

Unlike doors, frames are mortised into the head and tenoned into the stile, the head projects beyond the outside of the stiles to give a 'horn' to build into the brickwork. The inside of the 'jamb' should be grooved to receive the jamb lining or plaster as the case may be. A complete section is shown in Fig. 103. The foot of the jamb is secured by dowels let into the stone or concrete step and grouted in cement, the remaining portion having been previously driven into the end of the jamb.

Doors are divided into the following headings:

Ledged doors.
Ledged and braced doors.
Framed, edged and braced doors.
Panelled doors.
Solid doors.

The most common kind of door to be met with nowadays is the Ledged door, which is made up of a number of beaded or V-jointed lengths of match-boards to the required width and nailed to battens or ledges on the back of the door. These are out of 4″ or 6″ × 1½″ in thickness (Fig. 104). An improvement on the last is the Ledged and Braced door; an inspection of Fig. 105 will show how the introduction of braces will prevent the door from sagging. It should be remembered that the lower end of the brace should be pointing towards the hinge to enable the brace to fulfil its function.



Figs. 104 and 105.

The Framed, Ledged and Braced door has a mortised and tenoned frame; braced as before and inset are the matchboards; the additional framing adds strength to the door (Fig. 106). The top rail or head is grooved to receive the end of the boards; the stiles are sometimes grooved similarly. The middle and bottom rails are thinner than the stiles by the thickness of the matchboarding and have bare-faced tenons in consequence (see Fig. 107). The general idea one connects with the term door is a framing with panels inset and moulded edges running round each panel. This is the panelled door, the patterns being many and varied. The ordinary four-panelled door is seen in Fig. 108, but the modern tendency is to use a high-waisted door as in Fig. 109, which is still a four-panelled door, but the arrangement of the panels is different. In Fig. 108 the position of the lock or middle rail is controlled by the height of the lock being a convenient height from the floor, and is usually taken as the keyhole, being 2 feet 8 inches from the floor or 3 feet to the top edge of the rail.

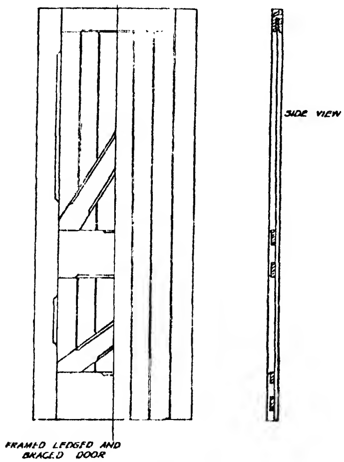


Fig. 106.

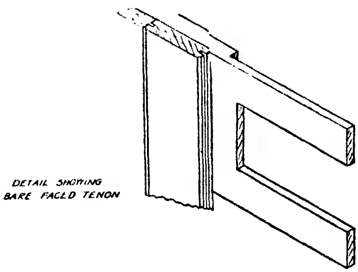


Fig. 10'.

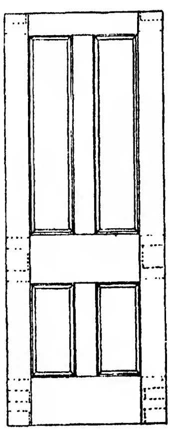


Fig. 108.—
4-Panelled Door.

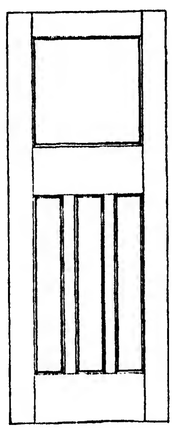


Fig. 109.—
4-Panelled Door.

The stiles and head are $4\frac{1}{2}$ inches in width fc standard sizes of doors, the muntins, i.e. the uprights in ie centre, are 4 inches in width, or whatever the width othe stiles the muntins should be $\frac{1}{2}$ inch narrower, the reasn being, when the door is closed the stiles are recessed intohe rebate of the frame which is ½ inch, and therefore when seen from the outside the stiles and muntins will appear to be the same width.

This type of door is dependent on the mortise and tenon joint and an isometric sketch of the joint appears in Fig. 110. It is important to remember that in setting out all work where panels are introduced the tenon is usually taken from the bottom of the groove which receives the panel; therefore, taking the case of a lock rail, the tenons are standing in from the upper and lower edges by ½ inch on each edge.

Haunched tenons are used in this instance. Where a door stile is cut off level with the top or bottom edge the

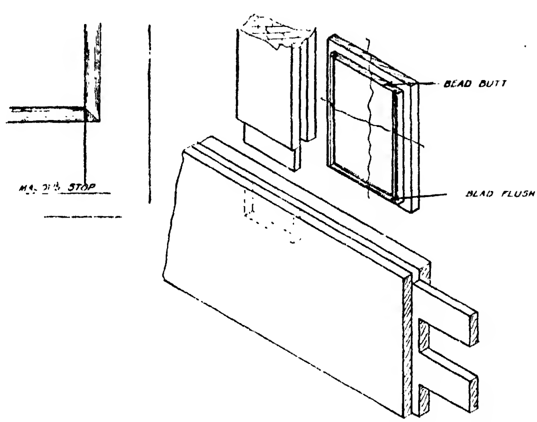


Fig. 110.—Sketch showing Position of Groove for Panel and Haunching in Tenons.

tenon would have no resistance to wedging if allowed to continue. It is usual in this case to set back the tenon and allow a 'haunch' of solid wood which enables the joint to be tightly wedged (Fig. 110). Stiles, rails, &c., must be grooved to receive panels. There are different kinds of panels. The ordinary interior door has a sunken panel, which in order to break the monotonous appearance has a mould inset. This is pinned into the sunk portion or is sometimes moulded or chamfered on the solid. When the mould is 'stuck' on the solid, a mason's stop is sometimes introduced at the mitre to save the process of 'scribing', but to get a proper intersection of the members in wooden mouldings a mitred or scribed joint is preferable. If it is desired to raise the moulding beyond the surface of the door a Bolection mould is required, details of which appear later.

Flush Panels. Sometimes, as in the case of back doors, a thicker panel is used, which is finished 'flush' with the outside but sunk on the inside. This is accomplished in two ways. It is usual to break a flat joint by a bead, so a bead butt panel may be used which finishes butt up to the rails at their ends as in Fig. 110, or the bead may run round the panel on all four sides, giving a bead flush panel. It is customary in preparing doors and such-like fittings to commence making as soon as the foundations of the job have been started, and fitted together loosely and allowed to lie in the shop carefully stacked to ensure all the shrinking taking place that possibly can. When ready for delivery they are finally wedged up with glued joints for internal work and painted joints for external work, and cleaned off ready for priming by the painter or receiving any special treatment required.

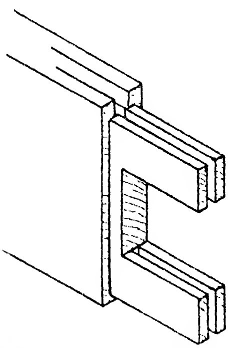


Fig. 111.—Double Tenon.

If it is required to fit mortise locks in the lock rail the side requiring the lock—sometimes both sides have double tenons fitted as seen in Fig. 111.

Doors in partitions such as office doors or even front entrance doors to dwellings are sometimes glazed, and in order to increase the area of glass and therefore reflect more light in the upper portion, the stiles are reduced in width, making what is known as a diminished, or gun-stock stile. This is shown in Fig. 112.

Sliding, folding and double-margin or storm doors are dealt with in advanced works.

The hinges screwed to the doors are principally of two kinds, 'strap' and 'butt'. The Strap or Cross Garnett type is used for ledged doors and screws to the face of the door and frame, whilst the butt hinge is sunk into the edge of the door on one side and the rebate of the frame on the other. In all cases the pivot of the hinge is made to 'line up' with the joint, and if the plates are sunk just flush, the distance between the plates will give the required space or 'play' as it is termed. In fitting the doors the carpenter should 'shoot' one edge of the door with the trying plane and place the door in its approved position in the frame. Probably it will be too wide and too high, so if the 'shot' edge is fitted against the rebate the pencil can be run down the other edge along the opposite rebate and the door is then planed off accordingly.

The joint between the door and the frame should not be

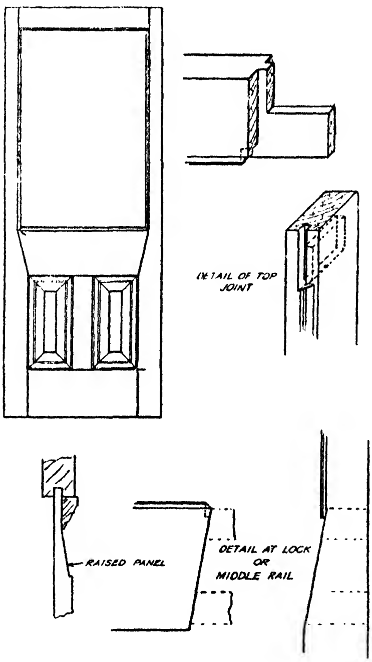


Fig. 112.

too great. A good guide as to thickness of joint is a penny-piece being able just to be pushed into the gap. The same thickness of joint is given to the head, but about $\frac{1}{4}$ inch off the floor, although the type of floor covering will decide the 'play'. Sometimes where a thick carpet is to be laid the clearance can be improved by using what are known as rising butts; these will raise the door off the floor as it is opened (see Fig. 113). Doors should always be hung so that the room is screened as the door opens.

When fixing locks, the student should realize that right- and left-handed locks are needed, and difficulty is sometimes met by the uninitiated in determining the correct

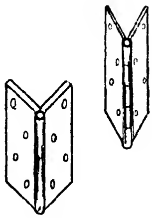


Fig. 113.

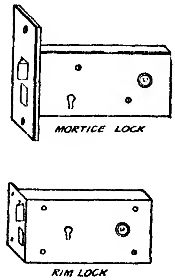


Fig. 114.

hand. Stand on the outside of the door, and whichever way the lock has to be turned to make it operate, so the lock is of that hand.

Mortise locks form the best lock for panelled doors, but

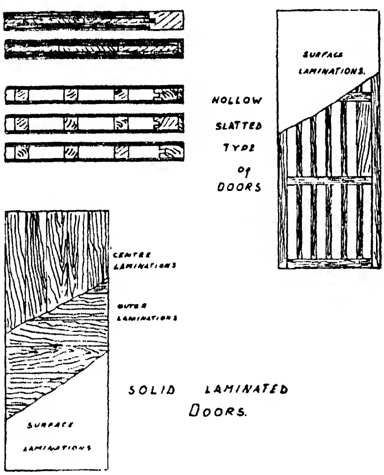


Fig. 115.

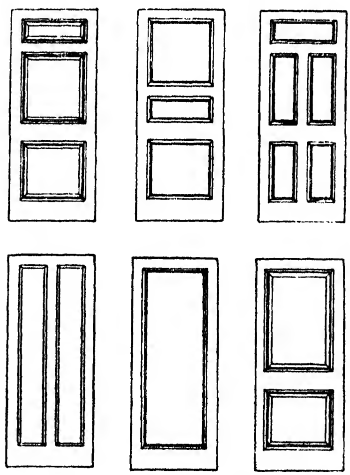


Fig. 116.—Designs of Panelled Doors.

these require a deep mortise being 'worked' in the stile, and to obviate this rim locks are sometimes used; these screw on the face of the door (Fig. 114).

If a fitting is secured to a door and fastens it without the aid of a key but has a sliding catch it is called a rim latch.

There are accepted sizes for doors.

Front entrance doors are from 7 feet in height and 3 feet in width down to 6′ 8″ × 2′ 8″. Internal doors are from 6′ 8″ × 2′ 8″ to 6′ 3″ × 2′ 3″, the customary size for a room door usually being 6′ 6″ × 2′ 6″. The most common kind of door for outside use, such as outhouses or garage doors, is the ledged door. Various styles of doors are shown in Figs. 115 and 116.

QUESTIONS ON CHAPTER XIV

1. What are the standard sizes of doors?
2. Where would you place the hinges in a ledged and braced door?
3. Draw to a large scale the lock rail in a panelled door.
4. How would you ensure the maximum of light in a glazed door?
5. Draw in isometric a bead butt panel and show its position and jointing in relation to the frame.
6. Draw the section of a door stile with raised panel and Bolection mould.
7. What wood should be used in dividing off parts of a warehouse by sliding doors?

