# Module 1

## Building stones, bricks and tiles

# CHAPTER-1 STONES

## Introduction:

All the building structures are composed of different types of materials. These materials are either called building materials or materials of construction. It is very essential for a builder, may be an architecture or engineer or contractor, to become conversant thoroughly with these building materials. The knowledge of different types of material, their properties and uses for different purposes provides and important tool in the hands of the builders in achieving economy in material cost. The material cost in a building ranges 30 to 50 percent cost of total cost construction. In addition to material economy, the correct use of material results in better structural strength, functional efficiency and esthetic appearance

## Classification of Rocks:

Building stones are obtained from rocks occurring in nature and classified in three ways.

1. Geological classification
2. Physical classification
3. Chemical classification

## I. Geological Classification:

According to this classification, the rocks are of the following type.

a. **Igneous rocks:** Rocks that are formed by cooling of Magana (molten or pasty rocky material) are known as igneousrocks. Eg: Granite, Basalt and Dolerite etc.

b. **Sedimentary rocks:** these rocks are formed by the deposition of production of weathering on the pre-existing rocks. Examples: gravel, sandstone, limestone, gypsum, lignite etc.

c. **Metamorphic rocks.** These rocks are formed by the change in character of the pre-existing rocks. Igneous as well as sedimentary rocks are changed in character when they are subject to great heat and pressure. Known as metamorphism. Examples: Quartzite, Schist, Slate, Marble and Gneisses.

## II. Physical Classification:

This classification based on general structure of rocks.

According to this, the rocks are classified into three types

a. **Stratified Rocks:** These rocks posses planes of stratification or cleavage and such rocks can be easily split along these planes
Ex: sedimentary rocks

b. **An stratified rocks:** The structure may be crystalline granular or compact granular. Examples: Igneous rocks and Sedimentary rocks affected by movements of the earth.

c. **Foliated Rocks:** These rocks have a tendency to split up in a definite direction only. Ex: Metamorphic rocks.

## III. Chemical Classification:

According to this classification rocks are classified into three types.

a. **Siliceous rocks:** In these rocks, silica is predominates. The rocks are hard; durable and not easily effected by weathering agencies. Ex: Granite, Quartzite, etc.

b. **Argillaceous Rocks:** In these rocks, clay predominates. The rocks may be dense and compact or may be soft.

Ex: slates, Laterites etc.

c. **Calcareous rocks:** In these rocks, calcium carbonate predominates. The durability to these rocks will depend upon the constituents present in surrounding atmosphere. Ex: Lime Stone, marble etc.

## Uses of stones:

1. **Structure**: Stones are used for foundations, walls, columns, lintels, arches, roofs, floors, damp proof course etc.
2. **Face works.** Stones are adopted to give massive appearance to the structure. Wall are of bricks and facing is done in stones of desired shades. This is known as composite masonry.
3. **Paving stones:** These are used to cover floor of building of various types such as residential, commercial, industrial etc. They are also adopted to form paving of roads, foot paths etc.
4. **Basic material**: Stones are disintegrated and converted to form a basic material for cement concrete, morum of roads, calcareous cements, artificial stones, hallow blocks etc.
5. **Misalliances**: Stones are also used for (i) ballast for railways (ii) flux in blast furnace (iii) Blocks in the construction of bridges, piers, abutments, retaining walls, light houses, dams etc.

**Qualities of a good building stone:**

The following are the qualities or requirements of a good building stone.

1. **Crushing strength:** For a good building stone, the crushing strength should be greater than l000kg per $cm^2$.
2. **Appearance**: Good building stone should be a uniform colour, and free from clay holes, spots of other colour bands etc capable of preserving the colour for longtime.
3. **Durability**: A good building stone should be durable. The factors like heat and cold alternative wet and dry, dissolved gases in rain, high wind velocity etc affect the durability.
4. **Fracture**: For good building stone its fracture should be sharp, even and clear.
5. **Hardness**: The hardness greater than 17, treated as hard used in road works. It is between 14 to 17, medium hardness, less 14 said be poor hardness.
6. **Percentage wear**: For a good building stone, the percentage wear should be equal to or less then 3 percent.
7. **Resistance to fire**: A good building stone be fire proof. Sandstone, Argillaceous stone resists fire quite well
8. **Specific gravity**: For a good building stone the specific gravity should be greater then 8.7 or so.
9. **Texture**: A good building stone should have compact fine crystalline structure should be free from cavities, cracks or patches of stuff or loose material.
10. **Water absorption:** For a good building stone, the percentage absorption by weight after 24 hours should not exceed 0.60.
11. **Seasoning**: Stones should be well seasoned before putting into use. A period of about 6 to 12 months is considered to be sufficient for proper seasoning.
12. **Toughness Index**: Impact test, the value of toughness less than 13 – Not tough, between 13 and 19 – Moderate, greater than 19- high

**Characteristics of stones**

In order to ensure suitable selection of stone of particular work, one must be conversant with its composition, characteristics, uses and place of availability.

**Granite**

1. Igneous rock
2. Composed of quart, felspar and mica and minerals
3. Available in grey, green, brown and pink and red
4. Hard and durable
5. High resistance to weathering
6. The texture varies with its quality
7. Specify gravity 2.7 and compressive strength 700 to 1300 $kg/cm^2$
8. Used for ornamental, road metal, railway ballast, aggregate for concrete; for construction of bridges, piers and marine works etc.

**Balast**

1. Igneous rock
2. It is compact, hard and heavy
3. Available in red, yellow grey, blue and greenish black colour
4. Specific gravity is 3 and compressive strength varies 1530 to 1890 kg/cm2.
5. Used for ornamental, rail road ballast, aggregates for concrete etc.

**Sand Stone:**

1. Sedimentary rock
2. It is available in variety of formations fine grained, coarse grained compact or porous
3. Available in white, green, blue, black, red and yellow.
4. Specific gravity 2.65 to 2.95
5. Compressive strength is 650kgs / cm2
6. Used for ashlar works

**Lime Stone:**

a. Sedimentary rock: It is available in a variety of forms which differ from one another in colour Compaction, texture, hardness and durable
b. Compact lime stone
c. Granular limestone
d. Magnesia lime stone
e. Kanker lime stone
f. Used for paving, road metal, etc

**Marble**

1. Metamorphic rock
2. Available in white, blue, green, yellow black and red colour
3. High compactness,
4. Suitable for decorative works, wall lining columns, pile, table slabs, hearths, tiled floors, steps of stair case etc.

**Slate:**

1. Metamorphic rock
1. Non absorbent, compact fine grained and produce metallic ringing sound when struck
2. Available in black, dark blue, grey, reddish brown etc.
3. Used for providing damp proof course, paving dados etc

**Selection of stones**

In contemplating the use of stone for various engineering works, the selection of the nature and quality of stone is governed by the purpose in view, cost of stone, its ornamental value and durability Suitability various types of stones for different purposes and situation is briefly discussed below

a. For face work, in general marble, granite and close-grained sand stone are used in the form of thin slabs (veneers) where the structure subjected to adverse weather effects.
b. For pillars, balustrade, pedestals, columns statues and door and window sill and paving stone, granite marble and compact lime stone can be recommend because they can take good polish.
c. For ornamental works such as moulding and carvings, fine- grained sand stone, fine grained marble and fine grained granite are used.

d. For bridges, piers, docks, break-waters and other marine structures the stone should be very hard, heavy, strong and durable granite and gneiss are recommended for this purpose

e. For road metal, stones should be hard, tough, resistant to abrasion and durable. Basalt and course-grained granite are generally recommended for this purpose.

f. For railway ballast, the stone should be hard, dense, durable, tough and easily workable sandstone, compact lime stone, trap and quartzite are commonly used

g. In situation like steps, doors sills, pavings etc where there is a regular flow of traffic, stone should be hard, dense, easily workable and durable. Marble, slates and sand stones are commonly use in such places.

h. In fire proof construction, compact sand stone should always be prefferred.

**Artificial stones:** These are also known as cast stones or reconstructed stones. Artificial stones may take up various forms such as

**a. Cement concrete:** This is the mixture of cement, fine aggregates, coarse aggregates and water. It may be cast in site or pre-cast if steel is used with cement concrete, it is known as reinforced cement concrete.

**b. Mosaic tiles:** Pre-Cast concrete tiles with marble chips at top surface are known as tiles. They are available in different shades and widely adopted at present.

**c. Terrazo :** This is a mixture of marble chips and cement. It is used for bathrooms residential buildings, temples etc.

**Advantages of artificial stones:**

1. Cavities may be kept in artificial stones to convey pipes, electric wires etc.
2. Grooves can be kept in artificial stone while it is being cast which are useful for fixing various fittings.
3. It can cast in desired shape
4. It can be made in a single piece and hence trouble of getting large blocks of stone for lintels, beams etc is avoided.
5. It can be made stronger than natural stone
6. It is cheap and economical
7. It is more durable than natural stone
8. Natural bed is absent in artificial stones and hence, the question of taking precautions with respect to the natural bed of stones does not arise.

**Aggregates - Grading:** Aggregates is derived from igneous, sedimentary and metamorphic rocks or is manufacture from clays, slag etc. The properties of concrete are directly related to those of its constituents and should be hard, strong, durable, and free from clay, loam, vegetables and other such foreign matters. The presence of clay or dirt coating prevents the adhesion of cement on the surface of aggregates and ultimately retards the setting and hardening of cement and reduces the strength, durability and soundness of concrete.

Depending upon their size, the aggregates are classified as (i) Fine Aggregative (ii) coarse aggregates.

(i) **Fine Aggregates:** The material, most of when passes through 4.75mm I.S. sieve size, is termed as fine aggregates. It should not contain more than 1 to 8% of fine particles, which may be obtained from sea, river, lake or pit may be used as fine aggregates but care should be taken all its impurities must be removed

(ii) **Coarse Aggregates:** The material whose particles are of such size as are retained on 4.75mm, I.S sieve are called coarse aggregates. The size of the coarse aggregates used depends upon the nature of work. The maximum size may be 23mm for mass concrete such as dams etc. and 63mm for plain concrete. Crushed hard stone and gravel is the common materials used as coarse aggregates for structural concretes. Coarse aggregates usually obtained by crashing granite, gneiss, crystalline lime stone and good variety of sandstone etc.

**QUARRYING OF STONES:** The process of taking out stones from exposed surface of natural rock beds is known as the quarrying. While selecting a quarry site, one should remember that the availability of quantity;

desired quality, transportation facilities, cheap local labour, and free from the permanent structures in the vicinity , drainage of rainwater etc..
In case of a quarry, the operations are carried out at ground level (in an exposed condition) whereas in case of mine, the operations are carried out under the ground at greater depths.

SELECTION OF A SITE FOR QUARRYING:

(i) Availability of Raw material, Tools, Power, Labour

(ii) Space for dumping of refuse material.

(iii) Distance of quarry from roads, railways..

(iv) Proximity to the transportation facilities.

(v) Easy availability of clean water in sufficient quantity throughout the year.

(vi) Economy in quarrying

(vii) Blasting material availability

(viii) Absence of permanent structures

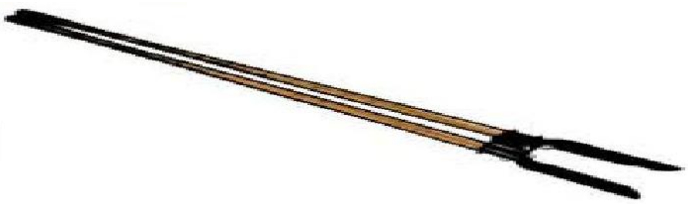
(ix) Geological data regarding rock formations.

## STONE QUARRYING TOOLS

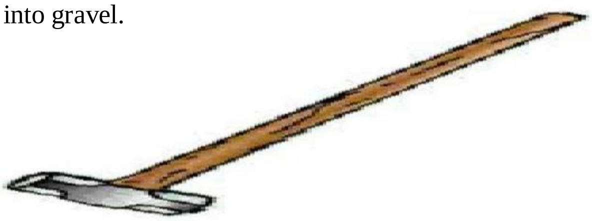
**Tamping Bar:** A tamping bar has a small blade at one end for loosening compacted or rocky soil and a flattened end for tamping.

**Shovels:** Shovels are available in various shapes and handle lengths. shovels are most common for trail work and are used to move loosened soil, to dig trenches. They can also be used for cleaning of culvert outlets.

**Post Hole Digger:** Used for removing soil from holes. Soil should be lifted from the holes.



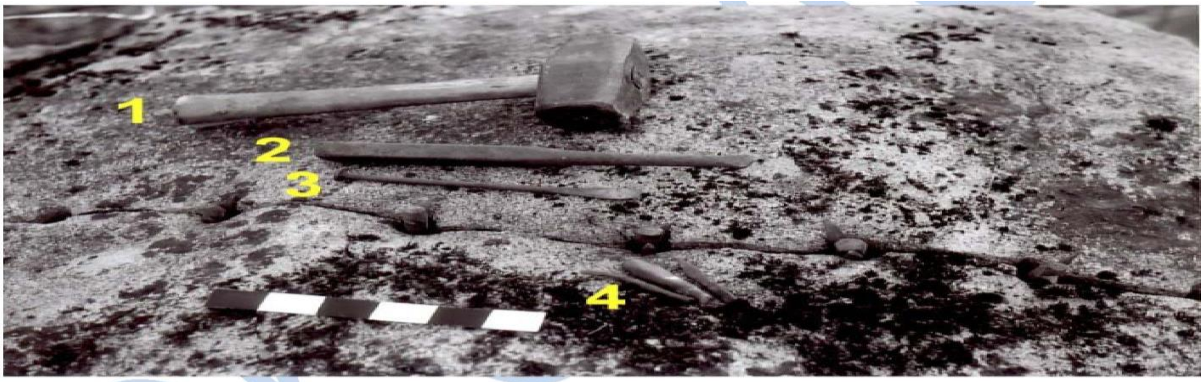
**Sledge hammer:** A sledgehammer with a 6 to 8 pound head and a 3 foot-long handle is most useful for trail work. It can be used to crush rock into gravel.



**Single Jack Hammer:** A single jack (3 to 4 pound head with short handle) hammer can be used with a star drill to punch holes in rock.

**Star Drill:** Star drills are usually about a foot long and weigh a pound. They are used with single jack hammers to punch holes in rock.

**The plug & feather method** involves drilling a series of round holes in the rock spaced every six inches or so apart. The typical round hole ranges for 1/2 inch to 1 inch in diameter and 3 to 4 inches deep. These holes are drilled using either a single bladed plug drill or a star drill. The drill is struck by a hammer. The stone dust which accumulates in the holes is removed using a simple tool called a scrapping spoon. Once the holes are drilled, two shims called feathers or half-rounds are placed in the hole and a wedge called a plug is placed between the two feathers.





**Typical Plug Drills - (Top) drill with a round blade (bottom) drill with pointed blade**


**Scrapping spoon**


**Two feathers (shims) with a plug (wedge) between them**


**Hand plug drills**


**Flat wedge plug**

**METHODS OF QUARRYING:** The purpose of quarrying is to obtain building stones for various engineering purposes. Depending upon the nature of rocks and the purpose for which stones are needed, quarrying is done by adopting the following methods:

Quarrying is carried out by employing hand tools for **digging / excavation, Heating, Wedging and Blasting.**

**1. Digging / excavation:** In this method, the stones are merely excavated with the help of suitable hand tools such as Pick axes, Hammers, Spades, Chisels. This method is useful when soft stones occur in the form of small blocks.

**2. Heating:** In this method, the surface of rock is heated by placing pieces of wood or by piling a heap of fuel over the surface and fired for a few hours. Due to unequal expansion, the upper layer of rock separates out. The detached portion of rock is then removed by suitable hand tools.

This method is suitable when the rock formation consists of horizontal layers of shallow depth. Sometimes, intermediate layers are to be separated from the top and bottom layers. In such a case, the intermediate layer is heated and the expansion separates it from the other two.

**3. Wedging:** This method of quarrying is usually adopted for rocks such as Sandstone, Limestone, Marble, Slate, Laterite etc.. About 10 – 15 cm deep holes, at around 10 cm spacing are made vertically in the rock. Steel Pins and Wedges or Plugs are inserted in them. These plugs are then struck simultaneously with sledge hammer. The rock splits along the lines of least resistance through the holes.

**4.Blasting:**In this method, the explosives are used to convert rocks into small pieces of stones and the main purpose of quarrying stones by blasting is to loosen large masses of rocks. Explosives such as Gun powder (Blasting powder), Dynamite, (Gelatin), Detonators, Fuse coil etc. are used.

The blasting powder and dynamite are commonly used as the explosives. The blasting powder is also known as the Gun Powder which is a mixture of charcoal, salt petre (KNO3) and sulphur.

**Fuses:** It is required to ignite the explosives. It is in the form of a small rope of cotton coated with tar and with a core of continuous thread of fine gun powder. The rate of burning of a good fuse is about 10 mm per second.

**Gun cotton:** The clean cotton is saturated in a mixture of nitric acid and sulphuric acid. It is pressed into blocks or sticks while it is wet. It is as strong as dynamite. But its shattering power is less.

**Liquid Oxygen:** It is oxygen in liquid state. It is stored in a special container. It is comparatively cheap and used for blasting on a large scale for mining operations.

**DRESSING OF A STONE:** The stones, after being quarried, are to be cut into suitable sizes and this process is known as the dressing of stones. The dressing of stones is carried out for the following purposes:

- To obtain a definite and regular shape.
- To make the transport from quarry easy and economical.
- Provides pleasing appearance
- To suite to the requirements of stone masonry.
- At quarry site, it is possible to get cheap labour for the process of dressing of stones.
- It is possible to sort out stones for different works
- The irregular and rough portions of the stones are removed which decrease the weight of stones.

Following are the varieties of finishes obtained by the dressing of stones:

- **Dragged (or) Combed finish:** In this type of finish, a piece of steel which is similar to a comb is rubbed on the surface in all directions and surface of the stone. This finish is suitable for soft stones only.
- **Punched finish:** On the stone surface, the depressions are made by using a punch. The surface of the stone takes the form of a series of hollows and ridges.
- **Reticulated finish:** This type of finish represents a net-like appearance. A margin about 20mm wide is marked on the edges of stone and irregular sinking's are made on the enclosed space. A pointed tool is used to put the marks on the sunk surface so as to present a pock-marked appearance.
- **Tooled finish:** The stone surface is finished by means of a chisel and parallel continuous marks either horizontal or inclined or vertical are left on the surface.
- **Rock faced finish:** Some stones, as obtained from the quarry, possess smooth surface and they can be directly placed on the work. Such a stone surface is termed as Rock – faced (or) quarry – faced finish.
- **Vermiculated finish:** This finish is similar to reticulated type except that the sinking's are more curved.

# BRICKS

Bricks are obtained by moulding clay in rectangular blocks of uniform size and then by drying and burning these blocks. As bricks are of uniform size, they can be properly arranged, light in weight and hence bricks replace stones.

**Composition - Manufacture Process.**

**Composition** – Following are the constituents of good brick earth.

| | |
|---|---|
| Silica | 50 – 60 % |
| Alumina | 20 – 30 % |
| Calcium | 10 % |
| Mg | < 1 % |
| Ferric Oxide | < 7 %    < 20 % |
| Alkalis | < 10 % |
| SO3; H2O | < 2 % |

**Alumina**: **-** It is the chief constituent of every kind of clay. A good brick earth should contain 20 to 30 percent of alumina. This constituent imparts plasticity to earth so that it can be moulded. If alumina is present in excess, raw bricks shrink and warp during drying and burning.

**Silica-**A good brick earth should contain about 50 to 60 percent of silica. Silica exists in clay either as free or combined form. As free sand, it is mechanically mixed with clay and in combined form; it exists in chemical composition with alumina. Presence of silica prevents crackers shrinking and warping of raw bricks. It thus imparts uniform shape to the bricks. Durability of bricks depends on the proper proportion of silica in brick earth. Excess of silica destroys the cohesion between particles and bricks become brittle.

**Lime** – A small quantity of lime is desirable in finely powdered state to prevents shrinkage of raw bricks. Excess of lime causes the brick to melt and hence, its shape is last due to the splitting of bricks.

**Oxide of iron-** A small quantity of oxide of Iron to the extent of 5 to 6 percent is desirable in good brick to imparts red colour to bricks. Excess of oxide of iron makes the bricks dark blue or blackish.

**Magnesia-** A small quantity of magnesia in brick earth imparts yellow tint to bricks, and decreases shrinkage. But excess of magnesia decreases shrink leads to the decay of bricks.

The ingredients like, lime, iron pyrites, alkalies, pebbles, organic matter should not present in good brick earth

**Manufacture of bricks:**

The manufacturing of brick, the following operations are involved

1. Preparation of clay
2. Moulding
3. Drying
4. Burning

**(i)** **Preparation of clay :-** The preparation of clay involves following operations

a) **Unsoiling** :- Top layer of 20cm depth is removed as it contain impurities.

b) **Digging**: **-** Clay dug out from ground is spread on level ground about 60cm to 120cm heaps.

c) **Cleaning**:-Stones, pebbles, vegetable matter etc removed and converted into powder form.

d) **Weathering**:**-** Clay is exposed to atmosphere from few weeks to full season.

**e) Blending**:- Clay is made loose and any ingradient to be added to it is spread out at top and turning it up and down in vertical direction**.**

f) **Tempering**:- Clay is brought to a proper degree of hardness, then water is added to clay and whole mass is kneaded or pressed under the feet of men or cattle for large scale, tempering is usually done in pug mill as shown in the fig2.1

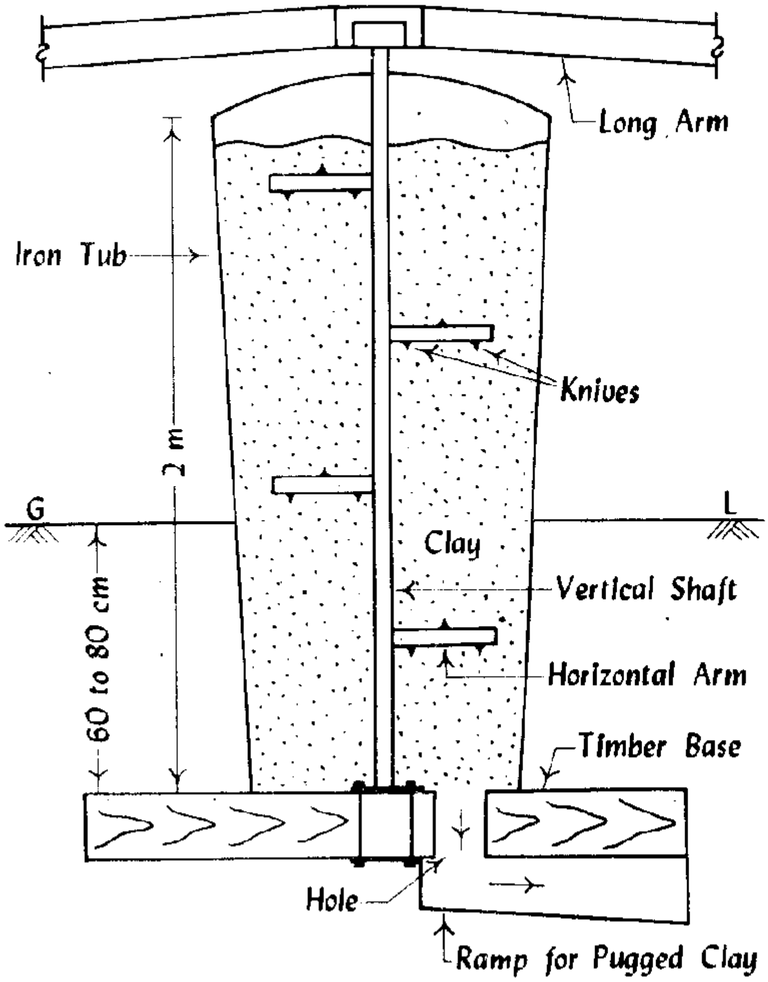



**Fig 2.1 Pug Mill**

**Process**:- Clay with water is placed in pug mill from the top. When the vertical staff is rotated by using electric pair, steam or diesel or turned by pair of bullocks. Clay is thoroughly mixed up by the actions of horizontal arms and knives when clay has been sufficiently pugged, hole at the bottom of tub, is opened cut and the pugged earth is taken out from ramp for the next operation of moulding.

**Moulding**: Clay, which is prepared form pug mill, is sent for the next operation of moulding. Following are the two ways of moulding.

**Hand Moulding:** Moulds are rectangular boxes of wood or steel, which are open at top and bottom. Steel moulds are more durable and used for manufacturing bricks on large scale as shown in fig 2.2. Bricks prepared by hand moulding are of two types.

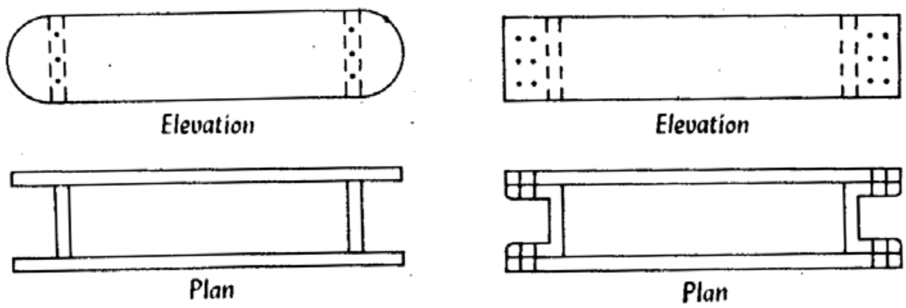



**Fig 2.2 Wooden mould & Steel mould**

a) Ground moulded bricks

b) Table moulded bricks

(a) **Ground moulded bricks:** ground is first made level and fine sand is sprinkled over it. Mould is dipped in water and placed over the ground to fill the clay. Extra clay is removed by wooden or metal strike after the mould is filled forced mould is then lifted up and raw brick is left on the ground. Mould is then dipped in water every time lower faces of ground moulded bricks are rough and it is not possible to place frog on such bricks.

Ground moulded bricks of better quality and with frogs on their surface are made by using a pair of pallet boards and a wooden block

(b) **Table-moulded bricks**: Process of moulding these bricks is just similar to ground bricks on a table of size about 2m x 1m.

(1) **Machine moulding:** This method proves to be economical when bricks in huge quantity are to be manufactured at the same spot. It is also helpful for moulding hard and string clay. These machines are broadly classified in two categories

(a) Plastic clay machines

(b) Dry clay machines

a) **Plastic clay machines:** This machine containing rectangular opening of size equal to length and width of a brick. Pugged clay is placed in the machine and as it comes out through the opening, it is cut into strips by wires fixed in frames, so there bricks are called wire cut bricks.

b) **Dry clay machines:** In these machines, strong clay is first converted into powder form and then water is added to form a stiff plastic paste. Such paste is placed in mould and pressed by machine to form hard and well shaped bricks. These bricks are behavior than ordinary hand moulded bricks. They carry distinct frogs and exhibit uniform texture.

(2) **Drying**: The damp bricks, if burnt, are likely to be cracked and distored. Hence moulded bricks are dried before thay are taken for the next operation of burning. Bricks are laid along and across the stock in alternate layers. The drying of brick is by the following means

(i) **Artificial drying** – drying by tunnels usually $120^0$C about 1 to 3 days

(ii) **Circulation of air-** Stacks are arranged in such a way that sufficient air space is left between them free circulation of air.

(iii) **Drying yard-** special yards should be prepared slightly higher level prevent the accumulation of rain water

(iv) **Period for frying** – usually about 3 to 10 days to bricks to become dry

(v) **Screens** – screens are necessary, may be provided to avoid direct exposure to wind or sun.

(3) **Burning:** This is very important operation in the manufacturing of bricks to impart hardness, strength and makes them dense and durable. Burning of bricks is done either in clamps or in kilns. Clamps are temporary structures and they are adopted to manufacture bricks on small scale. Kilns are permanent structures and they are adopted to manufacture bricks on a large scale. A typical clamp is as shown in fig 2.3

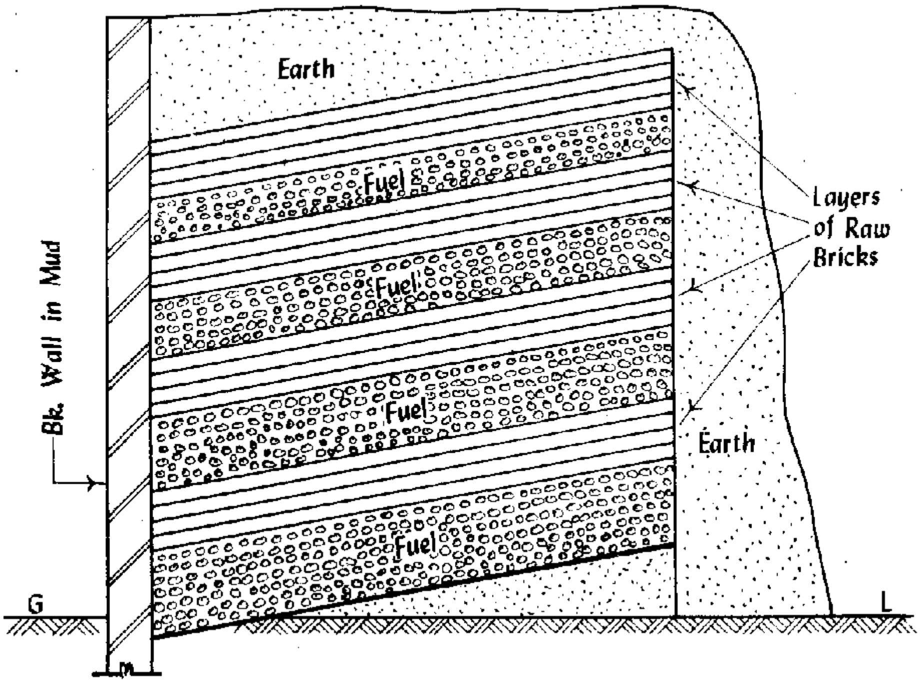



**Fig 2.3 Clamp**

(1) A trapezoidal shape in plan with shorter is slightly in excavation and wider end raised at an angle of $15^0$ from ground level

(2) A brick wall with mud is constructed on the short end and a layer of 70cm to 80cm thick fuel (grass, cow dung, ground nuts, wood or coal) laid on the floor.

(3) A layer consists of 4 or 5 courses of raw bricks laid on edges with small spaces between them for circulation of air

(4) A second layer of fuel is then placed, and over it another layer of raw bricks is putap. The total height of clamp in alternate layers of brick is about 3 to 4 m

(5) When clamp is completely constructed, it is plastered with mud on sides andtop and filled with earth to prevent the escape of heat

(6) The period of burning is about one to two months and allow the same time for coding

(7) Burnt bricks are taken out from the clamp

**Advantages:**

(i) The bricks produced are tough and strong because burning and cooling are gradual

(ii) Burning in clamps proves to be cheap and economical

(iii) No skilled labour and supervision are required for the construction of clamps

(iv) There is considerable saving of clamps fuel

**Disadvantages:**

(i) Bricks are not of required shape

(ii) It is very slow process

(iii) It is not possible to regulate fire in a clamp

(iv) Quality of brick is not uniform

**Kilns:** A kiln is a large oven, which is used to burnt bricks by

1) Intermittent kilns

2) Continuous kilns

**1) Intermittent kilns:** These intermittent in operation, which means that they are loaded, fired, cooled and unloaded.

a) Intermittent up-draught kilns

b) Intermittent down-draught kilns

**a) Intermittent up-draught kiln**: This is in the form of rectangular with thick outside walls as shown in the fig 2.4. wide doors are provided at each end for loading and unloading of kilns. A temporary roof may be installed to protect from rain and it is removed after kiln is fired. Flues are provided to carry flames or hot gases through the body of kiln.

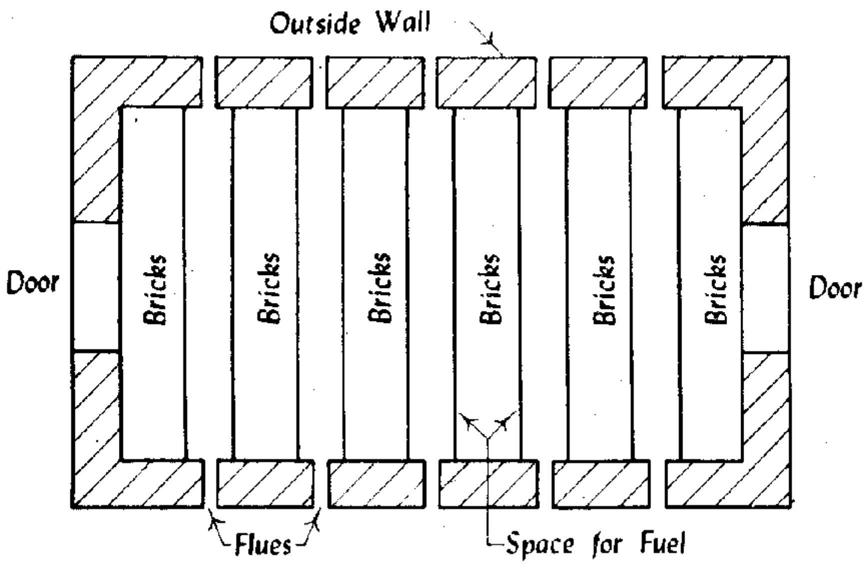



**Fig 2.4 Intermittent kiln**

(i) Raw bricks are laid in row of thickness equal to 2 to 3 bricks and height 6 to 8 bricks with 2 bricks spacing between rows

(ii) Fuels are filled with brush wood which takes up a free easily

(iii) Loading of kiln with raw bricks with top course is finished with flat bricks and other courses are formed by placing bricks on edges

(iv) Each door is built up with dry bricks and are covered with mud or clay

(v) The kiln is then fired for a period of 48 to 60 hours draught rises in the upward direction from bottom of kiln and brings about the burning of bricks.

(vi) Kiln is allowed to cool down and bricks are then token out

(vii) Same procedure is repeated for the next burning

Bricks manufactured by intermittent up drought kilns are better than those prepared by clamps but bricks burnt by this process is not uniform, supply of bricks is not continuous and wastage of fuel heat.

**(b) Intermittent down-draught kilns:**

These kilns are rectangular or circular in shape. They are provided with permanent walls and closed tight roof. Floor of the kiln has opening which are connected to a common chimney stack through flues. Working is same as up-draught kiln. But it is so arranged in this kiln that hot gases are carried through vertical flues upto the level of roof and they are then released. These hot gases move down ward by the chimney draught and in doing so, they burn the bricks.

**Advantages:**

(i) Bricks are evenly burnt

(ii) Performance of this kiln is better than that of up-draught kiln

(iii) This kiln is suitable for burning of structural clay tiles, terra cota because of close control of heat.

**2. Continuous kilns:**

These kilns are continuous in operations. This means that loading, firing, cooling and unloading are carried out simultaneously in these kilns. There are three types of continuous kilns.

a) Bull's trench kiln

b) Hoffman's kiln

c) Tunnel kiln

**a) Bull's trench kiln:** This kiln may be of rectangular, circular or oval shape in the plan as shown in fig 2.5. It is constructed in a trench excavated in ground either fully under ground partially projecting above ground openings is provided in the outer walls to act as flue holes. Dampers are in the form of iron plates and they are used to divide the kilns in suitable sections and most widely used kiln in India.

