CHAPTER 8

TIMBER

Timber is one of the most important building materials in use today, and this is because of its strength compared to volume ratio and its workability.
Timber is divided into softwoods (coniferous) and hardwoods (broad leaf). This grouping has nothing to do with the hardness of the timber concerned, but is based solely on its structure**.**

1) Soft wood trees:

These have the following general characteristics:

a) A trunk, which is very straight and cylindrical.
b) A crown that is narrow and pointed.
c) Needle-like leaves.
d) A bark, which is course and thick.
e) The seeds are borne in cones.
f) They are evergreen i.e. they do not drop all their leaves at once in autumn.

2) Hard wood trees:

These have the following general characteristics:

a) An irregular, less cylindrical trunk.
b) A crown that is wide rounded and contains large heavy branches.
c) Have broad leaves.
d) The bark varies widely: it can be very smooth and thin to very course and thick, and range from white to black colours.
e) They have covered seeds, e.g. berries, corns and stored fruits.
f) They are mainly deciduous e.g. they shed their leaves in winter.

Conversion of timber:

This is the sawing up or breaking down of the tree into various sized pieces of timber for a specific purpose. This can be done by sawing the trunk in either a tangential direction or in a radial direction, which terms refer to the cut surfaces of the timber in relation to the growth rings of the trees.

1) **Tangential conversion**: This is where timber is converted so that the annual rings meet the wider surface of the timber over at least half its width less than 45 degrees. **See fig 8.1a.**
2) **Radial conversion**: This is where timber is converted so that the annual rings meet the wider surface of the timber throughout its width at an angle of 45 degrees or more. **See fig 8.1b**

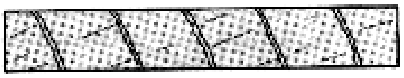


Fig 8.1a Tangential Cut **Fig 8.1b Radial Cut**

Methods of converting timber:

There are four methods of converting timber and these include; through and trough, Tangential, Quarter and Boxed heart.

1) Through and trough method:

This method is also known as slash or slab sawing. It is the simplest and cheapest way to convert timber, with very little wastage. The majority of boards produced in this way are prone to a large amount of shrinkage and distortion.

Note: Approximately two-thirds of the boards will be tangential and one-third (the middle boards) will be radial. **See fig 8.1c**

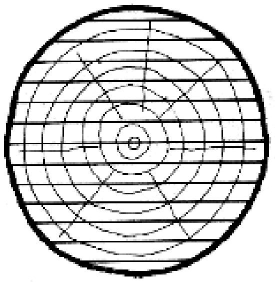


Fig 8.1c Through and Through conversion

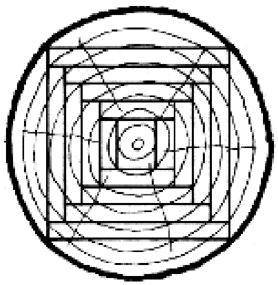


Fig 8.1d Tangential conversion

2) Tangential method:
This method is used when converting timber for floor joists and beams, since it produces the strongest timber. It is also used for decorative purposes on timbers that have distinctive annual rings, e.g. pitch pine and Douglas fir, because it produces flame figuring or fiery grain. **See fig 8.1d**

3) Quarter method:
This is the most expensive method of conversion, although it produces the best quality timber, which is ideal for joinery purposes. This is because the boards have very little tendency to shrink or distort. In timber where the medullar rays are prominent, the boards will have a figured finish, e.g. figured or silver-grained oak. **See fig 8.1e**

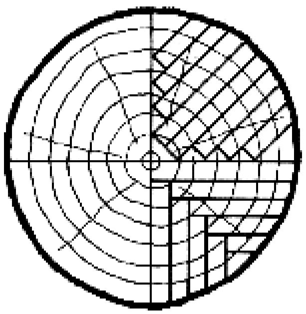


Fig 8.1e Quarter conversion

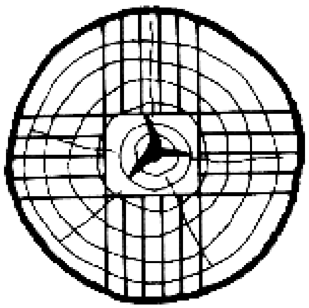


Fig 8.1f Boxed heart conversion

4) Boxed heart:
This is a type of radial sawing and is done when the heart of a tree is rotten or badly shaken. It is also known as floorboard sawing as the boards produced are ideal for this purpose because they wear well and do not distort. The waste pieces of timber are of an inferior quality but are often used for fencing, etc. **see fig 8.1f**

Moisture in timber

Moisture occurs in the timber in two forms:

a) As free water in the cell cavities.

b) As bound water in the cell walls.

When all of the free water in the cell cavities has been removed, the ***fibre saturation*** point is reached and at this point the timber normally has a moisture content of between 25 and 30 per cent.
When the moisture content of the timber is reduced below the fibre saturation point than ***shrinkage*** occurs. The timber should be dried out to a moisture content which is approximately equal to the surrounding atmosphere in which it will be used. This moisture content is known as the ***equilibrium moisture*** content and, providing the moisture content and temperature of the air remains constant, the timber will remain stable and not shrink or expand.

Determining the moisture content

The moisture content of timber is expressed as a percentage. This refers to the weight of the water in the timber compared to the dry weight of the timber.
In order to determine the average moisture content of a stack of timber, select a board from the center of the stack, cut the end 300mm off and discard it as this will normally be dryer than sections nearer the center. Cut off a further 25mm sample and immediately weigh it. This is the wet weight of the sample. Place this sample in a drying oven and remove it periodically to check its weight. When no further loss of weight is recorded, assume this to be the dry weight of the sample.
The moisture content of a piece of timber can now be found by using the following formula:

$$\text{Moisture content (per cent)} = \frac{\text{wet weight} - \text{dry weight}}{\text{dry weight}} \times 100$$

Example

Wet weight of sample = 50g
Dry weight of sample = 40g

$$\text{Moisture content} = \frac{50 - 40}{40} \times 100 = 25 \text{ per cent}$$

An alternative way of finding the moisture content of timber is to use an electric moisture meter. Although not as accurate, it has the advantage of giving an on-the-spot reading and it even be used for determining the moisture content of timber already fixed in position.
The moisture meter measures the electrical resistance between the two points of a twin electrode which is pushed into the surface of the timber. Its moisture content can then easily be read off a calibrated dial.

Seasoning of timber

The term seasoning refers to the controlled drying by natural or artificial means of converted timber. There are many reasons why seasoning is necessary, the main ones being:

1) To ensure that the moisture content of the timber is below the dry rot safety line of 20%.
2) To ensure that any shrinkage takes place before the timber is used.
3) Using seasoned timber, the finished article will be more reliable and less likely to split or distort.
4) In general, dry timber is stronger and stiffer than wet timber.
5) Wet timber will not readily accept glue, paint or polish.

Timber may be seasoned in one of two ways and these are the natural means (air seasoning) and the artificial means (kiln seasoning)

Air seasoning

In this method the timber is stacked in open sided, covered sheds, which protect the timber from rain whilst still allowing a free circulation of air.

In most cases moisture content of between 18% and 20% can be achieved in a period of two to twelve months, depending on the size and type of timber.

Fig 8.2a Shows an ideal timber stack for the air seasoning of softwoods. The following points should be noted:

1) Brick piers and timber joists keep the bottom of the stack well clear of the ground and ensure good air circulation underneath.
2) The boards are laid horizontally, largest at the bottom, smallest at the top, one piece above each other. This reduces the risk of the timber distorting as it dries out.
3) The boards on each layer are spaced approximately 25mm apart.
4) Piling sticks of stickers as introduced between each layer of timber at approximately 600 mm distances, to support the boards and allow a free air circulation around them.
   Note: The piling sticks should be the same type of timber as that being seasoned otherwise staining may occur.
5) The ends of the boards should be painted or covered with strips of timber to prevent them from drying out too quickly and splitting.

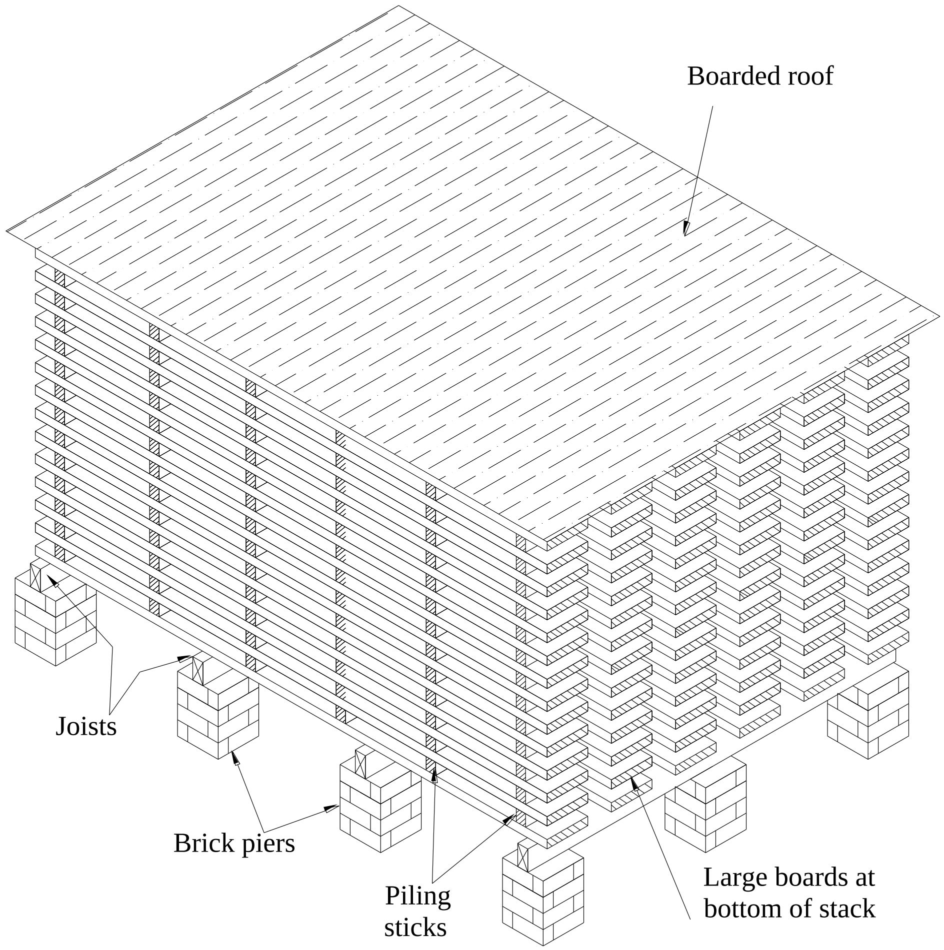


Fig 8.2a Timber stack

Hardwood can be seasoned in the same air-seasoning sheds but the boards should be stacked in the same order as they were cut from the log, as shown in **fig 8.2b**

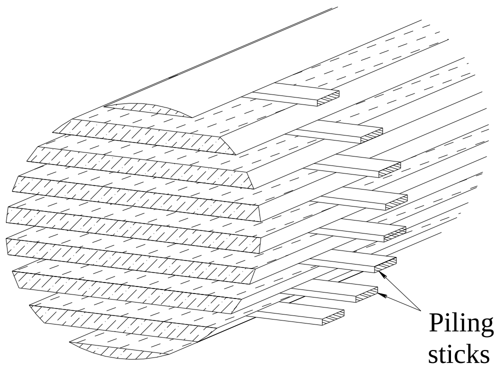


Fig 8.2b Hardwood stacked for seasoning

Kiln seasoning

Most timber for internal use is kiln seasoned, as this method, if carried out correctly, is able to safely reduce moisture content of the timber to any required level, without any danger or degrading (causing defects). Although timber can be completely kiln seasoned, sometimes when a sawmill has a low kiln capacity, the timber is air seasoned before being placed in the kiln for final seasoning. The length of time the timber needs to stay in the kiln normally varies between two days and six weeks according to the type and size of timber being seasoned.