CHAPTER XV

MOULDINGS

A KNOWLEDGE of the Principles of Ornament has been found by experienced craftsmen to be extremely useful in breaking up flat or bare surfaces to be pleasing to the eye and applying in correct form the proper mould—to state a simple case—in 'returning' a corner, &c. The present age being strictly utilitarian, many of the older forms of mouldings have disappeared because they are too ornate, have too many members to hold dust, and are over-fanciful. Compare the modern building with those of the Victorian era and you see straight lines broken with a 'fillet', a 'chamfer' or sometimes a 'motif', whereas we used to get fancy cornices overhanging mouldings, in fact everything overdone. It is still, however, necessary to adhere in principle to the main types of mouldings which may be divided into three classes:

(1) Classic.
(2) Gothic.
(3) Modern.

1. Classic mouldings are handed down to us from the Greeks and Romans. The Listle or Fillet (Fig. 117) is used

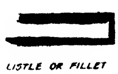


Fig. 117.

Fig. 118.

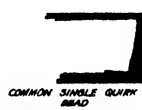


Fig. 119.

for separating members. It will be seen this is hardly a moulding, but is part of a classic entablature. The Astragal or Cock Bead (Fig. 118) is again a dividing member.

The Common or single Quirk Bead (Fig. 119) is a very useful mould to the joiner where two members are in close proximity, such as a drawer front sliding in its frame or a door fitting into its rebate the junction is broken by a quirk bead. If the mould is required on an external corner a Return

Bead, or bead with double quirk, is used. Its section is three-quarters of a circle (Fig. 120).

The Double Quirk or Sunk Bead (Fig. 121) is used to break wide surfaces.

Reeds or Reeding are a series of quirkless beads (Fig. 122).

The Torus is a large bead; in ancient work was used without a quirk (Fig. 123), but in modern work the quirk is brought into use. The following is a comparison of Roman and Grecian mouldings:

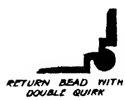


Fig. 120.

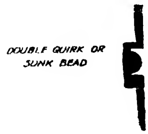


Fig. 121.

Fig. 122.

Fig. 123.

Ogee or Cyma Recta (Fig. 124). The Roman mouldings are parts of circles, the Greek are portions of ellipses or other conic sections.

Fig. 124.

Reversed Ogee or Cyma Reversa (Fig. 125).

The **Hollow** or **Cavetto** is much in use, the Roman being a quadrant of a circle, but the Grecian outline is much more refined (Fig. 126).

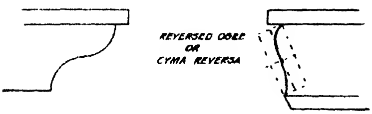


Fig. 125.

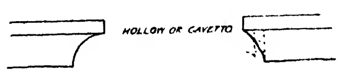


Fig. 126.

The **Ovolo** or **Round** is perhaps the commonest of all our mouldings. It is used in windows, doors, framing, etc. (Fig. 127).

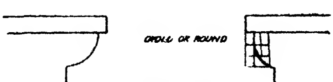


Fig. 127.

The **Roman Scotia or Trochilus** (Fig. 128) is described as follows:

Bisect the height *AB* in *E* and draw *EF* at right angles cutting the continuation of *C*. Divide *BC* into three equal parts—make *GE* equal to one part and *FH* equal to two of these. Taking *H* as centre and *H—c* as radius, describe

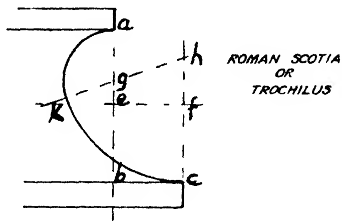


Fig. 128.

a quarter of a circle to *K*, which is found by drawing a line through *G—H*. From *G* as centre and *G—K* as radius describe an arc completing the curve.

Figs. 129 to 132 show respectively: Sash Ovolo, Sash Ogee

Fig. 129.

Fig. 130.

Fig. 131.

Fig. 132.

and Astragal, Sash Ogee, and Lamb's Tongue used in glazed fittings.

2. Gothic mouldings in woodwork are really based on similar mouldings in stone, principally the

Edge Roll or Round Bowtell,
Roll and Fillet,
Ogee, &c.

Figs. 133 to 135 show respectively these mouldings in the order named.

The Bolection mould came into being during the time of Wren and Inigo Jones; unlike the sunk panel moulding in Fig. 136 the Bolection mould in Fig. 137 is raised above the face of the work.

Different kinds of architraves are shown in Fig. 138. The wide skirting is 'built up' as shown; it reduces shrinkage and is not liable to split or fly in the fixing.

It would be interesting at this point for the student to consider the enlargement or reduction of mouldings. Take, for example, a portion of a cornice frieze and architrave.

Fig. 133.

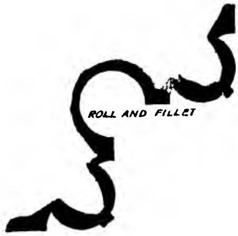


Fig. 134.

Fig. 135.

Draw line *A—B* and project the various members of the moulding upon it. Also describe the equilateral triangle

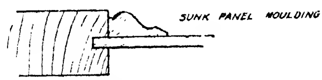


Fig. 136.

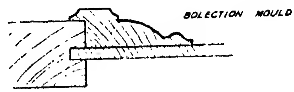


Fig. 137.

ABC on base line *AB*. Draw lines from the points of intersection of the various members with the base to the apex *C*.

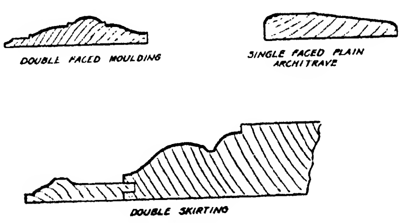


Fig. 138.

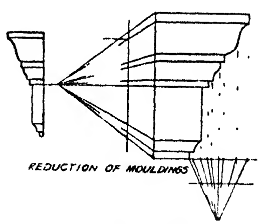
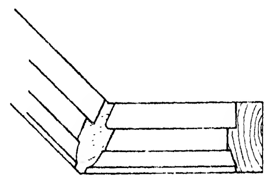


Fig. 139.

Set off the required distance to reduce the drawing and the points will be arrived at. See Fig. 139.

Raking Mouldings. If the student has had practical experience he will have no difficulty in seeing how members of a moulding, when set at a different line of inclination, will alter their shape, as in the sketch showing a Raking Moulding (Fig. 140). The centre mould can be taken as a barge board running along the verge of a roof, whilst the left-hand mould is the soffit mould running along the eaves, and the right-hand mould is the opposite, being at the ridge, if it were possible to return the mould to that position. The important thing to remember in these mouldings is that at the intersection the mitre must be vertical, and that one moulding is in the inclined plane whilst the other is in the horizontal plane. Divide the profile of the moulding into a number of parts and from these points draw lines parallel with the edge of the raking mould; also from the same points draw vertical projectors to any horizontal line clear of the moulding. Lay off these dimensions upon the back of the raking mould and draw projectors from these perpendiculars to the pitch



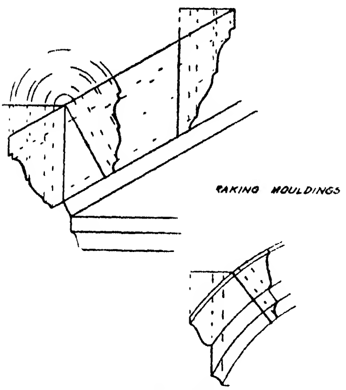


Fig. 140.

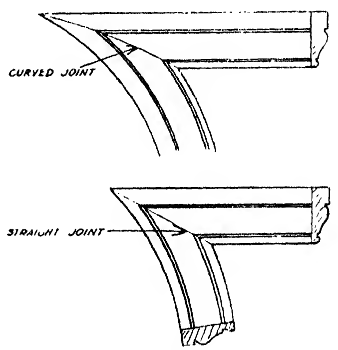


Fig. 141.

intersecting the raking lines from the correspondingly numbered points on the profile. At the upper end is shown the section of a level mould that would be required to make an upright mitre at that end.

The intersection of straight and curved mouldings is next shown. To mitre two mouldings of one section, one straight, the other curved, to fit in a circular panel, draw lines from the points of the curve in the section and the points of intersection will be a curve.

When a straight mitre is required the two mouldings must be of different sections. Assuming the straight moulding to be the given section, draw ordinates and take a straight line through the intersection of the extreme ordinates; the concentric curves from the points of intersection will give the required section (Fig. 141).

Ionic Volutes. These are frequently employed in the ornamentations for the heads of capitals, handrails, &c. The formation of volutes dates back to ancient ancestry, probably their institution originating from the periwinkle fish shell. Goldman's method, shown in Fig. 142, is the best to be relied upon, the construction being as follows:

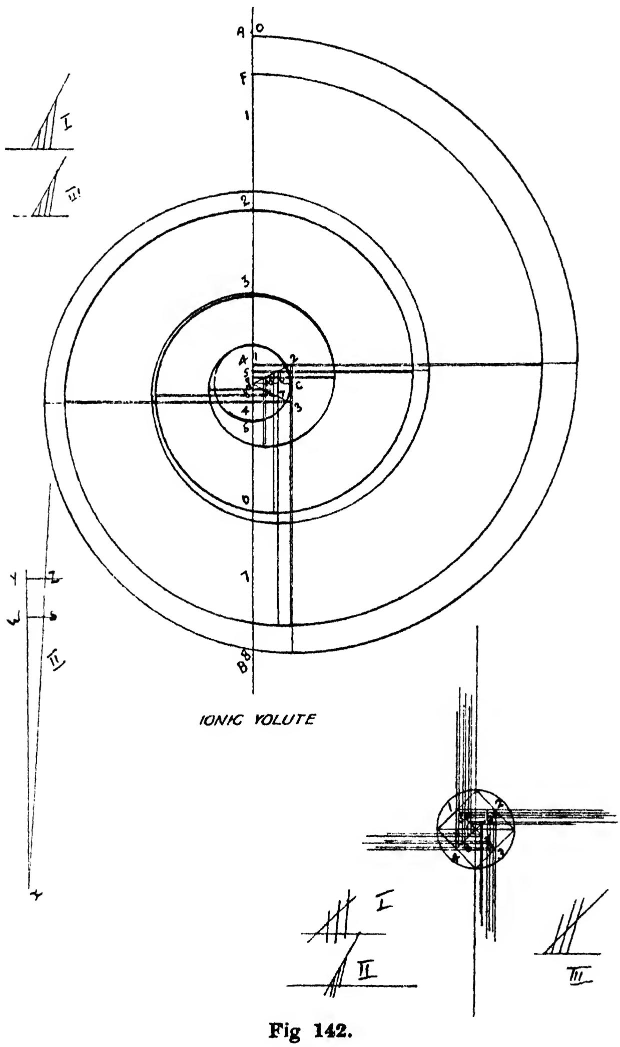


Fig 142.

The line *A—B* is divided into eight equal parts. Division 0—1 is bisected in order to form the fillet. F (or minor circle of the Volute Division 4—5) is the 'eye' of the volute and forms the diameter of the circle. Divide 4—5 into four equal parts. From *A—B* draw lines and a tangent through *C* at right angles, giving points 2 and 3. From these draw diagonals to centre *X*. Divide 1—*X* into three equal parts as in scale I, and follow lines round these points, giving centres of the outer circle of the volute and are numbered 1—12. To determine the centres for the inner circle or 'fillet' refer to scale II. *X—Y* equals the length of the divisions 0—4. *Y—Z* is the distance of 1—*X*. *W—Y* is the distance of the fillet or half 0—1. *W—S* is transferred to the 'eye' and then divided into three equal parts. Follow the line round as before; this gives the centres for the inner circle or fillet.

Second Method is to again divide the base into eight equal parts and describe the eye in 4—5 and then a square inside the square; draw diagonals and from the centre to corner divide into three equal parts, continuing the lines round. Divide one of the three parts into three and step off 1/3rd into three, again continuing round as before, and all the centres are determined.

QUESTIONS ON CHAPTER XV

1. What principle is adopted in forming Roman and Grecian mouldings?

2. From the 'orders' of mouldings draw the following: Bolection mould, sunk mould, sash bar mould, an angle mould for a lift enclosure, a series of moulds for a cornice.