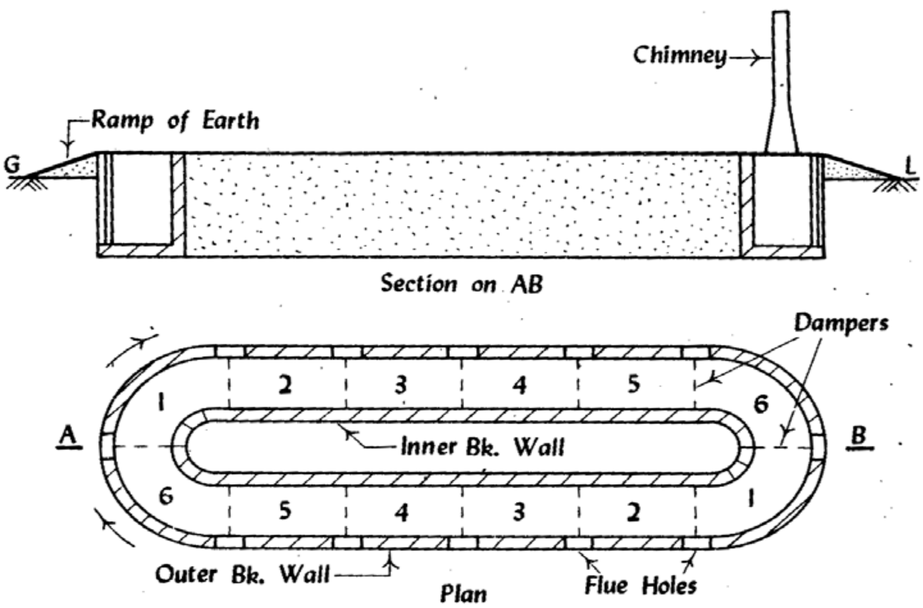


**Fig 2.5 Bull's trench kiln**

The bricks are arranged in such a way that flues are formed. Fuel is placed in flues and it is ignited through flue holes after covering top surface with earth and ashes to prevent the escape of heat usually two movable iron chimneys are employed to form draught. These chimneys are placed in advance of section being fired. Hence, hot gases leaving the chimney warm up the bricks in next section. Each section requires about one day to burn. The tentative arrangement for different sections may be as follows

Section 1 – loading Section 2 – empty Section 3 – unloading Section 4 – cooling Section 5 – Burning Section 6 – Heating

**b)** **Haffman's kiln**: this kiln is constructed over ground and hence, it is sometimes known as flame kiln. Its shape is circular to plan and it is divided into a number of compartments or chambers. A permanent roof is provided; the kiln can even function during rainy season. Fig 2.6 shows plan and section of Hoffman's kiln with 12 chambers

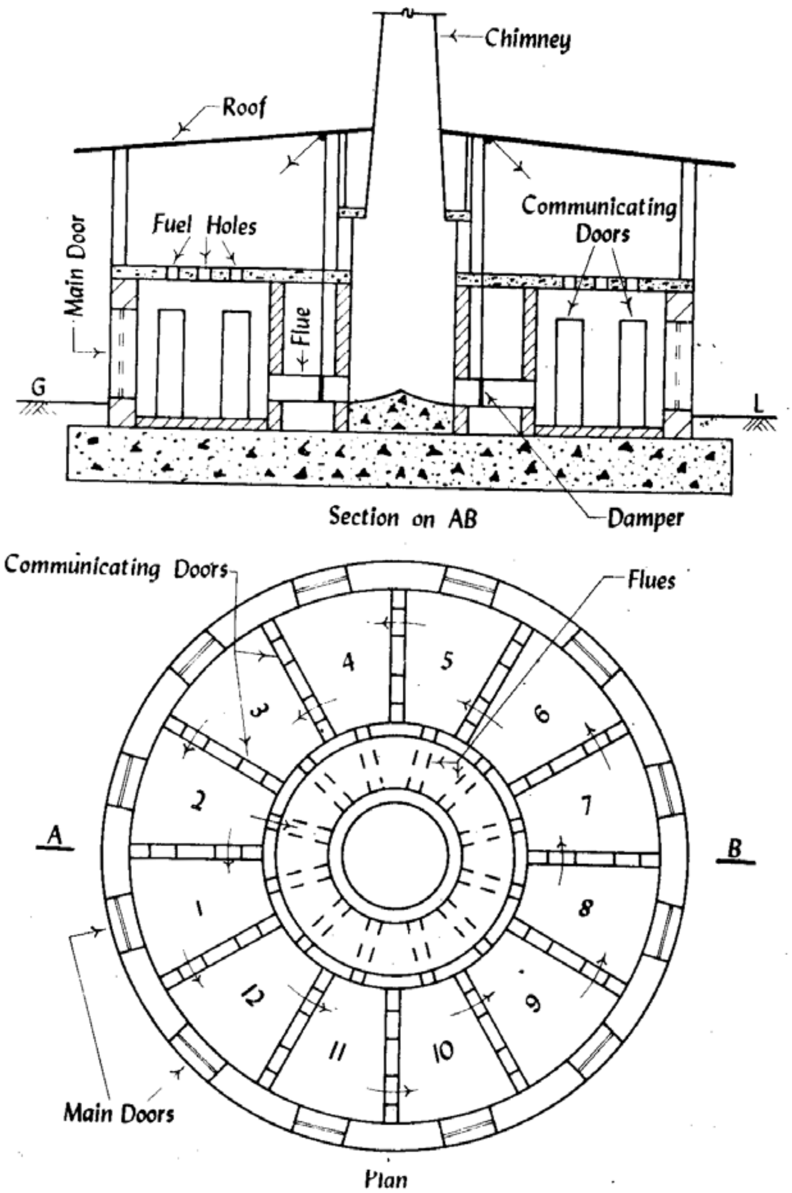



**Fig 2.6 Hoffman's kiln**

Chamber 1 - loading

Chamber 2 to 5 – drying and pre-heating

Chambers 6 and 7 - burning

Chambers 8 to 11 **-** cooling Chamber 12 – unloading

The initial cost in stalling this kiln is high, the following **advantages**

(i) Good quality of bricks are produced

(ii) It is possible to regulate heat inside the chambers through fuel holes

(iii) Supply of bricks is continuous and regular

(iv) There is considerable saving in fuel due to pre heating of raw bricks by flue gases

**c) Tunnel kiln:** This type of kiln is in the form of tunnel, which may be straight, circular or oval in the plan. Raw bricks are placed in trolleys which are then moved from one end too the other end of tunnel. Raw bricks get dried and pre-heated as they approach zone of fire. In zone of fire, bricks are burnt to the required deque and they are then pushed forward for cooling. When bricks are sufficiently cooled, they are unloaded. The kiln proves to be economical when the bricks are manufactures on a large scale. As temperature is under control, uniform bricks of better quality are produced.

## COMPARISON BETWEEN CLAMP-BURNING AND KILN-BURNING

| No. | Item | Clamp-burning | Kiln-burning |
|---|---|---|---|
| 1. | Capacity | About 20000 to 100000 bricks can be prepared at a time. | Average 25000 bricks can be prepared per day. |
| 2. | Cost of fuel | Low as grass, cow dung, litter, etc. may be used. | Generally high as coal dust is to be used. |
| 3. | Initial cost | Very low as no structures are to be built. | More as permanent structures are to be constructed. |
| 4. | Quality of bricks | Percentage of good quality bricks is small about 60% or so. | Percentage of good quality bricks is more about 90% or so. |
| 5. | Regulation of fire | It is not possible to control or regulate fire during the process of burning | Fire is under control throughout the process of burning. |
| 6. | Skilled supervision | Not necessary through- out the process of burn- ing. | Continuous skilled super vision is necessary. |
| 7. | Structure | Temporary structure. | Permanent structure. |
| 8. | Suitability | Suitable when bricks are to be manufactured on a small scale and when the demand of bricks is not continuous. | Suitable when bricks are to be manufactured on a large scale and when There is continuous demand of bricks. |
| 9. | Time of burn- ing and cool- ing. | It requires about 2 to 6 months for burning and cooling of bricks. | Actual time for burning of one chamber is about 24 hours and only about 12 days are required for cooling of bricks. |
| 10. | Wastage of heat. | There is considerable wastage of heat from top and sides and hot flue gas is not properly utilised. | Hot flue gas is used to dry and pre-heat raw bricks. Hence wastage of heat is the least. |

**Classification:**

Bricks can broadly be divided into two categories.

(i) Unburnt or sundried bricks

(ii) Burnt bricks

**(i) Un burnt or Sun dried bricks-** UN burn or sun dried with the help of heat received from sun after the process of moulding. These bricks can only be used in the constructions of temporary and cheap structures. Such bricks should not be used at places exposed to heavy rains.

**(ii) Burnt Bricks:** The bricks used in construction works are burnt bricks and they are classified into the following four categories.

a. **First Class bricks:** These bricks are table moulded and of standard shape. The surface and edges of the bricks are sharp, square, smooth and straight. The comply all the qualities of good bricks and used for superior work of permanent nature.

b. **Second class bricks:** These bricks are ground moulded and they are burnt in kilns. The surface of bricks is some what rough and shape is also slightly irregular. These bricks are commonly used at places where brick work is to be provided with a coat of plaster.

c. **Third class bricks:** These bricks are ground moulded and they burnt in clamps. These bricks are not hard and they have rough surfaces with irregular and distorted edges.

These bricks give dull sound when struck together. They are used for unimportant and temporary structures and at places where rainfall is not heavy.

d. **Fourth class bricks:** These are over burnt bricks with irregular shape and dark colour. These bricks are used as aggregate for concrete in foundation, floors, roads, etc because of the fact that the over burnt bricks have compacted structure and hence, they are some times found stronger than even first class bricks.

**Qualities of Good Brick:**

(i) Bricks should be table moulded, well burnt in kilns, copper coloured, free from cracks and with sharp and square edges.

(ii) Bricks should be uniform shape and should be of standard size.

(iii) Bricks should give clear ringing sound when struck each other.

(iv) Bricks when broken should show a bright homogeneous and compact structure free from voids.

(v) Bricks should not absorb water more than 20 percent by weight for first class bricks and 22 percent by weight for second class bricks, when soaked in coldwater for a period of 24 hours.

(vi) Bricks should be sufficiently hard no impression, should be left on brick surface, when it is scratched with finger nail.

(vii) Bricks should be low thermal conductivity and they should be sound proof.

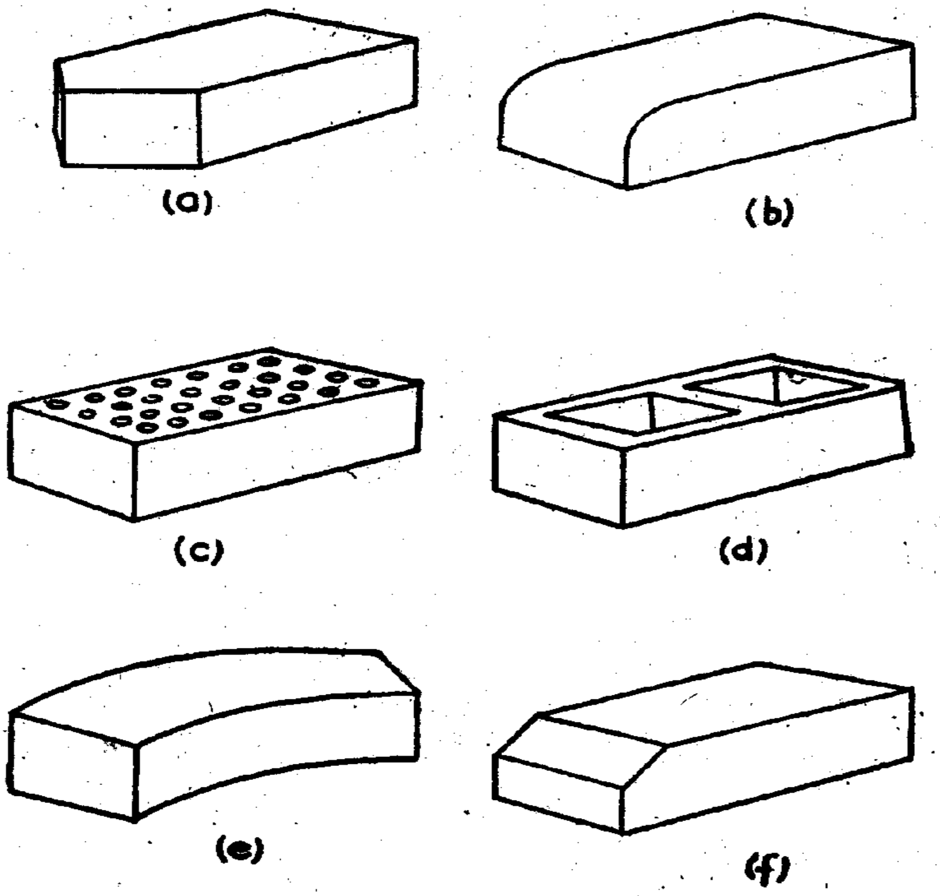
(viii) Bricks should not break when dropped flat on hard ground from a height of about one meter.

(ix) Bricks, when soaked in water for 24hours, should not show deposits of white salts when allowed to dry in shade.

(x) No brick should have crushing strength below 55kg/cm2

**Special Types:** Bricks are made in a wide range of shapes and to suit the requirements of the location where they are to be used. Special form of bricks may be needed due to structural consideration or for ornamental decoration as defined by the architect. Specially moulded bricks avoid the cumbersome process of cutting and rounding the rectangular bricks to the desired shape. Some of the special types of bricks commonly used are given below.

a. **Squint Bricks:** These bricks are made in a variety of shapes and are used to the construction of a cute and obtuse squint quoins as shown in the fig2.7.




(a) Squint brick.
(c) Perforated brick.
(e) Circular brick.
(b) Bull-nosed brick.
(d) Hollow brick.
(f) Plinth, cornice or string-

**Fig 2.7 Types of Special Bricks**

b. **Bull Nosed Bricks**: These bricks are used to form rounded quoins.

c. **Perforated Bricks:** These bricks may be standard size bricks produced with perforations running through their thickness. Perforated bricks are easy to burn and their light weight makes it possible to cut down the weight of the structure and effect in foundations. The aperture of the perforations is such that it gives maximum amount of ventilation. But does not permit the entry of rats or mice. These bricks are used for constructing load bearing walls of low buildings, panel walls for multistoried buildings and for providing partition walls.

d. **Hallow Bricks:** These bricks are made of clay and are provided with one or more cavities. Hallow bricks are light in weight and are used to increase insulation against heat and dampness. They are used for the construction of load bearing walls, partition walls or panel walls to multistoried buildings.

e. **Circular Bricks:** These bricks have internal and external faces curved to meet the requirement of the particular curve and radius of the wall. These bricks are used for wells, towers etc

**f.** **Plinth cornice and String Course Brick:** These bricks are moulded in several patterns with the object of adding architectural beauty to the structure and at the same time to helping to throw the rack water off the face of the walls**.**

g. **Coping Bricks:** These bricks are manufactured in a variety of shapes to set the thickness of the wall and are throated on the underside to throw off rain water as shown in the fig2.7

h. **Paving Bricks:** These bricks are specially made for paving the surface of streets and highways. These bricks are usually made from shale, fire clay on a mixture of the two. They are unaffected by weather and ordinary traffic wear. They are loaded on the bed of sand which in term rests on foundation of stone or concrete. The bricks are laid by grouting with cement mortar or asphalt. They are machine moulded and are burnt in a continuous kiln to ensure high degree of vitrification.

**Tests for bricks :**

A brick is generally subjected to following tests to find out its suitability of the construction work.

i. Absorption
ii. Crushing strength or compression strength
iii. Hardness
iv. Presence soluble salts
v. Shape and size
vi. Soundness
vii. Structure

1) **Absorption:** A good should not absorb not more than 20 percent of weight of dry brick
2) **Compressive strength:** crushing or compressive strength of brick is found out by placing it in compression testing machine. It is pressed till it breaks. Minimum crushing strength of brick is 35kg/cm$^2$ and for superior bricks, it may vary from 70 to 140 kg/cm$^2$.
3) **Hardness:** No impression is left on the surface the brick is treated to be sufficiently hard
4) **Presence of soluble salts**: The bricks should not show any grey or white deposits after immerted in water for 24 hours
5) **Shape and size:** It should be standard size and shape with sharp edges
6) **Soundness**: The brick should give clear ringing sound struck each other
7) **Structure**: The structure should be homogeneous, compact and free from any defects

**Grading of Bricks**

As per IS10719557 and 1970 code specifications,

a. Bricks with compressive strength not less than 140kg/cm2 – Grade A-A class.
b. Bricks with compressive strength not less than 105kg/cm2 – First class bricks **-** Grade A.
c. Bricks with compressive strength not less than 70kg/cm2 – Second class bricks – Grade B.
d. Bricks with compressive strength not less than the average value 35kg/cm2 – class III bricks – Grade C.

# TILES

## Tiles

Tiles are thin slabs of low meting clays used for various purposes in engineering constructions. Flooring tiles, Roofing tiles, wall tiles and partition tiles are some of the examples and they give a very pleasing appearance.

Clays and shales are used in making tiles for floor surfaces. Wall tiles differ from floor tiles principally in degree of burning. Wall tiles are burned at a comparatively low temperature and fired again in muffle kiln at a still lower temperature.

Tiles are made of clay ( pottery ) or terrazzo. These are available in different sizes and thickness. These are commonly used in residential houses, offices, schools, hospitals , etc……..

Tiles are made in the same manner as bricks, but are thinner and lighter. so require greater care. These are manufactured from a clay mass with or without colouring agents by moulding in machines and subsequent burning upto 1300oC, in continuous kilns.

Tiles in building construction are thin plates or elements used to cover surfaces like roofs, floors, and walls. Types of tiles and their applications are discussed.
Tiles in present scenario are a primary element in bringing building interior as well as exterior finishing and beauty. They are mainly made up of clay material or any form of inorganic raw material.

Nowadays tiles are also manufactured from recycled materials, making the element eco-friendlier. The shape of the tiles is obtained by the different processes like extrusion or pressing at room temperature or any other method.

After the shaping, they are allowed to dry. These dried elements are subjected to fire. This stage of firing is to ensure that they gain the required properties, that they are meant to acquire when they are in the market and in the building application.

Different types of tiles used in building construction are available in glazed or unglazed form. They are incombustible in its nature. Tiles are unaffected under the light.

### Types of Tiles based on Application

There is a different type of tiles used in building construction which are unique to the type of surface where it must be applied.

Following are the types of tiles based on surface of application:

- Roofing tiles,
- Flooring tiles,
- Wall tiles, and
- Partition tiles.

The **roofing tiles** are earthenware that is baked products. Its manufacture is similar to that of brick.
The **wall tiles** as well as the **floor tiles**, are employed in the interior as well as the exterior of the building. This is mainly employed based on the requirement of decoration or aesthetics. These belong to the class of ceramics and are called as white wares.
Tiles that are used on walls and floor are available in both glazed and in the unglazed forms. Mostly the wall tiles are glazed by a thin layer of glazing when it is available in the market.

**Floor tiles** are too designed to bring the beauty of flooring and movement. But it is subjected to higher load, pressure and other undesirable material action. So, these tiles are made more durable, abrasion resistant, water impervious and easy clean form.
Floor tiles along with the mentioned properties should also provide good aesthetics. The degree of burning is the parameter that differentiates the wall and the floor tiles.

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When compared to floor tiles, the wall tiles burned at a lower temperature. After this, it is glazed and re-fired at a lower temperature.

### Type of Tiles based on Materials and Manufacture

Based on material and manufacture, following are the types of tiles used in building construction:

- Ceramic tiles or non-porcelain tiles, and
- Porcelain tiles.

**Ceramic Tiles**

Ceramic tiles are used for the interior floors, swimming pools, exterior floors, walls and for special installation both in interior and exterior cases.

Most types of tiles come under the category of ceramic tiles. They are made from a mixture of clay and other materials. They are fired in a kiln.

**Following are the various types of unglazed and glazed forms of ceramic tiles:**

1. Earthenware tiles
2. Terracotta and faience
3. Fully vitrified tiles
4. Glazed tiles
5. Stoneware Tile

The **earthenware tiles** are made of clay while the **stoneware tiles** have a large quantity of silica that is present in the form of sand, crushed stoneware etc. Silica in the stoneware tiles are added to prevent the shrinkage when the fixing process is carried out.

**Terracotta tiles** are manufactured by the use of high-grade fired clay. When the firing is done twice unlike the case of terracotta tiles, we obtain the **faience**. Faience initially is subjected to fire, that is initially terracotta. After glazing the terracotta tiles, it is again fired. This will finally give Faience.

The Faience is available in large variety of color change. This would help for improving the terracotta works.

**Fig.: Terracotta Tiles**

**Fig.: Faience Tiles**

**Glazed and Vitrified Ceramic Tiles**

Glazed and vitrified tiles ceramic are developed presently. The glazed tiles were only used for walls, at initial stages. Glazed ceramic tiles are mainly manufactured by two processes.

- **Step 1:** With the help of special white clay that is fired at a temperature of 1200 degree Celsius, the body of the tiles are made. These final elements are called biscuits.
- **Step 2:** The biscuits are accompanied by glazing and decorations if any, and are fired in the oven.

**The glazes in ceramic tiles can be of two types:**

- Earthenware glazes, and
- Colored enamels.

**The colored enamels are also of different types.**

- Bright or glossy surface
- Eggshell, vellum finishes
- Matt finishes

For different types of floor and different abrasion due to traffic, the glazing techniques can be improved.

**Vitrified ceramic tiles** are tiles that are made from clay materials plus other finely ground materials. These are subjected to a higher temperature firing. Fully vitrified tiles are those tiles whose whole thickness are also vitrified.
Vitrified ceramic tiles have higher abrasion resistance and can be employed in the areas of heavy traffic. These tiles are said to hard as granite. These are polished with the help of carbide or diamond abrasive tools.

When compared to vitrified tiles, the glazed tiles are not long lasting.

**Porcelain Tiles**
The manufacture, absorbing capacity and the breaking strength of porcelain tiles differ from the ceramic tiles. The porcelain tiles are also made from clay. But compared with the ceramic tiles, they make use of heavy or denser clay.

Porcelain tiles during manufacture are subjected to heavy temperature for a longer time. This baking is carried out until all the water present in the element is evaporated. This unique method of manufacture makes these tiles harder and denser compared to ceramic tiles.

This is the reason why **porcelain tile** is regarded as a superior product when factors of durability, design, color and value factors are considered.
Porcelain tiles are highly impervious to water. It has a water absorption rate lesser than 0.5%.

The cost of porcelain tiles is higher when compared to the ceramic tiles. The porcelain tiles gain more application in surface areas that have high traffic. These tiles are a type of vitrified tiles. It is sometimes referred to as porcelain vitrified tiles.

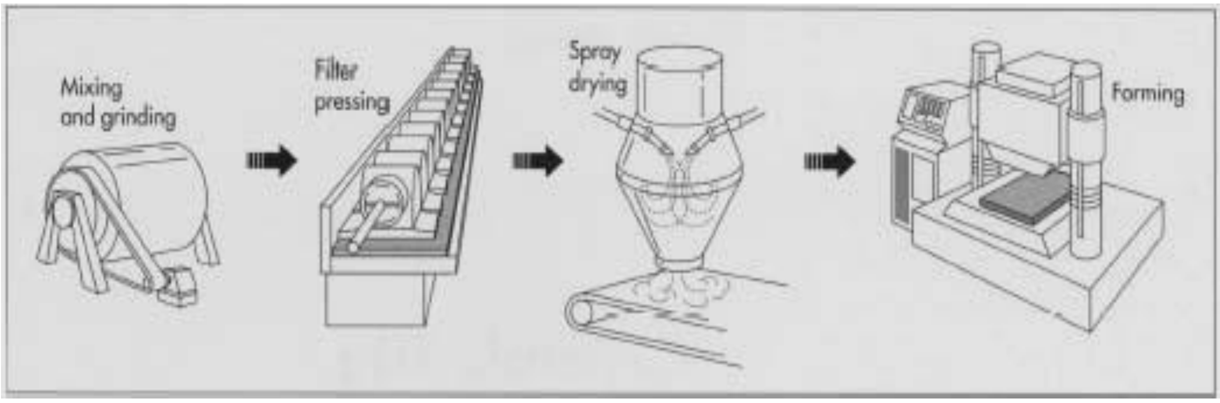
The porcelain tiles demand special cement for their installation. These tiles are harder and denser compared to ceramic tiles. So, when these tiles are used for wall surfaces, the cement that has high adhesive property are used.

The porcelain tiles that are polished are also available in the market. After firing of the tiles, they can be polished. This would bring a shine in the tile, without any glazing.

**THE RAW MATERIALS**

The raw materials used to form tile consist of clay minerals mined from the earth's crust, natural minerals such as feldspar that are used to lower the firing temperature, and chemical additives required for the shaping process. The minerals are often refined or beneficiated near the mine before shipment to the ceramic plant.

The raw materials must be pulverized and classified according to particle size. Primary crushers are used to reduce large lumps of material. Either a jaw crusher or gyratory crusher is used, which operate using a horizontal




The **initial** step in ceramic tile manufacture involves mixing the ingredients. Sometimes, water is then added and the ingredients are wet milled or ground in a ball mill. If wet milling is used, the excess water is removed using filter pressing followed by spray drying. The resulting powder is then pressed into the desired tile body shape.

squeezing motion between steel plates or rotating motion between steel cones, respectively.
Secondary crushing reduces smaller lumps to particles. Hammer or muller mills are often used. A muller mill uses steel wheels in a shallow rotating pan, while a hammer mill uses rapidly moving steel hammers to crush the material. Roller or cone type crushers can also be used.

A third particle size reduction step may be necessary. Tumbling types of mills are used in combination with grinding media. One of the most common types of such mills is the ball mill, which consists of large rotating cylinders partially filled with spherical grinding media.

Screens are used to separate out particles in a specific size range. They operate in a sloped position and are vibrated mechanically or electromechanically to improve material flow. Screens are classified according to mesh number, which is the number of openings per lineal inch of screen surface. The higher the mesh number, the smaller the opening size.

A glaze is a glass material designed to melt onto the surface of the tile during firing, and which then adheres to the tile surface during cooling. Glazes are used to provide moisture resistance and decoration, as they can be colored or can produce special textures.

**THE MANUFACTURING PROCESS**

Once the raw materials are processed, a number of steps take place to obtain the finished product. These steps include batching, mixing and grinding, spray-drying, forming, drying, glazing, and firing. Many of these steps are now accomplished using automated equipment.

Batching

- 1 For many ceramic products, including tile, the body composition is determined by the amount and type of raw materials. The raw materials also determine the color of the tile body, which can be red or white in color, depending on the amount of iron-containing raw materials used. Therefore, it is important to mix the right amounts together to achieve the desired properties. Batch calculations are thus required, which must take into consideration both physical properties and chemical compositions of the raw materials. Once the appropriate weight of each raw material is determined, the raw materials must be mixed together.

Mixing and grinding

- 2 Once the ingredients are weighed, they are added together into a shell mixer, ribbon mixer, or intensive mixer. A shell mixer consists of two cylinders joined into a V, which rotates to tumble and mix the material. A ribbon mixer uses helical vanes, and an intensive mixer uses rapidly revolving plows. This step further grinds the ingredients, resulting in a finer particle size that improves the subsequent forming process (see step #4 below).

  Sometimes it is necessary to add water to improve the mixing of a multiple-ingredient batch as well as to achieve fine grinding. This process is called wet milling and is often performed using a ball mill. The resulting water-filled mixture is called a slurry or slip. The water is then removed from the slurry by filter pressing (which removes 40-50 percent of the moisture), followed by dry milling.

Spray drying

- 3 If wet milling is first used, the excess water is usually removed via spray drying. This involves pumping the slurry to an atomizer consisting of a rapidly rotating disk or nozzle. Droplets of the slip are dried as they are heated by a rising hot air column, forming small, free flowing granules that result in a powder suitable for forming.

  Tile bodies can also be prepared by dry grinding followed by granulation. Granulation uses a machine in which the mixture of previously dry-ground material is mixed with water in order to form the particles into granules, which again form a powder ready for forming.

Forming

- 4 Most tile is formed by dry pressing. In this method, the free flowing powder—containing organic binder or a low percentage of moisture—flows from a hopper into the forming die. The material is compressed in a steel cavity by steel plungers and is then ejected by the bottom plunger. Automated presses are used with operating pressures as high as 2,500 tons.

  Several other methods are also used where the tile body is in a wetter, more moldable form. Extrusion plus punching is used to produce irregularly shaped tile and thinner tile faster and more economically. This involves compacting a plastic mass in a high-pressure cylinder and forcing the material to flow out of the cylinder into short slugs. These slugs are then punched into one or more tiles using hydraulic or pneumatic punching presses.

  Ram pressing is often used for heavily profiled tiles. With this method, extruded slugs of the tile body are pressed between two halves of a hard or porous mold mounted in a hydraulic press. The formed part is removed by first applying vacuum to the top half of the mold to free the part from the bottom half, followed by forcing air through the top half to free the top part. Excess material must be removed from the part and additional finishing may be needed.

  Another process, called pressure glazing, has recently been developed. This process combines glazing and shaping simultaneously by pressing the glaze (in spray-dried powder form) directly in the die filled with the tile body powder. Advantages include the elimination of glazing lines, as well as the glazing waste material (called sludge) that is produced with the conventional method.

Drying

- 5 Ceramic tile usually must be dried (at high relative humidity) after forming, especially if a wet method is used. Drying, which can take several days, removes the water at a slow enough rate to prevent shrinkage cracks. Continuous or tunnel driers are used that are heated using gas or oil, infrared lamps, or microwave energy. Infrared drying is better suited for thin tile, whereas microwave drying works better for thicker tile. Another method, impulse drying, uses pulses of hot air flowing in the transverse direction instead of continuously in the material flow direction.

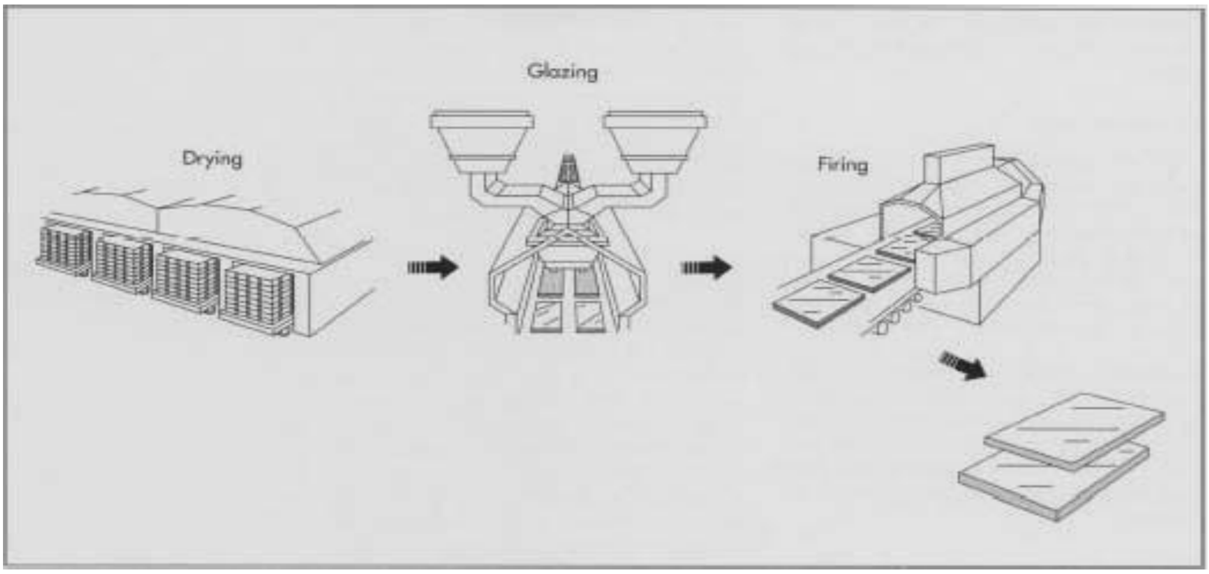
Glazing

- 6 To prepare the glaze, similar methods are used as for the tile body. After a batch formulation is calculated, the raw materials are weighed, mixed and dry or wet milled. The milled glazes are then applied using one of the many methods available. In centrifugal glazing or discing, the glaze is fed through a rotating disc that flings or throws the glaze onto the tile. In the bell/waterfall method, a stream of glaze falls onto the tile as it passes on a conveyor underneath. Sometimes, the glaze is simply sprayed on. For multiple glaze applications, screen printing on, under, or between tile that have been wet glazed is used. In this process, glaze is forced through a screen by a rubber squeegee or other device.

  Dry glazing is also being used. This involves the application of powders, crushed frits (glass materials), and granulated glazes onto a wet-glazed tile surface. After firing, the glaze particles melt into each other to produce a surface like granite.

Firing

- 7 After glazing, the tile must be heated intensely to strengthen it and give it the desired porosity. Two types of ovens, or

  After forming, the file is dried slowly (for several days) and at high humidity, to prevent cracking and shrinkage. Next, the glaze is applied, and then the tile is fired in a furnace or kiln. Although some types of tile require a two-step firing process, wet-milled tile is fired only once, at temperatures of 2,000 degrees Fahrenheit or more. After firing, the tile is packaged and shipped.

  kilns, are used for firing tile. Wall tile, or tile that is prepared by dry grinding instead of wet milling (see #2 and #3 above), usually requires a two-step process. In this process, the tile goes through a low-temperature firing called bisque firing before glazing. This step removes the volatiles from the material and most or all of the shrinkage. The body and glaze are then fired together in a process called glost firing. Both firing processes take place in a tunnel or continuous kiln, which consists of a chamber through which the ware is slowly moved on a conveyor on refractory batts—shelves built of materials that are resistant to high temperatures—or in containers called saggers. Firing in a tunnel kiln can take two to three days, with firing temperatures around 2,372 degrees Fahrenheit (1,300 degrees Celsius).

  For tile that only requires a single firing—usually tile that is prepared by wet milling—roller kilns are generally used. These kilns move the wares on a roller conveyor and do not require kiln furnitures such as batts or saggers. Firing times in roller kilns can be as low as 60 minutes, with firing temperatures around 2,102 degrees Fahrenheit (1,150 degrees Celsius) or more.

- 8 After firing and testing, the tile is ready to be packaged and shipped.

# MODULE-2. CEMENT and ADMIXTURES.

Cement in its broadest term means any substance which acts as binding agent for materials.

Natural cement : It is obtained by burning and crushing the stones containing clay, carbonates & some amout of carbonate of magnesia.