There are two main types of kiln in general use:

1. The compartment kiln
2. The progressive kiln.

The compartment kiln: This is normally a brick or concrete building in which timber is stacked. The timber will remain stationary during the drying process, while the conditions of the air are adjusted to the correct levels as the drying progresses.

Note: The timber should be stacked in the same way as that used for air seasoning.

Fig 8.2c shows a section through a compartment kiln in which the drying of the timber depends on three factors:

1. Air circulation, which is supplied by fans.
2. Heat, which is normally supplied by heating coils through which steam flows.
3. Humidity (moisture content of the air). Steam sprays are used for raising the humidity. They are installed along the whole length of the compartment.

The progressive kiln: This is a tunnel full of open trucks containing timber that are progressively moved forward from the loading end to the discharge end. The drying conditions in the kiln become progressively more severe so that the loads at the different distances from the loading end are at different stages of drying. Progressive kilns are mainly used in situations where there is need for continuous supply of timber.

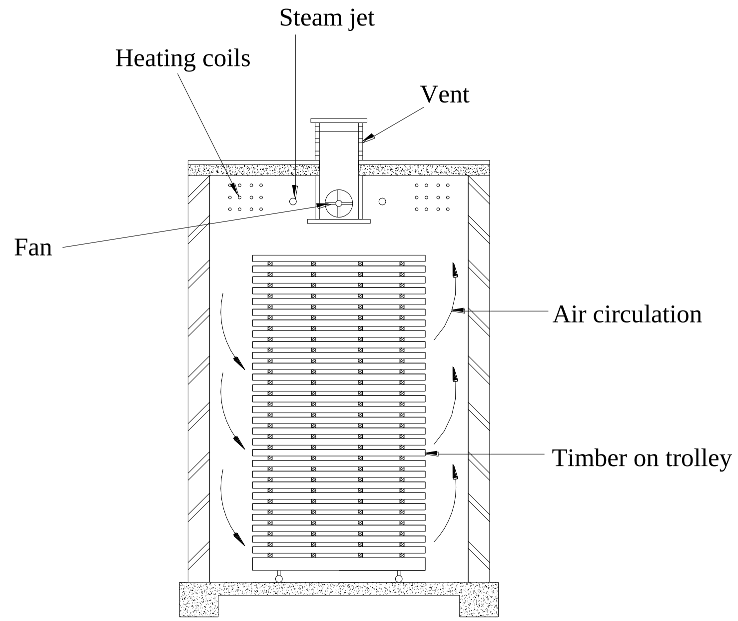


Fig 8.2c Compartment kiln

Storage of seasoned timber

Since the seasoning of timber is a reversible process, great care must be taken in the storage of seasoned timber. Carcassing and external joinery timber that is delivered on the site at an early stage should be stacked clear of the ground using piling sticks between each layer and then covered with water proof tarpaulins.

Internal joinery or low moisture timber should not be delivered or installed before the building is fully glazed and its heating system in operation so as to maintain a low humidity.

Defects in timber:

Timber is subject to many defects, which should, as far as possible, be cut out during its conversion. These defects can be divided into two groups:
1) Seasoning defects
2) Natural defects

Seasoning defects:
Fig 8.3a shows a number of timber defects that are as a result of poor seasoning of timber and these include the following;

1. **Bowing:** This is a curvature along the face of a board, and often occurs where insufficient piling sticks are used during seasoning.
2. **Springing:** This is a curvature along the edge of the board where the face remains flat. It is often caused through bad conversion of curved grain.
3. **Winding:** This is a twisting of the board and often occurs in timber, which is not converted parallel to the pith of the tree.
4. **Cupping:** This is a curvature across the width of the board and is due to the fact that timber shrinks more tangentially than it does radially.
5. **Shaking:** These are splits which develop along the grain of a piece of timber particularly as it ends, and is the result of the surface or ends of the timber drying out too fast during seasoning.
6. **Collapse:** This is also known as wash boarding and is caused by cells collapsing through being kiln dried too rapidly.
7. **Case hardening:** This is also the result of too rapid kiln drying. In this case the outside of the board is dry but moisture is trapped in the center cells of the timber. This defect is not apparent until the board is re-sawn when it will tend to twist.

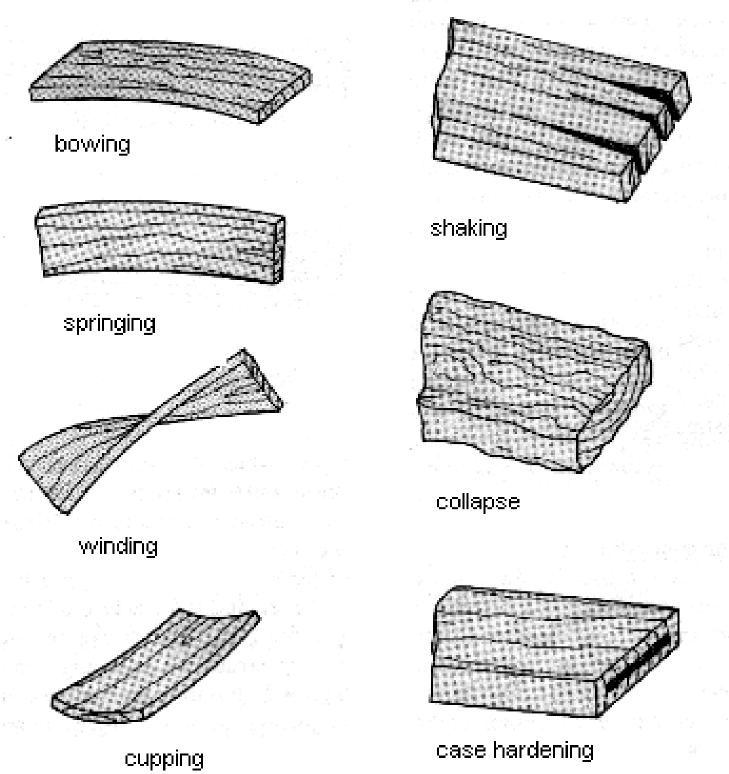


Fig 8.3a Seasoning defects

Natural defects in timber

Fig 8.3b shows a number of natural timber defects that are as a result of the natural growing of the tree. These defects include the following;

1. **Heart shakes:** These are splits along the heart of a tree and are probably due to over-maturity.
2. **Star shakes:** These are a number of heart shakes, which form an approximate star.
3. **Radial shakes:** These are splits along the outside of the log, which are caused by the rapid drying of the outside of the log before it is converted.

4. **Cup shakes:** This is a separation between the annual rings and is normally the result of a lack of nutrients. It is also caused by the rising sap freezing during early spring cold spells.
5. **Waney edge:** This is where the bark is left on the edge of converted timber and is the result of too economical a conversion.
6. **Knots:** These are the end sections of branches where they grow out of the trunk. Knots can be considered as being either sound, i.e. knots which are firm in their socket and show no signs of decay, or dead, i.e. knots which have become loose in their sockets or show signs of decay. All knots can be a serious defect in timber but this is especially true of dead knots. The presence of knots on the surface of a piece of timber often causes difficulties when finishing because of the distorted grain that the knots cause. Although mainly considered to be a defect, knots are sometimes used to provide a decorative feature, e.g. knotty pine cladding.
7. **Upsets:** This defect is also known as thunder shake and is a fracture of the timber fibres across the grain. Upsets can be caused by the tree being struck by lightening some time during growth, but they are mainly caused by the severed jarring the tree receives when being felled. This is a serious defect, which is most common in mahogany and is not apparent until the timber has been planed.
8. **Sloping grain:** This is where the grain does not run parallel to the edge of the board and is often caused by bad conversion. When the sloping grain is pronounced, the defect is called short graining. This seriously affects the strength of the timber and it should not be used for structural work.
9. **Sap stain:** This is also known as blue sap stain of blueing and often occurs in felled logs while still in the forest. It can also occur in damp timber that has been improperly stacked close together without piling sticks or with insufficient air circulation. The stain is the result of a harmless fungus feeding on the contents of the sapwood cells. No structural damage is caused by this fungus and it is only considered as a defect in timber that is to have a polish of clear varnish finish.

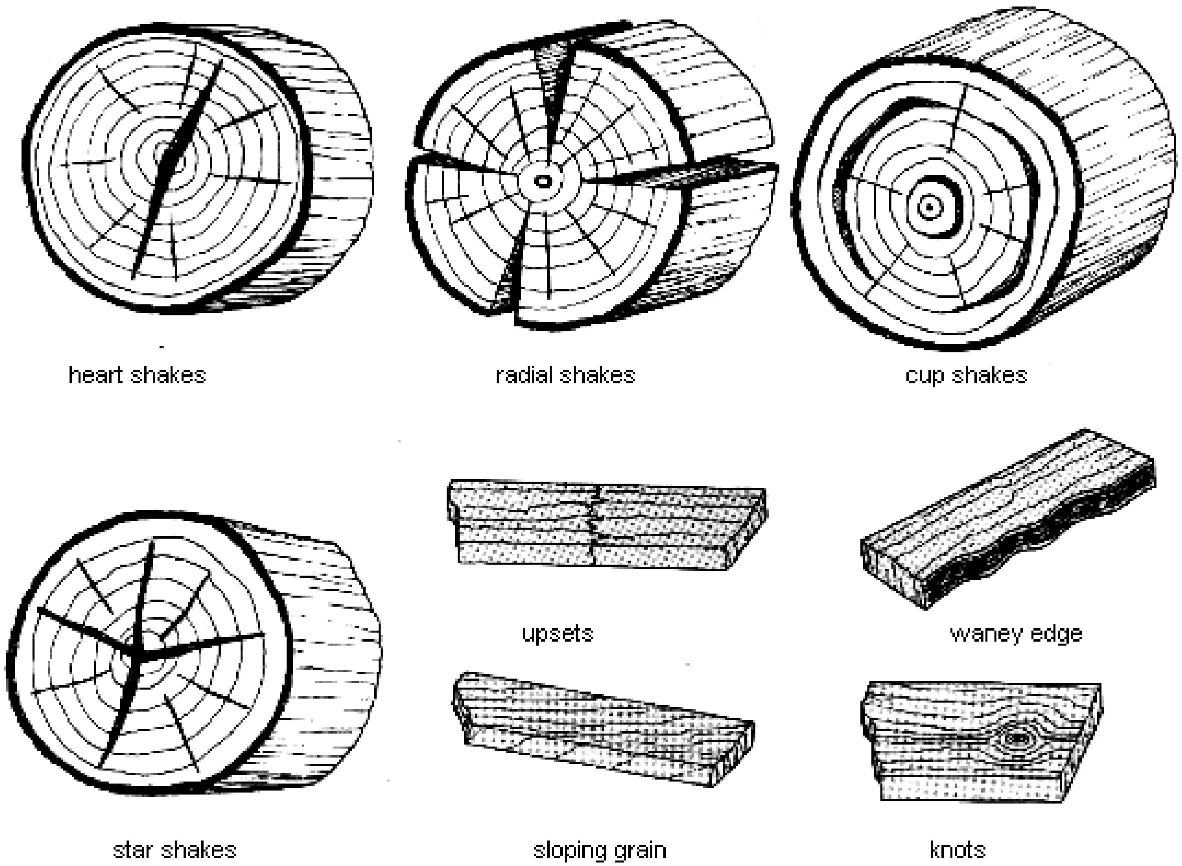


Fig 8.3b Natural defects

Decay of timber

The decay of timber is mainly caused by one or both of the following:

a) An attack by wood-destroying fungi
b) An attack by wood-boring insects.