CHAPTER XVI

SOUND INSULATION

THE present-day carpenter and joiner is frequently called upon to erect or lay sheets of one of the many brands of wall boarding. This convenient method of covering surfaces has grown by rapid strides during recent years and is capable of very artistic finishing, quick in erection, light in weight, and cheap to purchase in comparison to many other commodities.

Perhaps its principal claim is insulation against sound penetration. Most building materials are good transmitters of sound and when sound has entered a building it often reverberates through the building.

The study of acoustics to-day is linked up with the building trades more than ever. The cinema, church and public building has each its acoustical problem to solve, and compo or fibre board is often the cure. Sound waves travel at the rate of approximately 1,100 feet per second and, unless trapped, spread outwards in all directions.

A building used for speech may not be suitable for music and vice versa, but to-day we are able to arrange for both to be properly and comfortably heard. Apart from these, sound is transmitted from outside into our homes. The noise generated by machinery in the factory can be intolerable in the adjacent office, but technical research has done much to eliminate this. Fibre board is made from wood pulp, often spruce fibre. It is tough, strong, free from laminations and light in weight, does not contain impurities or defects, such as sap, resin or knots; it can also be made fire-resisting. Laid under roof tiles it protects from summer heat and winter cold, and for external work can be rough cast. Internally it can be treated as plaster work in papering, distempering, plastic work, painting, &c. Laid under floors as shown in sketches it is sound-resisting, and in the case of partition walls is highly eminent in resisting noises from an adjacent room.

Fibre board is also used as an insulation against heat,

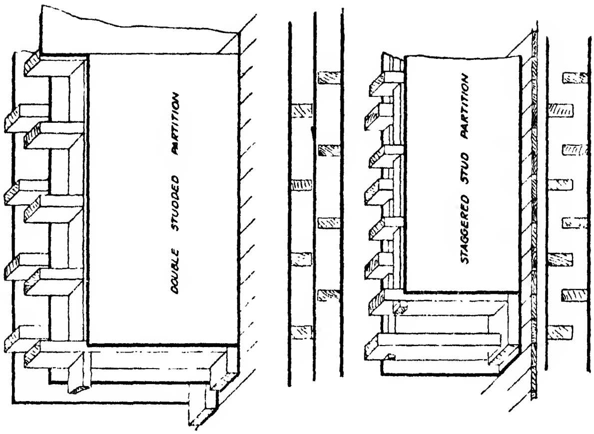


Fig. 143.—Showing Insulation in Walls.

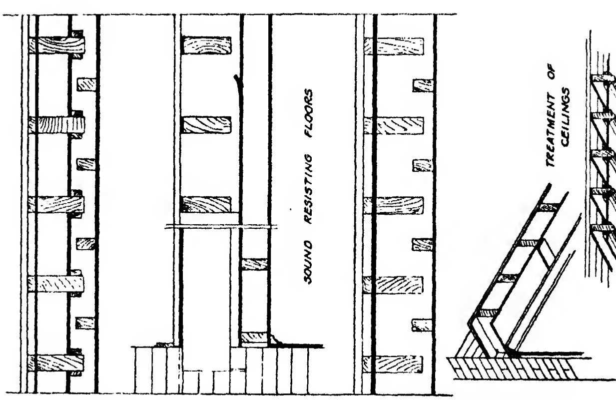


Fig. 144.—Showing Insulation in Floors and Ceilings.

a preventive of condensation, and is supposed to ensure against insect attack.

It is advisable to open all bundles 48 hours before use and stack the sheets loosely on edge.

All timbers in the framing must be brought to even planes and regular lines, and cross nogging pieces must be placed to receive all end joints. Timbers must be fixed to conform

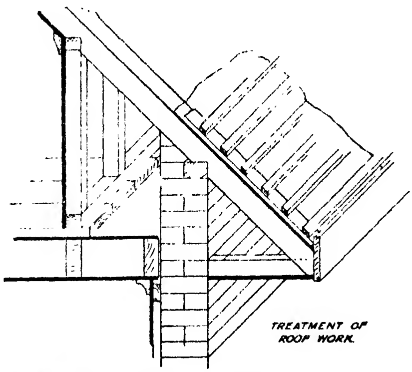


Fig. 145.—Showing Insulation in Roofs.

to the size of sheets of fibre board in use, usually 3 feet or 4 feet in width and from 8 feet to 15 feet in length.

The sketches given under each heading show the methods of resisting sound in floors and partitions, and also how to finish the surface of the walls and ceilings (see Figs. 143 to 145).

The writer is indebted to Messrs. The Tentest Fibre Board Company, of Astor House, Aldwych, for much valuable information and advice.

CHAPTER XVII

STAIRS AND STAIR BUILDING

The study of stair building is undoubtedly one of the most interesting that the joiner can take up. Coupled with handrailing it forms probably the highest grade of craftsmanship the joiner can achieve, and although there has always been an element of mystery surrounding the 'wreathed' handrail and stair string there is really nothing outstanding in the work if the student has studied the geometrical principles which form the basis of the work. The best conditions, the highest pay and the sense of superiority which this craftsman commands is sufficient testimony to his ability. We do not touch 'wreathed' work in this volume, but our purpose is to ground the student in the laying out of ordinary stairs, to give him the correct viewpoint as to suitable 'Rise' and 'Go', construction of straight work, &c. This will form a sound foundation for a further study of this interesting subject, as an advanced study is useless without a mastery of the rudiments.

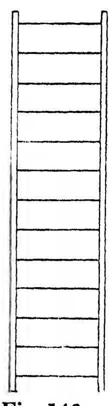


Fig. 146.—Straight Flight.

The function of a stair is to ascend or descend from one floor to another, and in modern times stairs are made not only in wood but other materials such as steel and concrete. All stairs are alike in principle but differ in their lay-out. Where it is possible to ascend to an upper floor in one continuous or unbroken flight—which should not be more than 12 steps, although it is often imperative to introduce more to get the height required—we get a straight flight. These are the simplest kinds of stairs, but are often tedious and tiring where there is a considerable height between the floors (Fig. 146).

In order to gain the necessary height we sometimes turn the direction of the stair by introducing winders which should, whenever possible, be placed at the foot of a flight. It has been the practice in class work to impress upon students the necessity of making stairs safe for everybody;

for instance, awkwardly placed winders might be fatal to a blind person, or badly proportioned steps may cause suffering to an invalid. Our readers will understand the logic of this and perhaps recall the feelings of insecurity in climbing a stair that is steep and narrow and, conversely, shallow and wide. There must therefore be a limit between these two extremes, and that limit gives safety and comfort. The average person takes a step of approximately 23 inches, so that whether walking on the level, climbing or descending, the average requires to be maintained as far as possible.

It has been computed that double the energy is required in climbing to walking on the level, therefore by expending the same energy in climbing we only ascend half the distance. This gives us a formula which can be used in all staircase work which is Twice Rise + Tread = 23. Many joiners work only on this rule, and if they can get what is called the pitch in this ratio, having a tread in the neighbourhood of 11 or 9 inches and a rise of 6 or 7 inches respectively, a safe and comfortable stair is assured.

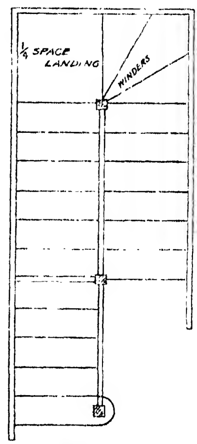


Fig. 147.—Dog Legged Stair.

Another useful rule is to multiply the rise by the tread to equal as nearly as possible 66. Thus an 11-inch tread and 6-inch rise will equal 66, but a 9-inch tread and 7-inch rise, which is a common pitch, only gives 63, but is a near approach.

The dog-legged stairs shown in Fig. 147 forms the first change from the straight flight when these are found to be unsuitable. In reality it is two straight flights running in opposite directions, being united half-way up by a landing and winders, or a landing only.

In the former a quarter-space landing would be required, and in the latter a half-space landing which stretches across the width of both flights of stairs. Fig. 147 shows a dog-legged stair with winders.

The next stair to be considered is the open Newel stair (Fig. 148) and is at once the most useful, the most pleasing and therefore the most satisfactory kind of stair with which we come in contact. This kind of stair is fitted into a well-hole, sometimes very spacious, and has three flights of stairs running around its three sides, or it may have only two flights with an intervening space taken up by a landing. The other types of stairs are the Geometrical stair and the Circular stair, but it is not proposed to deal with these in this book.

The method of jointing up the treads and risers is shown

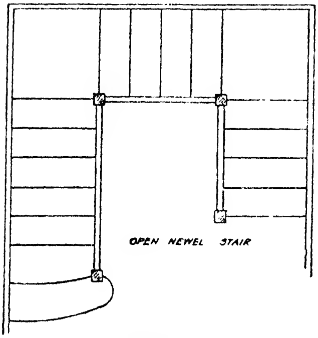


Fig. 148.

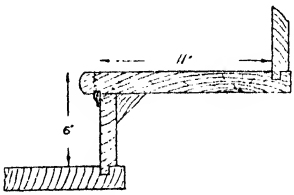


Fig. 149.—Detail showing 'Jointing' of Treads and Risers.

in the diagrams and explain themselves (Fig. 149). The risers are usually got out of 1-inch material and the treads out of 1¼-inch or 1½-inch stuff, the outer edge of the tread being rounded off or bullnosed.

The fliers, that is the straight parallel steps, are 'housed' into the strings; these are the side supports that run from

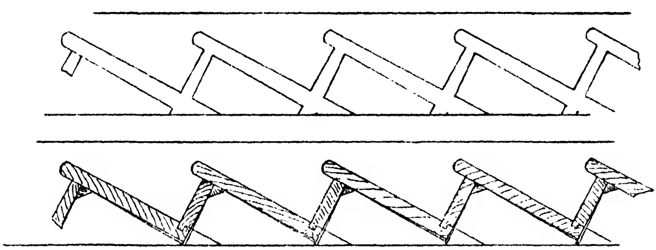


Fig. 150.—Showing 'marking out' and 'cutting' in Strings.

floor to floor or floor to landing and are about 1½ inches or 2 inches in thickness and 10 or 11 inches in width.

The 'housings' in the strings are cut tapered to enable the treads and risers to be wedged into position. These should never be nailed from the outside, as the subsequent shrinkage will allow a certain amount of movement, and the consequence is the stairs creak when walked upon (Fig. 150).

The centre of the stair, which is not less than 3 feet in width, is supported on rough carriages, with brackets nailed

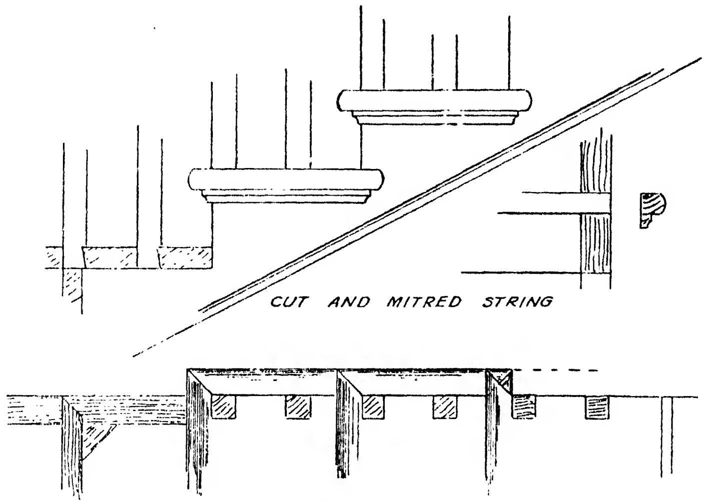


Fig. 151.

to them, running from top to bottom. In ordinary stairs 'close' strings are used. The 'wall string' is always a close

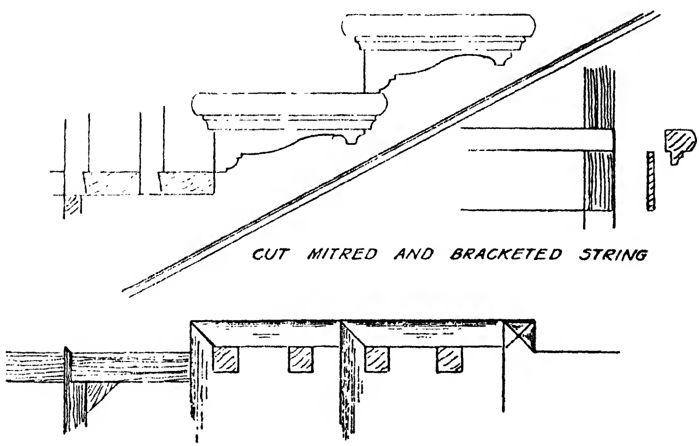


Fig. 152.

string, but the outer string may be treated in different ways. Figs. 151 and 152 show cut strings which give a stepped outline and may be treated as cut and mitred strings, or cut, mitred and bracketed strings. The riser is mitred to the string, and the moulded edge, although sometimes returned on the end in the solid, is better done by returning a loose mould slot screwed to the tread.