Artifical cement : It is obtained by burning at high temp. a mixture of calcareous and argillaceous material in correct proportion. It is also known as ordinary or portland cement

Ingredients - Functions:

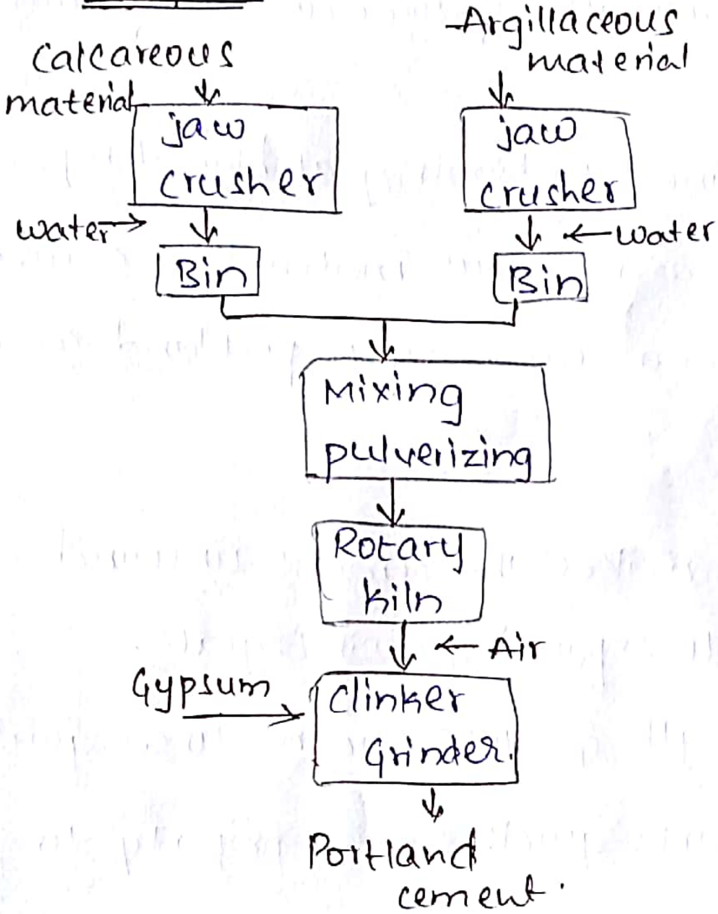
1. Lime (CaO) :- 62% ; Excess makes the cement unsound and causes the cement to Expand & disintegrate.
   Less leads to ↓se in strength & causes cement to set quickly
2. Silica ($SiO_2$) :- 22% ; Imparts quick setting property to imparts strength to cement.
3. Alumina ($Al_2O_3$) - 5% ; Imparts quick setting property.
4. Calcium Sulphate ($CaSO_4$) :- 4% ; It is in the form of gypsum and its function is to ↑se the initial setting time of cement
5. Iron oxide ($Fe_2O_3$) - 3%.
6. Magnesia (MgO) - 2% ; Impart hardness & colour to cement
7. Sulphur - 1% ; Useful in making sound cement. Excess causes the cement to become unsound.
8. Alkalies - 1%.

# Cement Manufacture :

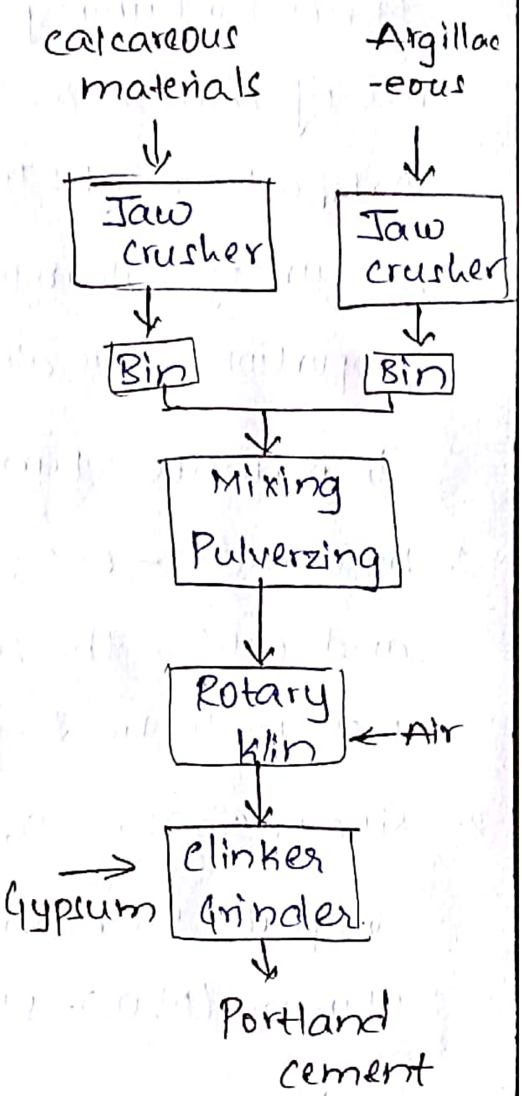
① Mixing of Raw materials :-

- wet process
- Dry process.

## Wet process:




## Dry process




② Burning :-

Carried in rotary klin which rotating at 1-2rpm at its longitudinal axis. It steel tubes having 2.5-3m ø & length varies from 90-120m.

In upper part, water or moisture in the material is Evaporated at 400°c temp. so it is known as drying zone.

Scanned by CamScanner

In central part, temp around 1000°c, where decomposition of lime stone takes place. After Escapes of $CO_2$, Remaining material in form of small lumps called Nodules.

$$CaCO_3 \longrightarrow CaO + CO_2 .$$

The lower part have temp. in between 1500°-1700°c where Lime & clay are reacts to yielding calcium Aluminate & calcium silicates.

$$2CaO + SiO_2 \longrightarrow Ca_2SiO_4 \ (C_2S) \text{ dicalcium silicate.}$$

$$3CaO + SiO_2 \longrightarrow Ca_3SiO_5 \ (C_3S) \text{ tri " "}$$

$$3CaO + Al_2O_3 \longrightarrow Ca_3Al_2O_6 \ (C_3A) \text{ di " Aluminate}$$

$$4CaO + Al_2O_3 + Fe_2O_3 \rightarrow Ca_4Al_2Fe_2O_{10} \ (C_4AF) \text{ Tetracalcium Aluminoferrite.}$$

③ Grinding:

cooled clinkers are ground to fine powder in ball mill or tube mill. 2-3% powdered gypsum is added as Retarding agent during final grinding.

$$2CaO \cdot Al_2O_3 + x\,CaSO_4 \cdot 7H_2O \rightarrow 3CaO \cdot Al_2O_3 \cdot x\,CaSO_4 \cdot 7H_2O$$

④ Storage & packaging :-

The ground cement is stored in silos, from which it is marketed Either in container load or 50kg bags

Properties:

① Tricalcium Silicate ($C_3S$) :- Hardens rapidly & is largely responsible for initial set & early strength.

② Dicalcium silicate ($C_2S$): Hardnes slowly & contributes largely to strength 1ses at ages beyond 7 days.

③ Tricalcium Aluminate ($C_3A$) : It affects setting Time.

④ $C_4AF$: contributes very slightly to strength gain. Acts as flux during Manufacturing. Contributes colour Effects. make cement gray.

Types of cement:

① Acid Resistance cement
② Blast furnace "
③ coloured cement
④ Expanding "
⑤ High Alumina cement
⑥ Hydrophobic "
⑦ Low Heat cement
⑧ Pozzuolona "
⑨ Quick setting "
⑩ Rapid Hardening cement
⑪ Sulphate Resisting "
⑫ White cement

Why gypsum is to be added during the Manufacture of cement ? ( $CaSO_4 \cdot 2H_2O$ ) → 79.1% - calcium sulphate, 20% - $H_2$

It has No. of valuable properties like bulk density, Incombusibility, good absorbing capacity, good fire resistance, Rapid drying, etc..,

Plaster of paris ( $CaSO_4 \cdot \frac{1}{2} H_2O$ ). Pop is mixed with water to form a paste which releases heat & then hardens once dried under Normal temp.

Field Tests & Lab Tests for cement

→ cement should feel smooth when touched.

→ If it is felt rough, it indicates adulteration with Sand.

→ If hand is inserted in bag of cement, feel cool not war

→ when cement is added in water it should sink in it.

→ colour be uniform & typical cement colour gray.

→ cement should free from hard lumps.

Determing the acceptability of cement are :

① Soundness :

It refers to the ability of hardened cement paste to retain its vol after setting without delayed destructive Expansion. It's caused by Excessive amour of CaO or MgO.

② **Strength:** Compressive & tensile strength.
Hydration of cement: chemical Reaction b/w cement & water.
**Compressive strength :-** It is the Basic data required for mix design. By this test, the quality & quantity of concrete can be controlled & degree of adulteration is checked. It End of 3 days, 7 days & 28 days. are given in table. Expressed in N/mm².

**Tensile Strength :** It may be determined by Briquette Test method or by split Tensile Strength Test. It End of 3 days and 7 days for OPC - 2.0N/mm² & 2.5 N/mm².

③ **Consistency Test :-** (Vicat Apparatus).
This is a test to Estimate the quantity of mixing water to form a paste of Normal consistency.

④ **Fineness :-** This test is used to check proper grinding of cement.

There are 3 methods for testing fineness:

① The sieve method - using 90 μ sieve.

② The air permeability method (Lea Nurse & Blains method)

③ The Sedimentation method (Wagner Turbidmetere)

# MODULE -3

# LINTELS

22/9/2015
Tue



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# UNIT – III

## BUILDING COMPONENTS

**Lintels :-**
A lintel is a horizontal member which is placed across the opening.

A lintel is thus a sort of beam, the width of which is equal to the width of the wall, and the ends of which are built into the wall.

The bearing of lintel should be the minimum of the following :-

(i) 10 cm
(ii) Height of lintel
(iii) $\frac{1}{10}$th to $\frac{1}{12}$th of the span of the lintel.

Lintels are simple and easy to construct

**Classification of lintels:-**

According to the materials of their construction :-

(1) Timber lintels
(2) stone lintels
(3) Brick lintels
(4) steel lintels
(5) Reinforced Concrete lintels.

**(1) Timber lintels :-**

These are oldest types of lintels. They are used in hilly areas. Timber lintels are relatively

(2)

costlier, structurally weak and vulnerable to fire. They also liable to decay if not properly (that may be wounded) ventilated.

Sometimes timber lintels are strengthened by the provision of mild steel plates at their top and bottom, such lintels are called "flitched lintels".

(2) Stone lintels :-

These are the most common types, where stone is abundantly available.

Stone lintels can also be provided over openings in brick walls.

Dressed stone lintels give good architectural appearance.

Stone is very weak in tension.

It cracks if subjected to vibratory loads. Hence stone lintels should be used with caution where shock waves are quite common.

(3) Brick lintels :-

These are structurally not strong.

These are used only when the opening is small (less than 1 m) and loads are light.

It is constructed over temporary wooden centering. The bricks with frogs are more suitable for the construction of lintel since the frogs, when filled with mortar, form Joggles which increase the shear resistance of end joints. Such lintels are known as "Joggled brick lintels".

Reinforced Brick lintel :-

where loads are heavy, or span is more, lintels may be made of reinforced brick work.

vertical shear stirrups of 6mm dia wire are provided in every third vertical joint.

Main reinforcement provided at the bottom of the lintel, consists of 8 to 10 mm dia bars which are cranked up at the ends.

(4) steel lintels :-

These are provided, where the opening is large and where the superimposed loads are also heavy.

It consists of rolled steel Joists (RSJ) (or) channel sections either used singly (or) in combination of two (or) three units.

(5) Reinforced cement concrete lintels :-

R.C.C. lintels have replaced practically all other types of lintels because of their strength, rigidity, fire resistance, economy and ease in construction.

They can be used on any span.

Its width is kept equal to the width of the wall. The depth and reinforcement depends upon the span and magnitude of loading.

longitudinal reinforcement, consisting of mild steel bars, are provided near the bottom of lintel to take up tensile stresses. Half these bars are cranked up near the ends. shear stirrups are provided to resist transverse shear.

R.C.C. lintels are also available (4)
as pre-cast units.

for cast-in-situ units, form work is required for construction.

## R.C.C. boot lintels:-

These are provided over cavity walls. It gives better appearance, and reduces quantity of Concrete.

The toe section of the boot lintel should be strong enough to sustain the loads.

A flexible D.P.C (Damp-proof course) is provided above the lintel.

# ARCHES

## INTRODUCTION

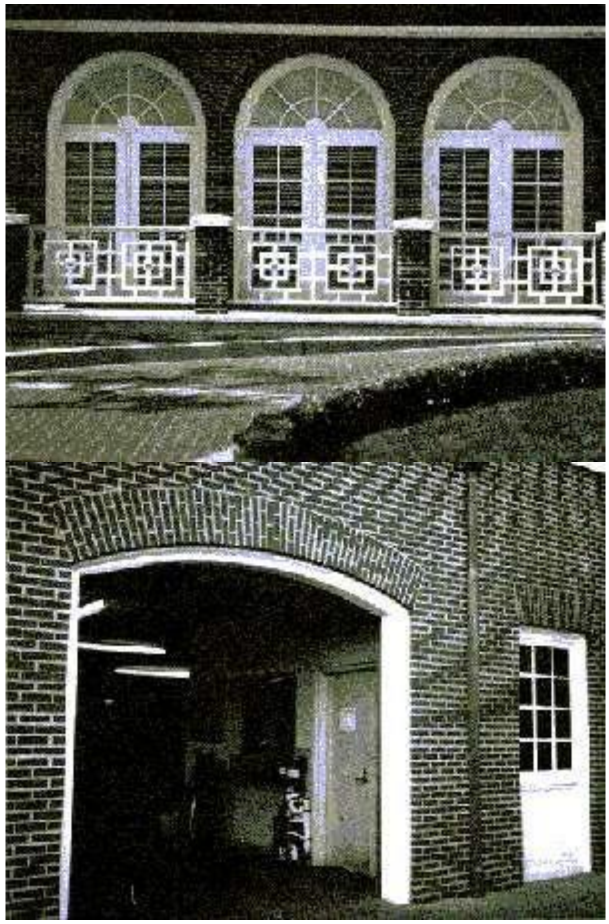
In the latter part of the 19th century, an arch was discovered in the ruins of Babylonia. Archeologists estimate that the arch was constructed about the year 1400 B.C. Built of well-baked, cigar-shaped brick and laid with clay mortar, this arch is probably the oldest known to man. The Chinese, Egyptians and others also made use of the arch before the Christian era. Later, more elaborate arches, vaults and domes with complicated forms and intersections were constructed by Roman builders during the Middle Ages.

The brick arch is the consummate example of form following function. Its aesthetic appeal lies in the variety of forms which can be used to express unity, balance, proportion, scale and character. Its structural advantage results from the fact that under uniform load, the invoiced stresses are principally compressive. Because brick masonry has greater resistance to compression than tension, the masonry arch is frequently the most efficient structural element to span openings.

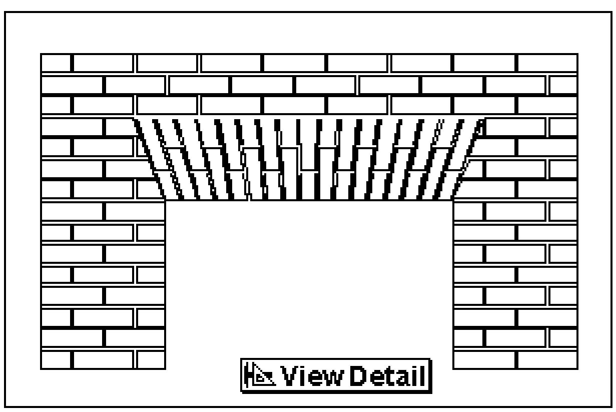
This Technical Notes addresses the detailing and construction of brick masonry arches. The common types of brick masonry arches are presented, along with proper arch terminology. Methods of selecting the type and configuration of brick masonry arches most appropriate for the application are discussed. Proper material selection and construction methods are recommended. Other Technical Notes in this series discuss the structural design of brick masonry arches and lintels.

## ARCH TYPES AND TERMINOLOGY

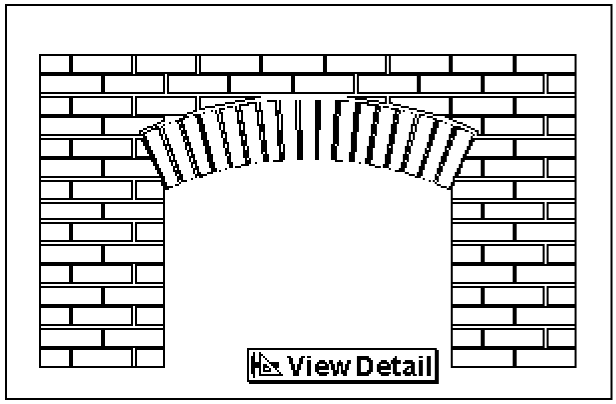
Many arch forms have been developed during the centuries of use, ranging from the jack arch through the circular, elliptical and parabolic to the Gothic arch. Figure 1 depicts examples of structural masonry arches used in contemporary construction. An arch is normally classified by the curve of its intrados and by its function, shape or architectural style. Figure 2 illustrates some of the many different brick masonry arch types. Jack, segmental, semicircular and multicentered arches are the most common types used for building arches. For very long spans and for bridges, semicircular arches are often used because of their structural efficiency.



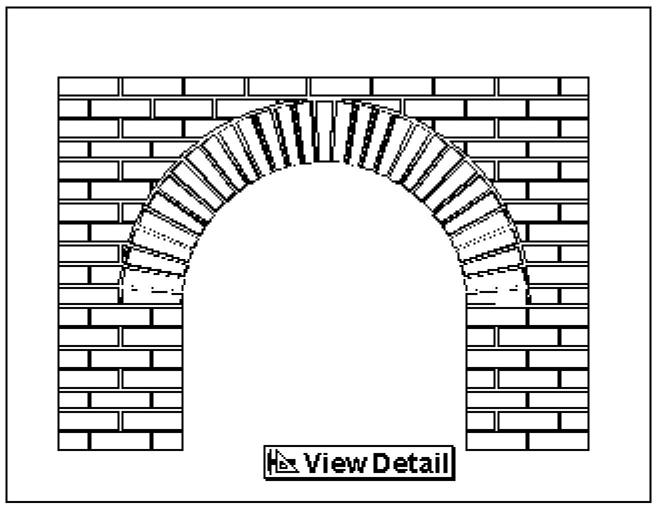
**Structural Brick Arches**
**FIG. 1**



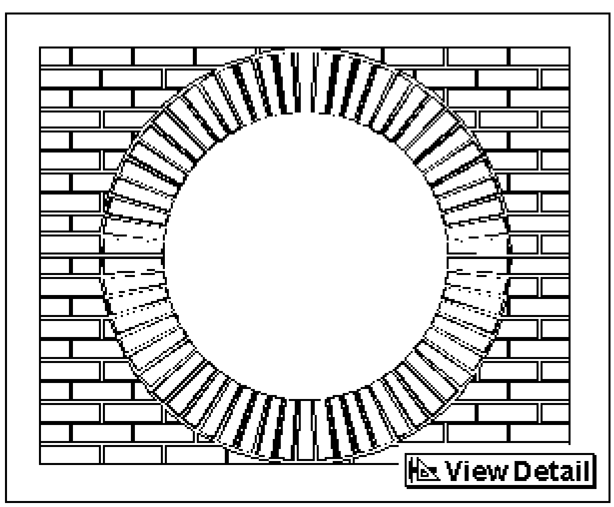

**Arch Types: Jack**
**FIG. 2a**



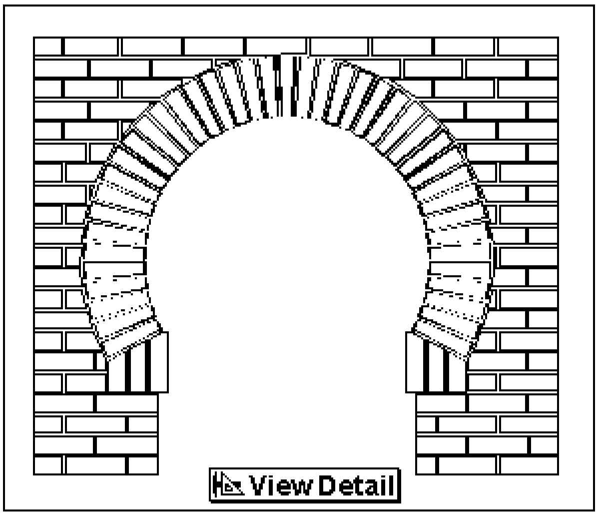

**Arch Types: Segmental**
**FIG. 2b**



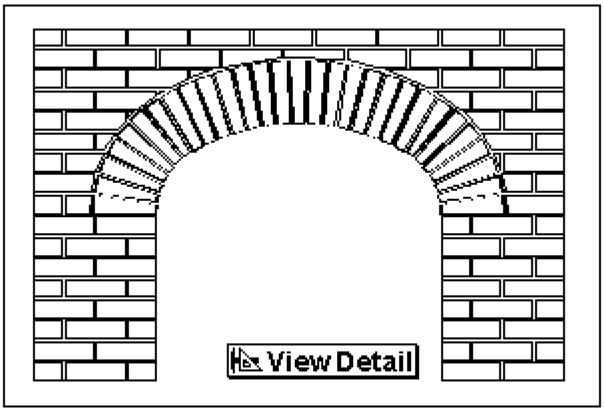

**Arch Types: Semicircular**
**FIG. 2c**



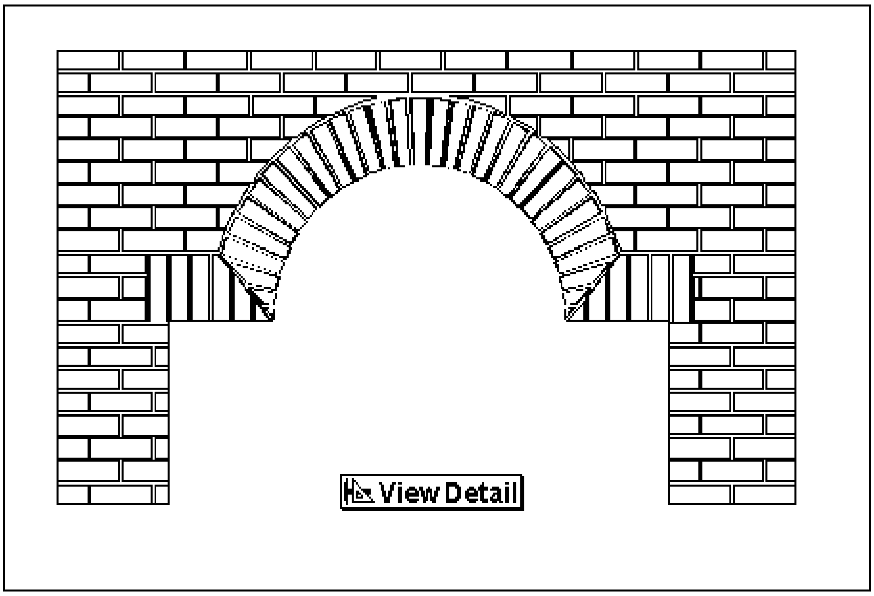

**Arch Types: Bulls eye**
**FIG. 2d**




Arch Types: Horseshoe FIG. 2e

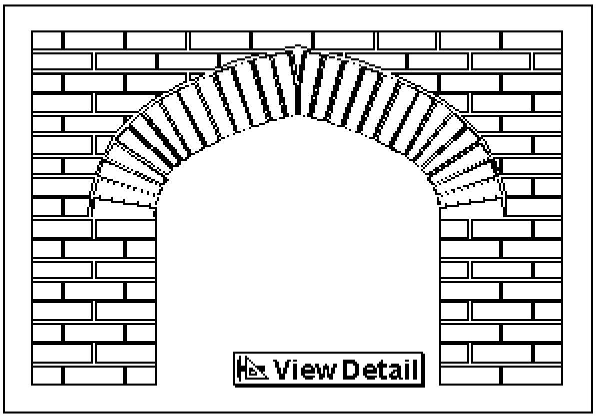



Arch Types: Multicentered
FIG. 2f

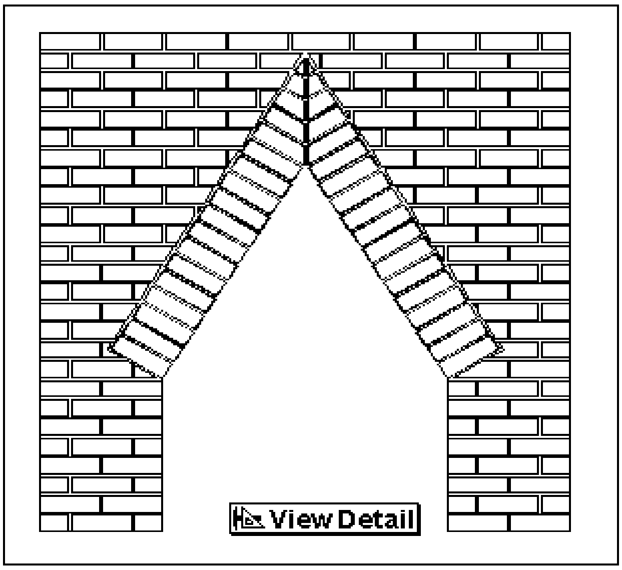



Arch Types: Venetian

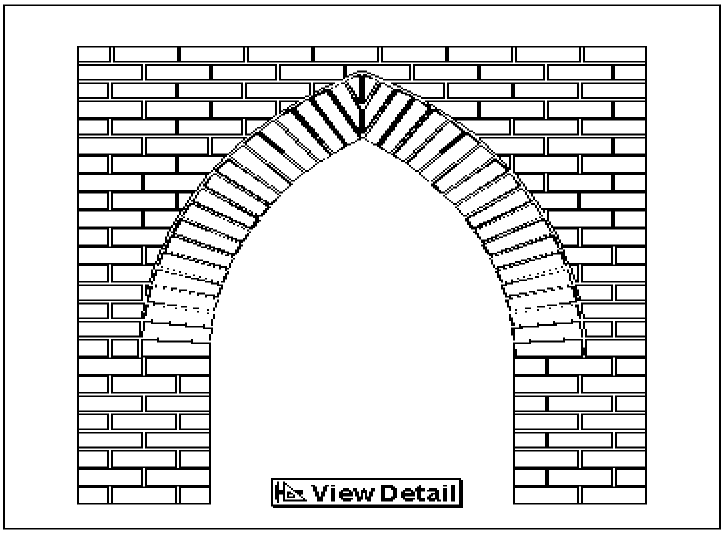
FIG. 2g




**Arch Types: Tudor**
**FIG. 2h**




**Arch Types: Triangular**
**FIG. 2i**




**Arch Types: Gothic**

**(FIG. 2j)**

Mainly due to their variety of components and elements, arches have developed their own set of terminology. Following is a glossary of arch terminology. Figure 3 illustrates many of the terms defined in this glossary.
Technical Notes in this series will use this terminology.

**Abutment:** The masonry or combination of masonry and other structural members which support one end of the arch at the skewback.

**Arch:** A form of construction in which masonry units span an opening by transferring vertical loads laterally to adjacent voussoirs and, thus, to the abutments. Some common arch types are as follows:

Blind -An arch whose opening is filled with masonry.

Bullseye -An arch whose intrados is a full circle. Also known as a Circular arch.

Elliptical -An arch with two centers and continually changing radii.

Fixed -An arch whose skewback is fixed in position and inclination. Masonry arches are fixed arches by nature of their construction.

Gauged -An arch formed with tapered voussoirs and thin mortar joints.

Gothic -An arch with relatively large rise-to-span ratio, whose sides consist of arcs of circles, the centers of which are at the level of the spring line. Also referred to as a Drop, Equilateral or Lancet arch, depending upon whether the spacings of the centers are respectively less than, equal to or more than the clear span.

Horseshoe -An arch whose intrados is greater than a semicircle and less than a full circle. Also known as an Arabic or Moorish arch.

Jack -A flat arch with zero or little rise.

Multicentered -An arch whose curve consists of several arcs of circles which are normally tangent at their intersections.

Relieving -An arch built over a lintel, jack arch or smaller arch to divert loads, thus relieving the lower arch or lintel from excessive loading. Also known as a Discharging or Safety arch.

Segmental -An arch whose intrados is circular but less than a semicircle.

Semicircular -An arch whose intrados is a semicircle (half circle).

Slanted -A flat arch which is constructed with a keystone whose sides are sloped at the same angle as the skewback and uniform width brick and mortar joints.

Triangular -An arch formed by two straight, inclined sides.

Tudor -A pointed, four-centered arch of medium rise-to-span ratio whose four centers are all beneath the extrados of the arch.

Venetian -An arch formed by a combination of jack arch at the ends and semicircular arch at the middle. Also known as a Queen Anne arch.

**Camber:** The relatively small rise of a jack arch.

**Centering:** Temporary shoring used to support an arch until the arch becomes self-supporting.

**Crown:** The apex of the arch's extrados. In symmetrical arches, the crown is at the midspan.

**Depth:** The dimension of the arch at the skewback which is perpendicular to the arch axis, except that the depth of a jack arch is taken to be the vertical dimension of the arch at the springing.

**Extrados:** The curve which bounds the upper edge of the arch.

**Intrados:** The curve which bounds the lower edge of the arch. The distinction between soffit and intrados is that the intrados is a line, while the soffit is a surface.

**Keystone:** The voussoir located at the crown of the arch. Also called the key. **Label Course:** A ring of projecting brickwork that forms the extrados of the arch. **Rise:** The maximum height of the arch soffit above the level of its spring line.
**Skewback:** The surface on which the arch joins the supporting abutment.

**Skewback Angle:** The angle made by the skewback from horizontal.

**Soffit:** The surface of an arch or vault at the intrados.

**Span**: The horizontal clear dimension between abutments.

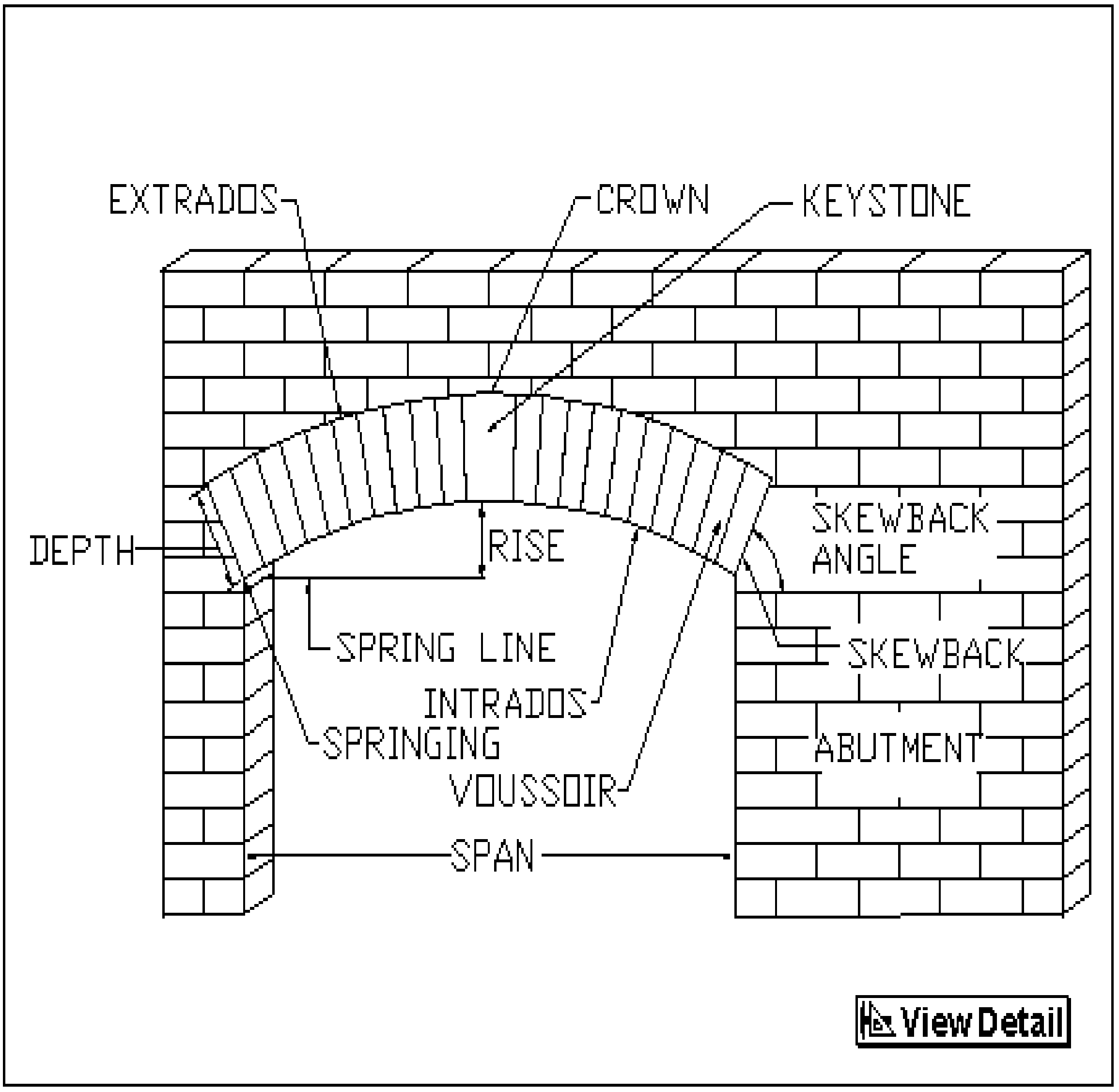
**Spandrel:** The masonry contained between a horizontal line drawn through the crown and a vertical line drawn through the upper most point of the skewback.

**Springing:** The point where the skewback intersects the intrados.

**Springer:** The first voussoir from a skewback.

**Spring Line:** A horizontal line which intersects the springing.

**Voussoir:** One masonry unit of an arch.




Arch Terms FIG. 3

**WALLS**

6/10/15 ॐ walls ①

Wall:- function of a wall is to enclose or divide space of the building to make it more functional and useful.
They provides privacy, afford security and give protection against heat, cold, sun and rain.
They provide support to floors and roofs.
They should be so designed as to have provision of adequate
(i) strength and stability
(ii) weather resistance
(iii) durability
(iv) fire resistance
(v) Thermal insulation
(vi) Sound insulation

Walls may be defined as a vertical load-bearing member, the width (ie length) of which exceeds four times the thickness.

Types:-
(a) load-bearing walls
(b) Non-load bearing walls

Each type may further divided as
(i) External (or) enclosing walls
(ii) Internal (or) divide walls.

Load-bearing walls:- These are those which are designed to carry super-imposed loads (transferred through roofs etc.) in addition to their self weight.

Non - load bearing walls :-

They carry their own load only. They generally serve as divide walls (or) partition walls. The external non-load-bearing wall, commonly related to framed structures is termed as "panel wall".

Partition wall :-

A partition wall is a thin internal wall which is constructed to divide the space within the building into rooms or areas. It may either be non-load-bearing (or) load bearing.

Internal wall :-

A load-bearing partition wall is called an "internal wall".

Party wall :- It is a wall seperating adjoining building belonging to different owners (or) occupied by different persons. It may, or may not, be load-bearing.

Separating wall :-

It is a wall seperating different occupancie within the same building.

Curtain wall :-

It is a self supporting wall carrying no other vertical loads but subject to lateral loads. It may be laterally supported by vertical (or) horizontal structural members where necessary.

Cross - wall construction :-

It is a particular form of load-bearing wall construction in which all the loads are carried by interna walls, running at right angles to the length of the building.

load bearing walls further divided into following Types :-

(a) solid masonry wall
(b) Cavity wall
(c) faced wall
(d) Veneered wall

(a) solid masonry wall :-

These are the one most commonly used. These are built of individual blocks of material, such as bricks, clay (or) concrete blocks, (or) stone, usually in horizontal courses, cemented together with suitable mortar. A solid wall is constructed of the same type of building units throughout its thickness. It may have openings for doors, windows etc:

(b) cavity wall :- (or) Hollow wall :-

It is a wall comprising two leaves, each leaf being built of structural units and seperated by a cavity and tied together with metal ties or bonding units to ensure that the two leaves act as one structural unit. The space between the leaves is either left as a continuous cavity (or) is filled with non-load-bearing insulating and water proofing material.

(c) faced wall :- It is a wall in which the facing and backing are of two different materials which are bonded together to ensure common action under load.

(d) Veneered wall :-

It is a wall in which the facing is attached to the backing but not so bonded as to result in a common action under load.