Dry rot (weeping fungus)

This is the most common wood-destroying fungus known as *Merulius lacrymans* that is mainly found in damp conditions. As well as being the most common, it is also more serious and more difficult to eradicate than other fungus. It attacks the cellulose found mainly in sapwood causing the affected timber to:

a) Loose strength and weight
b) Develop cracks, both with and across the grain.
c) Become so dry and powdery that it can be easily crumbled in the hand.

The initial factors that will lead to an attack of dry rot in timber are:

a) *Damp timber*. Timber with a moisture content above 20 per cent.
b) *Bad or non-existent ventilation*. Where there is no circulation of air.

Prevention

By paying attention to the following points an attack of dry rot can be prevented.

a) Always keep all timber dry (even before fixing into the building)
b) Always ensure good ventilation
c) Always use well seasoned timber
d) Always use preservative-treated timbers in un-favorable or vulnerable positions.

Wet rot (cellar rot)

This is another common type of wood-destroying fungus known as *Coniophora cerebella* that is mainly found in wet conditions such as:

a) Neglected external joinery
b) Ends of rafters
c) Under leaking sinks or baths
d) Under impervious (waterproof) floor coverings

Prevention

Wet rot does not normally involve such drastic treatment to eliminate as dry rot since it does not spread to adjoining dry timber. What is needed is to cure the source of wetness and where the decay has become extensive, or where structural timber is affected some replacement will be necessary.

Preservation of timber

This is the poisoning of the food supply in the timber (especially in the sapwood) by applying a toxic liquid to it. This is intended to prevent the fungi and insects from attacking the timber.

The ideal requirements of a timber preservative are as follows:

1. It must be toxic to the fungi and insects, but safe to animals and humans.
2. It should be permanent and not be bleached out by sunshine or leached out by rain.
3. It should be economical and easy to obtain.
4. It should not corrode or affect metal in any way.
5. It should be easy to handle and apply.
6. It should as far as possible, be odourless.
7. It should not affect the subsequent finishing of the timber, e.g. painting or polishing.
8. It should be non-flammable.

Note: although these are the ideal requirements of a preservative, its important to note that most preservatives will not embody all of these points.

Types of preservatives

There are three main types of timber preservatives available and these are:

a) **Tar oils**. These are derived from coal and are dark brown or black in colour. They are fairly permanent, cheap, effective and easy to apply. However they should not be used internally as they are inflammable and possess a strong lingering odour. They should never be used near foodstuffs, as the odour will contaminate them. The timber once treated will not accept any further finish e.g. it cannot be painted. Its main uses are for the treatment of external timber such as fences, sheds, telegraph poles, etc.

b) **Water-soluble preservatives.** These are toxic chemicals which are mixed with water. They are suitable for use in both internal and external situations. The wood can be painted subsequently and they are odourless and non-flammable.

c) **Organic solvent preservatives.** These consist of toxic chemicals which are mixed with a spirit that evaporates after the preservative has been applied. The use and characteristics of these types of preservatives are similar to those of water-soluble preservatives. However some of the solvents used are inflammable and some have a strong odour. In general, these preservatives are the most expensive type to use but are normally considered to be superior because of their excellent preservation properties.

Methods of application

To a large extent it's the method of application rather than the preservative that governs the degree of protection obtained. This is because each method of application gives a different depth of preservative penetration and the greater the depth of penetration the higher the degree of protection.

The methods of application can be classed in two groups:

a) Non-pressure treatment, e.g. brushing, spraying, dipping and steeping.
b) Pressure treatment, e.g. empty-cell process and full-cell process.

Non-pressure treatments

1. **Brushing.** The preservative is just brushed on giving very limited penetration of the preservative into the timber.
2. **Spraying.** The preservative is sprayed on giving limited penetration of the preservative into the timber.
3. **Dipping.** Timber is immersed in a container full of preservative and after a certain length of time the timber is taken out and allowed to drain. The depth of penetration depends upon the length of time that the timber is immersed.
4. **Steeping.** This is known as the hot and cold method. The timber is immersed in large tanks containing the preservative which is heated for about two hours and then allowed to cool. As the preservative is heated the air in the cells of the timber expands and escapes as bubbles to the surface. On cooling the preservative is sucked into the spaces left by the air. Fairly good penetration can be achieved making this by far the best non-pressure method.

Pressure treatments

This is the most effective form of timber preservation as full penetration of the cells is achieved. It includes the following:

1. **Empty-cell process.** The timber is placed in a sealed cylinder. The air in the cylinder is then subjected to pressure which causes the air in the timber cells to compress. At this stage the preservative is run into the cylinder and the pressure increased further forcing the preservative into the timber. The pressure is maintained at this high level until the required amount of penetration is achieved. The pressure is then released and the surplus preservative is pumped back into a storage container. As the air pressure is reduced, the compressed air in the cells expands and forces out most of the preservative, leaving only the cell walls coated.
2. **Full-cell process.** The timber is placed into the sealed cylinder as before but this time, instead of compressing the air, it is drawn out. This creates a vacuum in the cylinder, as well as a partial vacuum

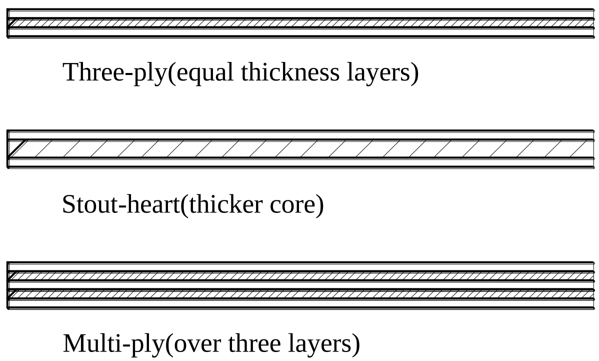
in the cells of the timber. At this stage the preservative is introduced into the cylinder. When the cylinder is full, the vacuum is released and the preservative is sucked into the timber cells by the partial vacuum. This method is ideal for timbers which are to be used in wet locations e.g. marine work, docks, piers, jetties, etc. as water cannot penetrate into the timbers cells because they are already full of preservative.

Timber-based manufactured boards

The main types of timber-based manufactured boards used in the building industry are:

1. Plywood
2. Laminated boards
3. Chipboards
4. Fireboards

1. **Plywood.** These consist of an odd number of thin layers of timber with their grains alternating across and along the panel or sheet. These are then glued together to form a strong board that will retain its shape and not have a tendency to shrink, expand or distort. **Fig 8.4a** shows three types of plywood.
2. **Laminated boards.** These consist of strips of wood, which are laminated together and sandwiched between two veneers. The width of the strips varies with each type of board. **See fig 8.4b**
3. **Chipboard.** This is manufactured mostly from soft woods and is also known as particleboard. It's made up of a mixture of wood chips and wood flakes, which are impregnated with resin. They are then pressed to form a flat, smooth-surfaced board.
4. **Fibreboards.** These are manufactured from pulped wood, which is mixed with an adhesive and pressed into sheets to the required thickness. They include hardboards and insulating boards.



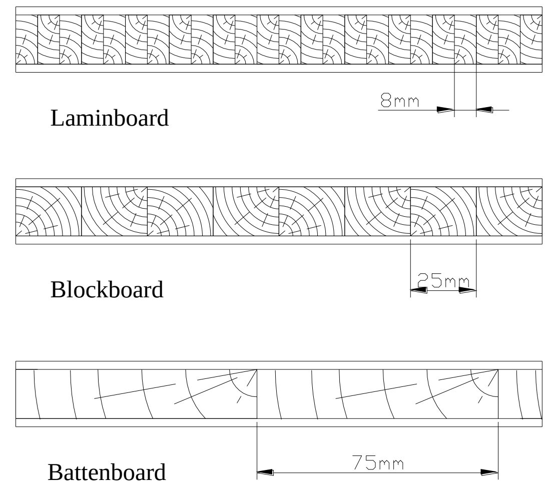


Fig 8.4a Types of plywood

Fig 8.4b Types of laminated boards

EXERCISE

1(a) Name two families of timber and give two examples of each

(b) Give reasons why it is necessary to preserve timber before use

(c) Sketch and describe the causes of the following timber defects

- (i) Cup shake
- (ii) End shake
- (iii) Shrinkage away from the heart
- (iv) Knots.

2(a) What is timber

(b) (i) Why should timber be seasoned

(ii) Choose any method of seasoning and describe how the operation is done

(d) Why is timber used in construction

3(a) Explain why structured timber should be properly seasoned.

(b) Discuss briefly the process of kiln seasoning and air seasoning.

(c) Write short notes on the following timber products:

(i) Plywood (ii) Fibre board (iii) Block boards

CHAPTER 9

ROOFS

A roof is a protective covering to the upper surface of a building.

Functions of a roof

Building regulations require roofs to perform a number of functions and some of the more important are listed and described.

a) *Weather resistance.* The roof of a building should resist the passage of moisture to the inside of the building. It should also keep out rain, wind, snow and dust.
b) *Strength.* The roof structure or framework must be of adequate strength to carry its own weight together with the super-imposed loads of snow, wind and foot traffic.
c) *Durability.* The coverings should be able to withstand atmospheric pollution, frost and other harmful conditions. There should also be effective means for the speedy removal of rainwater from the roof, which might otherwise cause deterioration of the roof covering. With large concrete roofs and sheet-metal coverings provision must be made to accommodate thermal expansion.
d) *Fire resistance.* The roof of a building should resist the spread of fire over the roof and from one building to another.
e) *Insulation.* The roof should reduce heat losses to an acceptable level and prevent excessive solar heat gains in hot weather, thus ensuring a reasonable standard of comfort within the building.
f) *Condensation.* Adequate provision should be made to prevent excessive condensation in a roof or in a roof void above an insulated ceiling.
g) *Appearance.* The roof design has an important influence on the aesthetics (beauty) of the building both in regard to the form and shape of the roof, and as to the colour and texture of the covering material.

Choice of roof types

There is a wide range of roof types available and the choice may be influenced by the following factors.

a) *Size and shape of buildings.* Buildings of simple shape are readily covered with pitched roofs; whereas flat roofs are better suited for irregular shaped buildings.

b) *Appearance.* Aesthetic considerations may dictate a pitched roof for a small building and a flat roof for a large building.

c) *Economics.* Both capital and maintenance costs should be considered in selecting a roof type. Some roof coverings like zinc may not last the life of the building and therefore their replacement costs must be included in the overall calculations.

d) *Other considerations.* Other factors to be considered include the ease with which services can be accommodated in the roof space, weatherproofing, condensation, maintenance and similar matters.