The shaped brackets are about $\frac{3}{8}$ inch in thickness and are mitred to the end of the riser, which projects beyond the string the same amount as the thickness of the bracket. The return 'nosing' must also be long enough to form a seating for the heel of the bracket. Blocks glued into position support these parts on the under side.

The outer strings in all stairs have a handrail with balusters fixed to the underneath side, and to the string. In the case of the close string it is usual to fit a capping piece over the string to secure the balusters which in the open strings are sunk into the treads as shown, sometimes dovetailed into the end. The ends of the handrails are tenoned into a newel post at the top and bottom of each flight, except in the Geometrical or Continuous type of stair; also the handrail at the foot of a straight flight may terminate on to the top of a newel by a quarter-turn wreath and a scroll.

Scrolls. There are several methods of setting out a scroll, and the type adopted governs the size of the curtail step below, as the sweep of the curve in the step must, of course, follow that of the handrail. The first two are examples of

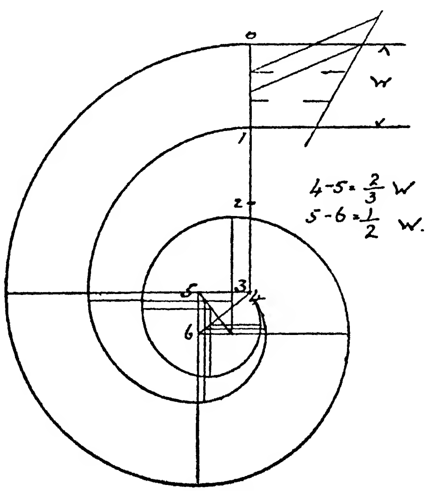
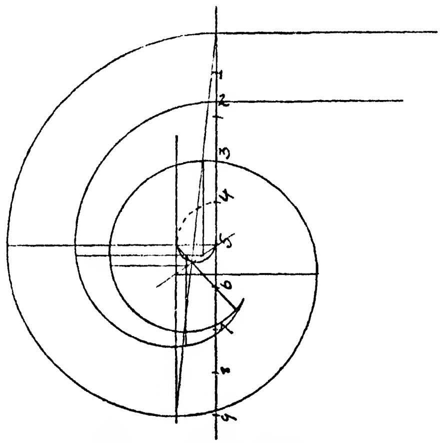


Fig. 158.

the most commonly used scrolls, whilst the third gives a larger 'eye' in the centre, affording better accommodation for the seating of a lamp standard, &c.

Sometimes a 'boss' or 'patera' is worked in the eye of the scroll. The most suitable section is one having a flat top as this will work off into a disc or circle in the eye, but in any case the moulding must be symmetrical. Figs. 153 and 154 are shown in construction and are explanatory in themselves, whilst the third scroll in Fig. 155 is detailed below and is confined to a given width, which is also the case in Fig. 154, whereas the first is not controlled for width.



SCROLLS FOR HANDRAILS

Fig. 154.

Draw the straight rail up to the springing; the position of the springing is a matter of arrangement which can only be determined in each particular case in hand.

Draw the springing line at right angles to the rail and mark the width of the rail upon it; divide this into 11 equal parts. With 6 as centre and radius 6—0 describe a quadrant to *A*. From *A* set off point *a* equal to 5 divisions, this is the centre for the second quadrant having *A*—*a* as radius. It is now necessary to find proportional radii for the remaining quadrants. Set up a^1—C^1 parallel and equal to 0—6 and set off from C^1 to *d* the second radius equal to *A*—*a*. Next draw C^1—*b* making an angle with a^1—C^1. With C^1 as centre describe the arc *d*—*e* and join a^1—*e*. Draw *d*—*g* parallel with a^1—e and describe an arc from g cutting a^1—e^1 in f. From this point draw another parallel, and so on as required. f—C^1 set off from B gives the third centre b^1,

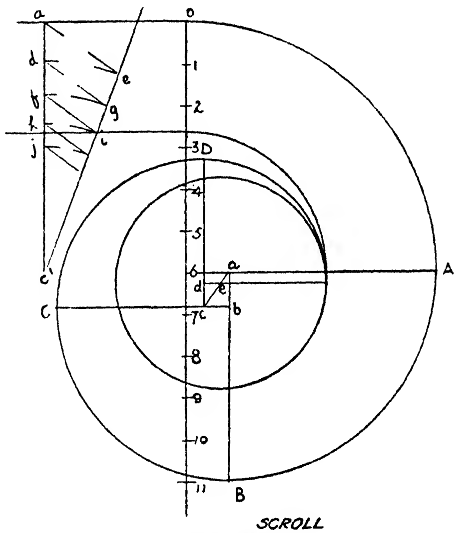


Fig. 155.

and C^1 set off from C gives the fourth centre, and so on in like manner. The centre of the eye is found at e by drawing the diagonal a—c.

The Monkey Tail or Vertical scroll in Fig. 156 is used for

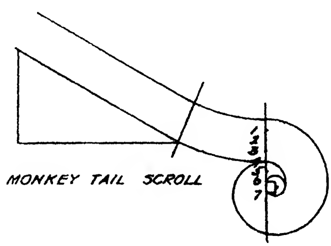


Fig. 156.

rails that are fixed to the wall, and do not terminate on a newel. Draw the rail as shown, and the easing of the shank is again a matter of arrangement. On the springing line divide the rail into 4 equal parts, setting off 3 more of these. Form a square on 6—7 and the 4 corners of this square give the centres for the 4 quadrants of the curve, starting at 6 and finishing at 7. When the curves reach the springing line, they must be finished freehand into the eye, which is of a radius equal to one side of the square and its centre in the middle of the outside.

Another form of Curtail step is shown in Fig. 157.

When newel posts are used, the string must also be tenoned into them as shown in Fig. 158. But they cannot always be attached to the string in the shop. It is customary to fit the parts together and dissemble for transport purposes, and finally fix them together on the job.

The following notes deal exclusively with the setting out and making of a flight of stairs. A simple example of a straight flight is taken, having a newel post attached to the top and bottom of the flight. Measurements must first

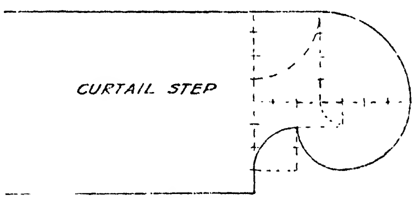


Fig. 157.

be carefully taken on the job itself. The staircase hand is sent to the job and he takes off his own sizes. Do not rely on loose scraps of paper, they get lost; use a notebook and make a rough sketch of the position of the walls, the height of the floor or landing, and leave nothing to chance. Having seen the job you have it in your mind, but other men will be working from your measurements and notes, therefore extreme caution must be taken.

The architect's drawing will give you the design of the stair, but not the required sizes. The measurements may have to be taken from the bare brickwork, or the finished plaster. Check all the corners for 'square'. Measure carefully the height from floor to floor and the space allotted for the 'Going'. Having ascertained these details, it is now possible to 'set out' the work in the shop. Proceed to check up the specification for materials to be used and make a story rod. The upper floor has a 'nosing strip' for the last tread, which means there is in the stair itself one tread less than the number of risers. Assuming the height on the story rod to be the normal height of the room of a dwelling-house, that is 8 feet, we must arrange the risers to divide equally as, of course, every step must be uniform. To give a 6-inch rise would mean 16 risers, but this is too many for a straight flight and 13 steps give a riser of $7\frac{5}{13}$ inches. This is rather too much to ensure safety, so some other arrangement must be made. The introduction of a quarter-space landing could be considered. This means

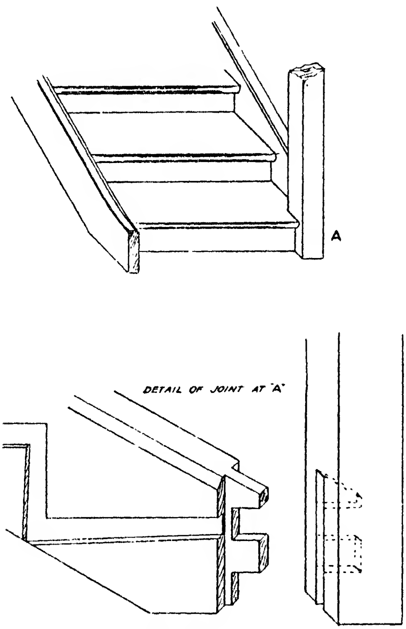


Fig. 158.

a turn in direction and we are assuming that the upper floor has been arranged for a straight flight. We can, however, make a turn at the foot of the stair which may be in the form of a quarter-space landing or winders, and for the sake of this example we suggest the use of winders. This should enable us to use a 6-inch riser, allowing 3 winders for the turn fixed on to a bull-nosed step; this gives a straight flight of 12 steps. The amount of 'Going' would be 11 treads at 11 inches each, which is 10 feet 1 inch on account of the turn; the width of the stair would have to be added to this, making 13 feet 1 inch overall, which is in reality less than if the straight flight had been made with 16 treads. We now have what is called the 'Pitch' of the stair. This represents the rise and tread of one step, and a template of three-ply wood is carefully cut in the form of a triangle, care being taken that the right angle is true, and the base

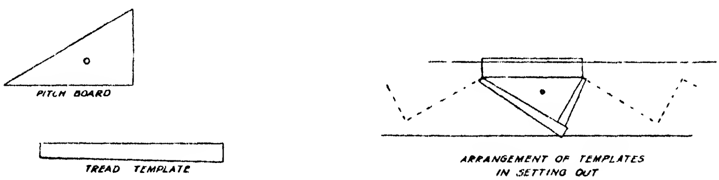


Fig. 159.

and altitude of the two sides accurately measured (Fig. 159). The margin template is next made to give the distance between the edge of the string and the junction of tread and riser (Fig. 160). The templates for the housings are now prepared and the setting out can be proceeded with. The position of the templates will be seen in the diagram and the pitch board is marked round the two sides, stepping along the string board until the required number of steps has been set out. The housings are prepared by placing the tread and riser templates in position and marking off each housing. The strings must be marked off in pairs and the wall string have a piece glued on the lower end to form a 'ramp', whilst the outer string is marked off to receive the newel post at each end. The winders are triangular in shape, the centre being in the form of a kite and is known by that name. These terminate at the newel on the outside and fit into the housings of the wall string in the usual way. The steps are prepared by grooving the treads to receive the riser, according to one of the methods shown, and each complete step after being glue blocked and allowed to set is placed in position in the strings.

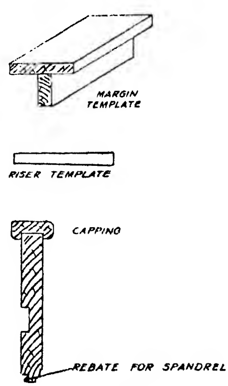


Fig. 160.

The flight is put together on a special bench fitted with overhead cramps, or ordinary joiners' cramps. Long wedges well glued are driven home along the tapered housings.

The bull-nose step is prepared as follows. The round end is 'blocked', i.e., built up to the required height on three pieces whose grain crosses each other, planed perfectly flat and screwed together, the rounded end is carefully cut and smoothed off to receive the veneered riser, as seen in Fig. 161. This is a piece of timber carefully chosen for its even grain and cut to about ⅛ inch in thickness. Secured to one end of the block with screws and bevelled shoulder, the veneer is glued and bent round the block, being secured with screws, but previously tightened up with a long thin wedge driven in the prepared shoulder where the veneer terminates. In fixing the stair into position the newel post is cut out to sit on the trimmer previously placed in position, and the wall

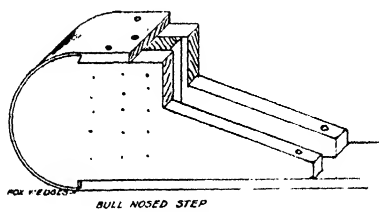


Fig. 161.

tring is cut over the trimmer, leaving the housing to receive the nosing strip and floor-board.