Cavity wall (or) Hollow wall :-

It is the one which consists of two seperate walls, called leaves (or) skins, with a cavity (or) gap in-between. The two leaves of a cavity wall may be of equal thickness if it is a non-load-bearing wall, (or) the internal leaf may be thicker than the external leaf to meet the structural requirements.

The two portions of the wall may be connected together by metal pins or bonding bricks at suitable interval. Cavity walls are often constructed for giving better thermal insulation to the building. It also prevents the dampness to enter and acts as sound insulation. Thus they are normally the outer walls of the building. The size of cavity varies from 4 To 10 cm the inner and outer skins should not be less than 10 cm each (half brick).

Advantages of cavity walls :-

(i) There is no direct contact between inner and outer leaves of the wall (except at the wall ties.). Hence the external moisture (dampness) cannot travel inside the building.

(5)

(2) Cavity between two leaves is full of air which is bad conductor of heat. Hence transmission of heat from external face to the inside the room is very much reduced. Cavity walls have about 25% greater insulating value than the solid walls.

(3) Cavity walls also offer good insulation against sound.

(4) The nuisance of efflorescence is also very much reduced.

(5) They are cheaper and economical.

(6) Loads on foundations are reduced because of lesser solid thickness.

---

## Partition walls :-

It is a thin internal wall which is constructed to divide the space within the building into rooms or areas.

It may be either non-load-bearing or load-bearing.

Generally partition walls are non-load bearing. A load-bearing partition wall is called an "internal wall."

### Types of Partition walls :-

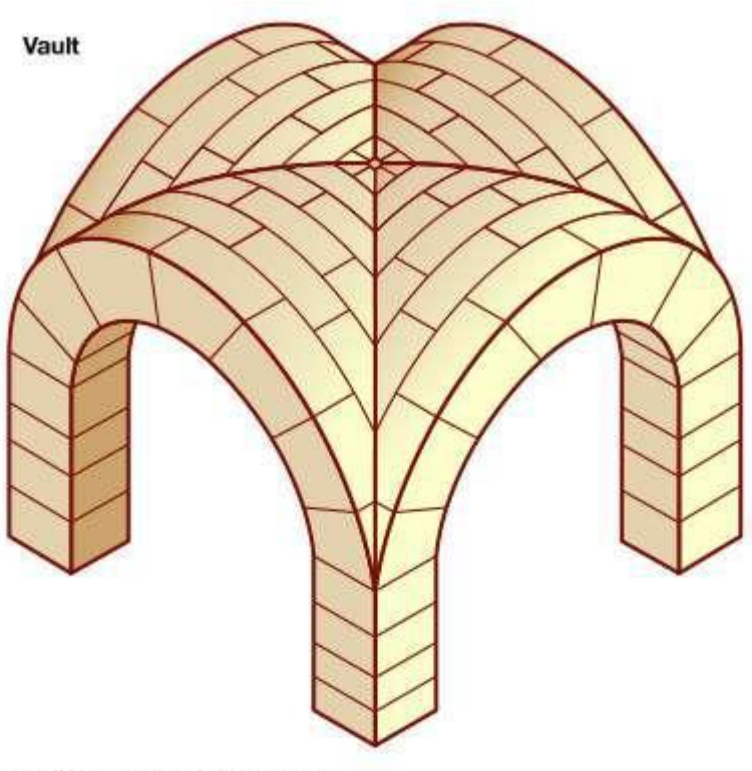
(1) Brick partitions

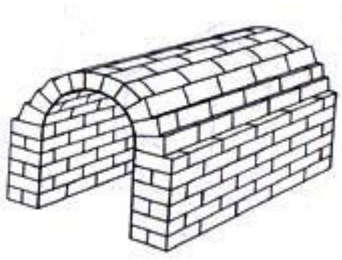
(2) clay block partitions

③ Concrete partitions
④ Glass partitions
⑤ Metal lath partitions
⑥ Asbestos sheet (or) G.I. sheet partitions
⑦ plaster slab Partition
⑧ wood ~~wood~~ wool slab Partition
⑨ Timber partitions.

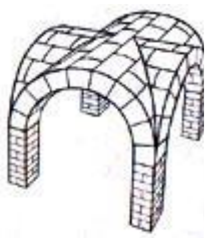
**VAULTS**

**Vault**, in building construction, a structural member consisting of an arrangement of arches, usually forming a ceiling or roof.

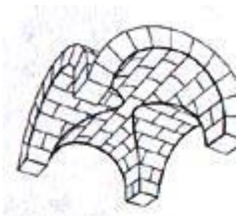


Barrel or Tunnel Vault



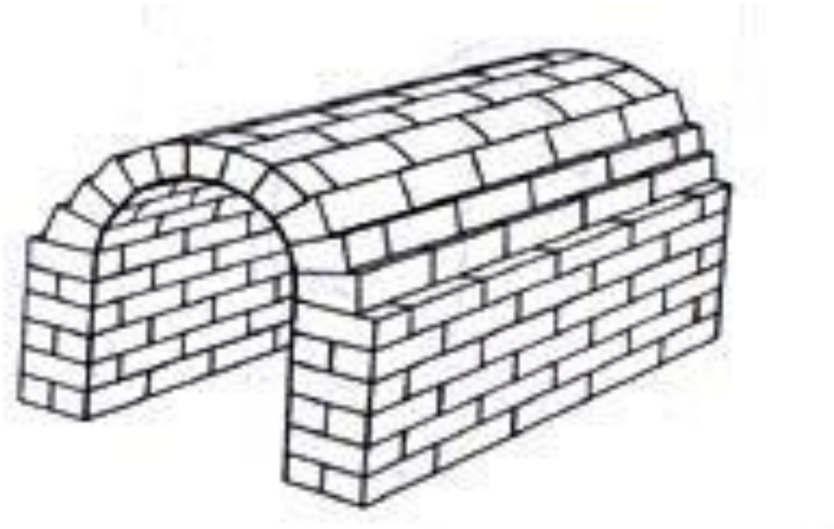
Groin Vault (from above)



Groin Vault (from below)

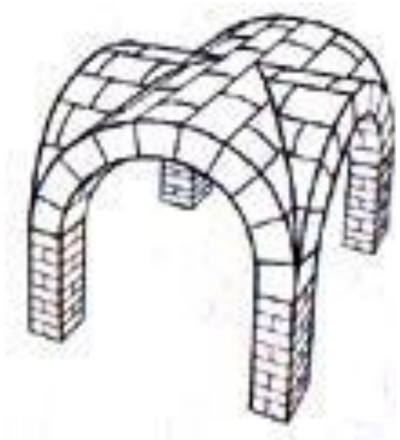
A **vault** is a ceiling of brick, stone, or concrete built in the principle of the arch.

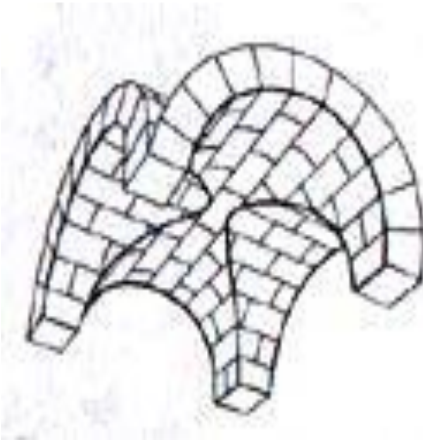
A **tunnel vault**, or **barrel vault**, is a tunnel-like, semi-cylindrical extension of an arch, which may be thought of as an unbroken series of arches pressed together, one behind the other. It cannot be lighted except at the ends without being structurally weakened, because, as in an arch, continuous abutment must be applied to absorb the thrust carried down along the haunches to the walls supporting it. However, arches may be introduced in the supporting walls and transverse ribs may be inserted in the vault to concentrate thrust at a few strongly buttressed points, thereby permitting a reduction of weight and thrust in the segments of vaulting between the ribs.



Barrel or Tunnel Vault

If a barrel vault is intersected at right angles by another barrel vault of the same size, a **cross vault**, or **groin vault**, is formed. This is a very efficient form of vaulting allowing full illumination from the sides. Groin vaults also allow a great saving in material and labor over the simple barrel vault; thrust is concentrated along the groins (the four diagonal edges formed along the points where the barrel vaults intersect), so the vault need only be abutted at its four corners.





Groin Vault (from above) Groin Vault (from below)

# STAIR CASES

## 14.1. INTRODUCTION

A *stair* is a set of steps leading from one floor to the other. It is provided to afford the means of ascent and descent between various floors of a building. The room or enclosure of the building, in which the stair is located is known as *stair-case*. The opening or space occupied by the stair is known as a *stairway*. It should be suitably located in a building. In a domestic building the stairs should be centrally located to provide easy access to all the rooms. In public buildings, stairs should be located near the entrance. In big buildings, there can be more than one stairs. Stairs may be constructed of timber, bricks, stone, steel or reinforced cement concrete. However, fire protection of staircases is extremely important. Staircases provide access and communication between floors in multi-storey buildings, and are a path by which fire can spread from one floor to another. Staircase, therefore, must be enclosed by fire resisting walls, floors, ceilings and doors. It is desirable that the linings to the walls and ceiling are non-combustible and of low flame spread. Another important aspect in the design of stairs is the strength aspect. It must be designed to carry certain loads, which are similar to those used for the design of the floor. Apart from stairs, other means of vertical transportation between the floors of a building are : lifts, ramps, ladders and escalators.

## 14.2. TECHNICAL TERMS

Fig. 14.1 shows the section of a stair, with its components. The technical terms associated with the design and construction of stairs are defined below :

**1. *Step*** : It is a portion of stair which permits ascent or descent. It is comprised of a tread and a riser. A stair is composed of a set of steps.

**2. *Tread*** : It is the upper horizontal portion of a step upon which the foot is placed while ascending or descending.

**3. *Riser*** : It is the vertical portion of a step providing a support to the tread.

**4. *Flight*** : This is defined as an unbroken series of steps between landings.

**5. *Landing*** : It is the level platform at the top or bottom of a flight between the floors. A landing facilitates change of direction and provides an opportunity for taking rest during the use of the stair.

**6. *Rise*** : It is the vertical distance between two successive tread faces.

**7. *Going*** : It is the horizontal distance between two successive riser faces.

**8. *Nosing*** : It is the projecting part of the tread beyond the face of the riser. It is usually rounded off from architectural considerations.

**9. *Scotia*** : It is a moulding provided under the nosing to improve the elevation of the step, and to provide strength to nosing.

**10. *Soffit*** : It is the underside of a stair.

**11. *Line of nosings:*** It is an imaginary line parallel to the strings and tangential to the nosings. It is useful in the construction of hand rails, giving the line with which the under-surface of the hand rail should coincide.

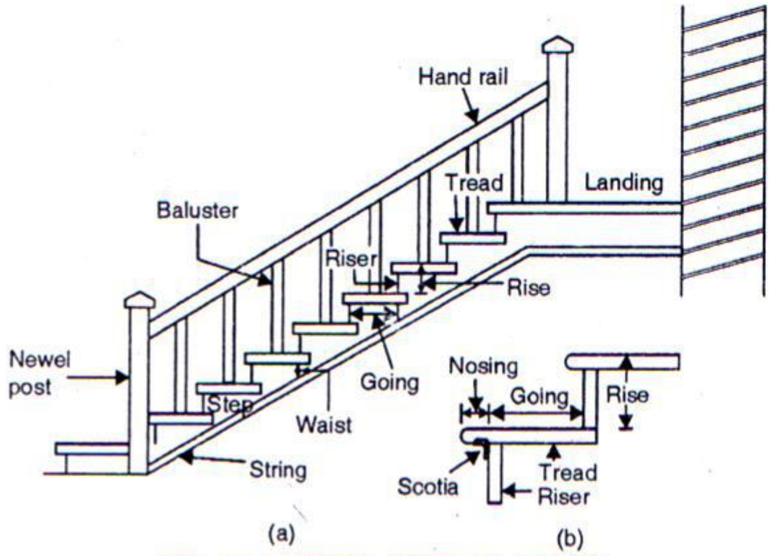



FIG. 14.1 TERMS USED IN STAIRS.

**12. *Pitch or slope*** : It is the angle which the line of nosing of the stair makes with the horizontal.

**13. *Strings or stringers*** : These are the sloping members which support the steps in a stair. They run along the slope of the stair.

**14. *Newel post*** : Newel post is a vertical member which is placed at the ends of flights to connect the ends of strings and hand rail.

**15. *Baluster*** : It is vertical member of wood or metal, supporting the hand rail.

**16. *Balustrade.*** : It consists of a row of balusters surmounted by a hand rail, to provide protection for the users of the stair.

**17. *Hand Rail*** : It is a rounded or moulded member of wood or metal following generally the contour of the nosing line, and fixed on the top of balusters.

**18. *Head Room*** : It is the minimum clear vertical distance between the tread and overhead structure (*i.e.*, ceiling etc.).

**19. *Run*** : It is the total length of stairs in a horizontal plane, including landings.

**20. *Header*** : It is the horizontal structural member supporting stair stringers or landings.

## 14.3 REQUIREMENTS OF A GOOD STAIR

Stair is the means of vertical transportation between the floors. It should, therefore, be designed so as to provide easy, quick and safe mode of communication between the floors. Following are the general requirements which a stair should fulfill.

**1. *Location*** : (*i*) It should be so located as to provide easy access to the occupants of the building. (*ii*) It should be so located that it is well lighted and ventilated directly from the exterior. (*iii*) It should be so located as to have approaches convenient and spacious.

**2. *Width of stair*:** It should be wide enough to carry the user without much crowd or inconvenience. Width of stairs depends upto its location in the building and the type of the building itself. In a domestic building, a 90 cm wide stair is sufficient while in public building, 1.5 to 1.8 m width may be required.

**3. *Length of flight*:** From comfort point view, the number of steps are not more than 12 and not less than 3.

**4. *Pitch of stair*:** The pitch of the stairs should match with the French theory : 'the labour of moving vertically is about twice that of moving horizontally, if the average human stride is taken as 23 inches. If the rise and going are measured in inch units, the best pitch of the stairs is that inclination which by twicing the rise and adding the going equals 23. When measured in cm units, a comfortable slope is achieved when twice rise plus going is equal to 60 approximately. Pitch should however, be limited to 30° to 45°.

**5. *Head Room*:** The clear distance between the tread and soffit of the flight immediately above it should not be less than 2.1 to 2.3 m, so that even a tall person can use the stair with some luggage on its head.

**6. *Balustrade*:** Open well stair should always be provided with balustrade, to provide safety to the users. Wide stair should have hand rail to both the sides.

**7. *Step dimensions*:** The rise and going should be of such dimensions as to provide comfort to the users. Their proportion should also be such as to provide desirable pitch of the stair. The going should not be less than 25 cm, though 30 cm going is quite comfortable. The rise should be between 10 cm (for hospitals etc.) to 15 cm. The width of landing should not be less than the width of stair.

**8. *Materials of construction*:** The material used for the construction of stair should be such as to provide (*i*) sufficient strength, and (*ii*) fire resistance.

## 14.4. DIMENSIONS OF A STEP

For comfortable ascent and descent, the rise and tread of a step should be well-proportioned. The following thumb rules are followed :

(*i*) $(2 \times \text{Rise in cm}) + (\text{Going in cm}) = 60$

(*ii*) $(\text{Rise in cm}) + (\text{Going in cm}) = 40$ to $45$

(*iii*) $(\text{Rise in cm}) \times (\text{Going in cm}) = 400$ to $450$

(*iv*) Adopt Rise = 14 cm and Going = 30 cm as standard ; then for every 20 mm subtracted from going, add 10 mm to the rise.

Thus, other combinations for rise and going would be 15 cm × 28 cm ; 16 cm × 26 cm ; 17 cm × 24 cm.

For residential buildings, the common size of the steps is 16 cm × 26 cm. In hospital etc., the comfortable size of the steps is 10 cm × 30 cm.

**Types of steps** : Steps in a stair may be of the following of types :

1. Flier
2. Bull nose step
3. Round ended step
4. Splayed step
5. Commode step
6. Dancing step
7. Winder.

A *flier* is an ordinary step of uniform width and rectangular shape in plan, as shown in Fig. 14.2 (*a*). A *bull nose step*, generally provided at the bottom of the flight, projects in front of the newel post. Its end near the newel forms the quadrant of a circle (Fig. 14.2*a*). A round ended step is similar to a bull nose step except that it has a semi-circular end which projects out from the stringer. A *splayed step* is also provided at the beginning of the flight, with its end, near the newel post, splayed as shown in Fig. 14.2 (*c*). A *commode step*, shown in Fig. 14.2 (*d*) has curved tread and riser. *Dancing or balancing steps* are the winders which do not radiate from a common centre. *Winders* are tapering steps, such as those which radiate from a point usually situated at the centre of a newel (Fig. 14.2 *f*).

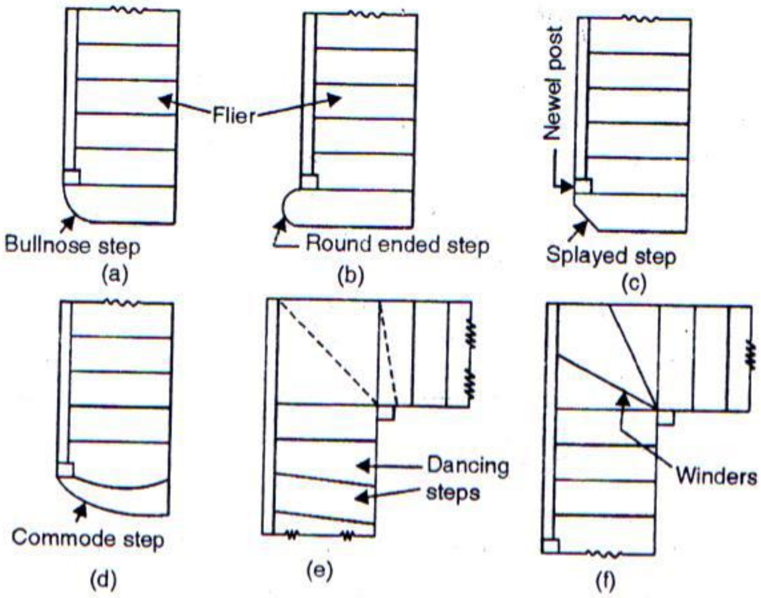



FIG. 14.2 VARIOUS TYPES OF STEPS.

## 14.5. CLASSIFICATION OF STAIRS

Stairs can be classified in two broad heads :

1. Straight stairs
2. Turning stairs

(*i*) Quarter turn stairs (*ii*) Half turn stairs (dog-legged and open well stairs) (*iii*) Three-quarter turn stairs (*iv*) Bifurcated stairs.

Each of the turning stairs are of three types :

(*a*) newel stairs (*b*) well or open-newel stairs, and
(*c*) geometrical stairs

A *newel stair* is the one which has a newel at the foot and head of each flight of the stair, and in which newels are conspicuous features. In *well or open newel stairs,* lateral space is left between the turning flights. Open newel stair present the best appearance and are strong. *Geometrical stairs* have the strings and hand rails continuous and are set out in accordance with geometrical principles. They may be *circular, spiral, helical,* or even *elliptical.* A newel may be introduced at the bottom and top of such a stair, though it is not an essential part of the construction. Geometrical stairs require care and good deal of skill in their construction. They are not so imposing as the open newel type, and are comparatively weak.

### 1. STRAIGHT STAIRS

In this type, this stair runs straight between the two floors. It is used for small houses where there are restrictions in available width. The stair may consist of either one single flight or more than one flight (usually two) with a landing, as shown in Fig. 14.3.

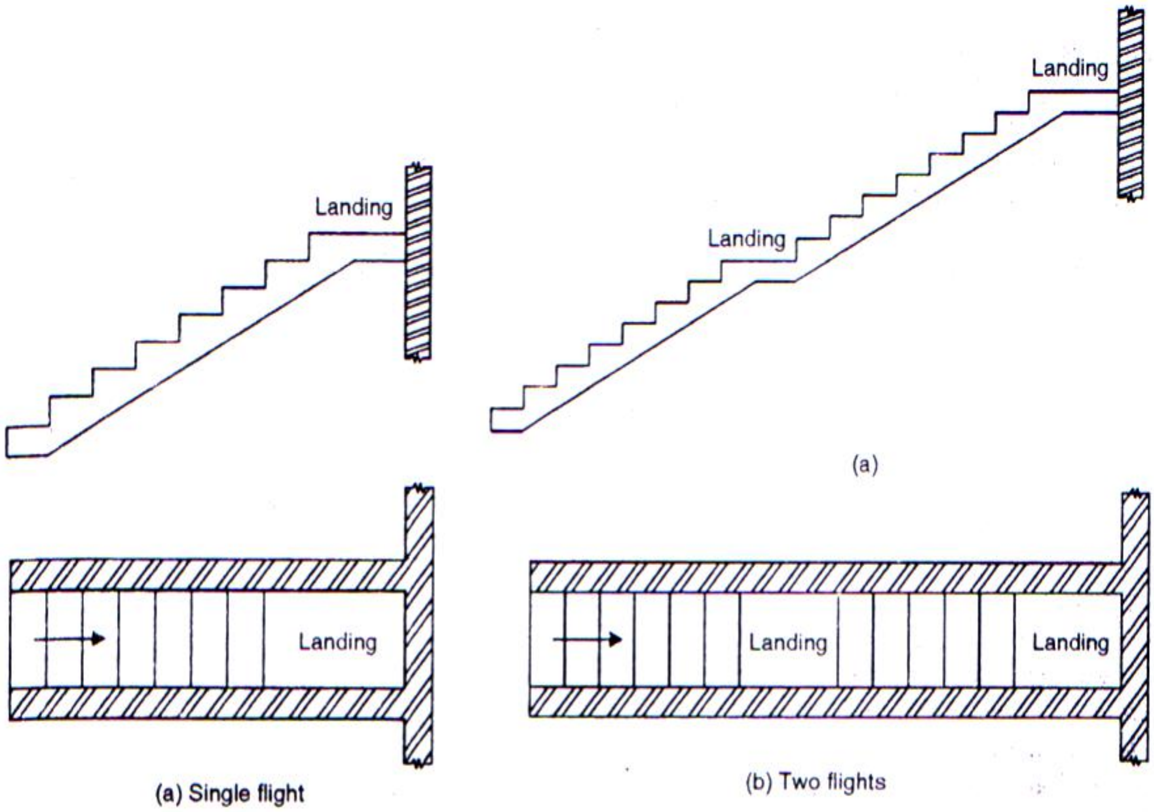



FIG. 14.3. STRAIGHT STAIRS.

## 2. QUARTER TURN STAIRS

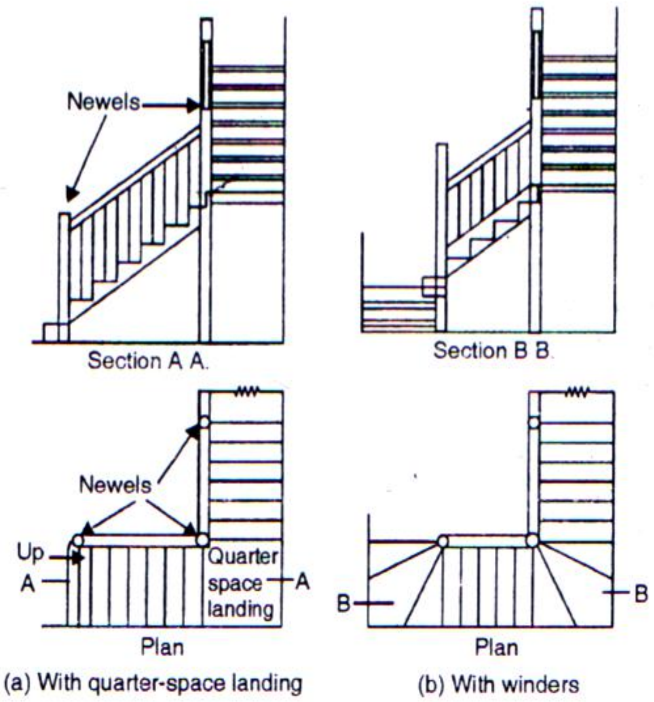



FIG. 14.4. NEWEL QUARTER TURN STAIRS

A *quarter turn stair* is the one which changes its direction either to the left or to the right, the turn being affected either by introducing a *quarter space landing* (Fig. 14.4 *a*) or by providing winders (Fig. 14.4 *b*).

Quarter turn stairs are of two types:

(*a*) Newel quarter turn stairs

(*b*) Geometrical quarter turn stairs.

**(*a*) Newel quarter turn stairs**

These stairs have the conspicuous newel posts at the beginning and end of each flight. At the quarter turn, there may either be quarter space landing or there may be winders. Two forms of this type are shown in Fig. 14.4.

**(*b*) Geometrical quarter turn stairs**

In geometrical stairs, the stringer as well as the hand rail is continuous, with no newel post at the landing. Two forms are shown in Fig. 14.5.

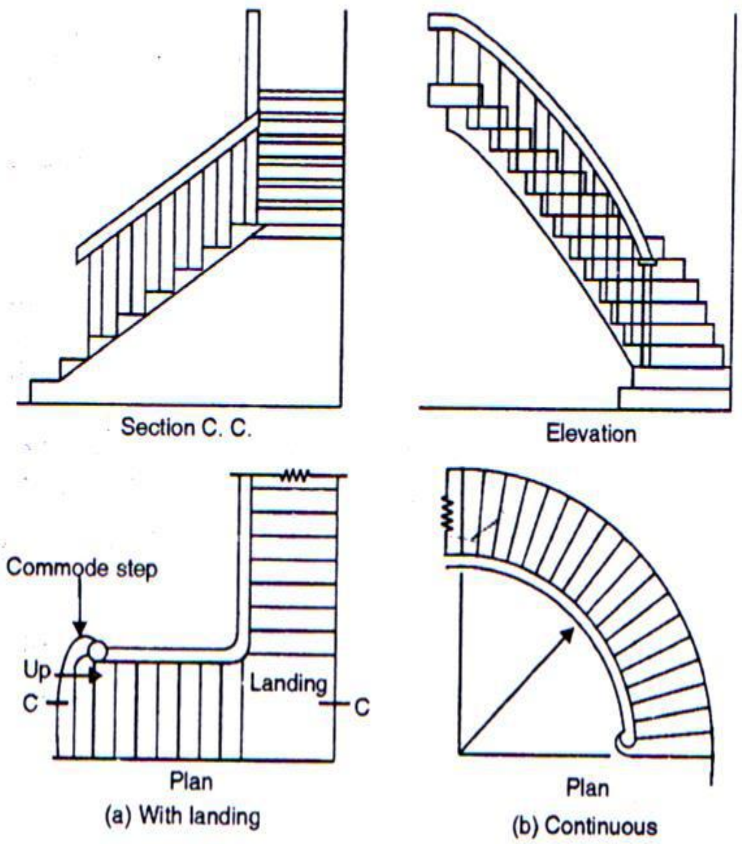



FIG. 14.5. GEOMETRICAL QUARTER TURN STAIRS.

## 3. HALF TURN STAIRS

Half turn stair is the one which has its direction reversed, or changed for 180°. Such stairs are quite common. These may be of three types :

(*a*) Dog-legged or newel half turn stairs.

(*b*) Open newel half turn stairs.

(*c*) Geometrical half turn stairs.

**(*a*) Dog-legged stairs**

This name is given because of its appearance in sectional elevation. It comes under the category of newel (or solid newel) stairs in which newel posts are provided at the beginning and end of each flight. These may be of two forms : (*i*) with half space landing, and (*ii*) with quarter space landing and winders. Generally, the former type (*i.e.*. without winders) is more common, as shown in Fig. 14.6. There is no space between the outer strings of the two flights.

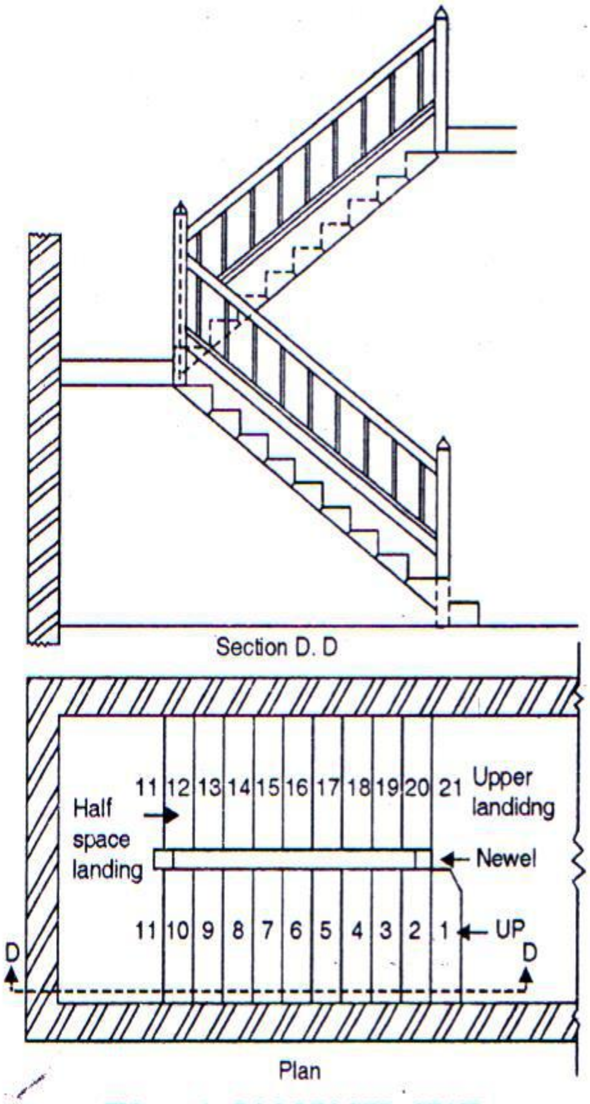



FIG. 14.6. DOG-LEGGED STAIR.

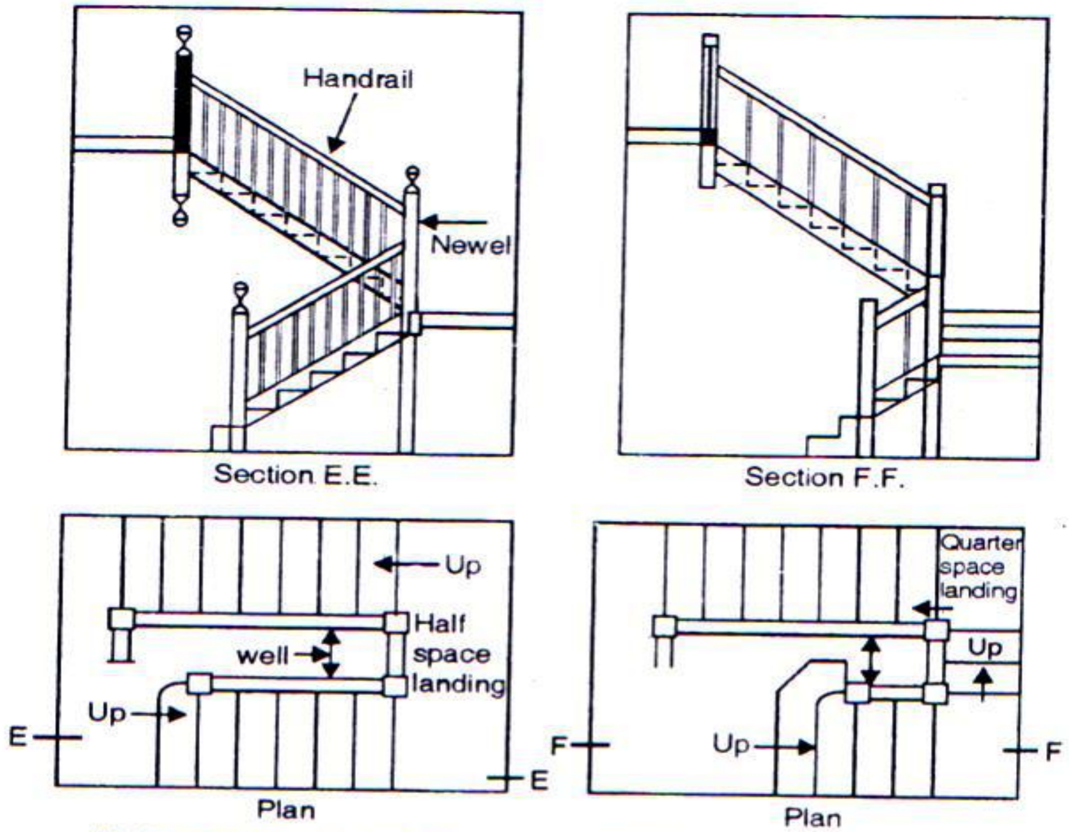
**(b) Open newel half turn stair** : Open well or open newel half turn stair has a space or well between the outer strings. This is the only aspect in which it differs from the dog-legged stair. The additional width is required between the two flights ; the space between the two strings may vary from 15 cm (min) to 100 cm. When the space left is more, a small flight containing two to four steps may be introduced at the turn, between the two quarter space landing, as shown in Fig. 14.7 (*b*). Otherwise, for small width well, a half space landing may be provided as shown in Fig. 14.7 (*a*).

**(*c*) Geometrical half turn stairs**

The essential features of such stairs are that the stringers and the hand rails are continuous, without any intervening newel post. These may be either with half-space landing (Fig. 14.8 *a*) or without landing (Fig. 14.8 *b*).

**4. THREE QUARTER TURN STAIRS**

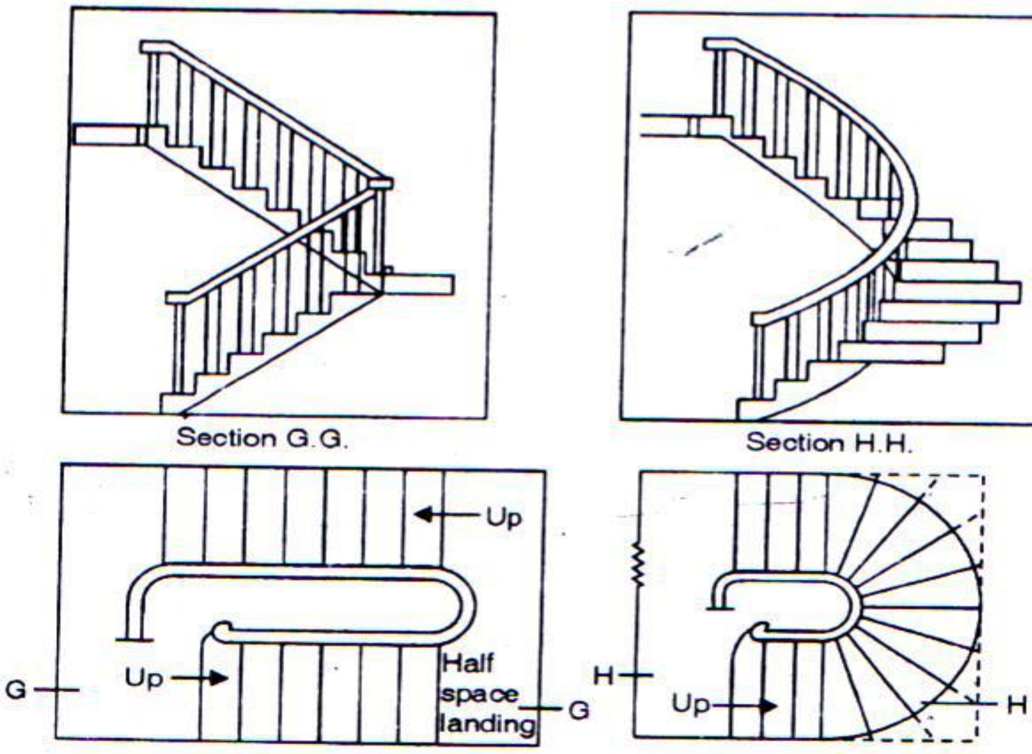
A three quarter turn stairs has its direction changed three times with its upper flight crossing the bottom one. It may either be newel type or open newel type. Such type of stair is used when the length of the stair room is limited and when the vertical




(a) With half space landing

(b) With quarter-space landing and intervening flight

FIG. 14.7. OPEN NEWEL HALF TURN STAIRS.