Types of roofs:

The most common types of roofs are:

1. The flat roofs.
2. The pitched roofs (lean-to roofs, gable-end roofs and hipped-end roofs)

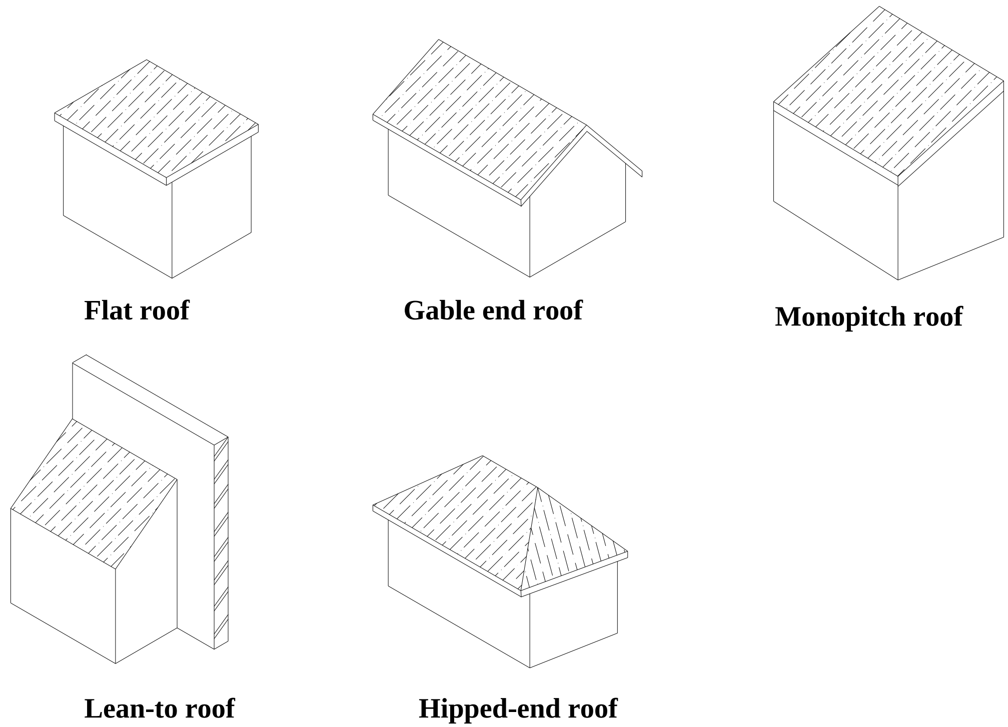


Fig 9.1a Types of roofs

Flat roofs

A flat roof is essentially a low-pitched roof with a pitch of 10^0 or less to the horizontal. These roofs are considered to be a simple form of construction, but unless if correctly designed and constructed they can be an endless source of trouble. The most common types of flat roofs are the timber flat roofs and the reinforced concrete slabs.

Advantages of a flat roof

1. They are a simple form of construction
2. They provide an extra area to a building for purposes of recreation.

Disadvantages of flat roofs

1. They are poor insulators against the transfer of heat.
2. They tend to give the low-rise building and an unfinished appearance.
3. Pools of water will collect on the surface causing local variations in temperature, which results in damage of the covering, and consequently high maintenance costs.

Timber flat roofs

This is a flat roof constructed of timber and covered with an impervious material to prevent rain penetration. This roof is usually constructed to fall in one direction towards a gutter or outlet and this is achieved by fixing ***firring pieces*** on top of the joists. **See fig 9.1b.**

Firring piece

This is a wedge shaped fillet fixed on top of a joist to provide the fall or slope to the roof. **See fig 9.1c**

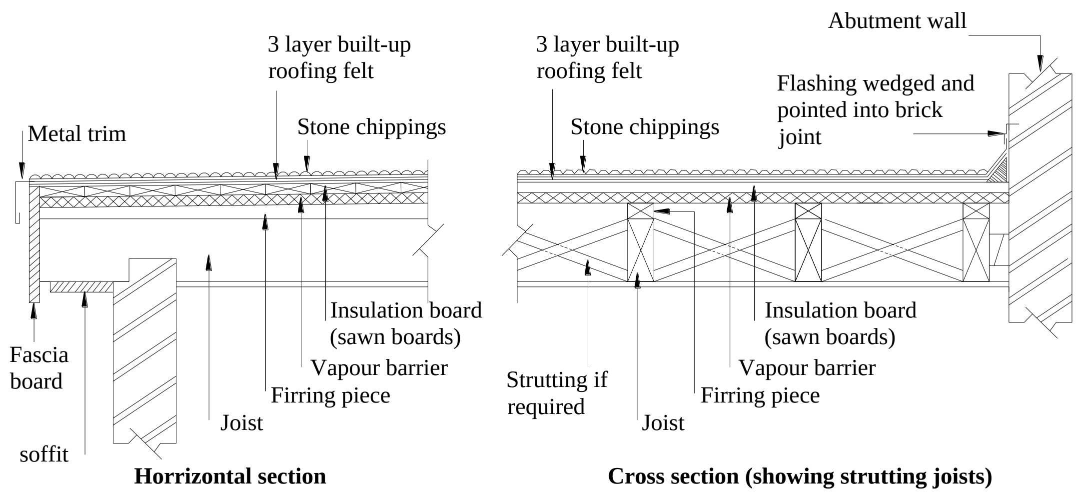
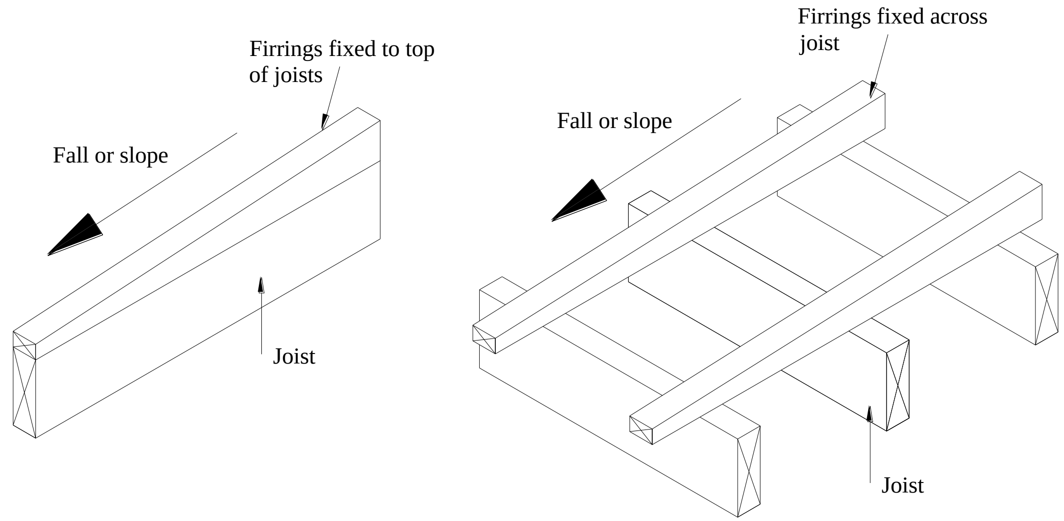


Fig 9.1b Timber flat roofs



Firrings fixed to top of joists **Firrings fixed across joists**

Fig 9.1c Firring pieces

Reinforced concrete flat roof:
This is a flat roof constructed of reinforced concrete and covered with built up roofing felt or asphalt covering to prevent the weather from damaging the concrete. **See fig 9.1d.**

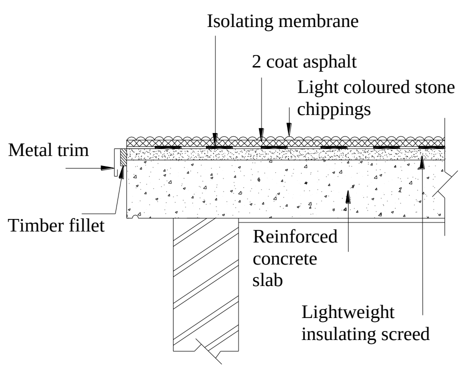


Fig 9.1d Reinforced concrete flat roof (with asphalt covering)

Pitched roofs

These are roofs whose angle of slope to the horizontal or pitch angle lies between 10^0 and 70^0, below this range it would be called a flat roof and above 70^0 it would be classified as a wall. Pitched roofs can be broadly classified into three main categories as follows:

a) Single roofs
b) Double roofs
c) Trussed or framed roofs

Single roofs

These are roofs whose rafters are supported at the ends only and do not require any immediate support. There are four types of single roofs and the type used is dependant upon the span of the roof. The four types are:

1. Lean-to roof.
2. Couple roof.
3. Closed couple roof.
4. Collar tie roof.

1. **Lean-to roofs**: These are mono-pitched roofs (only one sloping surface). They are mainly used for roofs to small single storey extensions. **See fig 9.2a**
2. **Couple roofs:** These are roofs with pairs of rafters fixed at one end to the wall plates and at the other to the ridge board. **See fig 9.2b**.

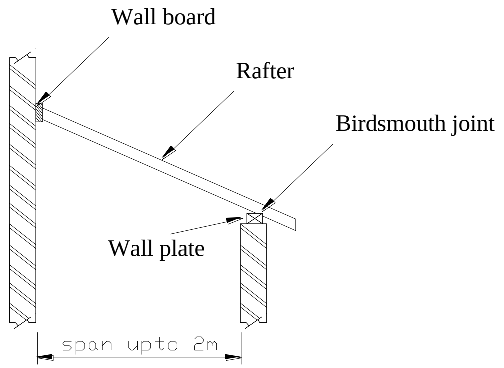


Fig 9.2a Lean-to roof

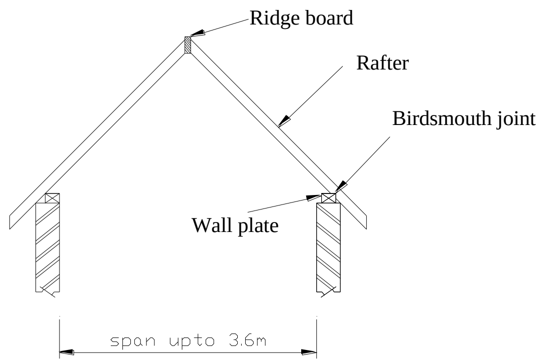


Fig 9.2b Couple roof

3. **Close couple roofs**: These are similar to the couple roofs but with the feet of the rafters closed with a tie. This enables the span to be increased. **See fig 9.2c**

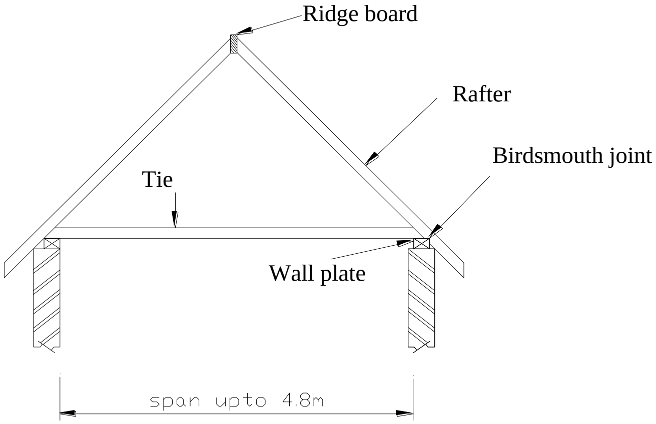


Fig 9.2c Close couple roof

4. **Collar tie roofs:** These are similar to the couple roofs, but in order to increase the span the tie is moved up the rafter to a maximum of one third of the rise. **See fig 9.2d**

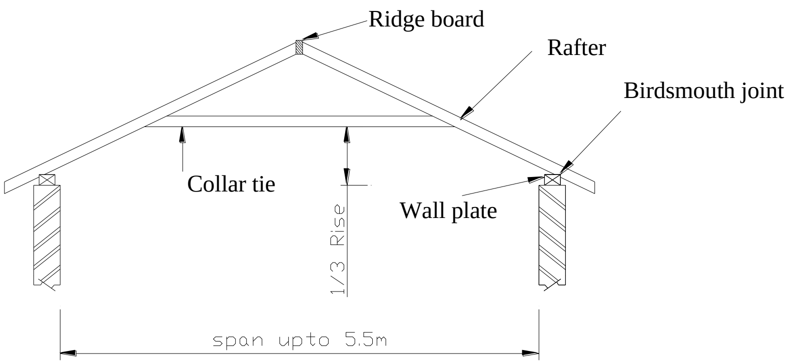


Fig 9.2d Collar tie roof

When the span exceeds 5m, single roofs are no longer suitable since their use would entail excessively large and uneconomical timbers.