Strings may be plugged to the wall, and the carriage-piece running down the centre of the stair on the underneath side adds to the solidity of the structure.

QUESTIONS ON CHAPTER XVII

1. What do you understand by the terms rise and go?
2. In what position should winders be placed?
3. What is a pitch board?
4. What is a margin template?
5. Explain the following kinds of stair: straight, dog-leg and open newel.
6. Draw ¼ full size one step in a stair showing method of jointing the parts and the position of the carriage-piece.
7. Draw a scroll 11 inches in width to fit over a curtail step, ½ full size.

CHAPTER XVIII

WORKSHOP PRACTICE AND SETTING OUT

MUCH could be written about the shop in which the joiner makes and assembles his work. Provision has to be made for large and small jobs, and jobs differing in nature. Machines have to be accommodated for practically all jobs but room is specially reserved for the bench-hand and also space allotted for wedging up. This kind of work demands abundant light and as much space as can be acquired, although this is often all too small. The machine shop is a building on its own, so arranged that long lengths of timber can be passed through the machines, but in close proximity to the joiners' shop.

In preparing a job, the Setter-Out, a man who spends his whole time in marking out for the various processes of the work, prepares a cutting list for the saw mill. This list gives rough sizes of the timber required, and a second size giving the finished size off the planing machine. When all this has been prepared the setter-out marks on the members of the work the positions of mortises, shoulders, and tenons, shapes of any mouldings necessary, sinkings, &c. These are then ready to be machined, and finally go to the joiners' shop for finishing off, that is, to fit any particular parts together that require special treatment, make sure of the intersection of parts being true, cleaning off panels and many other details that have to be completed before finally wedging up and finishing off.

Examples of simple instances in setting out are shown in Fig. 162 and a cutting list for the saw mill in Fig. 163.

In setting out a job certain points should particularly be remembered.

The rod on which the work is marked out should include everything that is required to be known about the job. In the case of the door (Fig. 162) a floor line is first drawn on the left-hand side. It is a good practice to make this a definite starting-off point and make all heights from this line. The next point of importance is the total or overall height. When

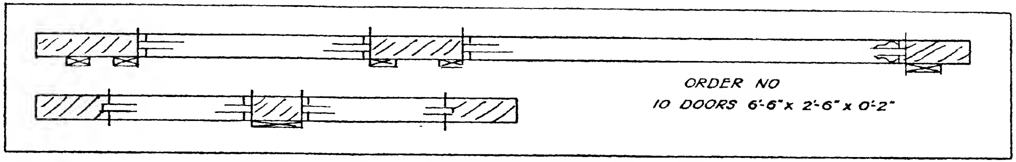
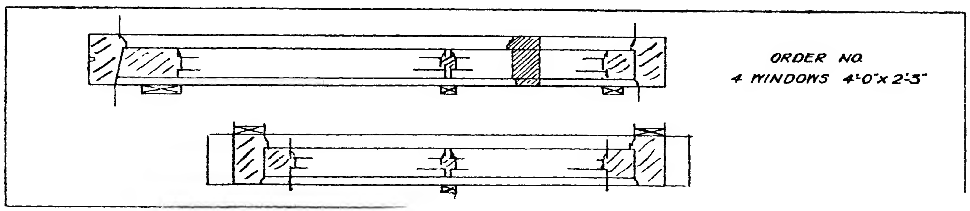


Fig. 162.—Example of Setting Out for 4-Panelled Door.

ORDER NO:
10 DOORS

NO	NAME	LENGTH	WIDTH	THICK--NESS	FINISHED SIZES.		
20	STILES	6'-9"	4½"	2"	6'-9"	4⅜"	1⅞"
10	B RAILS	2'-7"	9"	2"	2'-7"	8⅞"	1⅞"
10	M "	2'-7"	9"	2"	2'-7"	8⅞"	1⅞"
10	TOP "	2'-7"	4½"	2"	2'-7"	4⅜"	1⅞"
10	L MUNTIN	3'-5"	4⅛"	2"	3'-5"	4"	1⅞"
10	B. "	2'-0"	4⅛"	2"	2'-0"	4"	1⅞"
10	L PANELS	3'-1"	9"	⅝"	3'-1"	9"	½"
10	S. "	1'-7"	9"	⅝"	1'-7"	9"	½"
1	MOULD	50'-0"	1½"	¾"	TO SECTION		

Fig. 163.—Cutting List for 4-Panelled Door.



this has been marked on the board the intermediate lines can be drawn, that is, the top edge of the bottom rail, from which can be deduced the groove for the panel, and the positions of the mortises. Next draw in the position of the middle rail, again showing where the mortises come. Having gone thus far, we can get the true position of the shoulders of the tenons for the muntins. The same procedure is followed in the case of the width. Starting at the left-hand side and marking along we get the distance between the shoulders of the rails, and also the mortise for the muntins.

It is necessary to show the depth of the panel and the nature of mould to be used, this indication being sufficient to show that ½-inch panel is to be used and a sunk mould of a particular design. The boards or rods on which setting out is done are thin boards sufficiently wide to deal with the job in hand, and the surface carefully prepared by being covered in a preparation made up of whiting mixed with a little glue, just sufficient to make it 'bind', or not to rub off the working of the job. After the board has had a good coat of whiting, it is allowed to dry and is then papered down with glass-paper, when it is ready for setting out.

In setting out for frames to be built in brickwork it is very important to work from the brick openings, as it is not in every case possible in brickwork to follow to the fraction the architect's drawings; the bricklayer, too, is ilmited to size of the brick he has to use, which varies considerably.

Fig. 164 shows the setting out for a small casement window.

CHAPTER XIX

OBLIQUE WORK

One is often confronted with work in which two oblique or splayed surfaces are joined together. When two inclined planes meet, they appear at an angle of 45° on elevation, but the cuts required are not 45° unless, of course, the timbers are lying in the horizontal or vertical plane as the case may be. Window linings are often splayed to enable more light to be thrown into the room and the pitch of these

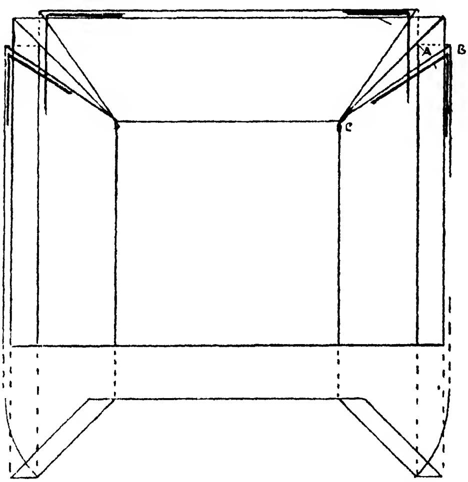


Fig. 165.—Showing development of Splayed Linings.

linings governs the cut or bevel required to enable the stile and head to properly fit together. This is explained in Fig. 165. To assist his efforts, the student is recommended to cut two pieces of stiff paper to a convenient width. Cut one end of each at 45° as this is a true mitre. Now place upright, but inclined to the edge of the drawing-board with the mitre uppermost. Next place the other piece of paper at right angles, forming the head or top and placed at 45° to the vertical plane, and you have an imitation of the head and stile of a splayed lining. If these two pieces are at 45°

or thereabouts it will be seen that the mitre cuts do not intersect. They cannot, because although they have been cut to their appearance on elevation, they must have another and different bevel. We explained in a previous chapter the importance of turning an inclined plane into either the vertical or horizontal plane, and in this case if we turn the upright sheet of paper which is at 45° to the edge of the drawing-board, we see the true width of the lining, and the top corner of the bevel has moved along a line from *A* to *B* (Fig. 165) and by joining up with *C* we are able to ascertain

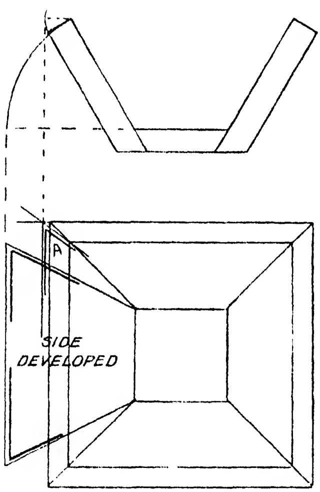


Fig. 166.—Showing development of Splayed 'Hopper'.

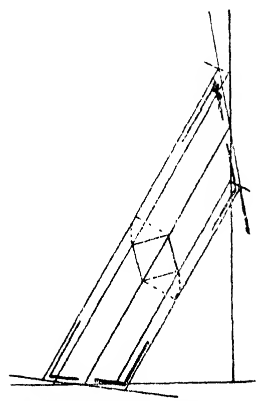


Fig. 167.—Showing 'Bevels' for a Corner Post whose Faces are inclined to the Vertical Plane.

the correct bevel. The head is opened out in the same way. The bevels will be identical with each other, and by cutting the strips of paper to the new bevels the pieces can now be brought together and they will be standing in their true position as a splayed lining. Fig. 166 shows a box with sloping sides, the principle of development being the same as in the last example. The top edge is left square off the side, and in order to find the required bevel to mitre the corners the edge must be developed as at *A*. In Fig. 167 a strut is fixed to a post. The corners of the strut lying in the shape of a diamond, the sides when opened out, or as we say developed, give the correct bevel.

An interesting example is given in Fig. 168 of a corner block. The student will readily see the need of having to set a bevel to cut the three edges of the triangle and also develop the figure to get its true shape. The same procedure has been followed but perhaps requires more concentration

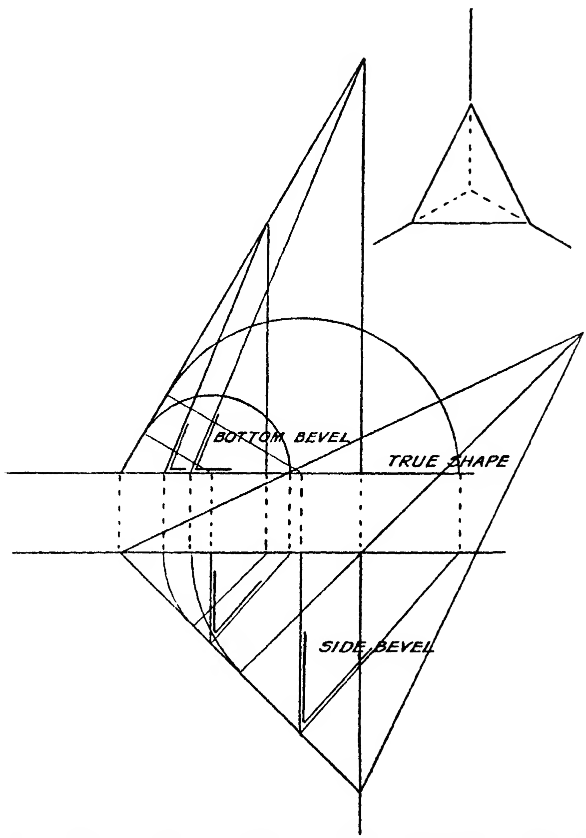


Fig. 168.—Obtaining the true Shape and the Bevels of a Corner Block.

of thought in following the principle adopted, which is not altered from the foregoing.

The following examples in curved work should be fully understood by the student before any more difficult work is attempted.

We have agreed that the base line of a hip is longer than the base line of its common rafter; in like manner the base of the hip to a groined roof seen in Fig. 169 causes an alteration in shape of the section. The curve is spaced out by a number of ordinates, and their extension into the plan gives their position in relation to the hip.