(a) With landing

(b) Continuous

FIG. 14.8. GEOMETRICAL HALF TURN STAITS.

distance between the two floors is quite large.

## 5. BIFURCATED STAIRS

This type of stair is commonly used in public buildings at their entrance hall. The stair has a wider flight at the bottom, which bifurcates into two narrower flights, one turning to the left and the other to the right, at the landing. It may be either of newel type with a newel post as shown in Fig. 14.9 (left side) or of geometrical type, as shown in the right portion of Fig. 14.9 with continuous stringer and hand rails.

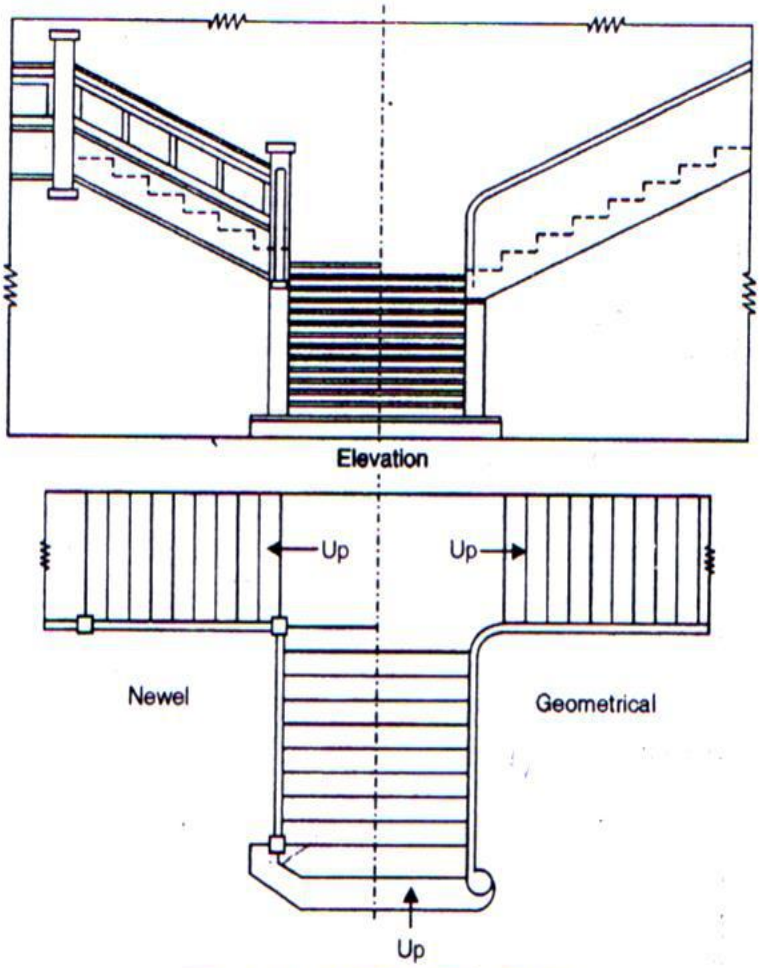



FIG. 14.9. BIFURCATED STAIR.

## 6. CONTINUOUS STAIRS

Continuous stairs are those which do neither have any landing nor any intermediate newel post. They are, therefore, geometrical in shape. Continuous stairs may be of the following types :

(*i*) Circular stairs,

(*ii*) Spiral stairs, and (*iii*) Helical stairs

*Circular stairs* are shown in Fig. 14.5 (*b*) and 14.8 (*b*). *Spiral stair* is shown in Fig. 14.10. Such a stair is usually made either of R.C.C. or metal, and is employed at a location where there are space limitations. These are also used as emergency stairs, and are provided at the back side of a building. All the steps are winders. The stair is, therefore, not comfortable.

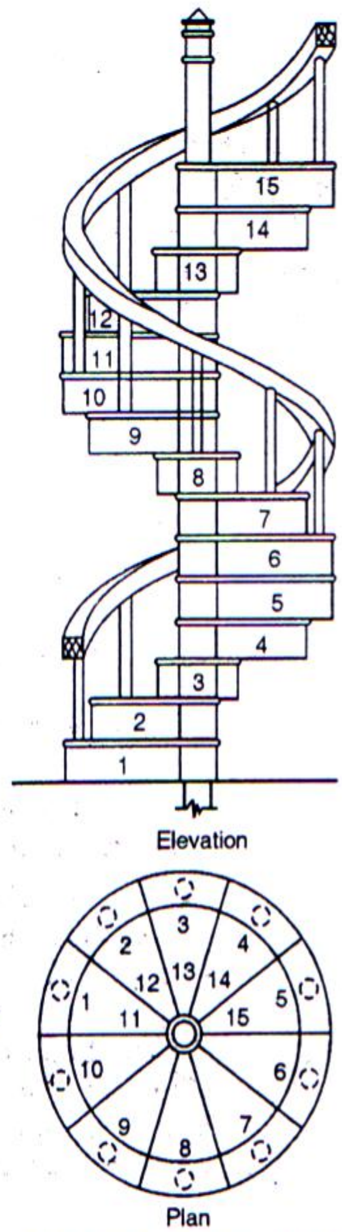



FIG. 14.10 SPIRAL STAIR.

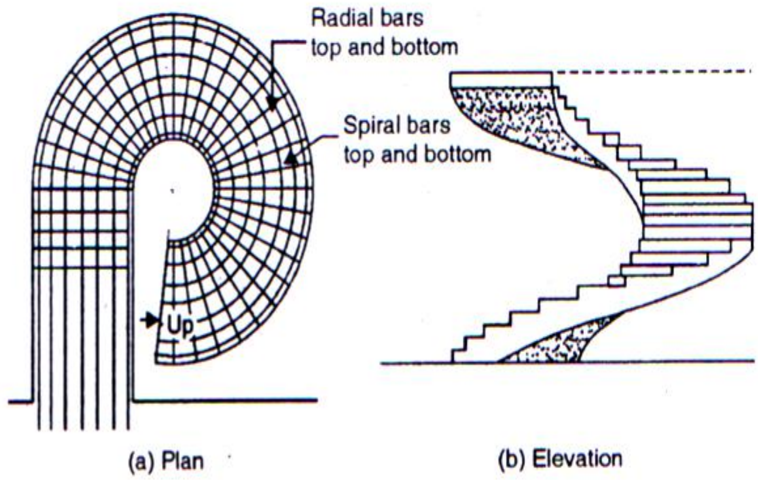



FIG. 14.11. HELICAL STAIR

A *helical stair*, shown in Fig. 14.11, looks very fine but its structural design and construction is very complicated. It is made of R.C.C. in which a large portion of steel is required to resist bending, shear and torsion.

## 14.6. STAIRS OF DIFFERENT MATERIALS

Stairs may be constructed of the following materials :

1. Timber
2. Stone
3. Bricks
4. Steel

and 5. R.C.C.

### 1. Timber stairs

Timber stairs are light in weight and easy to construct, but they have very poor fire resistance. They are used only for small rise residential building. They are unsuitable for high rise residential buildings and for public buildings. Sometimes, fire resisting hard wood (such as oak, mahogany etc.) of proper thickness may be used. The timber used for the construction should be free from fungal decay and insect attack, and should be well-treated before use. In timber stairs the strings are the support for the stair and act as inclined beams spanning between the floor and the landing. For additional support, a bearer or a carriage may be placed under the treads (Fig. 14.12). The normal practice is to provide one bearer. For a 90 cm wide staircase, and an additional bearer for every 40 cm of width. The thickness of strings may be 3 to 5 cm and depth may be between 25 to 40 cm.

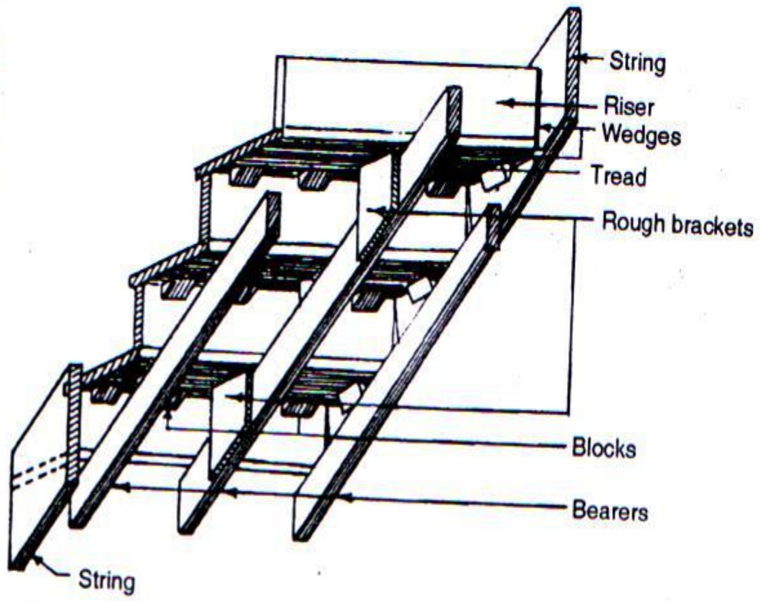



FIG. 14.12. CONSTRUCTION OF A SIMPLE TIMBER STAIRCASE.

***Steps*** : The thickness of tread of a timber stair should not be less than 32 mm ($1\frac{1}{4}$ inch) and that of riser 25 mm (1 inch). Fig. 14.13 shows timber risers and tread, jointed by tongue and grooved joints. The joints are nailed or screwed. The nosing of the step should not project beyond the face of the riser for more than the thickness of the tread. Scotia blocks may be provided to improve the appearance of the steps.

***Stringers***: These are the inclined beams of timber of 30 to 50 mm thickness and 25 to 40 cm deep, supported on newels, trimming joists or pitching pieces. These may be of four types : (*a*) cut string (*b*) housed string (*c*) rough string and (*d*) wreathed string. A *cut string* has its upper surface having carriages or houses accurately cut to

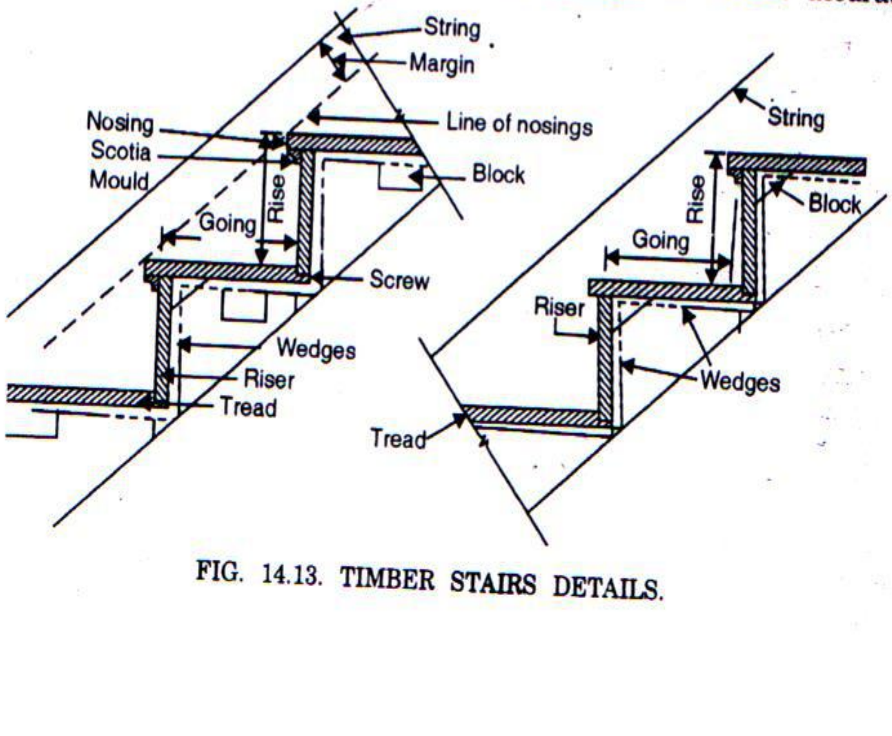



FIG. 14.13. TIMBER STAIRS DETAILS.

receive the treads and risers ; such strings improve very much the appearance of a stairs. However, its lower edge is kept parallel to the pitch of the stair. Because of cuts made, it becomes weak. A *housed or closed stringer* has its top and bottom edges parallel to the pitch of the stair. Grooves are cut on its inside to receive the treads and risers of the steps, which are generally nailed, glued and wedged to the stringers. The grooves or housings are tapered so that wedges may be driven below the treads and risers, thus forming a tight joint on the upper surface (Fig. 14.13). These wedges are best made from hard wood; they are dipped in glue before driving these. To add rigidity, blocks are glued between the string and the treads, and the treads and the risers. A *rough string* is an intermediate bearer provided for wider steps, as shown in Fig. 14.12. The carriage giving support to the treads and risers has rough brackets under the tread. A *wreathed string* is a curved or geometrical stair string, which may be either of cut or closed type.

***Landing*** : A landing is constructed of tongued and grooved boarding on timber joists which are supported on walls. In the case of half space landing, a timber joist, known as *timber,* is placed across the full width of the stair case. In the case of quarter space landing, a timber joist, known as *pitching piece,* is placed in the wall at one end and housed with the newel at the other end.

## 2. STONE STAIRS

Stone stairs are widely used at places where ashlar stone is readily available. Stone stairs are quite strong and rigid, though they are very heavy. Stone used for the construction of stairs should be hard, strong and resistant to wear. Stones are fire resistant also. The simplest form of stone stairs are those supported on both the ends, though an open well stair case can also be built. Dog-legged stairs, with cantilevered spandril steps are also constructed of sand stones, such as the type available at Jodhpur.

Stone stairs may have following types of steps :

(*i*) Rectangular steps with rebated joint.
(*ii*) Spandril steps.
(*iii*) Tread and riser steps.
(*iv*) Cantilever tread steps.
(*v*) Built-up steps.

### 1. Rectangular steps

These are the simplest type, prepared from rectangular blocks of stone ashlar. The steps are arranged with the front edge of one step resting on the upper back edge of the step below, with rebated joint cut into it (Fig. 14.14).

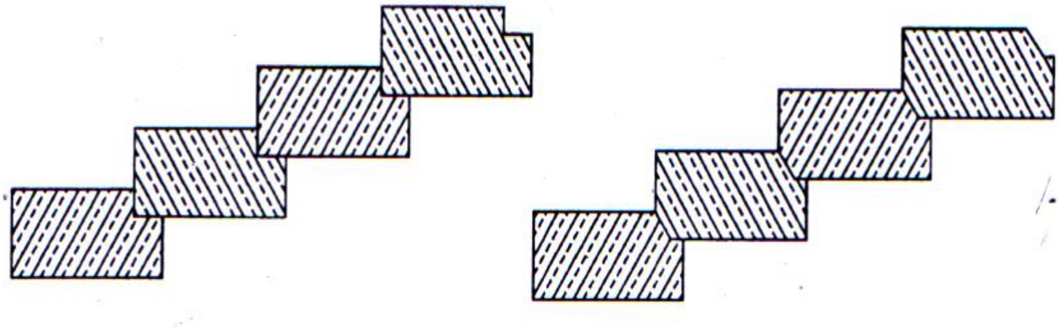


FIG. 14.14. REBATED RECTANGULAR STONE STEPS.

**2. Spandril steps**

These steps are nearly triangular in shape so as to get a plain soffit. At the end, each step is built in the wall. Such steps give pleasant appearance. The soffit may either be plain, broken or moulded, as shown in Fig. 14.15 (*a*), (*b*), (*c*) respectively. Steps are rebated to fit on the one's below.

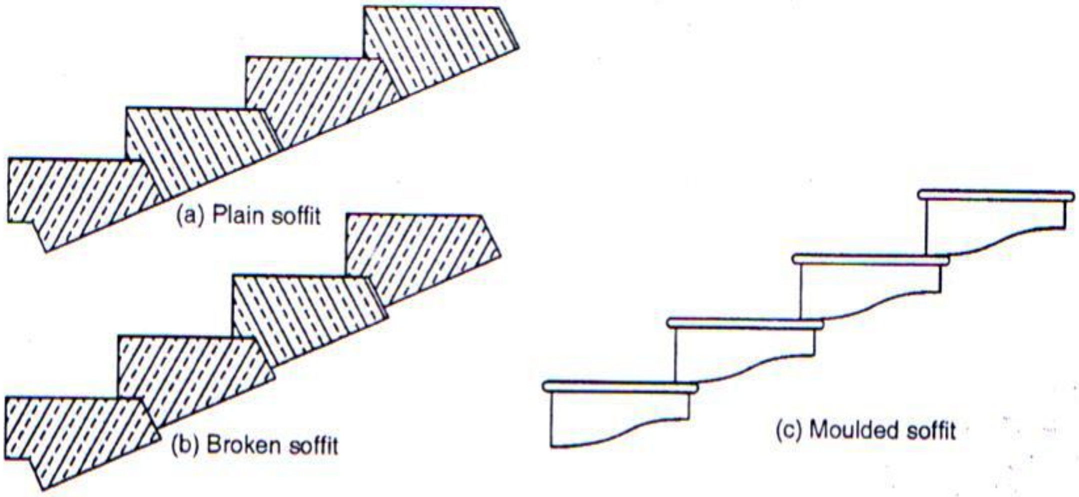



FIG. 14.15. SPANDRIL STEPS

**3. Slab tread and riser steps** : In this type, flag stone slabs are used as tread and risers, similar to the timber steps. The stone slab risers and treads may be connected through dowels, as shown in Fig. 14.16. The thickness of the stone slabs may vary from 5 cm to 8 cm.

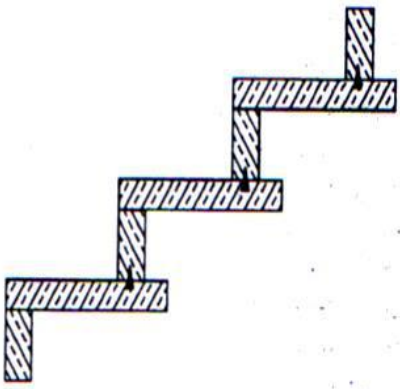


FIG. 14.16. SLAB TREAD AND RISER STEPS.

**4. Cantilever tread slab steps**

In this type, the steps are formed by treads only, made of thick stone slabs, without any riser. The tread slab is fixed at one end into the wall, and acts as cantilever. The steps may either be rectangular or triangularly shaped, as shown in Fig. 14.17.

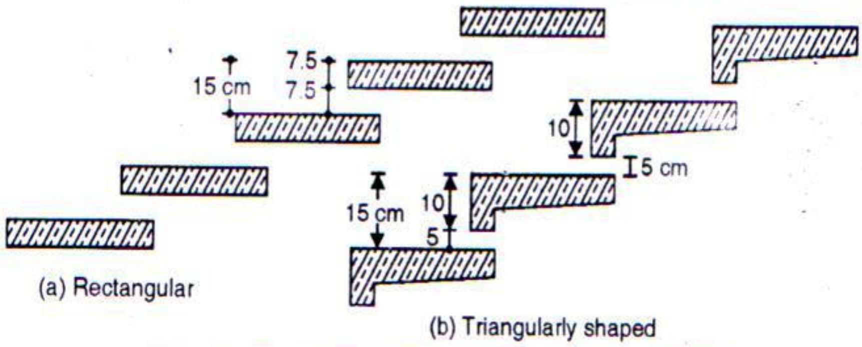



FIG. 14.17. CANTILEVER TREAD SLAB STEPS.

**5. Built-up steps**

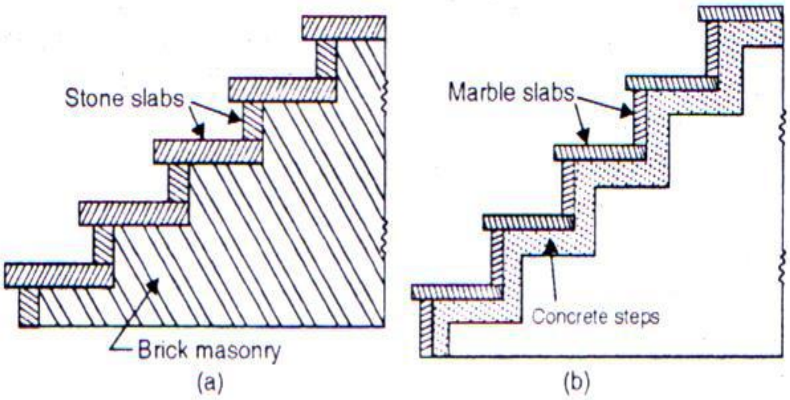



FIG. 14.18. BUILT-UP STEPS.

These steps use treads and risers in the form .of thin sawn stone or marble slabs, placed over brick or concrete steps. The thickness of stone slab may vary from 2 to 5 cm.

## 3. BRICK STAIRS

Brick stairs are not very common, except at the entrance. However, brick stairs of single straight flight are often made in village houses. The stair consists of either solid wall, or also, arched openings may be left for obtaining storage space, as shown in Fig. 14.19. The brick steps need frequent maintenance. Hence these may be *faced* with stone slabs. Alternatively, these steps may be cement-plastered at the top of treads and side of risers.

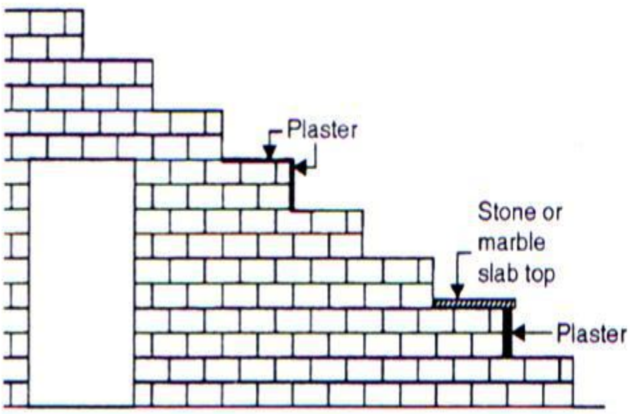



FIG. 14.19. BRICK STAIR.

## 4. METAL STAIRS

Stairs of mild steel or cast iron are used only as emergency stairs. They are not common in residential and public buildings, though they are strong and fire resistant. This is because they are not good looking and also, they make lot of noise when used by users. They are commonly used in factories godowns, workshops, etc. In its simplest form, a metal stair consists of rolled steel stringers (mostly channel sections), to which angle irons are welded or riveted and steel plates are used as treads. Another form of metal stairs commonly used are the spiral stairs.

## 5. R.C.C. STAIRS

R.C.C. stairs are the one which are widely used for residential, public and industrial buildings. They are strong, hard wearing and fire resisting. These are usually *cast-in-situ,* and a variety of finishes can be used on these. Based on the direction of span of the stair slab, concrete stairs may be divided into two categories :

(*i*) Stair with slab spanning horizontally.

(*ii*) Stair with slab spanning longitudinally.

**1. Stair with slab spanning horizontally**

In this category, the slab is supported on one side by side-wall or stringer beam and on the other side by a stringer beam. Sometimes, as in the case of straight stair, the slab may be supported horizontally by side-wall on one side of each flight and the common newel on the other side between backward and forward flights. In such a case the effective span $L$ is the horizontal distance between centre to centre of the supports. Each step is designed as spanning horizontally with the bending moment equal to $WL^2/8$, where $W$ is the uniformly distributed load, per unit area, on the step, inclusive of the self weight. Each step is considered equivalent to a rectangular beam of width $b$ (measured parallel to the slope of the stair) and an effective depth equal to $D/2$ as shown in Fig. 14.20. Main reinforcement is provided in the direction of $L$, while distribution reinforcement is provided parallel to the flight direction. A waist of about 8 cm is provided.

**2. Stair with slab spanning longitudinally**

In this category, the slab is supported at bottom and top of the flight and remain unsupported on the sides. Each flight of stair is continuous, and is supported on beams at top and bottom or on landings. In the latter case, the landings also become the part of the slab. Dog legged stairs are typical example of this type, shown in Fig. 14.21. The main reinforcement is provided parallel to the

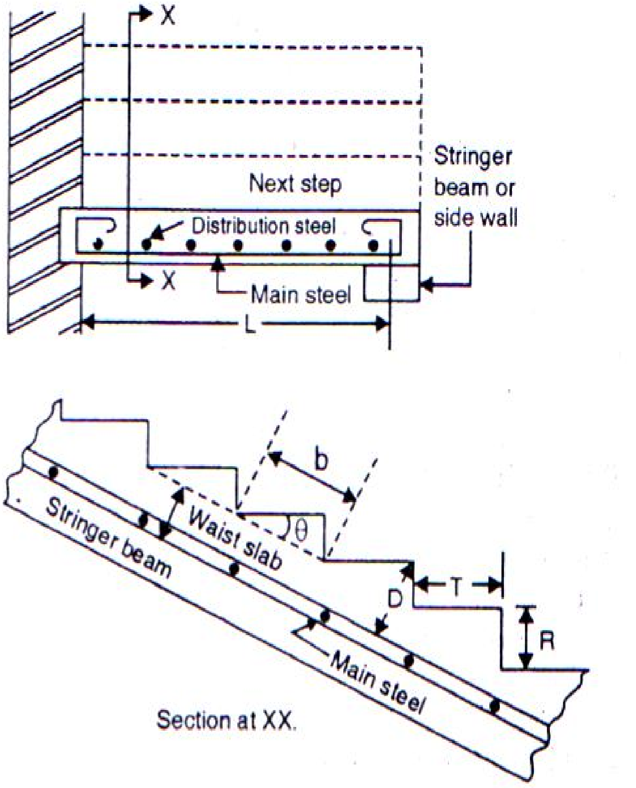



FIG. 14.20. STAIR SLAB SPANNING HORIZONTALLY.

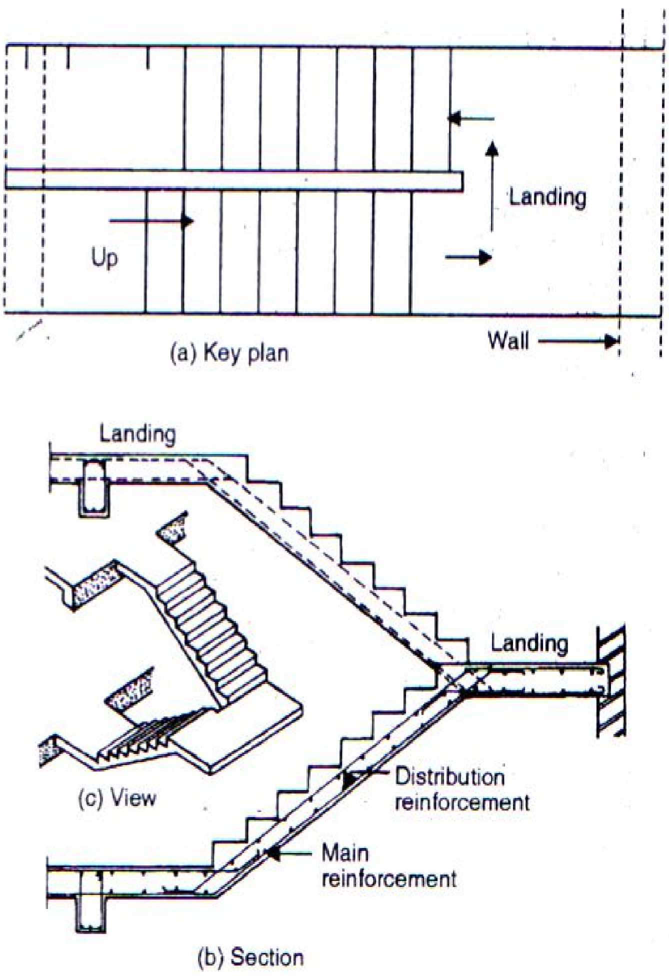



FIG. 14.21. R.C.C. DOG LEGGED STAIR.

direction of the flight, and the distribution reinforcement is provided along the width of the slab.

Sometimes, specially for wider stairs, a central stringer beam, spanning between the end walls or columns is provided on which the stairs slab (waist slab) is supported; the waist slab is designed as slab cantilevering both the sides of the stringer beam. The stringer beam itself is designed as a T-beam (Fig. 14.22).

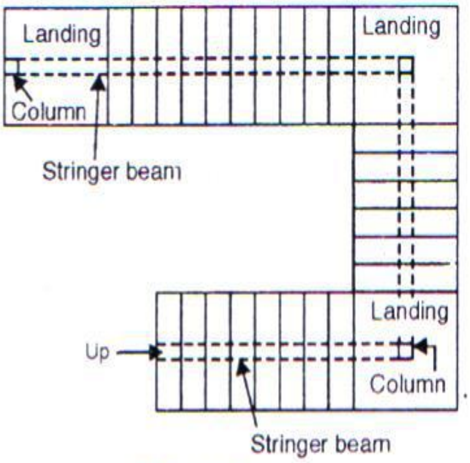


FIG. 14.22.

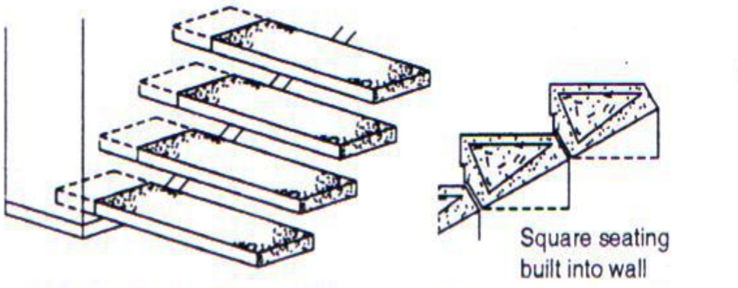
**R.C.C. helical stair**

R.C.C. can be used in constructing stair of any geometrical shape. Fig. 14.11 shows a helical stair, which is cast-in-situ. A large amount of steel reinforcement is used to resist bending moment, shear force and torsional moment. The continuous slab varies in thickness from top to bottom—less at top and increasing at the bottom. There are two or three sets of reinforcement with top and bottom layers in each : (*i*) continuous bars running the length of the spiral, (*ii*) cross or radial bars, and (*iii*) diagonal bars laid tangential in two directions to the inner curve.

**Pre-cast concrete stairs**

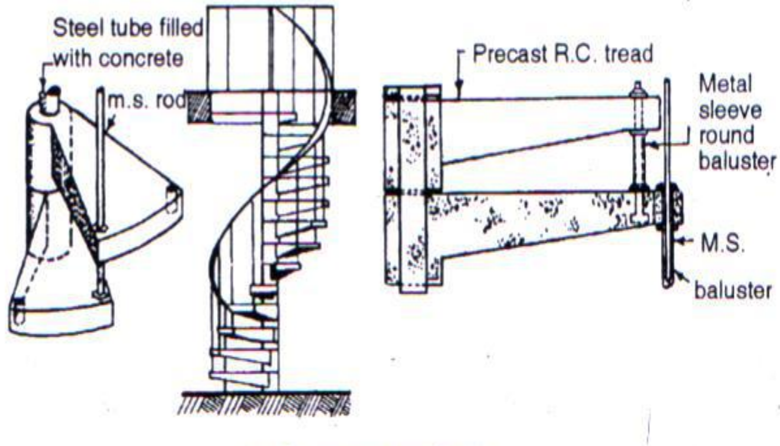
Precast concrete units are now-a-days available for the construction of concrete stairs of various shapes.

The three common types of precast units are : (*i*) rectangular cantilever steps (Fig. 14.23*a*), (*ii*) spandril cantilever steps (Fig. 14.23 *b*), and (*iii*) sector-shaped cantilever units. The latter type is used for the construction of open-riser spiral stair shown in Fig. 14.24.



(a) Rectangular cantilever steps (b) Spandrel cantilever steps

FIG. 14.23. PRECAST CONCRETE STEPS.



(c) Open riser spiral stair

FIG. 14.24. PRECAST OPEN RISER SPIRAL STAIR STEPS.

# FLOORS

whenever repairs are required, it should be such that repairs can be done easily, with least possible expenditure. Hard coverings like tiles, marble, terrazzo, concrete etc. require less maintenance in comparison to materials like cork, wood etc.

## 11.5. MUD FLOORING AND MURAM FLOORING

Mud and Muram floorings are used only in low cost housing, specially in villages.

**Mud flooring.**

Such flooring is cheap, hard, fairly impervious, easy to construct and easy to maintain. It has good thermal insulation property due to which it remains cool in summer and fairly warm in winter. The method of construction is very easy. Over a well-prepared ground, a 25 cm thick selected moist earth (mostly impervious) is spread and is then rammed well to get a compacted thickness of 15 cm. In order to prevent cracks due to drying, small quantity of chopped straw is mixed in the moist earth, before ramming. Sometimes, cow-dung is mixed with earth and a thin layer of this mix is spread over the compacted layer. Sometimes, a thin paint of cement-cow-dung (1 : 2 to 1 : 3) is applied.

**Muram flooring.**

Muram is a form of disintegrated rock with binding material. This flooring has practically the same properties as that of mud flooring. To construct such a floor, a 15 cm thick layer of muram is laid over prepared subgrade. Over it, a 2.5 cm thick layer of powder muram (fine muram) is spread and water is sprinkled over it. The surface is then rammed well. After ramming, the surface is saturated with a 6 mm thin film of water. The surface is well-trampled under the feet of workmen till the cream of muram rises to the top. The surface is levelled and then kept in that state for a day, and then rammed again with wooden rammers called *thapies* for 3 days, so that dry hard surface is formed. This surface is then smeared or rubbed with thin paste of cow-dung and rammed again for two days, during morning hours. Finally, a coating of mud-cow-dung mix or cement-cow-dung mix is applied over the surface.

## 11.6. BRICK FLOORING

Such flooring is used in cheap construction, specially where good bricks are available. This flooring is specially suited to ware- houses, stores, godowns etc. Well-burnt bricks of good colour and uniform shapes are used. Bricks are laid either flat or on edge, arranged in herring bone fashion or set at right angles to the walls, or set any other good looking pattern.

The method of preparing the base course for brick flooring varies from place to place. In one method, the subgrade is compacted properly, to the desired level, and a 7.5 cm thick layer of sand is spread. Over this, a course of bricks laid flat in mortar is built. This forms the base course, over which the brick flooring is laid in 12 mm thick bed of cement or lime mortar, in the desired pattern. In the second method, 10 to 15 cm thick layer of lean cement concrete (1 : 8 : 16) or lime concrete is laid over the prepared subgrade. This

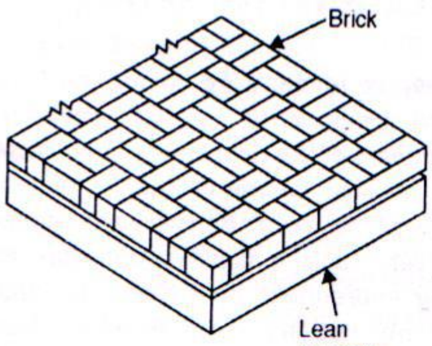



FIG. 11.3. BRICK FLOORING.

forms the base course, over which bricks are laid on edge (or flat) on 12 mm thick mortar bed in such a way that all the joints are full with mortar. In both the cases, the joints are rendered flush and finished. The work is then properly cured.