Double roofs (purlin roofs)

These are roofs in which purlins are used to give intermediate support to rafters. The purlins are in turn supported by struts, which rest on load bearing partitions or ceiling beams. To further strengthen and stiffen the roof, collars may be provided at each fourth pair of rafters and for longer spans, the introduction of hangers with connections to the purlin and ceiling binders provides additional strengthening of the roof. A typical double or purlin roof is shown in **fig 9.3a**

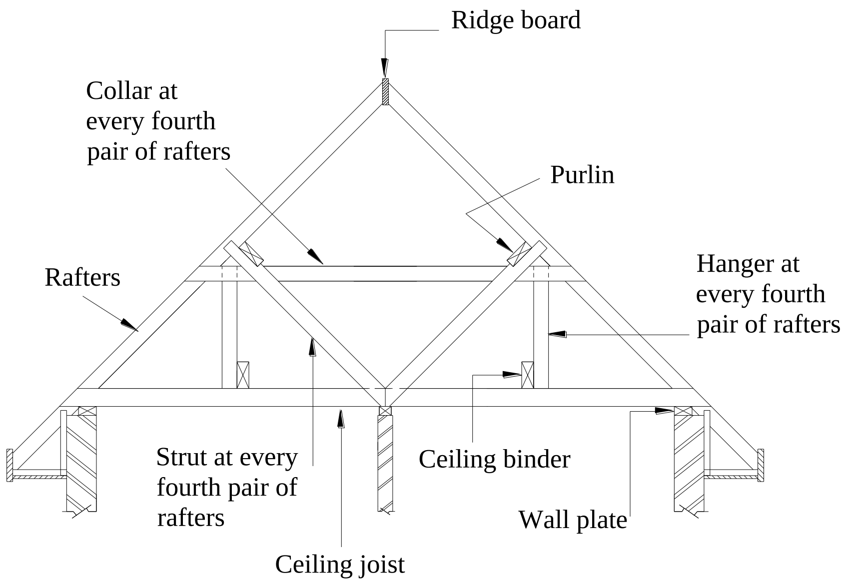


Fig 9.3a Double roof

Trussed or framed roofs

These are roofs mainly used over large spans (often in excess of 7.5m) where further support to purlins is provided in the form of roof trusses. In the earlier days these included the king post truss, queen post truss and the mansard truss. Although these trusses have now been superseded by the TRADA (Timber research and development association) timber and steel trusses, the student should be aware of the earlier trusses and the principles on which they were based.

a) *King post truss.* This was used for spans of 6 to 9m and consisted of a triangular frame, which supported the ridge and purlins. A strut was introduced under the midpoint of the principal rafter to prevent it sagging and the central post or king post prevented the tie beam from sagging and effectively stiffened and strengthened the truss. **See fig 9.4a**

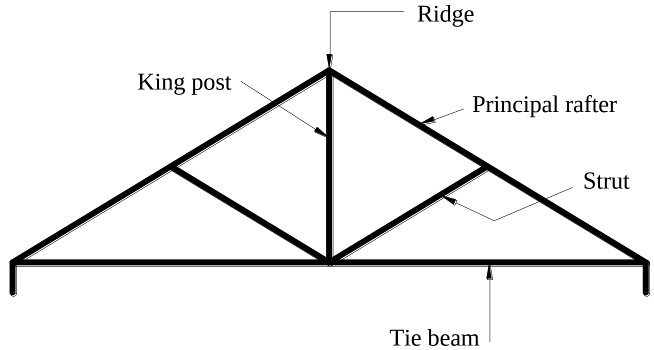


Fig 9.4a King post truss

b) *Queen post truss.* This was used for span of 9 to 12.75m and consisted of two vertical posts (queen posts), which are strutted apart at their heads by a straining beam. The principal rafters are supported by two purlins. **See fig 9.4b**

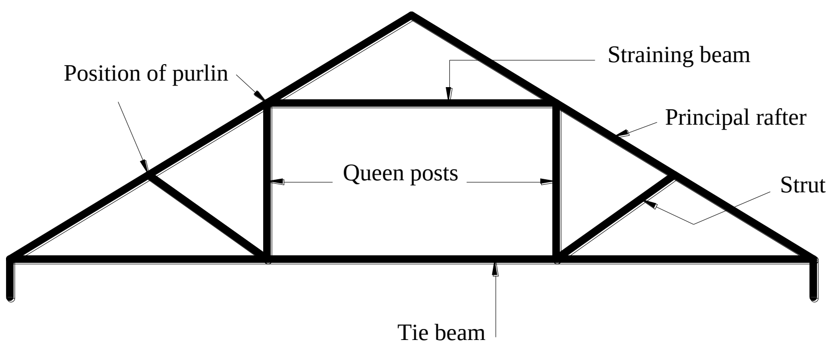


Fig 9.4b Queen post truss

c) *Mansard truss.* This incorporated both the king post and the queen post trusses and enabled accommodation to be provided in the roof space. The members of the roof trusses were arranged so that their centerlines intersected at joints. **See fig 9.4c**

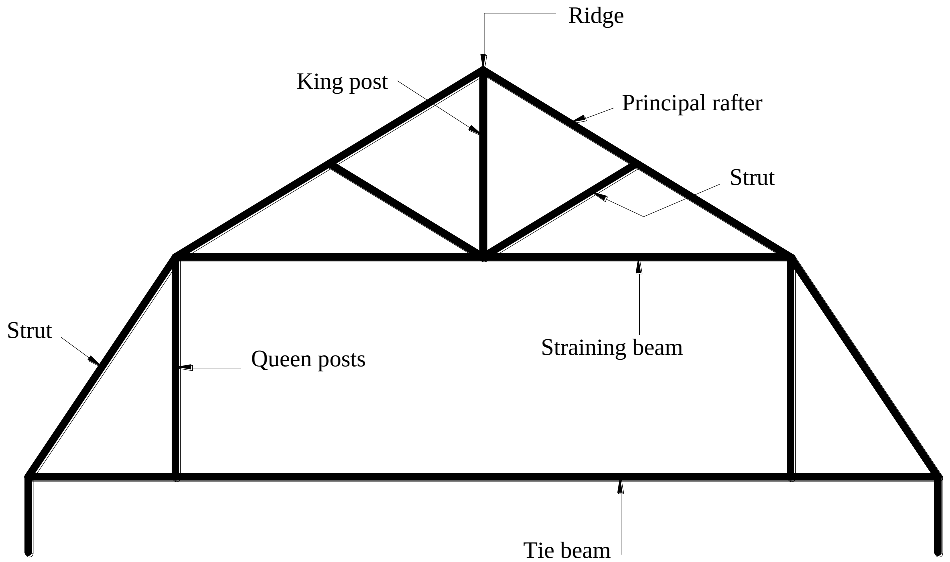


Fig 9.4c Mansard truss

TRADA roof trusses

The timber research and development association (TRADA) has designed standard timber trusses which are effective and dispense with the need for support from internal load bearing partitions, allowing greater flexibly in internal planning. These trusses are as follows:

a) *Timber truss*. These are structurally designed frames based on the principle of triangulation that are used on larger spans to give an area below the ceiling level that is free from load bearing partitions. The joints between truss members are formed with bolts and ***timber connectors*** *so as to make them rigid.* This truss is capable of supporting slates and tiles and the span can be up to 11m. **See fig 9.5a**

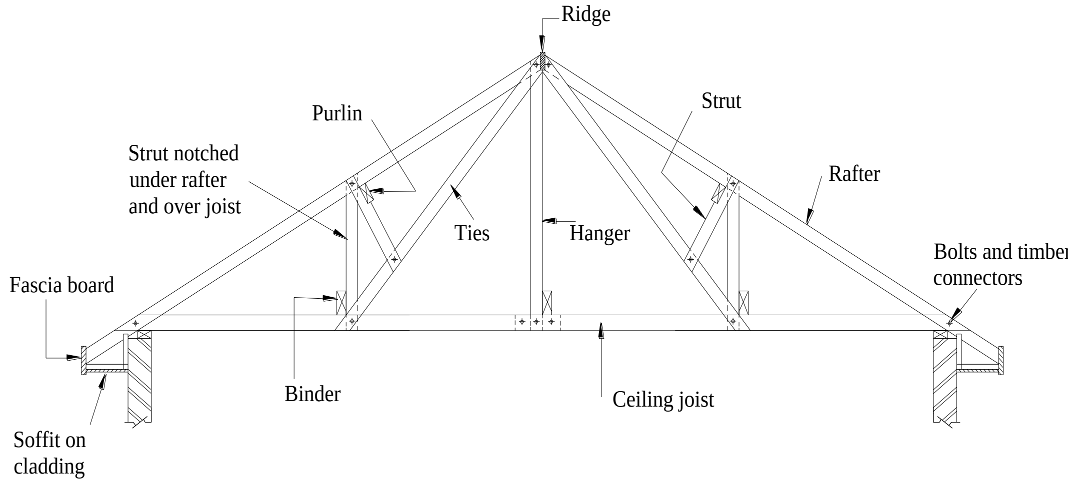


Fig 9.5a Timber truss

b) *Trussed rafters.* This is another approach to the formation of a timber roof giving a clear span and just like the timber truss it's based on the principle of triangulation. However in this case the members are but jointed and secured with ***truss plates*** or gusset plates of plywood. This truss is capable of supporting lightweight roof coverings and is suitable for spans of up to 6m. **See fig 9.5b**

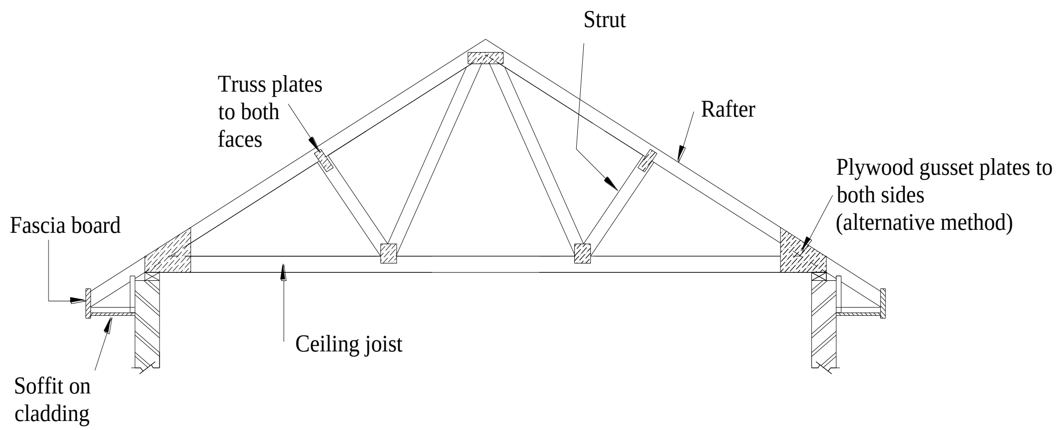


Fig 9.5b Trussed rafter

Timber connectors
These are square or circular toothed plates with teeth pointed up and down. When clamped between two timber members the teeth bite into the surface forming a strong connection and thereby spreading the stresses over a greater surface area. **See fig 9.5c**