These are next produced at right angles to the base of

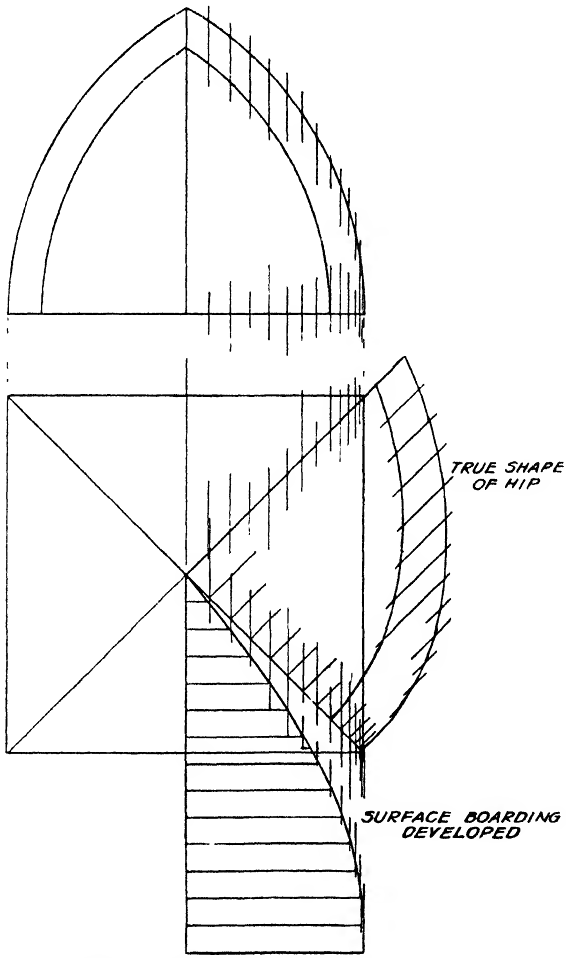


Fig. 169.—Showing the true Shape of a Groined Hip.

the hip and their various heights marked off, giving the true shape of the curve for the hip.

If the roof in this example is boarded, the curved surface will have to be extended or opened out into the horizontal plane as shown, from which is derived the true shape of each board.

Fig. 170 shows the bevels required in the making of a triangular louvre frame, the various developments operating as in previous examples. The following examples prove that if a cylindrical object is cut by an oblique plane, the section is an ellipse; for example, if a circular chimney shaft is built through a sloping roof, the aperture to be cut would be in the shape of an ellipse. This is explained in Fig. 171;

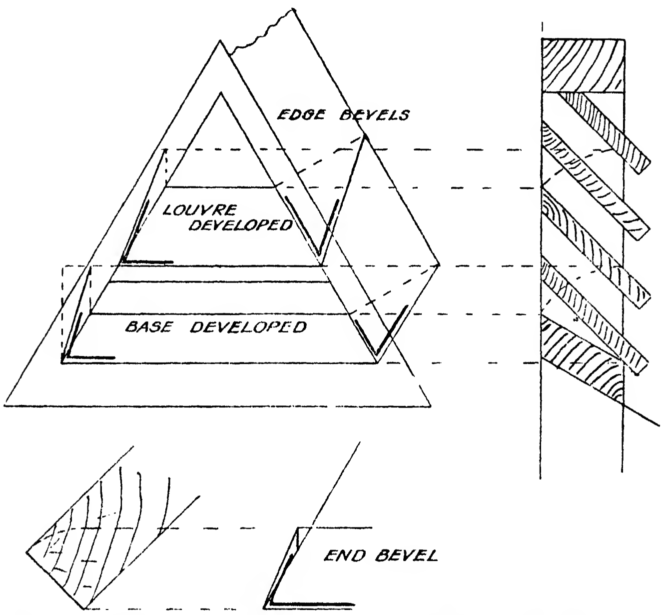


Fig. 170.—Showing Bevels and Developments for a Triangular Louvre Frame.

an additional drawing also shows the true shape of the ribbon flashing that would be required to bend around the junction of the roof and the stack.

In Fig. 172 a circular louvre frame is shown. In this case it is necessary to develop each louvre separately as they change their shape, as each louvre in the same plane cuts the arc of the circle at a different point in its circumference.

The next example (Fig. 173) shows the intersection of a church spire with a sloping roof. Here again the true shape of the intersection has to be arrived at before the lead or copper covering can be cut to its true shape. First draw the elevation of the spire and section of the roof, now draw half the plan of the spire base and mark off on the circumference a number of points equally spaced. Produce the line of the roof *AD* to *E*, *E* being the same height as *C*.

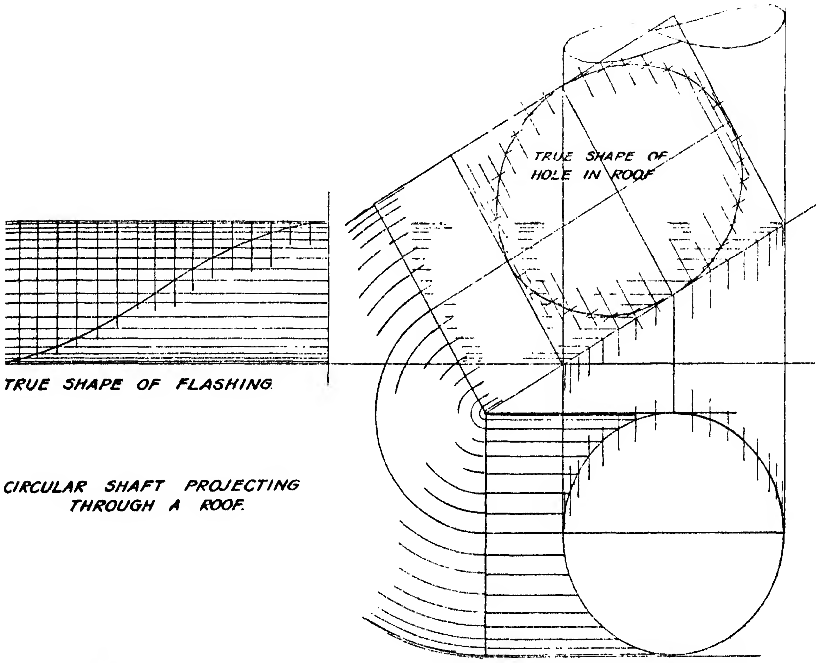


Fig. 171.—Showing the true Shape of a circular Shaft in an inclined Plane.

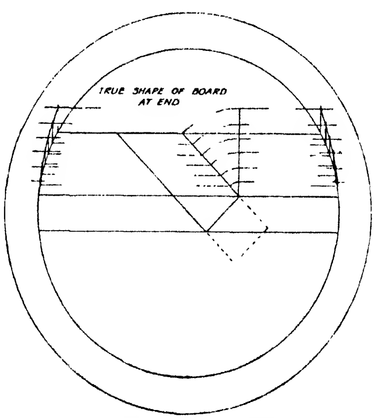


Fig. 172.—Showing true Shape of Louvre Boards in a Bull's Eye Frame.

Erect a perpendicular to *A—D* at *A* to *G*, and another perpendicular at *A* to *F*, and project the points on the cir-

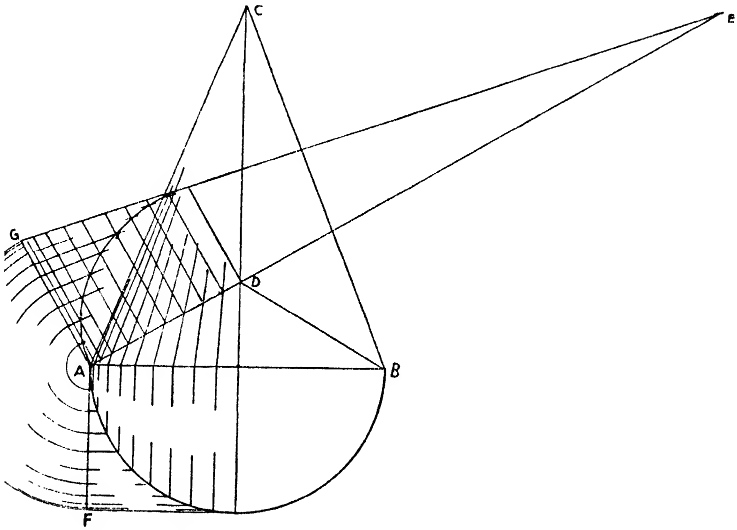


Fig. 173.—Showing to the Intersection of a Conical Spire with the Pitch of a Roof.

cumference to the line *A—F* and then on to *AG*. Connect all the points on *AG* to *E*.

Erect perpendiculars on *AD* connecting the correspond-

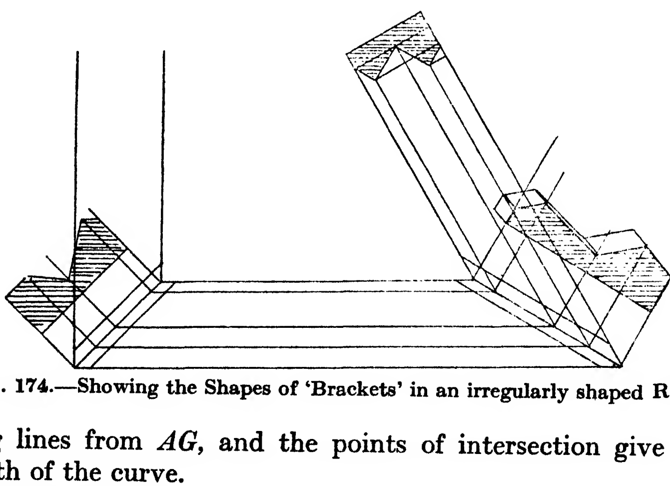


Fig. 174.—Showing the Shapes of 'Brackets' in an irregularly shaped Room.

ing lines from *AG*, and the points of intersection give the path of the curve.

It is sometimes necessary when rooms are not symmetrical to develop brackets or templates owing to the shape of the room. This is seen to be necessary in Fig. 174 where cornice brackets have to be made to suit the purposes called for in each corner. The normal bracket is drawn first, and following round the various points give the shape of the bracket required at each corner and which are all different from each other.

QUESTIONS ON CHAPTER XIX

1. Draw ½ full size one corner of a splayed lining at 45° to the wall, the lining is 6 inches in width and the correct bevels are to be developed.
2. Mark off the correct bevels on cardboard and place them in position.
3. Draw a segmental roof and develop the hip. Cut out in cardboard the segment to the common rafter and also the hip, place these in their positions and prove the accuracy of the curves.
4. Measure carefully the diameter of a round object, a bottle for instance, and draw out the plan and elevation of a chimney shaft on this size.
5. Develop the hole in the roof for a 30° pitch and cut out in paper the true shape and place it over the object to prove your work.

CHAPTER XX

MECHANICS

It is very important to the student that he should have a knowledge of the various forces that are brought into play in a building and be able to relate those forces to a job in hand.

In designing any structure it is essential that each component part should be strong enough to resist the forces that may be brought to act upon it. To ensure this result it is necessary to know the nature and distribution of the internal forces. The forces acting upon the structure are:

I. The Force of Gravity—that is, the weight of the parts of the structure and of any load they may have to carry, and

II. The Force of the Wind.

The first load, i.e. the force of gravity, may be divided into two parts, according to their nature, as Dead and Live loads. A dead load comprises the weight of the structure itself and any other, which may be gradually applied, and which remains steady. A live load is an incidental or intermediate load. It comprises all loads which are suddenly applied or applied to and removed from the structure at intervals. The comparative effect of dead and live loads is found by experiment to be that a live load produces nearly twice the effect that a dead load of the same weight would produce.

Force is that energy which produces or tends to produce change in all things material.

Stress is the equal and opposite action and reaction which takes place between two bodies, or two parts of the same body, transmitting force, and may be classified either as Tensile, Compressive, and Shear or Transverse stress.

Tensile Stress is that stress which exists between two parts of a body in which each draws the other towards itself. See Fig. 175.

In the case of a tie rod the pull P in lbs. in considering the line $X—X$ to be an imaginary plane perpendicular to the axis of the bar, the area of which is a square inches, the material at $X—X$ is therefore under tensile stress. The portion B exerts a pull on A, which just balances P, and is therefore equal and opposite to it. The average force exerted per square inch of section equals Pull over Area, which equals Intensity of Stress.

Compressive Stress is that stress which exists between

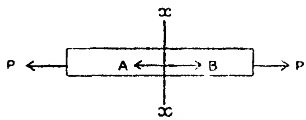


Fig. 175.

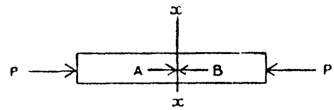


Fig. 176.

two parts of a body when each pushes the other from it. See Fig. 176.

Shearing Stress is that stress which exists between two parts of a body in contact, when the two parts exert a force on each other laterally, in a direction tangential to their surface of contact. See Fig. 177.

In the case of two plates riveted together there is a shear stress at the section $X—Y$ of a pin or rivet, when the two plates which it holds together sustain a pull P in the plane of the section $X—Y$. If the area of the section $X—Y$ is

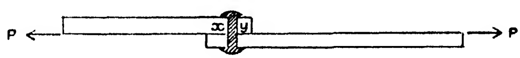


Fig. 177.

a square inches and the pull is P lbs., the total shear at the section $X—Y$ is the average force per square inch which equals Q, which is P over A, or the mean intensity of the shearing stress at the section $X—Y$.