## 11.7. FLAG STONE FLOORING

Flag stone is any laminated sand stone available in 2 cm to 4 cm thickness, in the form of stone slabs of square (30 cm × 30 cm, 45 cm × 45 cm or 60 cm × 60 cm) or rectangular size (45 × 60 cm). This type of work is also called paving. The stone slabs are laid on concrete base. The sub-soil is properly compacted, over which 10 to 15 cm thick lime concrete or lean cement concrete is laid. This forms the base course of the floor. The flag stones (stone slabs) are then laid over 20 to 25 mm thick layer of bed mortar (Fig. 11.4). In laying the slabs, work is started from two diagonally opposite corners and brought up from both sides. A string is stretched between two corner slabs laid first to correct level. Other slabs are then so laid that their tops touch the string. If any particular slab falls lower than the string level, it is re-laid by putting fresh layer of stiff mortar. When the stone slabs are properly set, mortar in the joints is raked out to a depth of about 15 to 20 mm and then flush pointed with 1 : 3 cement mortar. Proper slope is given to the surface for drainage. The work is properly cured.

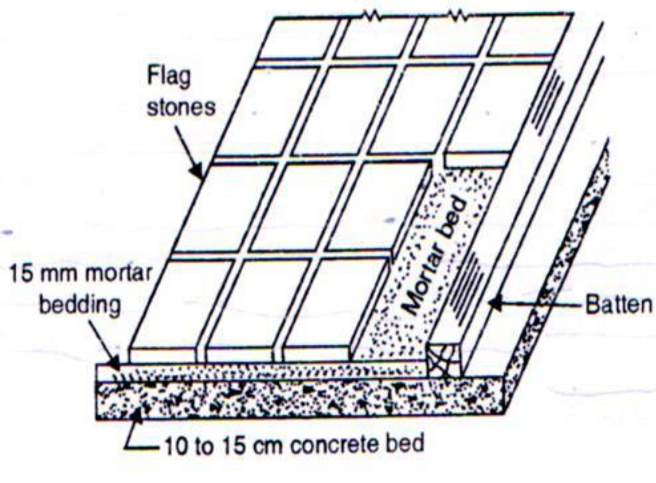



FIG. 11.4. FLAG STONE FLOORING.

## 11.8. CEMENT CONCRETE FLOORING

This is commonly used for residential, commercial and even industrial building, since it is moderately cheap, quite durable and easy to construct. The floor consists of two components: (*i*) base concrete, and (*ii*) topping or wearing surface. The two components of the floor can be constructed either monolithically (*i.e.* topping laid immediately after the base course is laid) or non-monolithically. When the floor is laid monolithically, good bond between the two components is obtained resulting in smaller over all thickness. However, such a construction has three disadvantages : (*i*) the topping is damaged during subsequent operations, (*ii*) hair cracks are developed because of the settlement of freshly laid base course which has not set, and (*iii*) work progress is slow because the workman has to wait atleast till the initial setting of the base course. Hence in most of the cases, non-monolithic construction is preferred.

The base course may be 7.5 to 10 cm thick, either in lean cement concrete (1 : 3 : 6 to 1 : 5 : 10) or lime concrete containing 40% mortar of 1 : 2 lime-sand (or 1 lime : 1 surkhi : 1 sand) and 60% coarse aggregate of 40 mm nominal size. The base course is laid over well-compacted soil, compacted properly and levelled to rough surface. It is properly cured.

When the base concrete has hardened, its surface is brushed with stiff broom and cleaned thoroughly. It is wetted the previous night and excess water is drained. The topping is then laid in square or rectangular panels, by use of either glass or plain asbestos strips or by use of wooden battens set on mortar bed. The panels may be $1 \times 1$ m, $2 \times 2$ m or $1 \times 2$ m in size. The topping consists of 1 : 2 : 4 cement concrete, laid to the desired thickness (usually 4 cm) in one single operation in the panel. Alternate panels are laid first. Prior to laying the concrete in the panel, a coat of neat cement slurry is applied. This cement slurry laid on rough-finished base course ensures proper bond of topping with the base course. Glass strips or battens should have depth equal to thickness of topping. Topping concrete is spread evenly with the help of a straight edge, and its surface is thoroughly tamped and floated with wooden floates till the cream of concrete comes at the top. Steel trowel is used for something and finishing the top surface. Further troweling is done when the mix has stiffened. Dusting of the surface with neat cement and then troweling results in smooth finish at the top. Other alternate layers are then laid after 72 hours, so that initial shrinkage of already laid panels take place, thus eliminating the cracks. The prepared surface is protected from sunlight, rain, other damages for 12 to 20 hours. The surface is then properly cured for a period of 7 to 14 days.

When monolithic construction is laid, the topping is laid 1 hour to 4 hours after placing the base concrete.

**Granolithic finish.**

In industrial building, hard wearing surface is sometimes required. This can be achieved by applying granolithic finish over the concrete topping described above. Granolithic finish consists of rich concrete made with very hard and tough quality coarse aggregate (such as granite, basalt, quartzite etc.) graded from 13 mm to 240 No. I.S. sieve. The concrete mix proportion varies from 1 : 1 : 2 to 1 : 1 : 3 for heavy duty floors to 1 : 2 : 3 for public buildings. The thickness of finish may be minimum 25 mm when laid monolithically with the top concrete, and 35 mm when laid over hardened surface. However, for public buildings such as schools, hospitals etc. the thickness of the finish may be 13 mm to 20 mm. using small size aggregate. If exceptionally hard surface is required, sand may be replaced by fine aggregate of crushed granite, and/or abrasive grit may be sprinkled uniformly over the surface (@ 1.5 to 2.5 $kg/m^2$), during floating operation.

## 11.9. TERRAZZO FLOORING

Terrazzo flooring is another type of floor finish that is laid in thin layer over concrete topping. It is very decorative and has good wearing properties. Due to this, it is widely used in residential buildings, hospitals, offices, schools and other public buildings. *Terrazzo* is a specially prepared concrete surface containing cement (white or grey) and marble chips (of different colours), in proportion to $1 : 1\frac{1}{4}$ to $1 : 2$. When the surface has set, the chips are exposed by grinding operation. Marble chips may vary from 3 mm to 6 mm size. Colour can be mixed to white cement to set desired tint. The flooring is, however, more expensive.

The sub-base preparation and concrete base laying is done in a similar manner, as explained for cement concrete flooring. The top layer may have about 40 mm thickness, consisting of (*i*) 34 mm thick cement concrete layer (1 : 2 : 4) laid over the base concrete, and (*ii*) about 6 mm thick terrazzo topping.

Before laying the flooring, the entire area is divided into suitable panels of predetermined size and shape. For this, aluminum or glass strips are used. The strips have the same height as the thickness of the flooring (*i.e.* 40 mm). The strips are jointed to the base concrete, with the help of cement mortar, and their tops are perfectly set to level and line. Alternate panels are filled. The width of the strips may be 1.5 to 2.0 mm.

The surface of base concrete is cleaned of dirt etc. and thoroughly wetted. The wet surface of the base concrete is smeared with cement slurry. Concrete of grade 1 : 2 : 4 is then laid in alternate panels levelled and finished to rough surface. When the surface is hardened, the terrazzo mix (containing cement, marble chips and water) is laid and finished to the level surface. Additional marble chips may be added during tamping and rolling operation, so that atleast 80% of the finished surface show exposed marble chips. The surface is then floated and trowelled, and left to dry for 12 to 20 hours. After that, the surface is cured properly for 2-3 days.

The first grinding is done, preferably by machine, using coarse grade (No. 60) carborundum stones, using plenty of water. The ground surface is then scrabbed and cleaned. Cement grout of cream-like consistency, of the same colour, is then applied on the surface so that pores and holes etc. are filled. The surface is cured for 7 days and then second grinding is done with carborundum stones of fine grade (NO. 120). The surface is scrabbed and cleaned thoroughly, and cement grout is again applied. The surface is cured for 4 to 6 days and final grinding is done with carborundum stones of 320 grit size. The surface is thoroughly scrabbed and cleaned, using plenty of water. The floor is then washed with dilute oxalic acid solution. Finally, the floor is polished, with polishing machines the wheels of which are fitted with felt or hessian bobs, to get fine shine. Wax polish is also applied with the help of the polishing machine, to get final glossy surface.

## 11.10 MOSAIC FLOORING

Mosaic flooring is made of small pieces of broken tiles of china glazed or of cement, or of marble, arranged in different pattern. These pieces are cut to desired shapes and sizes. A concrete base is prepared as in the case of concrete flooring, and over it 5 to 8 cm thick lime-surkhi mortar is spread and leveled, over an area which can be completed conveniently within working period so that the mortar may not get dried before the floor is finished. On this, a 3 mm thick cementing material, in the form of paste of two parts of slaked lime, one part of powdered marble and one part of puzzolana material, is spread and is left to dry for about 4 hours. Thereafter, small pieces of broken tiles or marble pieces of different colours are arranged in definite patterns and hammered into the cementing layer. The surface is gently rolled by a stone roller of 30 cm dia. and 40 to 60 cm long, sprinkling water over the surface, so that cementing material comes up through the joints, and an even surface is obtained.

The surface is allowed to dry for 1 day, and is, thereafter, rubbed with a pumice stone fitted with a long wooden handle, to get smooth and polish surface. The floor is allowed to dry for two weeks before use.

## 11.11. TILED FLOORING.

Tiled flooring is constructed from square, hexagonal or other shapes, made of clay ( pottery), cement concrete or terrazzo. These are available in different sizes and thicknesses. These are commonly used in residential houses, offices, schools, hospitals and other public buildings, as an alternative to *terrazzo* flooring, specially where the floor is to be laid quickly. The method of laying tiled flooring is similar to that for flag stone flooring except that greater care is required. Over the concrete base, a 25 to 30 mm thick layer of lime mortar 1 : 3 (1 lime and 3 sand or surkhi) is spread to serve as bedding. This bedding mortar is allowed to harden for 12 to 24 hours. Before laying the tiles, neat cement slurry is spread over the bedding mortar and the tiles are laid flat over it, gently pressing them into the bedding mortar with the help of wooden mallet, till levelled surface is obtained. Before laying the tiles, thin paste of cement is applied on their sides, so that the tiles have a thin coat of cement mortar over the entire perimeter surface. Next day, the joints between adjacent tiles are cleaned of loose mortar etc. to a depth of 5 mm, using wire brush, and then grouted with cement slurry of the same colour shade as that of the tiles. The slurry is also applied over the flooring in thin coat. The flooring is then cured for 7 days, and then grinding and polishing is done in the same manner as that for terrazzo flooring.

## 11.12. MARBLE FLOORING

It is a superior type of flooring, used in bath-rooms and kitchens of residential buildings, and in hospitals, sanitoriums, temples etc. where extra cleanliness is an essential requirement. Marble slabs may be laid in different sizes, usually in rectangular or square shapes. The base concrete is prepared in the same manner as that for concrete flooring. Over the base concrete, 20 mm thick bedding mortar of either 1 : 4 cement : sand mix or 1 (lime putty) : 1 ( surkhi) : 1 coarse sand mix is spread under the area of each individual slab. The marble slab is then laid over it, gently pressed with wooden mallet and levelled. The marble slab is then again lifted up, and fresh mortar is added to the hollows of the bedding mortar. The mortar is allowed to harden slightly, cement slurry is spread over it, the edges of already laid slabs are smeared with cement slurry paste, and then the marble slab in question is placed in position. It is gently pushed with wooden mallet so that cement pastes oozes out from the joint which should be as thin as possible (paper thick). The oozed out cement is cleaned with cloth. The paved area is properly cured for about a week.

## 11.13. TIMBER FLOORING

Timber flooring is used for carpentry halls, dancing halls, auditoriums, etc. They are not commonly used in residential buildings in India, because timber flooring is also quite costlier. However, in hilly areas, where timber is cheaply and readily available, and where temperature drops very low, timber flooring is quite common. One the major problems in timber flooring is the damp prevention. This can be done by introducing D.P.C. layer below the flooring.

Timber floors can either be of 'suspended type' (*i.e.*. supported above the ground) or 'solid type' (fully supported on the ground). The suspended type timber flooring is shown in Fig. 11.2. An alternative sketch of 'suspended' or 'supported' timber flooring is shown in Fig. 11.5. The hollow space between the flooring and over site concrete is kept dry and well-ventilated by providing air bricks in the outer walls, and voids in the sleeper wall. The flooring consists of boarding supported on bridging or floor joists of timber, which are nailed to the wall plates at their ends. Sleeper walls are not spaced more than 1.8 to 2 m.

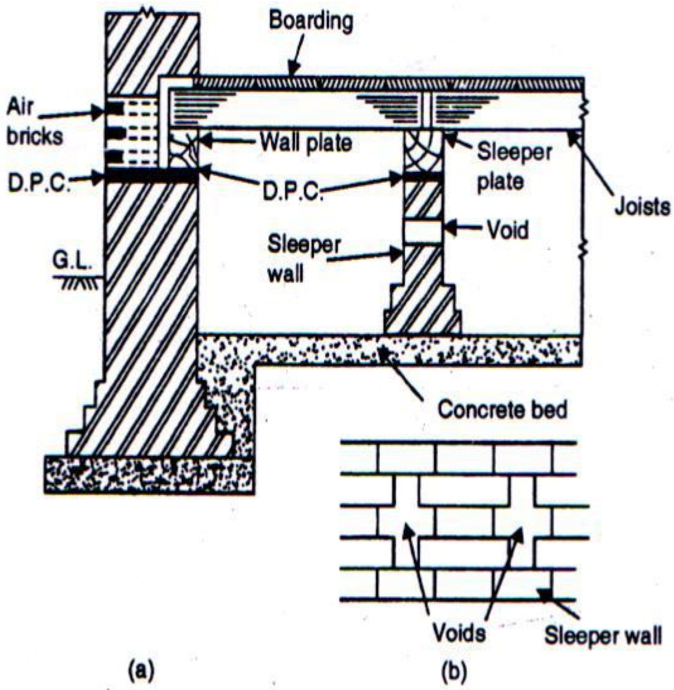



FIG. 11.5. SUPPORTED TYPE TIMBER FLOOR.

Where the problems of dampness is not acute, timber floors may be supported on the ground all along. For this type of construction, base concrete is first laid in 15 to 20 cm thickness. Over it, a layer of mastic asphalt is applied. Wooden block flooring is then laid over it, as shown in Fig. 11.6. Wooden blocks are short but thick

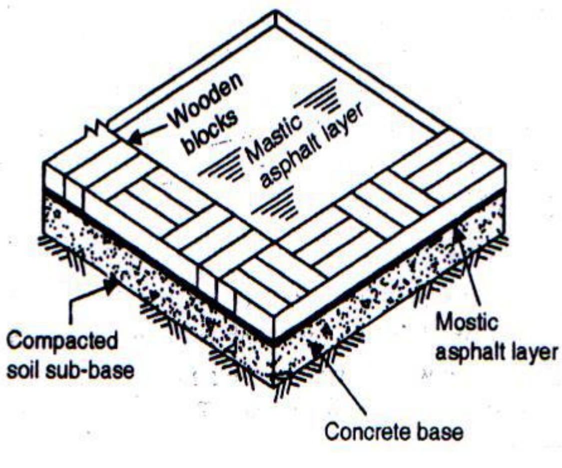



FIG. 11.6. WOODEN BLOCK-FLOORING

(with sizes 20 × 8 cm to 30 × 8 cm and thickness 2 to 4 cm) and are laid in suitable designs. In order to fix the wooden floor on concrete slabs, longitudinal nailing strips, with bevelled section, are embedded in concrete at suitable interval. Sometimes, special concrete, called nailing concrete may be used as an alternative to the nailing strips. Special flooring nails are used for nailing down the flooring.

## 11.14. ASPHALT FLOORING

Asphalt flooring are of many types :

(*i*) Asphalt mastic flooring

(*ii*) Asphalt tiles flooring,

(*iii*) Asphaltic terrazzo,

and (*iv*) Acid proof mastic flooring.

### 1. Asphalt mastic flooring.

Asphalt mastic is a mixture of sand (or grit) and asphalt in the ratio of 2 : 1, mixed hot and then laid in continuous sheets. It can also be applied cold, by mixing with mineral oil and asbestos. The thickness of the asphalt mastic may be 2.5 cm for ordinary construction. It is laid on cement concrete base course. The mix is poured on the concrete base, and is spread by means of trowel to get levelled surface. On the top of the surface, a thin layer of sand is spread, which is then rubbed with a trowel. The joints of mastic asphalt laid on successive days are properly lapped.

### 2. Asphaltic tiles.

These are prepared from asphalt, asbestos fibres, inert materials and mineral pigments, by pressing the mix in different sizes (20 cm square to 45 cm square), with thickness varying from 3 to 6 mm. These tiles are either directly cemented to concrete base or are fixed to wooden floors by using an intervening layer of mastic asphalt or asphalt saturated felt. Asphaltic tiles are cheap, resilient, sound proof, non-absorbant and moisture proof.

### 3. Asphaltic mosaic.

This is prepared similar to mastic asphalt, except that marble chips are used in the place of sand/grit. Asphalt may be either in black or other suitable colour, and is laid in hot condition.

### 4. Acid proof mastic flooring.

Acid proof blocks of asphalt are available, which are manufactured from moulding acid proof asphalt and inert crushed rock aggregate under high pressure. The asphalt blocks are first laid on concrete base then acid proof asphalt is uniformly spread over the surface of the blocks. [redacted] sand is spread over the liquid asphalt before it hardens.

Fine

## 11.15. RUBBER FLOORING

It consists of sheets or tiles of rubber, in variety of patterns and colours with thickness varying from 3 to 10 mm. The sheet or tile is manufactured by mixing pure rubber with fillers such as cotton fibre, granulated cork or asbestos fibre. The sheets or tiles are fixed to concrete base or wood by means of appropriate adhesives. rubber floorings are resilient and noise proof. However, they are costly.They are used only in office or public buildings.

## 11.16. LINOLEUM FLOORING (COVERING)

Strictly speaking, it is covering which is available in rolls, and which is spread directly on concrete or wooden flooring. Linoleum sheet is manufactured by mixing oxidized linseed oil in gum, resins, pigments, wood flour, corkdust and other filler materials. The sheets are either plain or printed, and are available in 2 to 6 mm thickness, and 2 to 4 m wide rolls. Linoleum tiles are also available , which can be fixed (or glued) to concrete base or wood floor, in different patterns. Linoleum sheet is either spread as such, or also may be glued to the base by inserting a layer of saturated felt. Linoleum covering are attractive, resilient, durable and cheap, and can be cleaned very easily. However, it is subjected to rotting when kept wet or moist for some time. It cannot, therefore, be used for bath-rooms, kitchens etc.

## 11.17. CORK FLOORING

Such type of flooring is perfectly noiseless, and is used in libraries, theatres, art galleries, broadcasting stations etc. Cork, which is the outer bark of cork oak tree, is available in the form of cork carpet and cork tiles. It is fixed to concrete base by inserting a layer of saturated felt. Cork carpet is manufactured by heating granules of cork with linseed oil and compressing it by rolling on canvass. Cork tiles are manufactured from high grade cork bar or shearings compressed in moulds to a thickness of 12 mm and baked subsequently.

They are available in various sizes (10 cm × 10 cm to 30 cm × 90 cm), various thicknesses (5 to 15 mm) and various shades.

## 11.18. GLASS FLOORING

This is a special purpose flooring, used in circumstances where it is desired to transmit light from upper floor to lower floor, and specially to admit light at the basement from the upper floor. Structural glass is available in the form of tiles or slabs, in thicknesses varying from 12 to 30 mm. These are fixed in closely spaced frames so that glass and the frame can sustain anticipated loads. Glass flooring is very costly, and is not commonly used.

## 11.19. PLASTIC OR P.V.C. FLOORING

It is made of plastic material, called Poly-Vinyl-Chloride (P.V.C.), fabricated in the form of tiles of different sizes and different colour shades. These tiles are now widely used in all residential as well as non-residential buildings. The tiles are laid on concrete base. Adhesive of specified make is applied on the base as well as on the back of P.V.C. tile with the help of a notched trowel. The tile is laid when the adhesive has set sufficiently (say within 30 minutes of its application) ; it is gently pressed with the help of a 5 kg weight wooden roller and the oozing out adhesive is wiped off. The floor is washed with warm soap water before use. P.V.C. tile flooring is resilient, smooth, good looking and can be easily cleaned. However, it is costly and slippery, and can be damaged very easily when in contact with burning objects.

# FLOORS

In order to sub-divide the portion between the plinth level or basement level and roof level, solid constructions are Carrie out. These constructions are known as floors and exposed top surface of floors are termed as floorings. Ground floors or basement floors, which directly rest on the ground, do not require the provision of a floor. But they are provided with suitable type of flooring.

**Types of Floors:**

Floors are classified into two categories

1. Timber Floors
2. Composite Floors

1. **Timber Floors:** In this floor, only timber is used as a material. Timber floors are further divided into four types.

a. Basement or Ground floor of timber

b. Single Joist timber beam

c. Double Joist timber beam

d. Framed triple joist timber floor.

**Features of Timber Floors:**

***(i)*** **Floor Boards:** These boards are provided at the top of bridging joists and they form the wearing surface of the floor. The width varies from 100mm to 200mm and thickness varies from 20mm to 40mm. the thickness may be changes when a floor subject to heavy traffic from 60 to 80mm. The floor boards are joined and widened by any suitable joint as shown in the figure.12.1

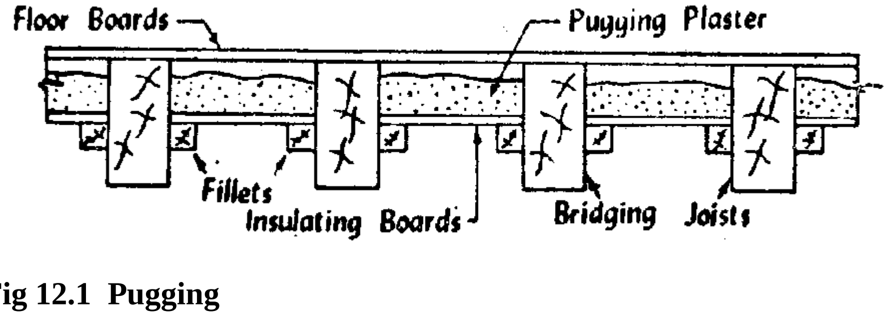



**Fig 12.1 Pugging**

***(ii)*** **Floor Ceilings:** To make the underside of the floor flat and to improve the appearance as a whole, ceilings may be provided rest on bridging joists or binders. The ceilings may consists of plaster boards or sheets of asbestors cement or some suitable material. In order to make ceilings strong and durable, ceiling joists may be provided at right angles to the bridging joists or the binders.

(i) **Pugging:** In order to make the timber floor sound proof, pugging may be resorted. Pugging plaster is a mixture of chopped straw and mortar. Insulating boards supporting on fillets are provided and hallows space between the floorboards and the insulating boards is filled up with the pugging plaster.

(ii) **Trimming:** When openings are to be provided in wooden floors, it is clear that bridging joists will not rest on the walls. In such cases, the process of trimming is required. Trimming joists support one or two trimmer joists to which trimmed joists are fixed. The trimming joists and trimmer joists have slightly greater section than bridging joists Fig. 12.2 shows a wooden floor with stair well.

(iii) **Use of stell sections:** Binders and girders of wooden floor can be replaced by mild rolled steel joists. The only precaution to be taken in this case would be to encase the R.S.J. by concrete so as to prevent rusting of R.S.J. The use of steel section makes the floor light and economical.

**a) Basement or ground floor of timber:**

In auditorium, to carry out dances or dramas timber floors are constructed on ground floor. Sleeper walls, which may be of one-half brick or one brick thickness, are constructed at centre to centre distance of 1.20m to 1.80m. Wall-plates are provided along the wall as well as along the sleeper walls and they reduce the spans of the building joists and serve as end supports for the bridging joists. On wall-plates rest the ends of bridging joists, which are usually provided at a centre to centre distance of about 30 cm. Finally, floor boards are provided to finish up the floor. The details are as shown in fig 12.2.

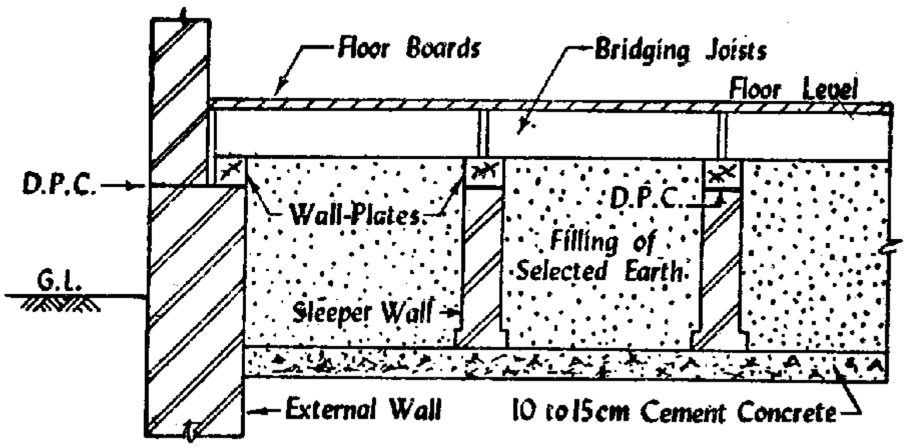



**Fig 12.2. Basement or ground floor of timber**

**b) Single Joist timber floor:**

These floors consist of single joist, which are placed below the floorboards. The joists are usually placed at a centre to centre distance of 30cm to 45cm. The joists are supported on wall-plates at their ends. A space of about 50mm is kept for the circulation of air as shown in fig 12.3. Single joist timber floor can be adopted for a maximum span of about

3.6m. When the span of joist exceeds 2.4m, it becomes necessary to strengthen the joist by providing bearing bone strutting. In this arrangement, inclined timber pieces are firmly fixed between the joists and the ends of these struts are nailed to the joist. At the end, wedges are provided between the wall and the joists.

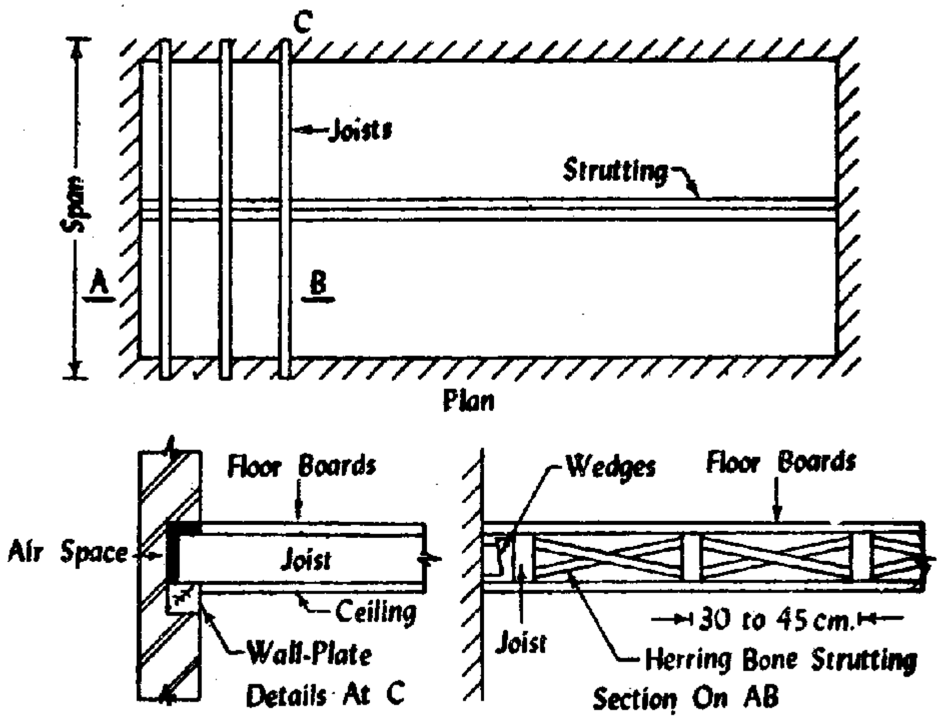


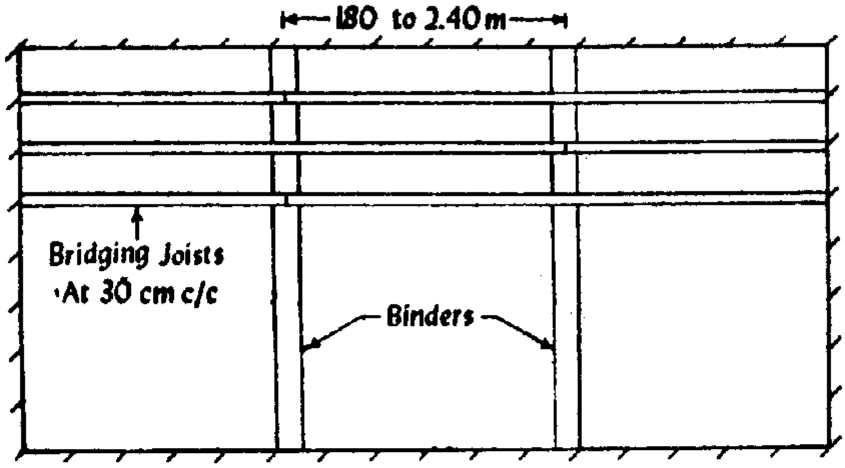

**Fig 12.3 Details of single joist timber floor**

**c) Double joist timber floors:**

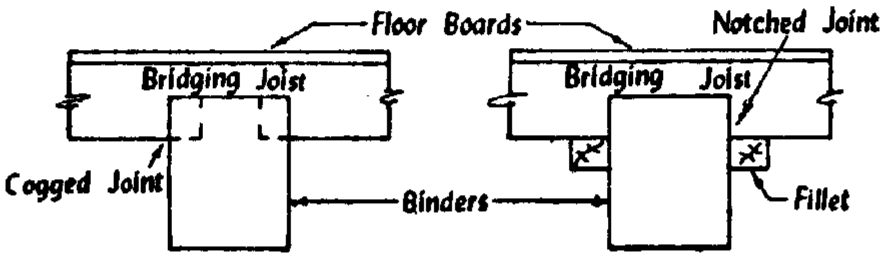
In this type of floors, intermediate supports known as binders, are provided for bridging joists. Binders are generally placed at a centre to centre distance of 1.80m to 2.40m as shown in fig 12.4. The ends of binders rest on wooden or stone blocks. Double joist timber floors are stronger than the single joist timber floors. They prevent the passage of sound in better way and they are suitable for spans of 3.60 to 7.50m. This type of floors has following disadvantages.

(i) The weight of floor is thrown on few points in a wall.

(ii) Depth of floor is increased by the use of binders and accordingly height of the room is decreased.




Plan of double joist timber floor




Methods of fixing binders with joists

**Fig 12.4**

**d) Framed or triple joist timber floor:**

In this type of floors, intermediate supports, known as girders, are provided for the binders. Thus, this type of floor consists of girders, binders, bridging joists and floor boards as shown in fig 12.5. Girders are generally placed at a centre to centre distance of 3 metres. Binders are staggered and connected to girders by tusk and tenon joints. Alternatively, the ends of binders are supported on the iron stirrups, which are fixed to the girders. The ends of girders rest on walls on stone or concrete templates. This type of timber floor is suitable for spans greater than 7.50.

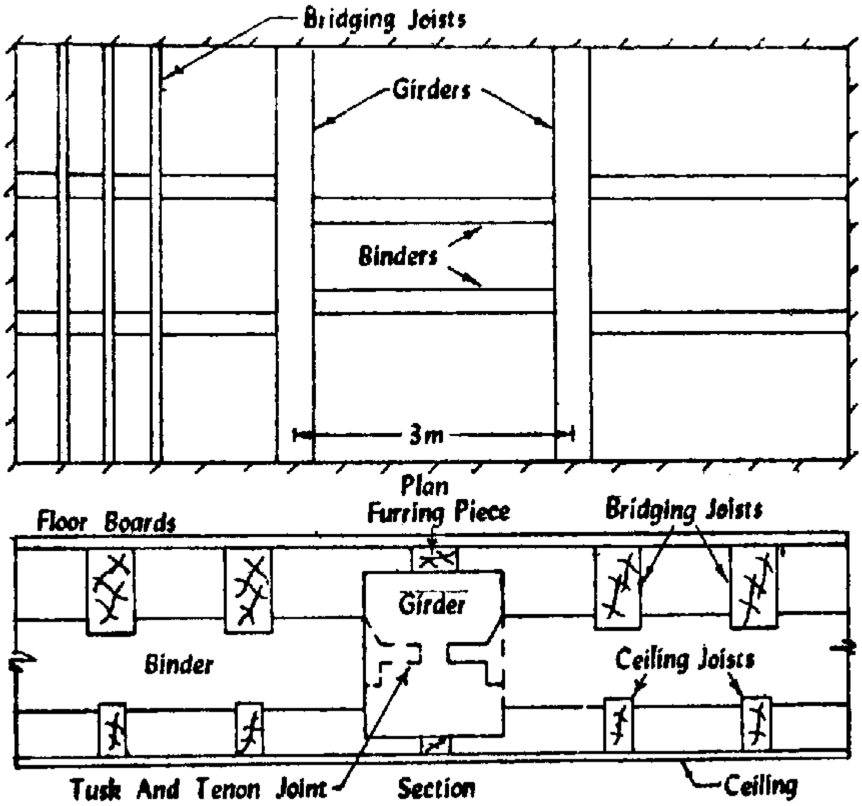



**Fig 12.5 Details of framed timber floors**

**II Composite Floors:**

Floors composed of more than one material are known as composite floors and they found to possess the following advantages.

(i) Resist fire and sound in better way than timber floors

(ii) Better hygienic because can be easily cleaned

(iii) Adopted for greater spans.

The following are the types of composite floors

(a) Double flag stone floors

(b) Filler Joists floors

(c) Jack arch floor

(d) R.C.C. floors

(e) Hallow block and rib floors

**a) Double flagstone floors:**

In this type of floors, flagstones are used in two layers as shown in fig 12.6. If span is about 4m, only rolled steel joists are provided and span exceeds 4m, a framework consists of rolled steel beams and joists is formed. Steel beams are placed at a distance of about 3m centre to centre and joists are placed at right angles to beams. Flagstones of about 40mm thickness and of suitable width are fixed on the lower flanges and upper flanges. The joints of top layer of flagstones are finished in a better way to give a nice appearance. Filling of selected earth or concrete is done in the space between the two layers of the flagstones.

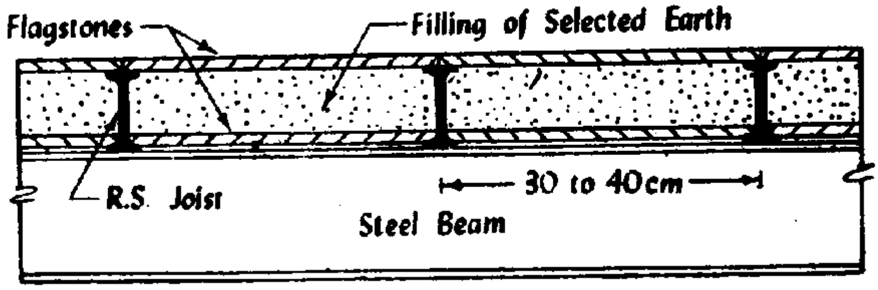



**Fig 12.6 Double Flagstone floor**

**b) Filler Joist floors:**

In this type of floors, small sections of rolled steel joists are placed in concrete, this joists may either rest on wall or on steel beam as shown fig 12.7. The joists act as a reinforced and are spaced at a centre to centre distance of 60cm to 90cm. Concrete should completely surround the rolled steel / joists and beams.