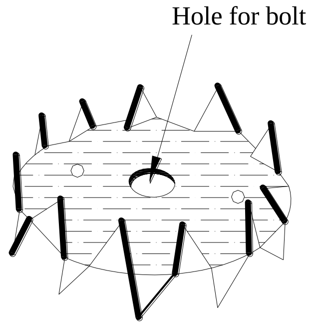


Fig 9.5cTimber connector

Truss plates (Nail plates)
These are of two types.

a) Plates with teeth that are punched and bent from the plate and are used in the factory assembly using heavy presses. **See fig 9.5d**
b) Plates with holes that are punched to take nails and are suitable for site assembly using a nailing gun. **See fig 9.5d**

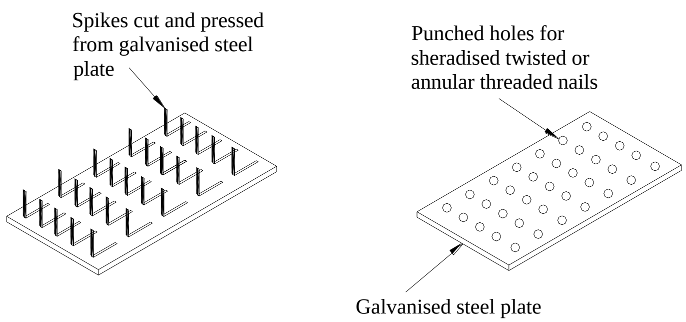


Fig 9.5dTruss plates

Steel roof trusses

These are constructed of mild steel angles, which are connected together with flat shaped plates called gussets. The members can be riveted, bolted or welded together to form a rigid triangulated truss

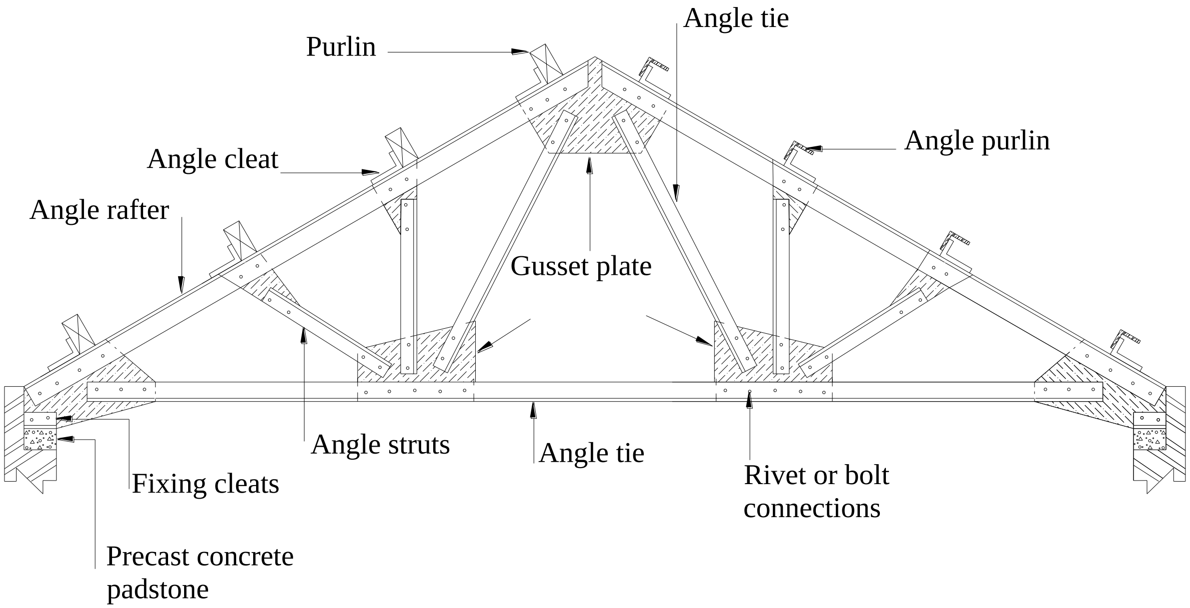


Fig 9.6a Mild steel roof truss

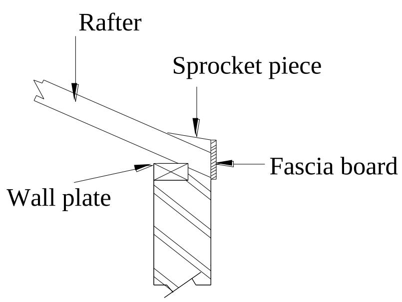
Eaves:

These are the lower ends of the rafters where they overhang the wall thus giving the wall a degree of protection and also providing the fixing medium for the rainwater gutter. There are three methods of finishing eaves in common use. **Fig 9.7a** shows the three methods, which include; flush eaves, open eaves and closed eaves. All the three eaves details have a sprocket pieces whose purpose is to reduce the pitch of the roof at the eaves and there by slowing down the flow of rain water off the roof reducing the tendency for it to overshoot the gutter. The use of sprocket pieces also adds to the appearance of the roof.

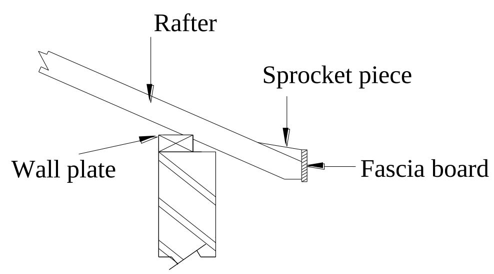
Roof coverings:

Covering materials to roof trusses should fulfill the following basic requirements:

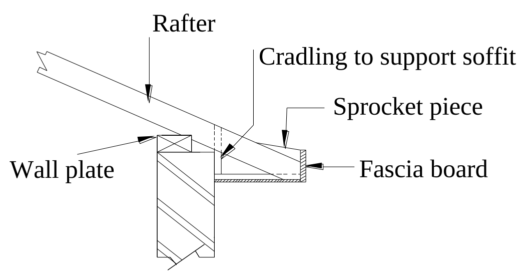
1. Sufficient strength to support imposed wind and snow loadings.
2. Resistance to the penetration of rain, wind and snow.
3. Low self weight, so that supporting members of an economic size can be used.
4. Reasonable standard of thermal insulation.
5. Acceptable fire resistance.
6. Durable to reduce the maintenance required during the anticipated life of the roof.



a) Flash eave



b) Open eave



c) Closed eave

Fig 9.7a Methods of finishing eaves

Types of roof coverings:
The types of roof coverings used in building are

1. Galvanised corrugated steel sheets

2. Plain tiles
3. Slates
4. Aluminium sheeting

NB. Corrugated asbestos cement has been banned as a roofing material through out the world because of its health related hazards.

Galvanised corrugated steel sheets

These sheets that are often referred to as corrugated iron sheets, are made of steel and coated with zinc a process known as galvanising. The sheets are secured to the purlins with nails, hook bolts, and drive screws or nuts. On exposure the galvanised coating oxidises, forming a thin protective film which is easily broken down by acids in the atmosphere and therefore to extend its life, the sheet should be regularly coated with paint containing a pigment of zinc dust, zinc oxide, calcium plumbate or zinc carbonate.

Advantages of corrugated steel sheets

1. Cheap to construct
2. Non-porous
3. Relatively strong and rigid

Disadvantages of corrugated steel sheets

1. Poor thermal insulation properties
2. Tend to buckle under typical fire conditions
3. They are noisy during rain

Tiles

These are made from clay or concrete by hand or machine and work upon the principle of either double or single lap. They are suitable for pitch angles between 35°-45° since a low pitch causes them to absorb water, expand and then fracture in cold weather. **See fig 9.8a**

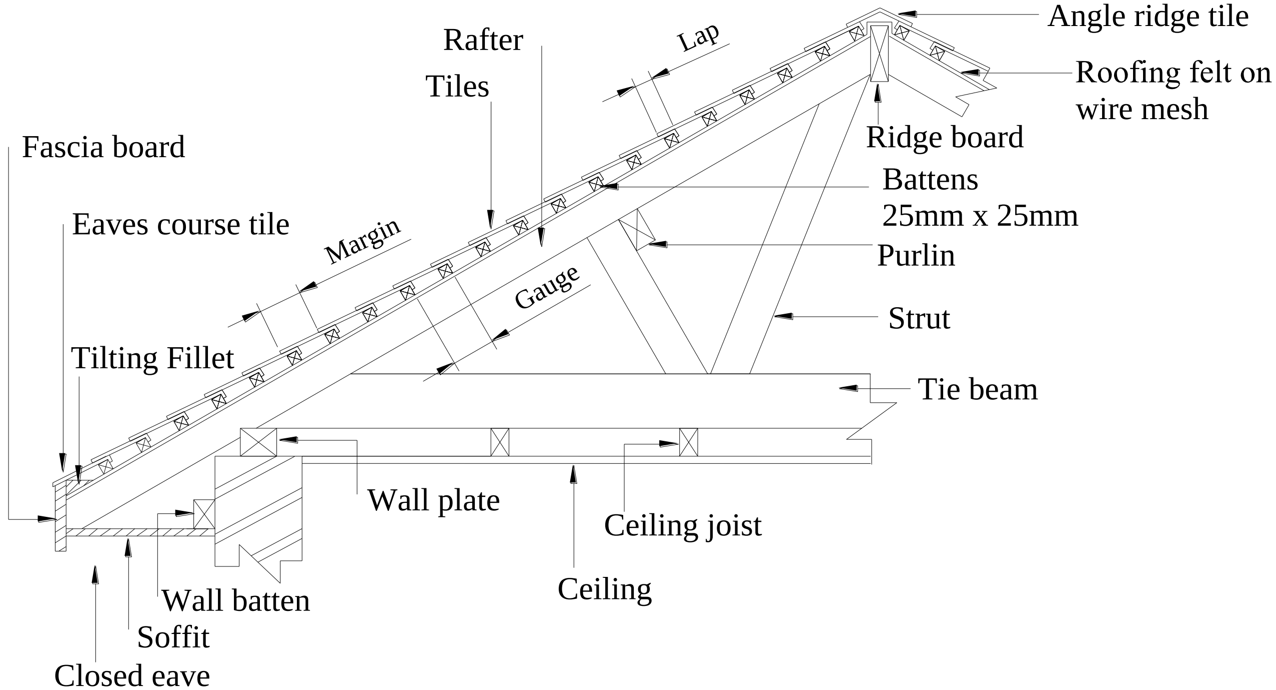


Fig 9.8a Tiles

Slates
These are naturally dense materials split into thin sheets that are twice nailed on to the battens and are laid to the same principle as tiles.

Aluminium sheeting
These sheets are made from an aluminium and manganese alloy, which gives a non-corrosive, non-combustible lightweight sheet. The sheets oxidise on the surface to form a protective film upon exposure to the atmosphere and therefore protective treatments are not necessary.

Roof terminology

Fig 9.9a shows a number of terms and members that have been commonly referred to in this chapter.