Intensity of Stress is the force in units of weight, divided by the area of the body in units, or in other words:

$$\frac{\text{Load}}{\text{Area}}.$$

Strain is the alteration of shape or dimension resulting from stress.

Tensile Strain is the stretch and result from a pull, which causes a condition of tensile stress and is the direction of a tensile stress and is measured by the fraction of elongation. See Fig. 178.

In the case of a bar the length is increased from L to $L + XL$, the strain is equal to $\frac{XL}{L}$ or the fraction of elongation, which is XL over the original length. The strain is

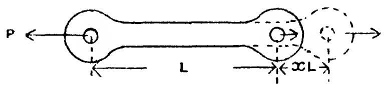


Fig. 178.

therefore equal numerically to the stretch per unit of length.

Compressive Strain is the contraction which is due to the compressive stress and is also measured by the ratio of the contraction to the original length. In the case of a bar L units in length is contracted to $L—XL$, the compressive strain being $\frac{XL}{L}$.

NOTE. Tensile strain causes contraction perpendicular to its direction. See Fig. 179.

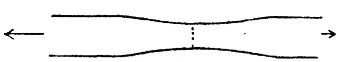


Fig. 179.

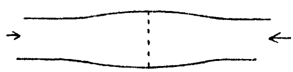


Fig. 180.

Whilst Compressive strain causes expansion perpendicular to its direction. See Fig. 180.

Shear Strain is the angular displacement produced by shear stress. If a piece of material is subjected to a pure shear stress in a certain plane, a change in inclination estimated in Radians, between the plane of inclination and the line originally perpendicular to it, takes place and is numerically the measure of the resulting shear stress. In general practice it is $\frac{XL}{L}$. See Fig. 181.

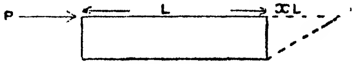


Fig. 181.

Limits of Stress for a given material in which the resulting strain completely disappears after the removal of the stress called the 'elastic limit', i.e. if a stress beyond the elastic limit is applied and part of the resulting strain remains after the removal of the stress, such a strain is called 'permanent set'.

Elastic Strain is that strain produced by stress within the limits of elasticity.

Elasticity. A perfect elastic body is one in which the whole of the strain produced by a stress disappears when the stress is removed. Within certain limits every material shows practically perfect elasticity.

Plasticity. A plastic body is one in which the strain does not disappear when it is relieved from the stress.

Ductility. A ductile body allows of its beam to be drawn out by tension to a smaller section.

Ultimate Strength. The ultimate strength of any material under any particular kind of stress is the maximum load necessary to rupture a specimen, divided by the original area of section at the point of fracture, and is usually estimated in lbs. or tons per square inch.

Factor of Safety is the ratio between the working stress of a structure and the ultimate strength. The factor of safety varies greatly according to the nature of stress, whether constant, variable or alternating, simple or compound. It is made frequently to cover an allowance for straining actions, such as shocks on which no reliable estimate can be made and for the diminution of section due to corrosion, &c.

Composition of Forces. Statics is that branch of mechanics which deals with force applied to a body or a number of bodies which remain at rest. Such forces are said to balance or be in equilibrium. Force is that energy which tends to move a body and may be measured in units of pounds, cwts. or tons; hence, if the magnitude of a force is known, a line may be drawn whose length will be proportional to the force. The force being exerted in a certain direction, the line representing it must be drawn in that direction.

Point of Application is the place at which the force is applied.

Known Forces are those forces in which the direction, magnitude, sense and point of application are known.

System of Forces. Any number of forces acting at a point upon a body may be called a system.

Resultant is that force which could replace a system of forces and still give the same effect upon the body they act upon.

Equilibrant is that force equal to and acting in the opposite direction and in the same plane as the resultant of a system of forces and produces equilibrium.

Equilibrium is a state of rest produced by the mutual counteraction of two or more forces.

Equal Forces. If two forces are equal, when applied to a body in opposite directions, the body remains at rest.

Polygon of Forces. The sum of a number of forces which have a known direction and magnitude acting upon a body are in equilibrium and can be represented in magnitude and direction by the sides of a polygon taken in order; if these forces are not in equilibrium the polygon will not close.

Bow's Notation is the method of numbering or lettering force diagrams. That is, by placing letters between consecutive forces, always in a clockwise direction.

If the direction and magnitude of more than one force is unknown in any system of forces it is impossible to use the force polygon to find the unknown.

The closing line in a force diagram gives the direction and magnitude of either the equilibrant or the resultant force of a system of unbalanced forces.

Triangular Forces. If three forces acting on a point can be represented in magnitude and direction by the sides of a triangle taken in order, they shall be in equilibrium. If the arrow denoting the direction of the force in the diagram is transferred to the drawing of the figure, it will give the nature of the stress in the members. If the arrow points towards the joint in question then the stress in that member is compression; if the arrow points away from the joint the stress in the member is tension. See Fig. 182.

Parallelogram of Forces. If two forces acting at a point are represented in magnitude and direction by the two adjacent sides of a parallelogram drawn from their points of application, their resultant can be represented in magnitude and direction by the diagonal of the parallelogram drawn from that point. See Fig. 183.

Experiment to prove that the measured forces in a structure agree with those determined by graphical method.

The experiment (see sketch) proves the triangle of forces in giving the stresses in the members of the crane and the magnitude of them. The three members in the crane withstanding the weight 7 lbs. are, the Tie which measures 63 centimetres, the Jib which measures 80 centimetres, and the Cable bearing the pull of 7 lbs., which is taken as 7 units

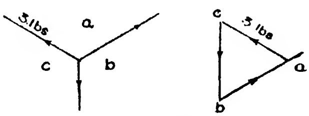


Fig. 182.

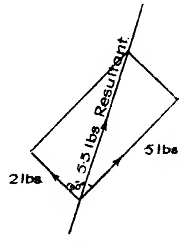


Fig. 183.

of length. By drawing the line *AB* as 7, and then taking the lines *bc* and *ca*, we get the triangle of forces. Given the stress in *ab* as 7, the length of the other members of the triangle determines the stress, and the nature of that stress

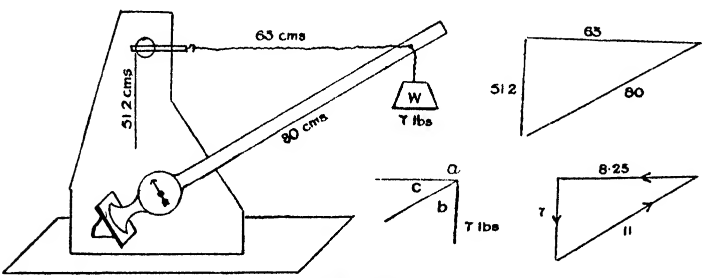


Fig. 184.

is determined by the arrows; first denoting the downward pull on *ab*, then following round, they determine the nature of stress in the other members, hence *ab* = tension, *bc* = compress and *ca* = tension. See Fig. 184.

Examples of Triangular Forces. A block weighing 20 lbs. is suspended by two chains *ac* and *bc* from the cable *AB* of a crane. Find the stress in each chain.

The stress in the cable *AB* must be 20 lbs., since the total upward pull must be equal to the weight suspended. At this point we have three forces: *AB* = 20 lbs. and *bc* and *ca* both unknown in magnitude but all three forces are known in direction. The force triangle is drawn beginning with *AB* = 20 units representing lbs.: from *A* draw *AC* parallel *AC* in sketch and

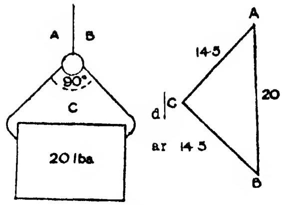


Fig. 185.

draw *Bc* similarly. These two lines intersect at *C* and determine by their length the stresses in the chains *ac* and *bc*. See Fig. 185.

Further examples are given below.

The following examples are dealt with as before.

The relation between Force, Stress and Strain is that Force in the motive power which tends to move or change the nature of the body on which such Force acts. Stress is the resistance offered to the force by the internal structure of the body. Strain is the alteration of shape due to the force and stress. Therefore.

Force is the motive power
Stress ,, ,, resistance acting against force
Strain ,, ,, result due to force and stress.

Moments. The moment is the tendency of a force to produce rotation of the body it is applied to. The moment of a force is generally expressed in inch-lbs., foot-lbs.; and

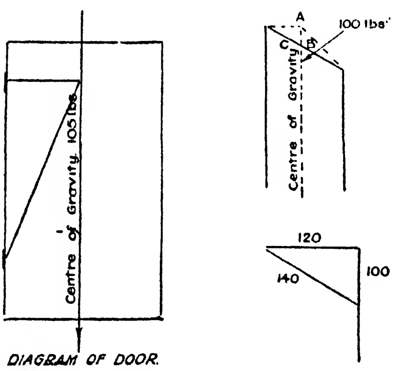


Fig. 186.

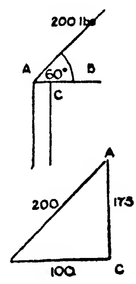


Fig. 187.

foot-cwts., &c. The moment of a force *P* about a point *O* is the product of *P* into the perpendicular distance drawn from *O* to the line of action of *P*. See Fig. 188.

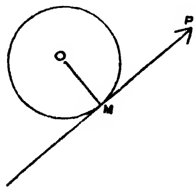


Fig. 188.

Thus—

P = Force
O = The point
OM = Perpendicular distance of O to the line of action
$P \times OM$ = Moment of force P about point O.

This moment measures the tendency of the force to procure rotation about that point. Moments of force which produce clockwise action or rotation are taken as positive and those acting anti-clockwise as negative. See Fig. 189.

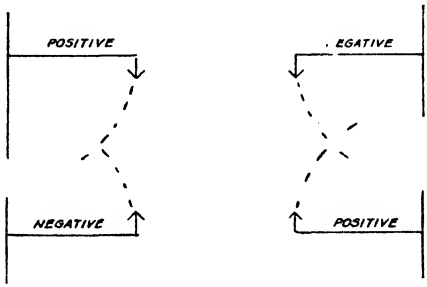


Fig. 189.

When a body is in equilibrium under the action of external forces in one plane the resultant moment of the forces at any point is zero, that is, the sum of the positive moments is equal to the sum of the negative moments. See Fig. 190.

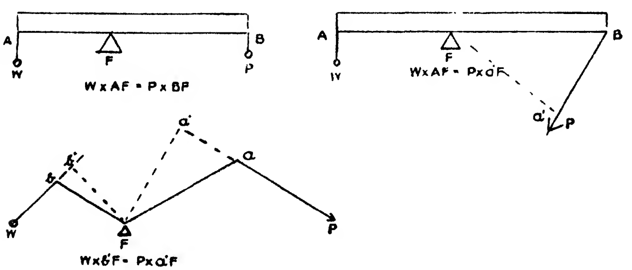


Fig. 190.

Example. A light rod 2 feet 4 inches long carries weights at its extremities of 2 and 5 lbs.: find the point in the rod about which it will balance. See Fig. 191.

$$AF = 28 \text{ in.} - x$$
$$= 2x(28 - x) = 5x$$
$$= 2(28 - x) = 5x$$

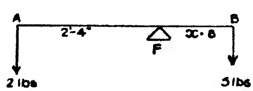


Fig. 191.

$$= 56 - 2x = 5x$$
$$= 56 = 7x$$
$$= 8 = x$$

Composition of Parallel Forces. Reaction is the existing force which a body produces when a force acts upon that body.

Reaction equals load multiplied by distance from centre of gravity to the other support divided by the length of beam between supports.

It will be obvious that when a beam or girder is rested on two walls—the girder spanning the intervening width—the walls must be strong enough to support the girder and any weight it may have to carry. The action of the load superimposed, and the reaction of the wall in resisting this load maintains equilibrium. In the case of the sketch below, the action of the weights is to push in a downward direction, whilst the balances below will register the weights in supporting them. Moreover, if the left-hand weight is moved to the right, so that the weights are not at equal distances

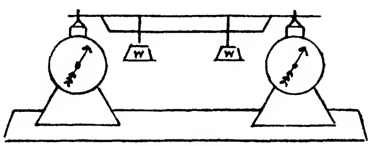


Fig. 192.

from their points of support, the right-hand weight will register more than the left-hand weight, but the sum of the two will be equal to the sum of the two weights. See Fig. 192. These can be calculated or drawn graphically.