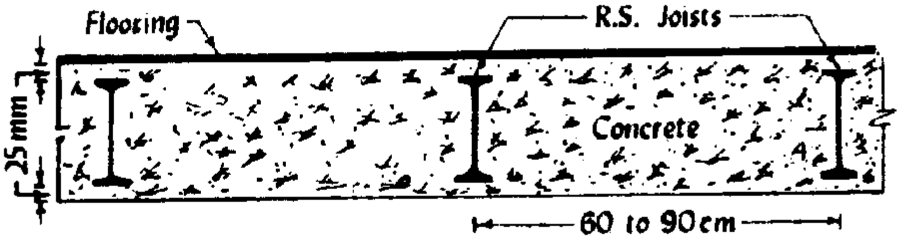



**Fig 12.7 Filler Joist Floor**

**c) Jack arch floors:**

In this type of floor, brick arches or cement concrete arches are constructed and these arches rest on the lower flanges of mild steel joists. The joists in turn rest either on wall or on beam. The joists are placed at a distance of about 80cm to 120cm center to center. The rise of arch should be 10cm to 20cm. and the minimum depth of concrete at the crown should be 15cm. The only disadvantage of this floor is that it does not give plain ceiling surface as shown in the fig 12.8. (a & b)

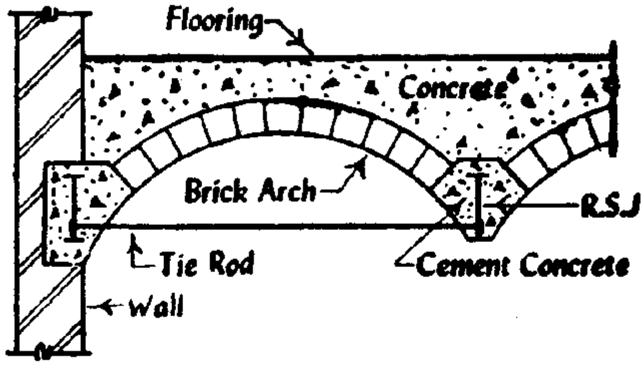
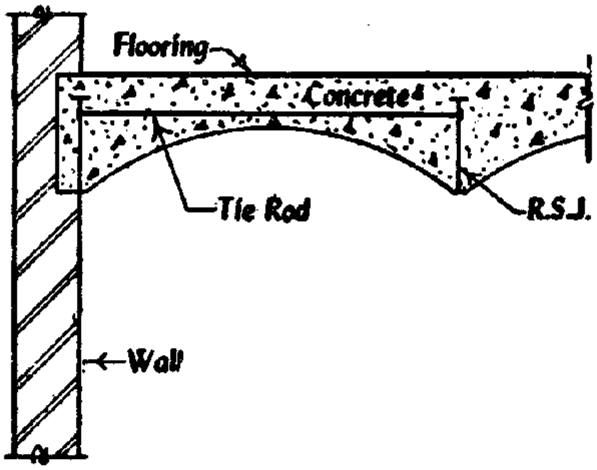



**Fig 12.8 (a) Brick Jack arch floor**



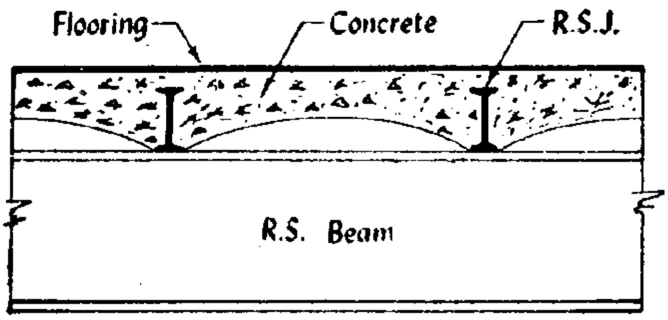




**Fig 12.8 (b) Concrete jack floor**

**d)** **R.C.C Floor:** In this type of floors steel bars and concrete are used to form a floor. This type of floor is widely used in modern construction. The slab and beam are designed as per loading coming on the floor and proper reinforcement is placed at a suitable place. In case of R.C.C. slab thickness varies from 80mm to 150mm and the main reinforcement is generally in the form of mild steel bars of diameter varying from 9mm to 12mm as shown in the fig. 12.9.

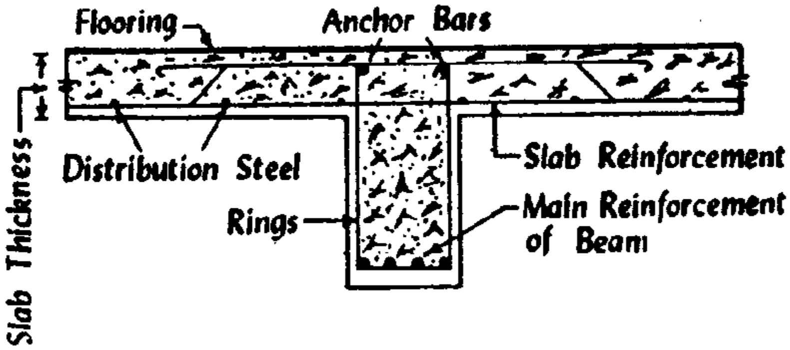



**Fig 12.9 R.C.C. Floor**

The reinforced concrete may be cast-in-situ or pre-cast, the former being very common. R.C.C. floors are less costly, durable, easy to construct and fire-proof. However, they are likely to transmit sound. In any case R.C.C. floors are fast replacing other types of floors.

**e)** Hallow Block and Rib Floors: In this type of floors, hallow blocks of clay or concrete are used to reduce the total weight of the floor. In one form, the blocks are placed 10cm apart and in this space, mild steel bars are placed as shown in the fig 12.10.A minimum cover of 80mm is kept at the top. Suitable flooring at the top and sealing finish are provided. The blocks are provided with rough or grooved surface so that they can develop enough bond with the concrete. This type of floor is economical, fire proof, sound proof and light in weight. If properly designed, this type of floor can even be used to carry heavy loads.

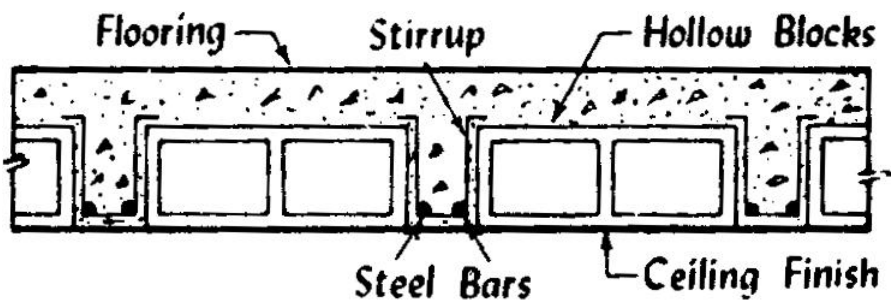



**Fig 12.10 Hallow Block and Rib floor**

**SYNOPYSIS**

1. In order to sub-divide the portion between the plinth level or basement level and roof level, solid constructions are known as floors.
2. The floors are classified into
   (i) Timber floors
   (ii) Composite floors
3. The timber floors are divided into
   (i) Basement or ground floor of timber
   (ii) Single joist timber beam (iii)Double joist timber beam (iv)Framed or triple joist timber beam
4. The composite floors are the following
   (i) Double flag stone floors
   (ii) Filler joists floors (iii)Jack arch floor (iv)R.C.C. floors
   (v) Hallow block or rib floors

## SHORT ANSWER QUESTIONS

1. Define floor
2. What are the types of floors?
3. Name the types of timber floors
4. What are the advantages of composite floors?
5. Name the types of composite floors.

## ESSAY TYPE QUESTIONS

1. Explain different types of timber floors briefly
2. Explain the following

a) double flag stone floors

b) jack arch floors

3. Explain the construction of composite floors briefly
4. Explain the following

a) R.C.C. floor

b) Hollow block and rab floors

# ROOFS

A roof is defined as the uppermost part of a building which is constructed in the form of a frame work to given protection to the building against rain, heat, snow, wind etc. A roof basically consists of structural elements provided at the top of building for the support of roof coverings.

Following are the requirements of well planned roof:

(i) It should be durable against the adverse effects of various agencies such as wind, rain, sun etc.

(ii) It should grant the desirable insulation against sound and heat.

(iii) It should be structurally stable and sound, it should be capable of taking the loads likely to come over it.

(iv) It should be well-drained

(v) It should have efficient water-proofing arrangement.

**Types of roofs-Methods of construction:**

The roofs classified into the following three categories;

(i) Pitched roofs

(ii) Flat roofs

(iii) Curved roofs

I. **Pitched roofs:** A sloping roof is known as pitched roof as shown in the fig 13.1. The technical terms in connection with the pitched roof are given below

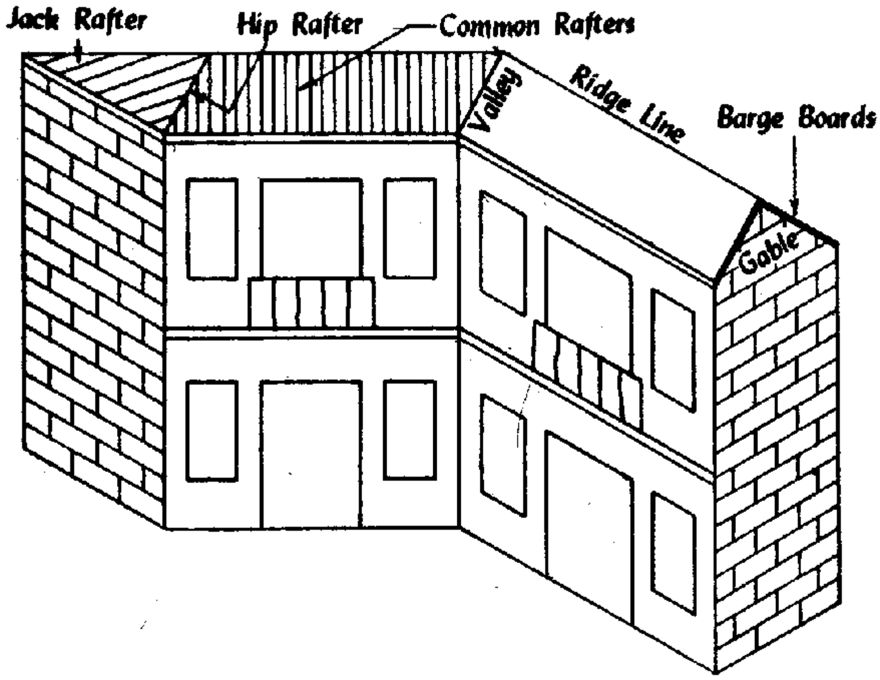



**Fig 13.1 Building with pitched roof**

(i) **Barge Boards:** Wooden planks or boards which are fixed on the gable end of the roof

(ii) **Battens**: Thin strips of wood which are fixed on rafters or ceiling to support the roof ceiling.

(iii) **Cleats**: Small blocks of wood which are fixed on truss to prevent the sliding of purlins.

(iv) **Dragon beam**: The diagonal piece of wood which is laid across the corner of the wall.

(v) **Eaves**: The lower edge of a roof which are resting upon or projecting beyond the supporting walls are known as eave as shown in the fig 13.2

(vi) **Gable**: The triangular upper part of a wall formed at the end of a pitched roof is known as gable.

(vii) **Hip**: The angle formed at the intersection of two roof slopes is known as hip.

(viii) **Pitch**: The inclination of sides of a roof to the horizontal plane is known as pitch, expressed in degrees or as a ratio of rise to span.

(ix) **Purlins**: The wooden pieces which are placed horizontally on principal rafters to carry the common rafters are known as purlins.

(x) **Rafters**: There are the pieces of timber which extend from the caves to the ridge

a) **Common rafters**: These are the intermediate rafters, which give support to the roof coverings a shown in the fig 13.2.

b) **Hip rafters**: Which provided at the junction of two roof slopes

c) **Jack rafters**: Any rafters, which is shorter than common rafters is known as Jack Rafters.

d) **Principal rafters**: These are the inclined members of a truss

(xi) **Ridge**: A wooden piece provided at the ridge line of a sloping roof is known as ridge or ridge board or ridge piece

(xii) **Span**: The horizontal distance between the internal faces of walls or supports is known as span or clear span.

(xiii) **Template**: A bidding block generally provided at the end of a truss. This block is known as template and it helps in spreading load over a large area. A template may be of wood or stone or R.C.C.

(xiv) **Verge**: The edge of a gable, running between the caves and ridge is known as a verge

(xv) **Valley**: When two roof surfaces meet together and form an internal angle, a valley is formed

(xvi) **Wall-plate**: These are long wooden members which are embedded on top of walls to receive the common rafters

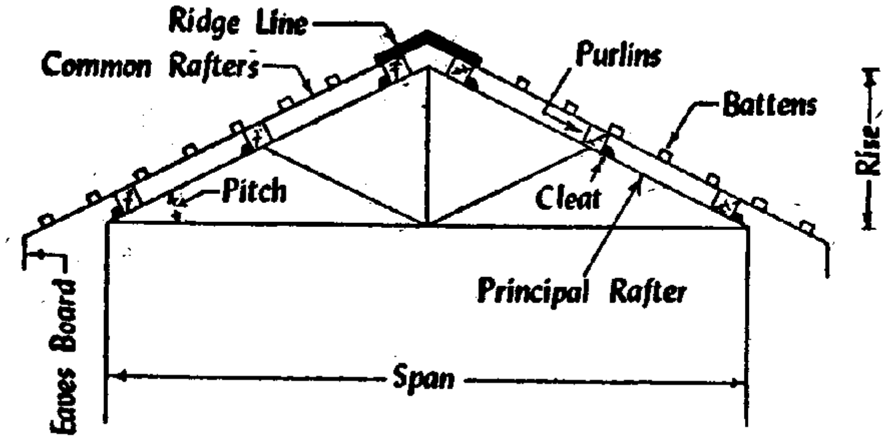



**Fig 13.2 Truss**

**Types of pitched roofs:**

(i) Single roof

(ii) Double or purlin roof

(iii) Trussed roofs

(i) **Single roof:** In this type of roofs, common rafters are provided to each slope without any intermediate support. The following are the varieties of single roof.

a) Lean to roof

b) Couple roof

c) Couple close roof

d) Collar beam roof

a) **Lean to roof:** It is the simplest form of a pitched roof and it is known as pent roof or Aisle roof. In this type of roof, one wall is carried up sufficiently higher than the other to give necessary slope to the roof. A lean-to roof is generally used for sheds, out-houses attached to main buildings verandah etc. This is suitable for a maximum span of 2.40m as shown in fig 13.3.

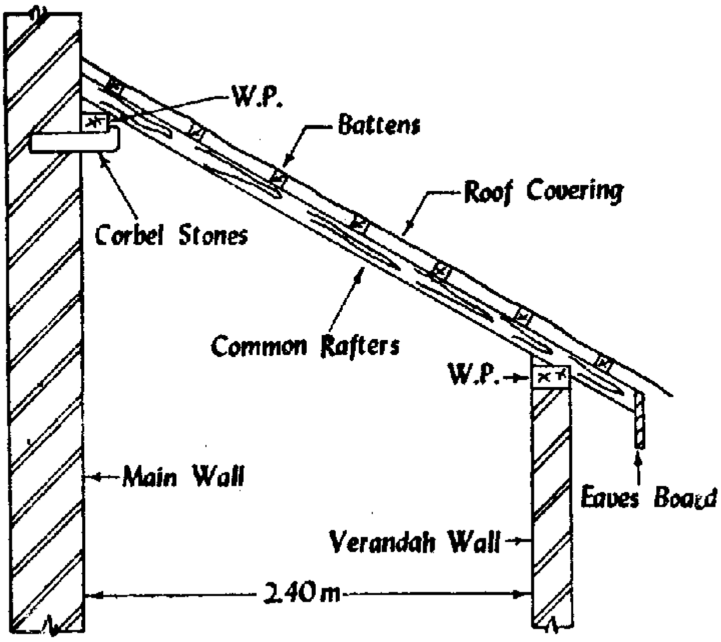



**Fig 13.3 Lean-to roof**

b) **Couple roof:** In this type of roof the common rafters slope upwards from the opposite walls and they meet on a ridge piece in the middle as shown in the fig 13.4. A couple roof is suitable for spans upto about 3.6m.

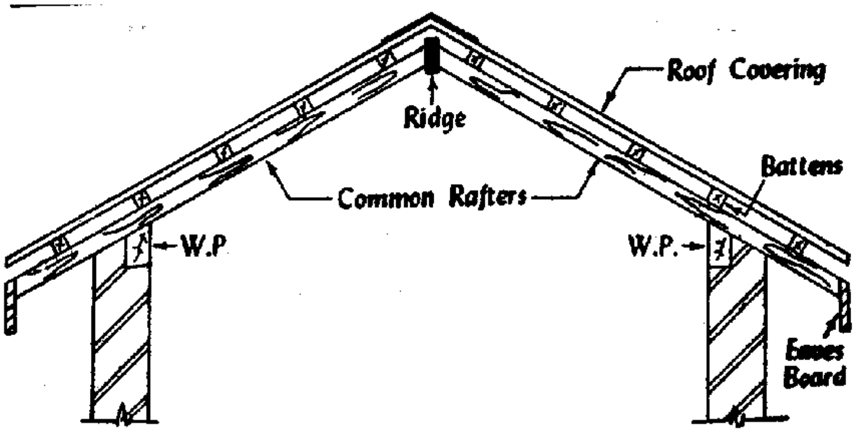



**Fig 13.4 Couple roof**

c) **Couple close roof**: This roof is just similar to couple roof except that the legs of the common rafters are connected by a tie beam as shown in the fig 13.5. The tie beam prevents the tendency of rafters to spread out and thus danger of overturning of the walls is avoided. This roof can be adopted economically upto the span of 4.2m.

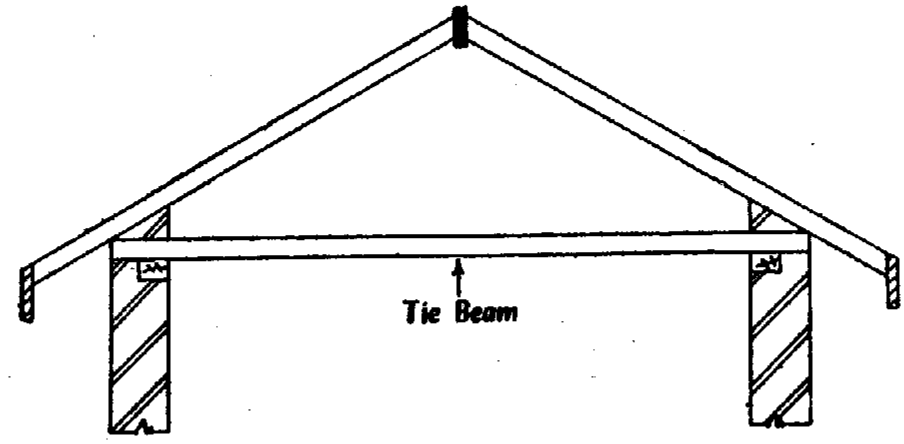



**Fig 13.5 Couple close roof**

d) **Collar beam roof:** The tie beam is raised and placed at a higher level as shown in fig 13.6 known as collar or collar beam. This beam roof is adopted to economise the space and to increase the height of a room. This roof can be adopted upto a maximum span of 4.8m.

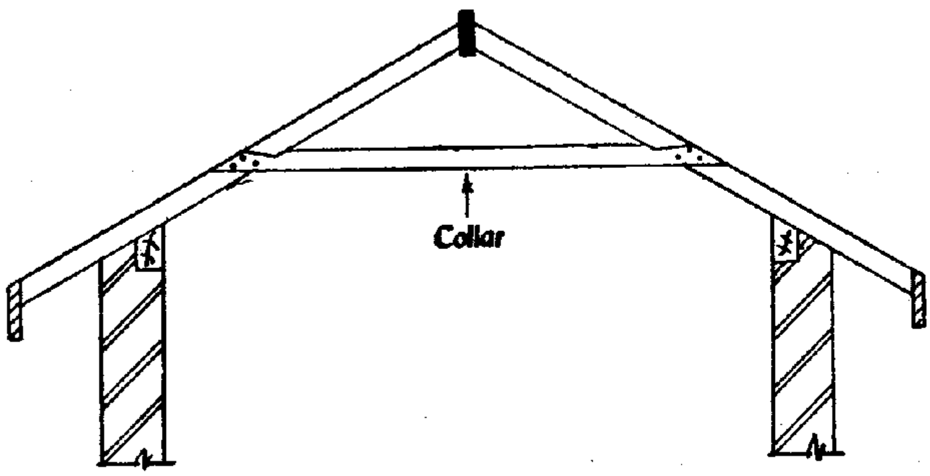



**Fig 13.6 Collar beam roof**

(i) **Double or purlin roofs:** When the span exceeds 2.4m, the necessary size for the rafters becomes uneconomical. Hence in order to reduce the size of rafters, intermediate supports called purlins are introduced under the rafters as shown in fig 13.7. This roof can be adopted economically upto 4.8m.

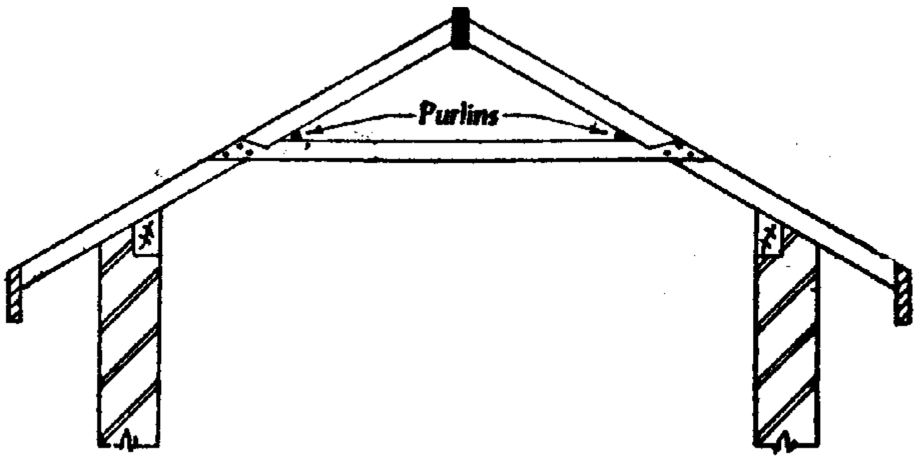



**Fig 13.7 Double or Purlin roof**

(ii) **Trussed roofs:** When the span exceeds 4.8m and when there are no inside supporting walls or partitions for purlins, framed structure known as trusses are on the roof, position of cross walls, span and material of the truss. The spacing is 3m for wooden trusses. Trusses carry the ridge piece and purlins on which the common rafters rest. Some of the usual forms of roof truss are given below.

a) King-post truss

b) Queen post truss

c) Mansard truss

d) Truncated truss

e) Bel-fast truss

f) Steel trusses

g) Composite trusses

a) **King post truss:** In this type of truss, the central post known as king-post forms support for the tie beam. The inclined members, known as structs, prevents the principal rafters from bending in the middle. A king-post truss suitable for roofs of span varying from 5 to 8 m as shown in fig 13.8.

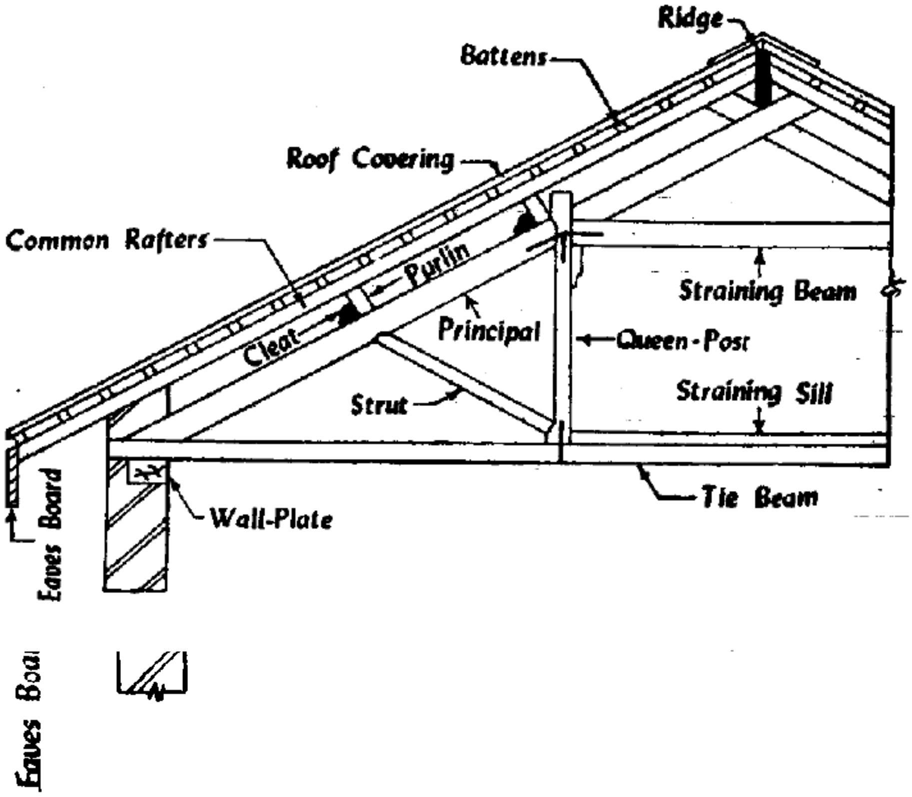



**Fig 13.8 King post truss roof**

b) **Queen post truss:** This truss is differ from a king-post truss in having two vertical members known as queen posts. The upper ends of the queen posts are kept in position by means of a horizontal member known as straining beam. Additional purlins are supported on the queen posts. A queen post truss is suitable for roof spans varying 8 to 12 m as shown in fig 13.9.

**fig 13.9 Queen post truss**

c) **Mansard truss:** this is a combination of king post and queen post trusses. Lower queen post & upper king post trusses. Use of mansard trusses results in the economy of space and room may be provided in the room as shown in the fig 13.10.

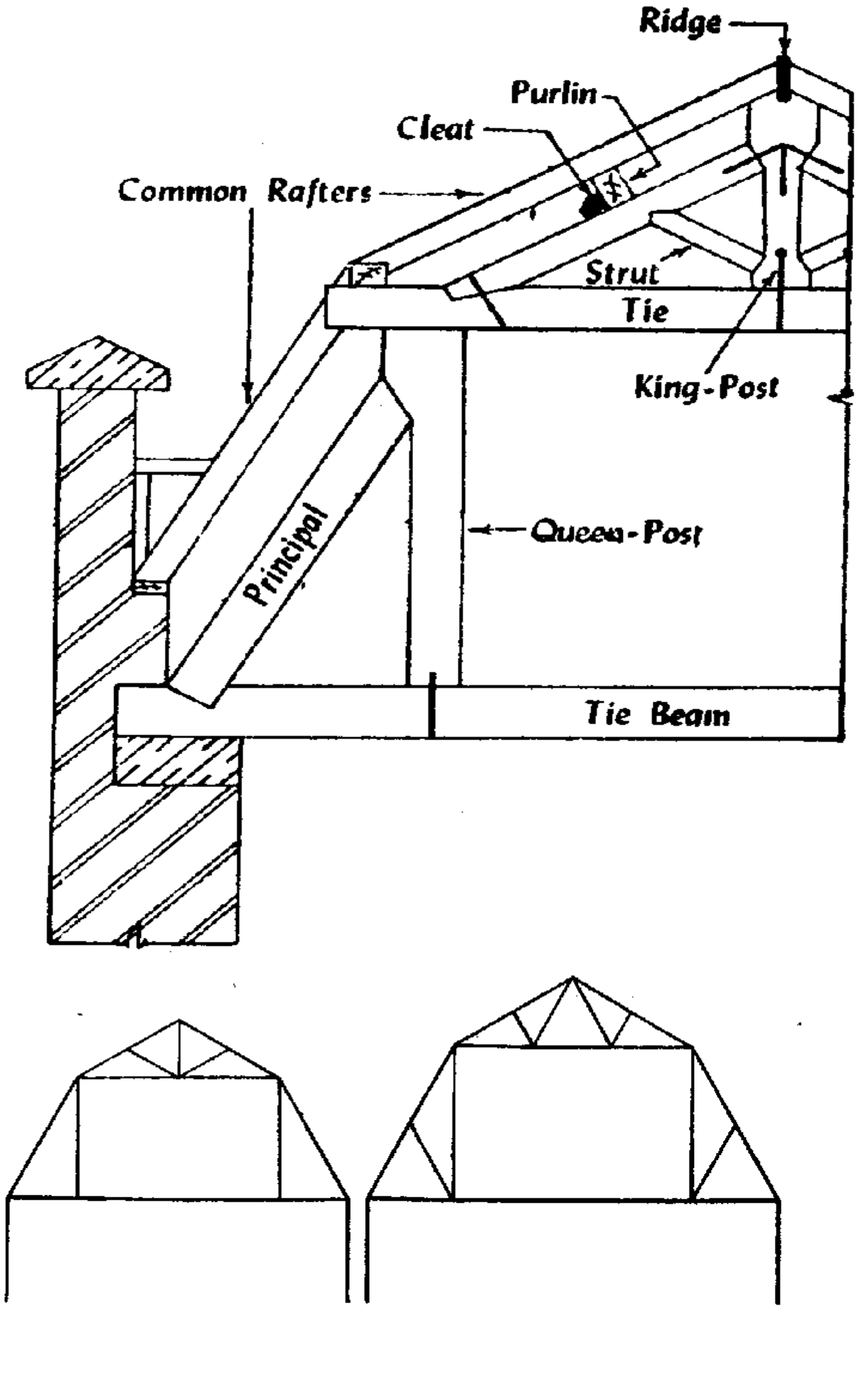



**Fig 13.10 Mansard truss**

d) **Truncated truss:** This is similar to mansard except that the top is finished flat as shown in fig 13.11.

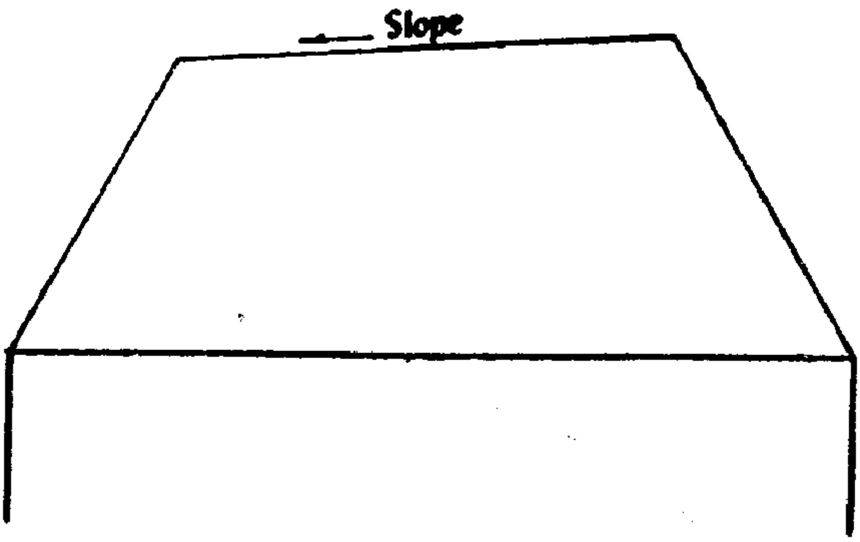
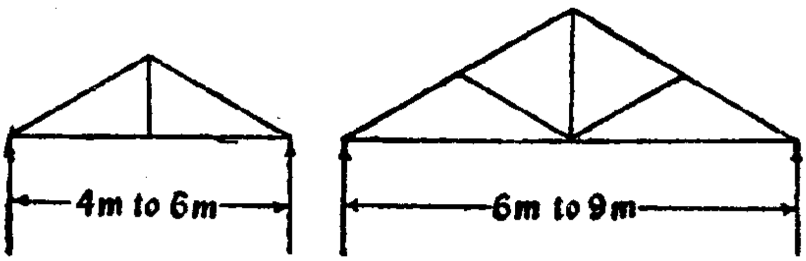



**Fig 13.11 Truncated truss**

e) **Steel trusses:** For spans greater 12m, it becomes economical to use steel trusses. For smaller spans, steel trusses consists of angles riveted or welded together through plates known as gusset plates. As steel resists both compression and tension stresses, the design of steel truss is simplified various types of steel trusses are shown in fig 13.12.



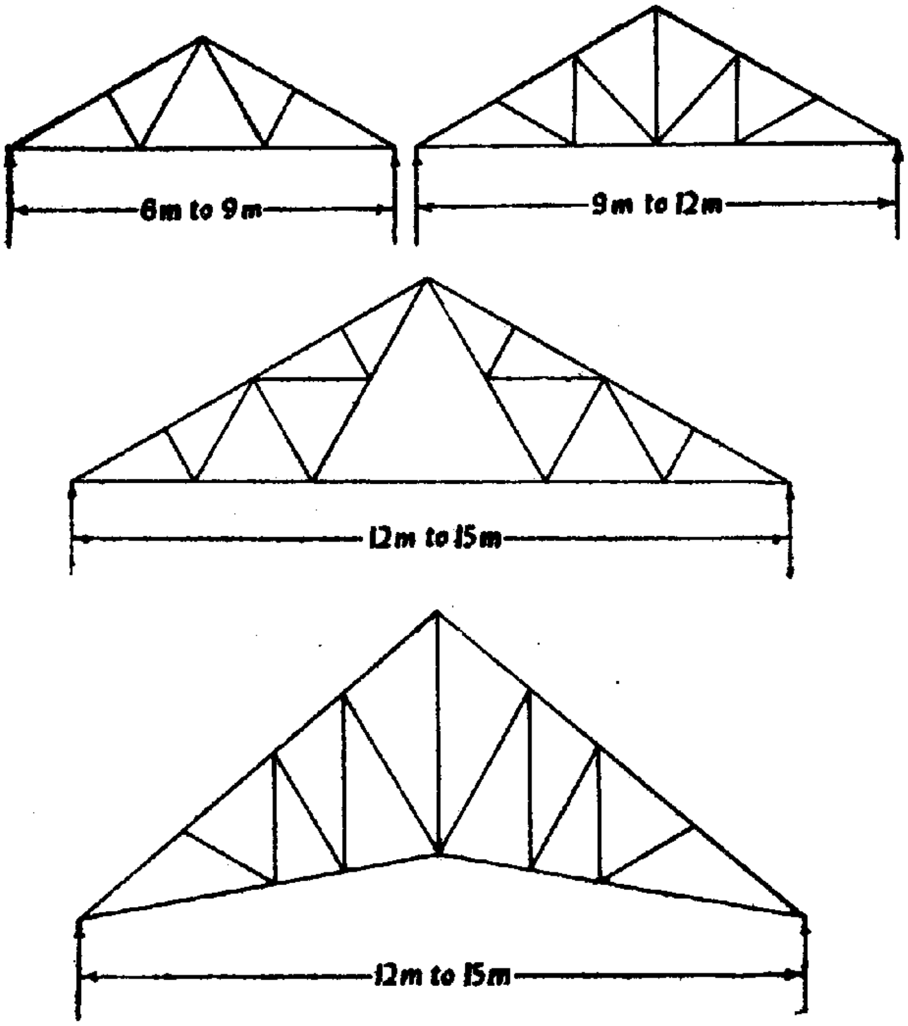



**Fig 13.12 Steel trusses**

f) **Composite stress:** This truss composed of wooden members and steel. Steel members resists tension. A composite truss is light and economical as shown in the fig 13.13.