Ridge: This is the spine of a roof and is essentially a pitching plate for the rafters, which are nailed to each other through the ridge board.
Common rafters: These are the main load-bearing members of a roof, they span between a wall plate at eaves level and the ridge.
Jack rafters: These fulfill the same function as common rafters but span from ridge to valley rafter or from hip rafter to wall plate.
Hip rafters: These are similar to a ridge but form the spine of an external angle and are similar to a rafter spanning from ridge to wall plate.
Valley rafters: These are similar to the hip rafter but form an internal angle.
Wall plates: These provide the bearing and fixing medium for the various roof members and distribute the loads evenly over the supporting walls; they are bedded in cement mortar on top of the load-bearing walls.
Dragon ties: This is a tie place across the corners and over the wall plate to help provide resistance to the thrust of a hip rafter.
Ceiling joists: These fulfill the dual function of acting as ties to the feet of pairs of rafters and providing support for the ceiling boards on the underside and many cisterns housed within the roof void.
Purlins: These act as beams reducing the span of the rafters enabling an economic section to be used. If the roof has a gable end they can be supported on a corbel or built in but in a hipped roof they are mitred at the corners and act as a ring beam.
Struts: These are compression members that transfer the load of a purlin to a suitable load-bearing support within the span of the roof.
Collars: These are extra ties to give additional strength and are placed at purlin level.
Binders: These are beams used to give support to the ceiling joists and counter act excessive deflections and are used if the span of the ceiling joist exceeds 2400 mm.
Hangers: These are vertical members used to give support to the binders and allow an economic section to be used; they are included in the design if the span of the binder exceeds 3600 mm.
Fascia board: This is the horizontal board that is fixed to the ends of the rafters. It provides a finish to the eaves and a fixing for the guttering.
Soffit: This is the boarding used to close the gap between the fascia board and the wall.
Verge: This is the sloping edge of the roof where it over hangs the gable wall.
Gable: This is the triangular section of brickwork at the end of a pitched roof.
Barge board: This is the continuation of the fascia board around the verge.
Pitch angle: This is the slope of the roof's surface

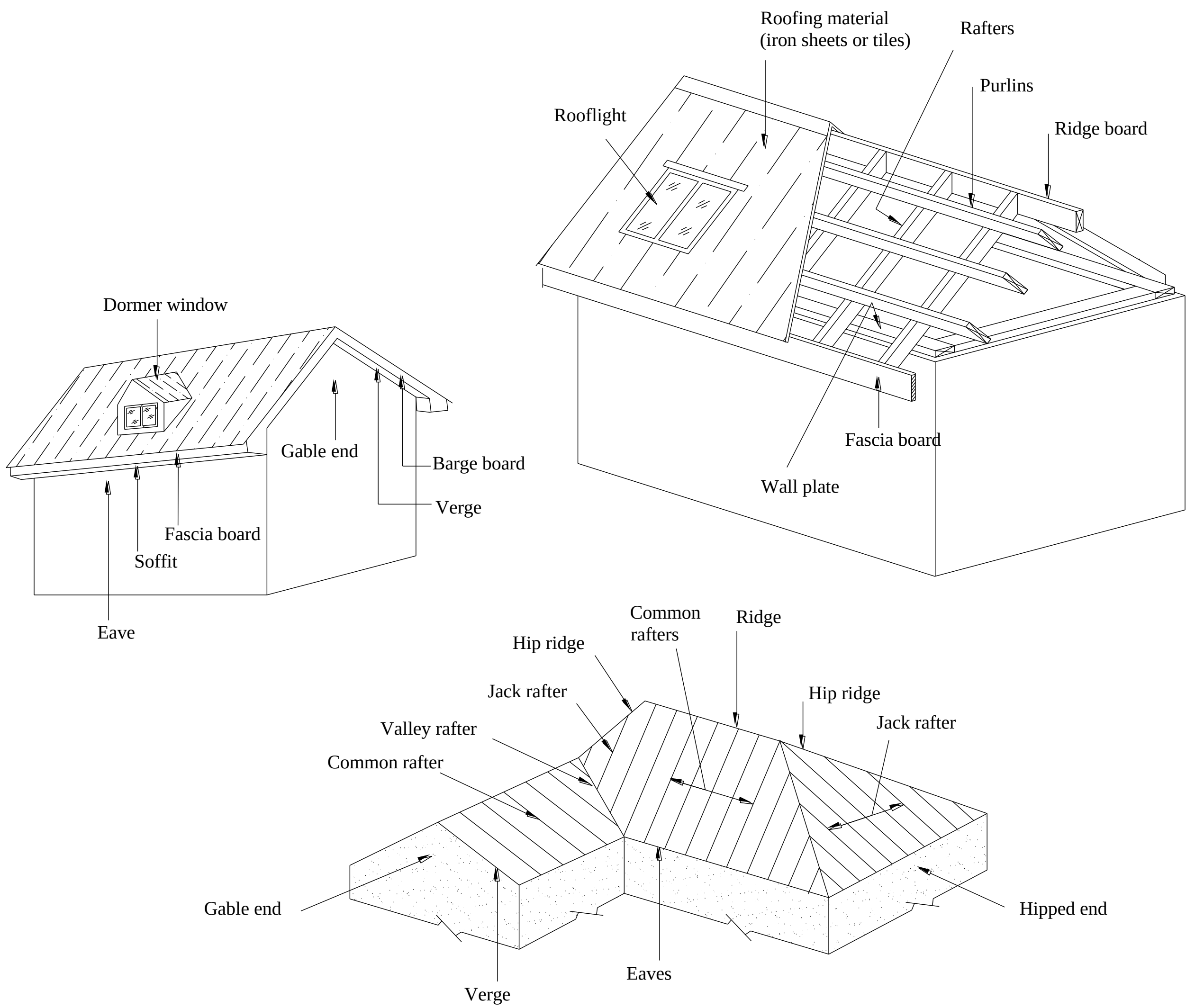


Fig 9.9a Roof terminologies

Joints used in pitched roofs

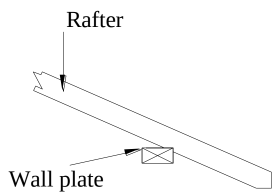
Birds mouth joint
This joint is used between the rafters and the wall plate. The bird's mouth is a combination of a plumb and a seat cut, which is taken out one-third the depth of the rafter. The joint is fastened by tosh nailing with wire nails. **See fig 9.10a (a)**

Butt joint
This joint is used between the rafters and the ridge board. The angle of the joint is a plumb cut. The joint is fastened with wire nails. **See fig 9.10a (b)**

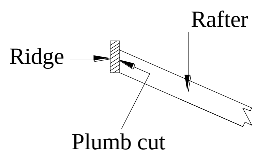
Scarf or half lapped joint
This is a joint used to lengthen wall plates. It is fastened with either 50 mm wire nails or preferably screws. **See fig 9.10a (c).**

Splayed scarf joint
This joint is used to lengthen the ridge board. The proportions of the joint are shown. It is tightened by the use of folding wedges. **See fig 11.6a (d).**

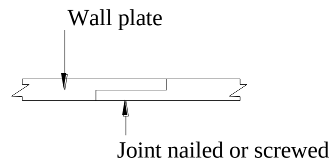
Splayed dovetail joint
This joint is used between the rafters and the collar tie. It is best fastened by the use of a bolt and timber connectors, but it is often fastened with wire nails. **See fig 9.10a (e)**



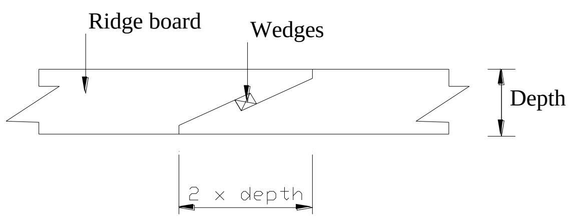
a) Birds mouth joint



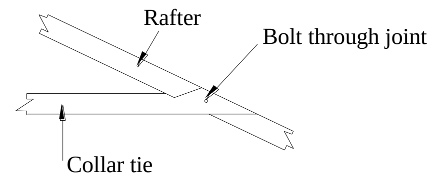
b) But joint



c) Half-lapped joint



d) Splayed scarf joint



e) Splayed dovetail joint

Fig 9.10a Roofing joints

EXERCISE

1(a) State the function of a Roof structure

(b) (i) List any five roofing materials

(ii) Briefly discuss any for roofing materials from the list in (i) above.

(c) Sketch a line diagram of a steel truss for a span of 6 meters

(d) Sketch the detail at the apex of a steel truss in (c) above, show the arrangement of the members used and name them.

2(a) Describe each of the following roof structures:

(i) Flat roof (ii) Gable roof (iii) Hipped roof

(b) Explain the following terms as related to roof construction:

(i) Timber connector (iv) Fascia board

(ii) Truss plate (v) Barge board

(iii) Eave

(c) Draw a portion of a roof structure covered with tiles and show the following:

(i) Lap	(iii) Margin	(v) Rafter
(ii) Gauge	(iv) Batten	(vi) Ridge piece

3(a) Illustrate, with simple sketches showing the following roof trusses:

(i) Couple roof (ii) Couple close roof (iii) Collar roof

(b) With the aid of a sketch draw a truss roof

(c) Draw a metal truss roof and label all the parts and their sizes

CHAPTER 10

FIREPLACES, CHIMNEYS AND FLUES

Fireplace

The primary objective of a fireplace is to heat the room in which it is placed it also often fulfills a secondary objective of providing a focal point in the living room or lounge of a dwelling. The fuels used for combustion are coal, smokeless fuels, oils, gas and wood.

To take maximum advantage of the heat the chimney should be built as part of an internal partition where its surrounded by inside air.

Domestic heating appliances are grouped into four main categories and these are as follows:

a) *Open fires without convection.* These are designed to radiate heat into the room from an open burning fire.
b) *Warm air heating appliances with natural convection.* These are designed to increase the efficiency of an open fire by passing back into the room warm air as well as the radiated heat from the burning fuel. The air in the chamber heats up and flows into the room by convection currents moving the air up and out of the opening at the top of the unit.
c) *Room heaters.* These are designed to burn smokeless fuels and operate as a closed unit. In some models the strip glass front is in fact a door and can therefore be opened to operate as an open fire.
d) *Independent boilers and freestanding cookers.* These are designed to heat water for the central heating system and may also provide hot water for domestic use. It is generally fixed in the kitchen because of the convenience to the plumbing pipe runs.

Principal requirements of a fireplace

Building regulations require a fireplace to fulfill the following principal requirements:

a) To secure maximum heat for the benefit of the occupants.
b) To take adequate precautions against spread of fire.
c) To ensure effective removal of smoke and avoidance of downdraught.

Conditions that can prevent the chimney operating satisfactorily

The following can prevent a chimney from operating satisfactorily

a) Insufficient air entering the room to replace that passing up the chimney.

b) Adverse flow conditions resulting from the poor design of passages through which the smoke passes (throat, gathering and flue)
c) Downdraught caused by the build-up of pressure at the top chimney top. This is influenced by the form of the building, neighboring buildings, trees and the topography of the site.

Terminology

Chimney breast
This is the projection of the structure accommodating the fireplace opening and flue into a room. The advantages of this projection are as follows:

a) The heated surfaces of the breast and chimney will transfer some heat to the inside by radiation and convection.
b) The projection (chimney breast) serves as a massive brick pier providing structural stability to the wall it's attached to.
c) The projecting breast will give some emphasis (center of attention) to the comparatively small fireplace opening.