If a beam is loaded centrally one-half of the load will be carried by each wall.

NOTE. The same effect is produced when the load is distributed over the length of the beam.

When the load is not central, the reactions are calculated as follows:

Multiply the distance in feet of the centre of the load in cwts. or tons and divide by the span. This gives the reaction for the other support, e.g.:

5 cwts. × 16 feet ÷ 20 feet =

$\frac{5 \times 16}{20}$ = 4 cwts. Reaction at left-hand support.

also 5 cwts. × 4 cwts. ÷ 20 feet =

$$\frac{5 \times 4}{20} = 1 \text{ cwt.} = \text{Reaction at right-hand support.}$$

See Fig. 193.

To prove the correctness of one's working the sum of the reactions must equal the load.

Taking a case of a beam unequally loaded each load must be calculated separately and the results added together to give the total reaction at each support.

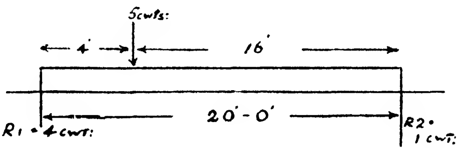


Fig. 193.

$$R1 = \frac{\text{loads} \times \text{distance to opposite support}}{\text{length}}$$

$$\therefore R1 = \frac{10 \times 9}{12} + \frac{20 \times 7}{12} + \frac{15 \times 3}{12}$$

$$= \frac{90 + 140 + 45}{12} = \frac{275}{12}$$

$\therefore R1 = 22\frac{11}{12}$ cwts. $\therefore R2 = 45 - 22\frac{11}{12} = 22\frac{1}{12}$ cwts.

The same result would be obtained when working from the other side.

To find the same result graphically:

1. Draw carefully to scale the example shown and mark out position and magnitude of forces.

2. Letter the diagram to Bow's Notation, i.e. one letter to each space.

3. Plot the loads to scale, commencing at the left hand.

4. Take any pole O and connect to points on load line; this gives the polar diagram.

5. Produce the lines of action of the forces which will divide the diagram into spaces.

6. Construct the funicular polygon, that is, in space A, draw a line parallel to ray OA of polar diagram. From B to OB in space B draw a line parallel to BO of polar diagram and so on. From the ends of the broken line thus obtained

draw a closing line. This transferred to polar diagram will give the magnitude of the reactions.

7. Produce the lines *OA* and *OD*; until they meet; this

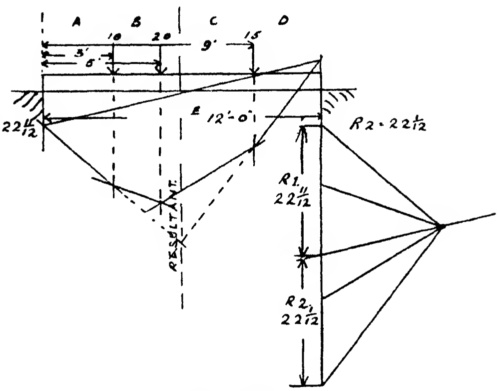


Fig. 194.

intersection will give the path through which the Resultant must pass.

Bending Moments and Shear Stress. The bending moment at any point along the span of a beam is the algebraic sum of the moments of all the forces on either side of the section. The shearing force at any point along the span of a beam is the algebraic sum of all the perpendicular forces acting on either side of the plane of section. See Fig. 196. Bending moments and shearing forces vary in magnitude from point to point along the length of the beam according to the nature of the load and the placing of the same.

The shearing force value at any given cross-section can be determined mathematically or graphically by plotting curves to scale. Shearing forces may be divided into two classes, vertical and horizontal. See Figs. 195 and 196.

VERTICAL SHEARING EXAGGERATED
Fig. 195.

HORIZONTAL SHEARING EXAGGERATED
Fig. 196.

Horizontal Shearing Stress at any point in a beam is equal to the vertical shearing stress at that point. To prove this construct a square on the neutral axis of a beam. If the beam is loaded so as to cause deflection, the square will be distributed into a rhombus.

Since the neutral layer of a rectangular beam has no direct stress the distortion must, therefore, have been produced by vertical stress (shearing) VV, acting as shown by the arrows, and it is opposed by the horizontal stress (shearing) H and H; now, since the beam is in equilibrium, H and

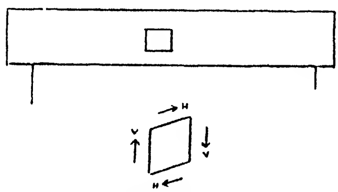


Fig. 197.

H must be equal to V and V or the horizontal shearing stress must be equal to the vertical shearing stress.

Vertical Shearing Force in Cantilevers. The vertical shearing force in cantilevers at any section is equal to the weight on the beam, between that section and the outer end and the weight of the beam beyond.

Theory of Bending. A beam carrying a number of transverse loads is in equilibrium under the action of the loads, and the supporting forces are $R1$ and $R2$.

Take a point x which divides the beam into two parts A and B. Each part is in equilibrium. The system that keeps the portion A in equilibrium consists of the three forces W^1W^2, W^3 and $R1$, together with the forces exerted on A by B across the section x in virtue of the stress.

MISCELLANEOUS EXAMPLES BY GRAPHICAL METHODS

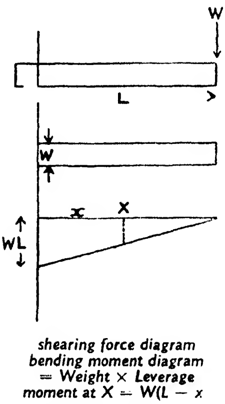


Fig. 198.—Cantilever weighted at the end only.

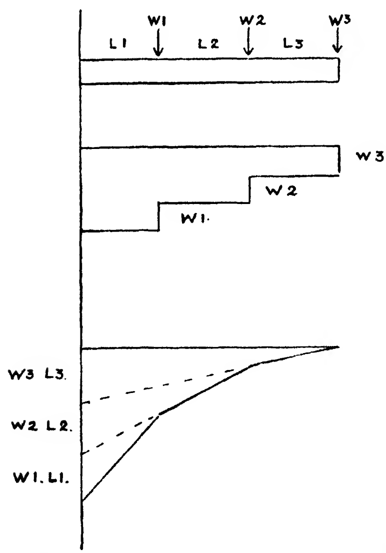


Fig. 199.—Cantilever weighted at intervals.

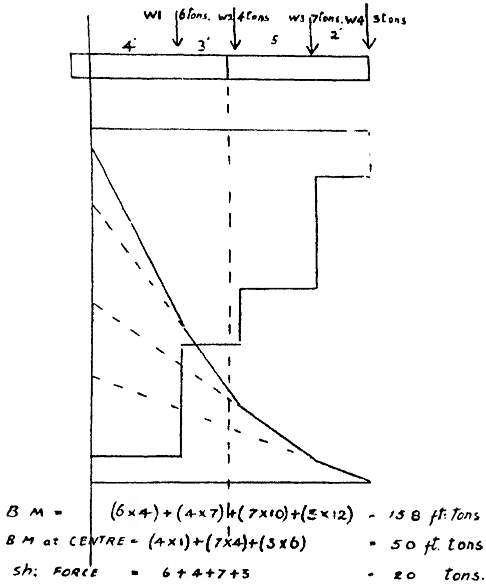


Fig. 200.—By moments.

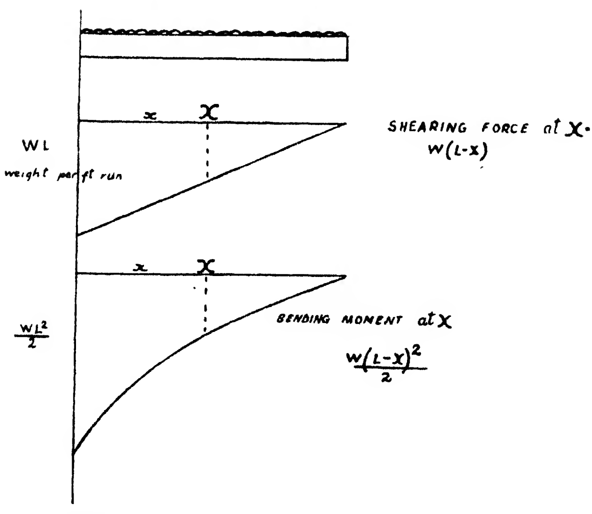


Fig. 201.—Cantilever with load evenly distributed.

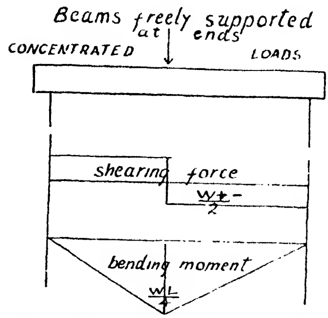


Fig. 202.—Beam freely supported—centrally loaded.

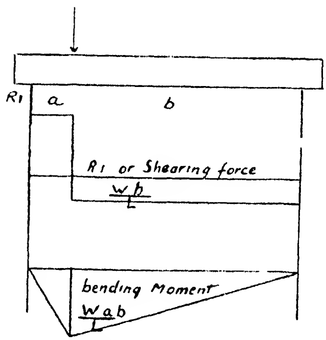


Fig. 203.—Beam freely supported—unequally loaded.

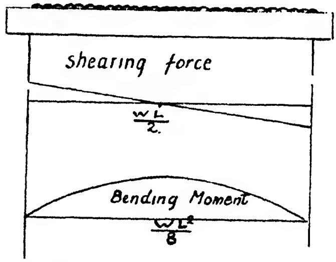
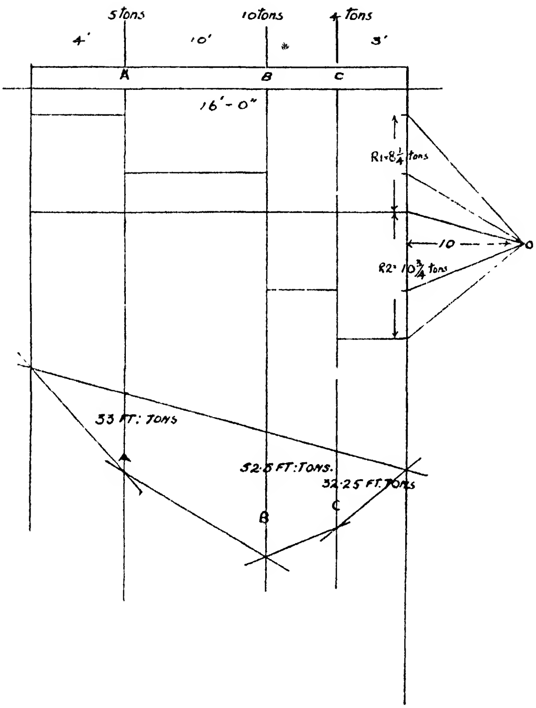


Fig. 204.—Beam freely supported with load evenly distributed.



TO FIND MOMENTS GRAPHICALLY

for BENDING MOMENTS multiply distances on funicular diagram by length of Pole O from load line.

$A = 3\frac{1}{4} \times 10 = 33$ ft.-tons.

$B = 5\frac{1}{4} \times 10 = 52\frac{1}{2}$

$C = 3\frac{9}{40} \times 10 = 32\frac{1}{4}$

MOMENTS :—

$$R1 = \frac{W1 + (L - L1) + W2(L - L2) + W3 \times (L - L3)}{L}$$

$$R2 = \frac{(W1 \times L1) + (W2 \times L2) + (W3 \times L3)}{L}$$

$$\therefore\ R1 = \frac{5 \times (16 - 4) + 10(16 - 10) + 4 \times (16 - 13)}{16} = 8{\cdot}25$$

$$\therefore\ R2 = \frac{(5 \times 4) + (10 \times 10) + (4 \times 13) = 10{\cdot}75}{16} = 10{\cdot}75$$

BM at $A = R1 \times L1 = 8{\cdot}25 \times 4 = 33$ ft.-tons.
BM at $B = (R1 \times L2) - (W1 \times [L1 - L2]) = 52{\cdot}5$ ft.-tons.
BM at $C = R2 \times (L4 - L3)$ $= 32\frac{1}{4}$ ft.-tons.

Fig. 205.—Beam freely supported—unequally loaded.

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