Fireplace recess
This is the opening of a fireplace that houses the fire grate on which combustion of the fuel takes place. **See fig 10.1a**

Throat
This is the contracted part of the flue immediately above the fireplace opening. It is restricted in size (contraction) so as to accelerate the flow of the flue gases and to ensure adequate draught. **See fig 10.1a**

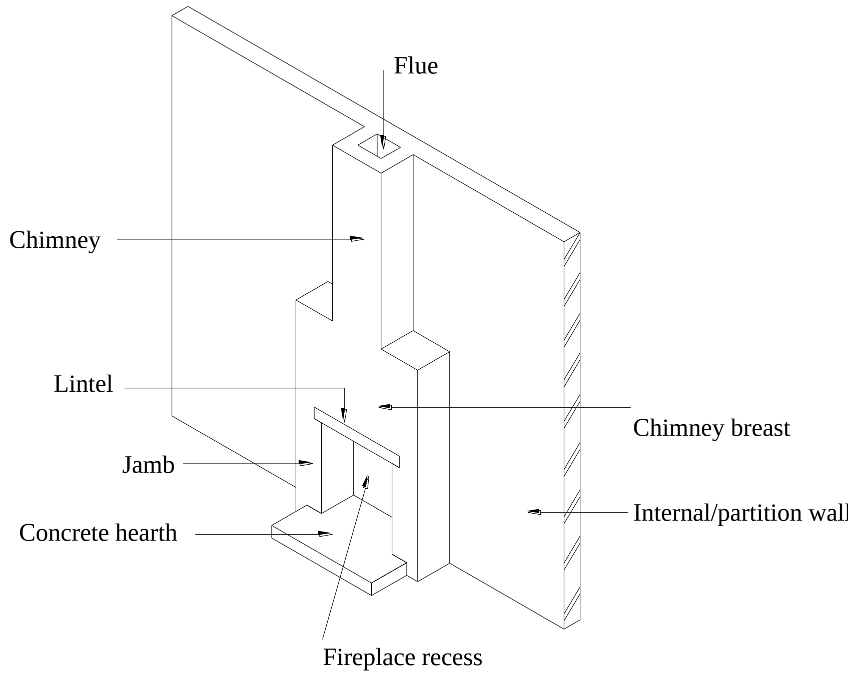


Fig 10.1a Chimney breast

Lintel

This is a pre-cast concrete unit that supports the brickwork load over the fireplace opening and transmits it to the fireplace jambs. **See fig 10.1a**

Jambs

These are piers or legs built on either side of the fireplace recess to support a brick arch or pre-cast concrete lintel. **See fig 10.1a**

Fireback

This is a material placed at the back of a fireplace whose functions are to contain the burning fuel, prevent the heat of the fire from burning the wall behind it and to radiate heat from the fire into the room. **See fig 10.1b**

Surrounds
This is the façade of a fireplace and its main function is to give an attractive appearance to the fireplace. It can be made of pre-cast concrete with an applied finish such as tiles and it's fixed by screws through lugs built into the edges of the fireplace. **See fig 10.1b**

Constructional hearth
This is the solid non-combustible base of a fireplace recess constructed of concrete and extending both under and in front of the opening. When formed on a solid concrete floor it becomes part of the normal floor construction and in case of a suspended timber floor it's supported on fender walls and hardcore stones. **See fig 10.1b**

Condensate
These are small droplets formed as heated products of combustion passing up the flue cool and condense on its surface. This condensate will combine with brick, block or stonework surrounding the flue to form water-soluble crystals which expand as they absorb water and may cause damage to the chimney and finishes such as plaster and paint. To avoid this damage, flue liners are built into the flue.

Flue liners
These are round or square linings with rounded corners built into flues as the chimney is raised so as to protect the flues from possible damage by the condensate, to encourage a free flow of air up the flue and to facilitate cleaning of the flue. **See fig 10.1b**

Chimney stack
This is the chimney brickwork that is raised above the roof to encourage the products of combustion to rise from the flue to the open air so as to avoid down draught. Building regulations require that the outlet of any chimney flue should be at least 1m above the top of any openable part of a window or skylight or any ventilator or similar opening which is in the roof or external wall. **See fig 10.1c**

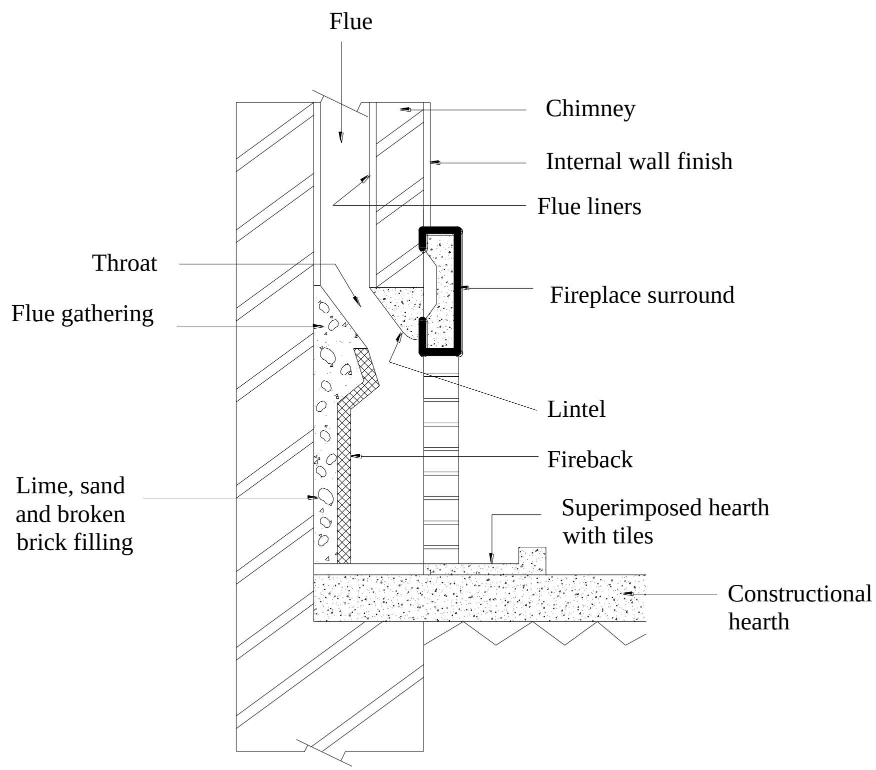


Fig 10.1b Section through fireplace

Chimney pots or terminals

These are either round or square section pots used as a traditional method of finishing the top of a brick chimney stack. They are used to provide a smooth sided outlet that encourages the outflow of combustion gases to the outside air and to provide a cover that protects the flue from the entry of rain or birds. **See fig 10.1c**

Oversailing courses

These are courses of bricks at the head of a chimney stack that project out at each course so as to protect the chimney stack from the effects of the weather. **See fig 10.1c**

Flaunching
This is the application of cement and sand mixes that are weathered to slope out around the chimney pots so as to provide resistance to the effects of the weather. **See fig 10.1c**

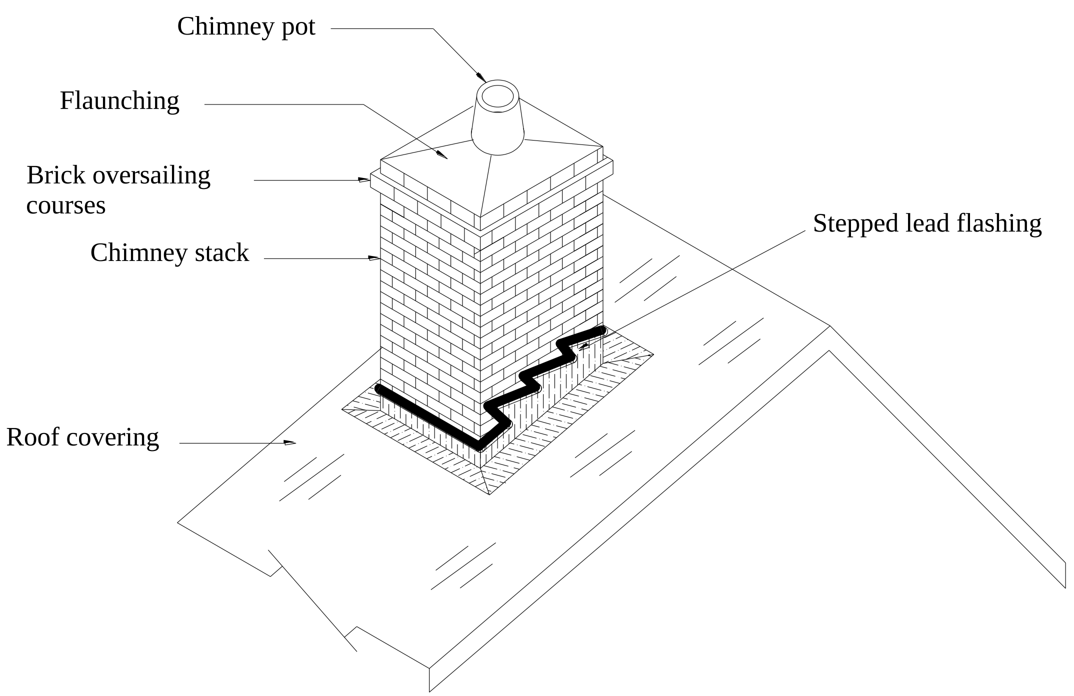


Fig 10.1c Chimney stack

Ashpit
This is a pit constructed below the firegrate to house a large ashpan capable of holding ash for several days.

Deep ashpit fire
This is a low front fire with a fret or grate being at or just below hearth level. The air necessary for combustion is introduced via the ash by means of a duct.

Weathering around chimneys

At the junction of roof coverings and chimney stacks it is necessary to provide some form of weathering to prevent the penetration of rain into the roof. This can be done in the following ways:

a) To form a fillet of coarse, sharp sand and cement spread and leveled up to the stack and down on the roof covering. The disadvantages of this system of weathering are that:
   i. The rigid cement and sand fillet will not accommodate the inevitable slight movements of the roof due to wind pressures, moisture and thermal movements.
   ii. The cement and sand fillet will suffer drying shrinkage and the crack.

b) To fix a system of lead stepped flashings that will accommodate movement between the roof and chimney stack. **See fig 10.1d**

Chimney stacks built of porous bricks or stone should be separated from the chimney below roof level by some form of damp proof course (dpc). A sheet of lead holed for flues should be built in to the chimney stack either in a horizontal course or stepped to coincide with the stepped lead flashings.

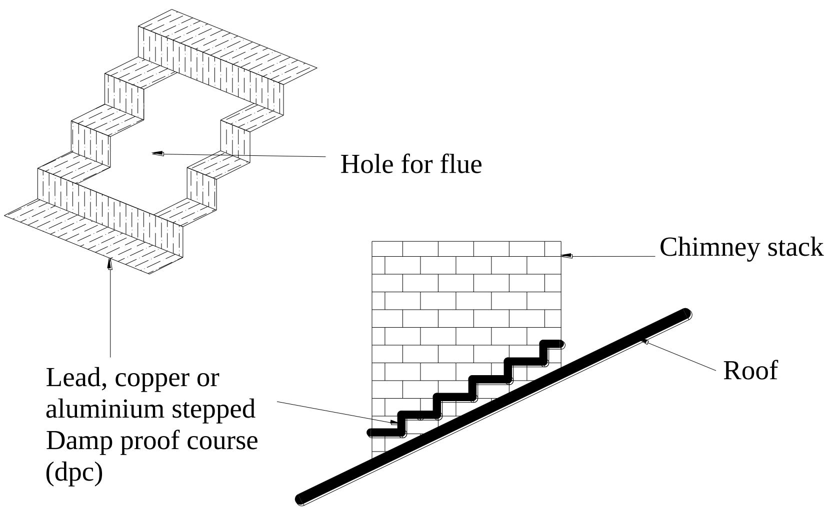


Fig 10.1d Damp proofing a chimney stack