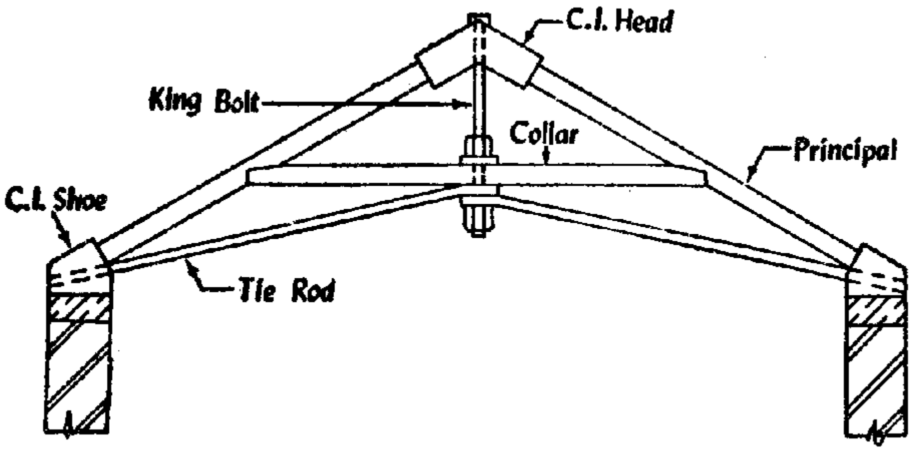



**Fig 13.13 Composite stress**

The factors should be considered before selecting the type of roof covering for pitched roof

(i) Climate of the locality

(ii) Nature of the building (iii)Initial cost and maintaince cost (iv)Resistance to fire and heat
(v) Special features of the locality.

**II** **Flat Roofs:** A roof which is nearly flat is known as flat roof. It should be noted that no roof can be laid perfectly level. The roof must slope in one direction or the other to cause rain water to flow off rapidly and easily. The construction of flat roof is same as that of floors except that the top surface is made slightly.

Sloping in case of flat roofs. The types of flat roofs commonly used are

1. Madras terrace roof

2. Bengal terrace roof

**1. Madras Terrace Roof: Procedure of construction:**

1. Teak wood joists are placed on rolled steel joists with a furring piece between the joists and rolled steel joists. The furring is placed sloping and gives necessary slope to the flat roof
2. A course of specially prepared terrace bricks of 150x75x25mm is laid diagonally across the joists with lime mortar
3. After the brick course, has set, a course of brick bat concrete of 75mm thick with 3 parts of brick bats, one part of gravel and sand and 50 percent of lime mortar by volume is laid.
4. The concrete is well rammed for three days and allowed to set
5. Flat tiles are laid over the layer of concrete of thickness 50mm
6. Finally, the surface of roof is finished with three coats of plaster given a slope of 1 in 30.
7. As this type of flat roof is widely used in madras state, it is known as madras terrace roof as shown in fig 13.14.

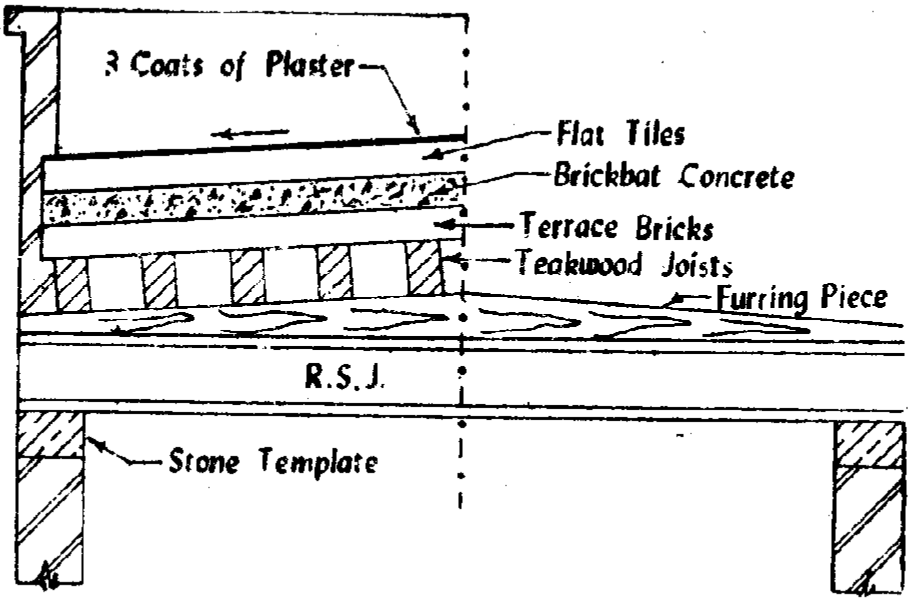



**Fig 13.14 Madras Terrace Roof**

2. **Bengal terrace roof: Procedure of construction:**

1. Rafters are placed, with a slight inclination, at 30cm to 50cm c/c. one end of the rafters is inserted into the main wall to a depth of 20cm and its other end is supported on a verandah wall.
2. Battens are placed at right angles to the rafters at a centre to centre distance of about 15cm
3. A course of flat tiles is then laid in mortar over the battens.
4. Finally, the surface of the roof is finished in any one of the following methods

(i) Two or more courses of flat tiles may be laid and the surface of roof is rubbed and polished with two or three coats of plaster

(ii) A layer of jelly concrete of 40mm thick may be laid over the first course of files. On this layer of concrete, another course of flat tiles is laid and the surface of roof is rubbed and polished with two or three coats of plaster

5. As this type of roof is mainly used in Bengal state to cover verandahs, it is known as Bengal Terrace roof as shown in fig 13.15.

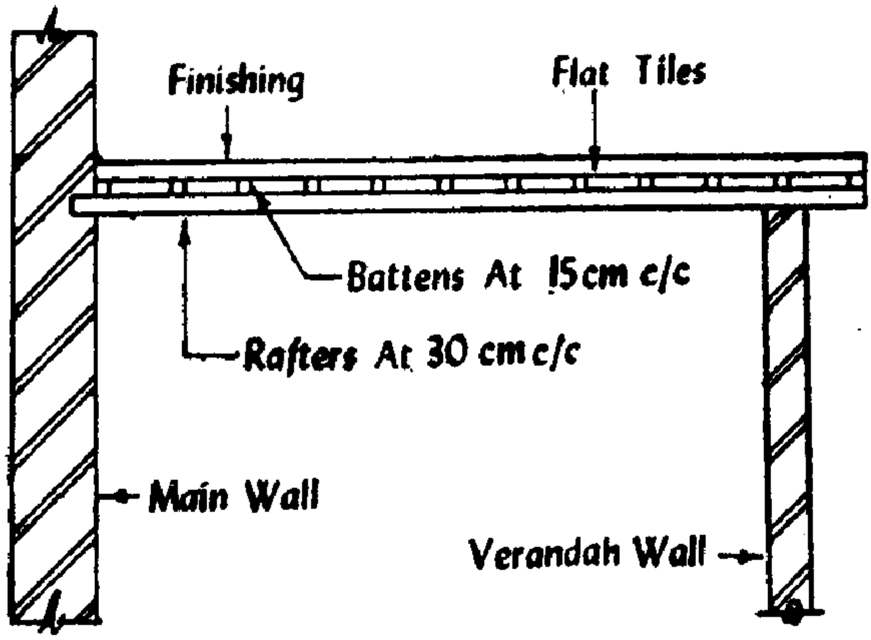



**Fig 13.15 Bengal Terrace roof Advantages of flat roofs:**

(i) The construction of roof is simplified

(ii) It is easier to make a flat roof fire-proof than a sloping roof

(iii) The roof are can be utilized as roof garden, dryling yards and conveniently be used for sleeping in hot season.

(iv) The construction of work of upper floors can be easily started where as pitched roof, the entire roof is to removed and is to be replaced by a new floor under such circumstances

(v) Flat roofs is found to be economical than pitched roof.

**Disadvantages**

1) Flat roofs cannot be used for long spans without introduction of intermediate pillars and beams
2) Cracks are developed on the surface of the roof due to the variation in temperature
3) Pockets of water are formed on the surface of the roof if slope is not sufficient and leads to leakage of roof
4) Flat roofs are not suitable, where rainfall is heavy
5) The dead weight of flat roof is considered and hence it proves to be more expensive, Initial cost is higher than pitched roof.

**III** **Curved roofs:** These are the just the modifications of pitched roofs and are frequently employed in modern age to cover large areas shed/roofs and domes are the varieties of curved roofs. They are useful for big structures such as factories, monumental works etc curved roofs may be constructed of timber or R.C.C. the latter material being very common now-a-days. They are two common forms of a shell roof

i) A north-light shell roof

ii) A barrel vault shell roof are as shown in fig 13.16 & 13.17

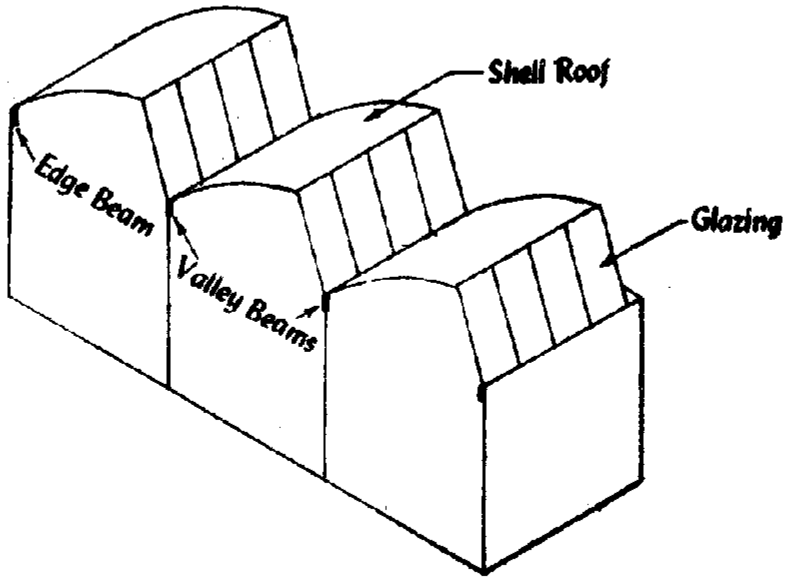



**Fig 13.16 North-light shell roof**

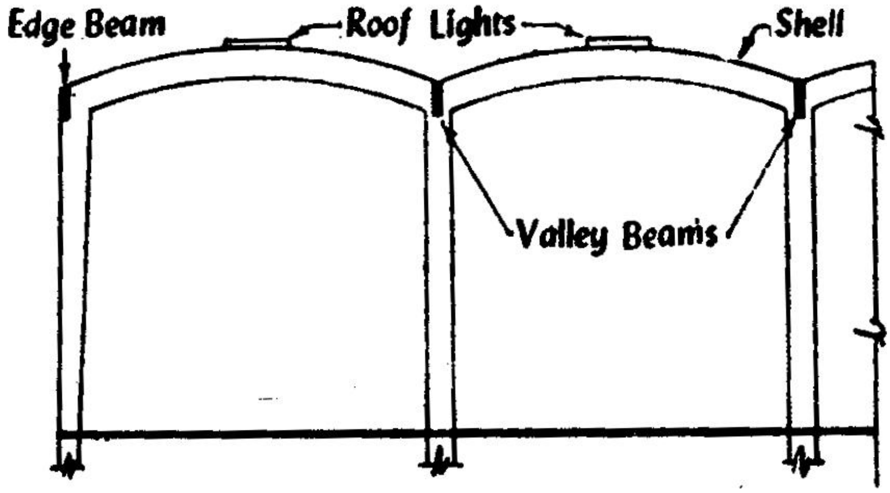



**Fig 13.17 Barrel vault shell roof**

A dome is a round vault forming a roof. It is useful when roof is to be provided on circular brick work or regular polygon shaped walls .

curved roofs afford pleasing appearance and due to arch action, the stresses are considerably reduced which results in thin sections for a curved roof.

**Procedure of construction**

(i) Pre-cast units of cement concrete tilis of size 70 x 70cm with a uniform minimum thickness of 20mm in the form of domes with a rise of about 50mm are used

(ii) Pre-cast units of R.C.C. 1:2:4 beams are prepared as per design usually 90mm deep and 130mm wide as per design usually 90mm deep and 130mm wide

(iii) The beams are suitably laid across the supporting walls

(iv) The tiles are placed in position after spreading some mortar on the edges of beams. The minimum bearing of tiles on beams should be 25mm and that on walls should be 50mm to 70mm

(v) The haunches between the humps of tiles are filled up with cement concrete of proportion 1:2:4

(vi) Suitable water-proofing treatment to the roof is given at the top. The roof thus exhibits a flat surface at the top and curved surface at bottom.

**Advantages**

1. It can be constructed in short time
2. It does not require skilled supervision
3. It is cheap in construction
4. It requires less frame work

* * *

**SYNOPYSIS**

1. A roof is defined as uppermost part of a building which is constructed in the form of a frame work to give protection to the building against rain, heat, snow, wind etc
2. A well planed roof requires following requirements

(i) Durable against adverse effects

(ii) Insulation against sound and heat

(iii) Stable

(iv) Well drained

(v) Efficient water-proofing

3. The types of roofs are

(i) Pitched roofs

(ii) Flat roofs

(iii) Curved roofs

4. A sloping roof is known as pitched roof are the following types

(i) Single roof

(ii) Double or purlin roof

(iii) Trussed roof

5. A single roof common rafters are provided to each slope without any intermediate support is the following types.

(i) Lean to roof

(ii) Couple roof

(iii) Couple close roof

(iv) Collar beam roof

6. When the span exceeds 2.4m, intermediate supports called purlins are provided in double or purlin roof upto 4.8m.

7. When the span exceeds 4.8m and when there are no inside supporting walls or partitions for purlins, framed structure known as truss of following types

(i) King post truss

(ii) Queen post truss

(iii) Truncated truss

(iv) Be-fast truss

(v) Steel truss

(vi) Composite truss

8. A roof which is nearly flat is known as flat roof commonly used flat roofs are

(i) Madras terrace roof

(ii) Bengal terrace roof

9. Curved roof are the just modified of pitched roofs to cover large areas
Ex: shell roofs, dome roofs.

## SHORT ANSWER QUESTIONS

1. Define roof.
2. What are the categories of roof?
3. Define common rafter.
4. What are the types of pitched roofs?
5. What are the advantages of flat roofs?
6. What are the advantages of curved roof?
7. Name the different types of single roofs.
8. What are the types of trussed roofs?
9. What is king post and queen post trusses?

## ESSAY TYPE QUESTIONS

1. What are the requirements of a well planned roof?
2. Explain the classification of roofs briefly.
3. Explain types of single roofs.
4. Explain king post and queen post truss.
5. Explain the construction of flat roof of madras terrace roof
6. Explain the construction of flat roof of Bengal terrace roof.
7. Explain the advantages and disadvantages of flat roofs.
8. Explain briefly about curved roofs.

* * *

# Roofs and Roof Coverings

## 15.1. INTRODUCTION

A roof may be defined as the uppermost part of the building, provided as a structural covering, to protect the building from weather (*i.e.*, from rain, sun, wind, etc.). Structurally, a roof is constructed in the same way as an upper floor, though the shape of its upper surface may be different. Basically, a roof consists of structural elements which support *roof coverings*. The structural element may be trusses, portals, beams, slabs (with or without beams), shells or domes. The *roof coverings* may be A.C. sheets, G.I. sheets, wooden shingles, tiles, slates or slab itself.

Roof and roof coverings receive rain and snow more directly and in much greater quantity than do the walls. It must, therefore, provide a *positive barrier* to the entry of rain, and vigorous weather proofing is most important. At the same time, the roof structure, which support the roof coverings must have adequate *strength* and *stability*. Apart from these, a roof must have *thermal insulation, fire resistance and sound insulation.*

**Requirements of a roof**

The requirements of a good roof are summarised below :

1. It should have adequate strength and stability to carry the super-imposed dead and live loads.

2. It should effectively protect the building against rain, sun, wind, etc., and it should be durable against the adverse effects of these agencies.

3. It should be water-proof, and should have efficient drainage arrangements.

4. It should provide adequate thermal insulation.

5. It should be fire resistant.

6. It should provide adequate insulation against sound. Most forms of roof construction provide for majority of buildings an adequate insulation against sound from external sources.

## 15.2. TYPES OF ROOFS

Roofs may be divided into three categories :

1. Pitched or sloping roofs,
2. Flat roofs or terraced roofs, and
3. Curved roofs.

The selection of the type of roof depends upon the shape or plan of the building, climatic conditions of the area and type of constructional materials available. *Pitched* *roofs* have sloping top surface. These are suitable in those areas where rainfall/snowfall is very heavy. Broadly, buildings with limited width and simple shape can generally be covered satisfactorily by pitched roofs. Buildings irregular in plan, or with long spans, present awkward problems in the design of a pitched roof, involving numerous valleys, gutters and hips. Buildings of large area, such as factories, when covered by a series of parallel pitched roofs, require internal guttering in the valleys. *Flat roofs* are considered suitable for buildings in plains or in hot regions, where rainfall is moderate, and where snowfall is not there. Flat roofs are equally applicable to buildings of any shape and size. *Curved roofs* have their top surface curved. Such roofs are provided to give architectural effects. Such roofs include cylindrical and parabolic shells and shell domes, doubly curved shells such as hyperbolic paraboloids and hyperboloids of revolution, and folded slabs and prismatic shells. Such roofs are more suitable for public buildings like libraries, theatres, recreation centres etc.

## 15.3. PITCHED ROOFS : BASIC ELEMENTS

A roof with sloping surface is known as a pitched roof. Pitched roofs are basically of the following forms :

1. Lean-to-roof
2. Gable roof
3. Hip roof
4. Gambrel roof
5. Mansard or curb roof
6. Deck roof.

**Lean-to-roof**: This is the simplest type of sloping roof, provided either for a room of small span, or for the verandah. It has slope only one side (Fig. 15.1 *a*).

**Gable roof** : This is the common type of sloping roof which slopes in two directions. The two slopes meet at the ridge. At the end face, a vertical triangle if formed (Fig. 15.1 *b*).

**Hip roof**: This roof is formed by four sloping surfaces in four directions (Fig. 15.1*c*). At the end faces, *sloped triangles* are formed.

**Gambrel roof** : This roof, like gable roof, slopes in two directions, but there is a break in each slope, as shown in Fig. 15.1(*d*). At each end, vertical face is formed.

**Mansard roof** : Mansard roof, like a hip roof, slopes in the four directions, but each slope has a break, as shown in Fig. 15.1(*c*). Thus, sloping ends are obtained.

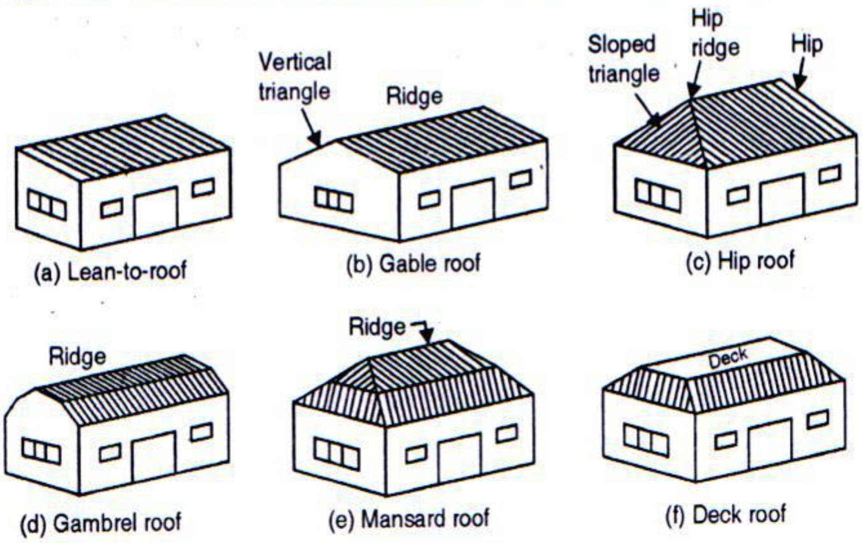



FIG. 15.1. VARIOUS FORMS OF SLOPING ROOFS

**Deck roof** : A deck roof has slopes in all the four directions, like a hip roof, but a deck or plane surface is formed at the top, as shown in Fig. 15.1 (*f*).

Fig. 15.2 shows various elements of pitched roof. These elements are defined below:

**1. Span.** It is the clear distance between the supports of an arch, beam or roof truss.

**2. Rise.** It is the vertical distance between the top of the ridge and the wall plate.

**3. Pitch.** It is the inclination of the sides of a roof to the horizontal plane. It is expressed either in terms of degrees (angle) or as a ratio of rise to span.

**4. Ridge.** It is defined as the apex line of the sloping roof. It is thus the apex of the angle formed by the termination of the inclined surfaces at the top of a slope.

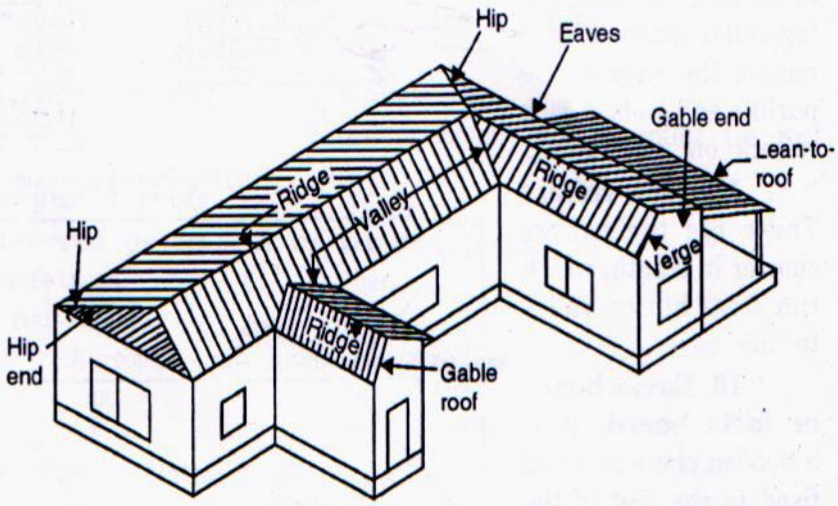



FIG. 15.2. VIEW OF A BUILDING WITH BASIC SLOPING ROOFS.

**5. Eaves.** The lower edge of the inclined roof surface is called eaves. From the lower edge (eaves), the rain water from the roof surface drops down.

**6. Hip.** It is the ridge formed by the intersection of two sloping surfaces,where the exterior angle is greater than 180°.

**7. Valley.** It is a reverse of a hip. It is formed by the intersection of two roof surfaces, making an external angle less than 180°.

**8. Hipped end.** It is the sloped triangular surface formed at the end of a roof.

**9. Verge.** The edge of a gable, running between the eaves and ridge, is known as a verge.

**10. Ridge piece, ridge beam or ridge board.** It is the horizontal wooden member, in the form of a beam or board, which is provided at the apex of a roof truss. It supports the common rafters fixed to it.

**11. Common rafters or spars** These are inclined wooden members running from the ridge to the eaves. They are bevelled against the ridge beam at the head, and are fixed to purlins at intermediate point. They support the battens or boarding to support the roof coverings. Depending upon the roof covering material, the rafters are spaced 30 to 45 cm centre to centre.

**12. Purlins.** These are horizontal wooden or steel members, used to support common rafters of a roof when span is large. Purlins are supported on trusses or walls.

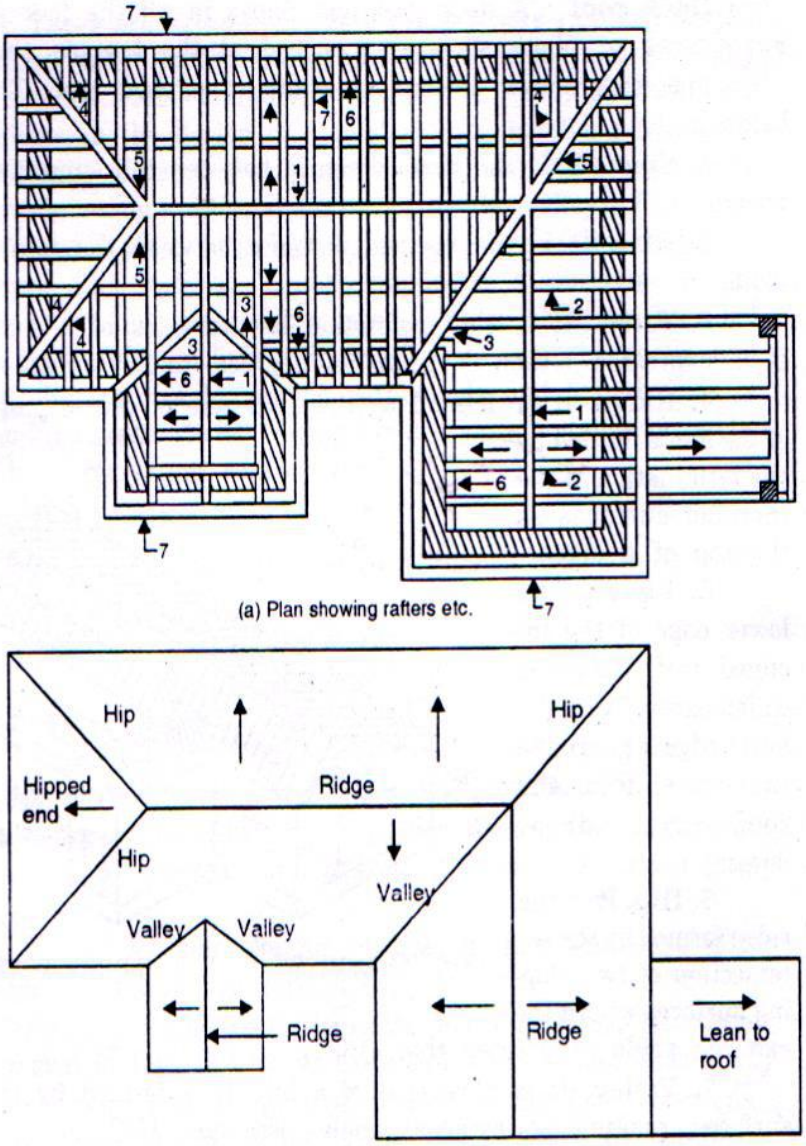
**13. Hip rafters.** These are the sloping rafters which form the hip of a sloped roof. They run diagonally from the ridge to the corners of the walls to support roof coverings. They receive the ends of the purlins and ends of jack rafters.

**14. Valley rafters.** These are the sloping rafters which run diagonally from the ridge to the eaves for supporting valley gutters. They receive the ends of the purlins and ends of jack rafters on both sides.

**15. Jack rafters** These are the rafters shorter in length, which run from hip or valley to the eaves.

**16. Eaves board or facia board**. It is a wooden plank or board fixed to the feet of the common rafters at the eaves. It is usually 25 mm thick and 25 mm wide. The ends of lower most roof covering material rest upon it. The eaves gutter, if any, can also be secured against it.

**17. Barge board.** It is a timber board used to hold the common rafter forming verge.




(a) Plan showing rafters etc.

(b) Plan showing slopes

1. RIDGE.
2. COMMON RAFTERS.
3. VALLEY RAFTERS.
4. JACK RAFTERS.
5. HIP RAFTERS.
6. WALL PLATE.
7. EAVES BOARD.

FIG. 15.3 PLAN OF THE BUILDING HAVING SLOPING ROOFS.

**18. Wall plates.** These are long wooden members, which are provided on the top of stone or brick wall, for the purpose of fixing the feet of the common rafters. These are embedded from sides and bottom in masonry of the walls, almost at the centre of their thickness. Wall plates actually connect the walls to the roof.

**19. Post plate**. This is similar to a wall plate except that they run continuous, parallel to the face of wall, over the tops of the posts, and support rafters at their feet.

**20. Battens.** These are thin strips of wood, called scantlings, which are nailed to the rafters for lying roof materials above.

**21. Boardings.** They act similar to battens and are nailed to common rafter to support the roofing material.

**22. Template.** This is a square or rectangular block of stone or concrete placed under a beam or truss, to spread the load over a larger area of the wall.

**23. Cleats.** These are short sections of wood or steal (angle iron), which are fixed on the principal rafters of trusses to support the purlins.

**24. Truss.** A roof truss is a frame work, usually of triangles, designed to support the roof covering or ceiling over rooms.

## 15.4. TYPES OF PITCHED ROOFS

Pitched roofs may be broadly classified into the following :

(*a*) **Single roofs**

1. Lean-to-roof (verandah roof).
2. Couple roof.
3. Couple-close roof.
4. Collar beam roof or collar tie roof.

**(*b*) Double or purlin roofs**

**(*c*) Triple-membered or framed or trussed roofs**

1. King-post roof truss.
2. Queen-post roof truss.
3. Combination of king-post and queen-post trusses,
4. Mansard roof truss.
5. Truncated roof truss.
6. Bel-fast roof truss or latticed roof truss.
7. Composite roof trusses.
8. Steel sloping roof trusses.

*Single roofs* consist of only common rafters which are secured at the ridge (to ridge beam) and wall plate. These are used when span is less so that no intermediate support is required for the rafters. A *double roof* is the one in which *purlins* are introduced to support the common rafters at intermediate point. Such roofs are used when the span exceeds 5 metres. The function of a purlin is to tie the rafters together, and to act as an intermediate support to the rafters. A *triple membered or trussed roof* consists of three sets of members : (*i*) common rafters, (*ii*) purlins, and (*iii*) trusses. The purlins, which give an intermediate support to the rafters, are themselves supported on *trusses* which are suitably spaced along the length of a room. A trussed roof is provided when the span of the room is greater than 5 metres, and when the length of the room is large, *i.e.* where there are no internal walls or partitions to support the purlins.

## 15.5. SINGLE ROOFS

Single roofs are those which consist of only the rafters which are supported at the ridge and at the eaves. Such roofs are used only when the span is limited to 5 metres, otherwise the size of the rafters will be uneconomical. The maximum span of the rafters is taken as 2.5 m. Single roofs are of four types : (*i*) lean-to- roof, verandah-roof or shed roof, (*ii*) couple roof, (*iii*) couple close roof, and (*iv*) collar beam roof.

### 1. Lean-to-roof

This is the simplest type of sloping roof, in which rafters slope to one side only. It is also known as *Pent roof or Aisle roof*. The wall to one side of the room (or verandah) is taken higher than the wall (or pillars) to the other side. A wooden wall plate is supported either on a steel corbel or a stone corbel, which are provided at 1 m centre to centre. The wall plate (or post plate) is embedded on the other side, to the wall or pillars. The difference in elevation between the two wall plates is so kept that the desired slope is obtained. Usual slope is 30°. The common rafters are nailed to wooden wall plate at their upper end, and notched and nailed to the wooden post plate at their lower end. Sometimes, iron knee straps and bolts are used to connect the rafters to the post plate. Eaves boards, battens and roof coverings are provided as shown in Fig. 15.4. This type of roof is suitable for maximum span of 2.5 m. These are provided for sheds, out-houses attached to main building, verandahs, etc.

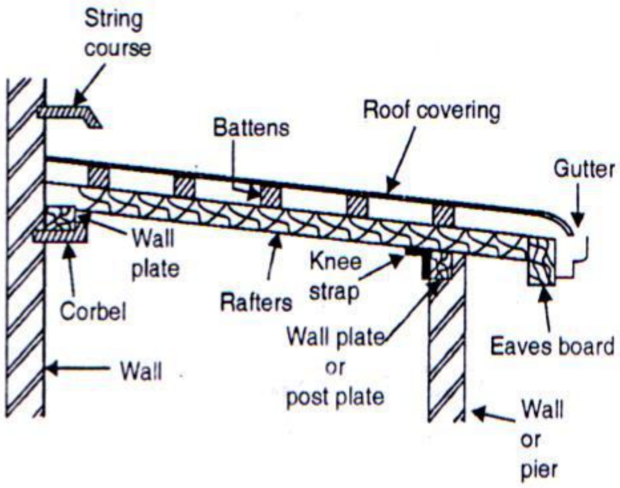



FIG. 15.4. LEAN-TO-ROOF.

### 2. Couple roof

This type of roof is formed by couple or pair of rafters which slope to both the sides of the ridge of the roof. The upper ends of each pair of rafter is nailed to a common ridge piece and their lower ends are notched and nailed to the wooden wall plates embedded in the masonry on the top of the outer walls. Such a roof is not very much favoured because it has the tendency to spread out at the feet (Wall plate level) and thrust out the walls supporting the wall plates. Due to this, the couple roof is used when the span is limited to 3.6 metres.

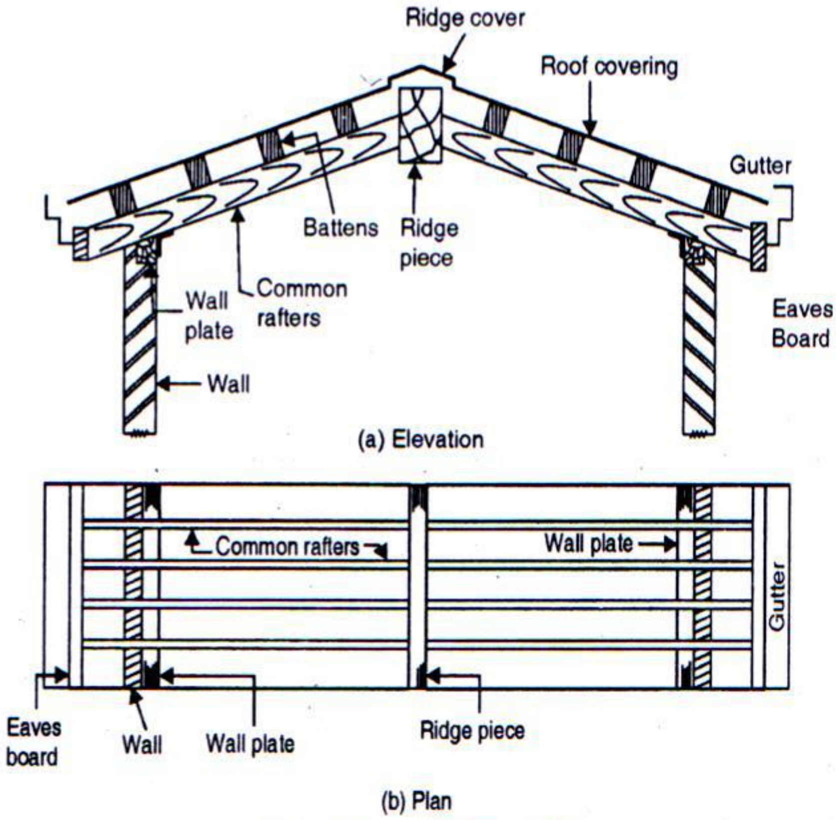



FIG. 15.5. COUPLE ROOF.

**3. Couple close roof**

A couple close roof is similar to the couple roof, except that the ends of the couple of common rafters is connected by horizontal member, called *tie beam,* to prevent the rafters from spreading and thrusting out of the wall. The tie beam may be a wooden member or a steel rod. The connection between wooden tie and feet of rafters is obtained by *dove tail halved joint.* For inferior work, the ties may just be spiked to the rafters. There is one tie beam for each pair of rafters. These tie beams can also be used as ceiling joists when required. A couple-close roof is economically suitable for spans upto 4.20 m. For increased span or for greater loads, the rafters may have tendency to sag in the middle. This can be checked by providing a central vertical rod, called *king rod* or *king bolt* which connects the ridge piece and the tie beam as shown in Fig. 15.6 (*b*).

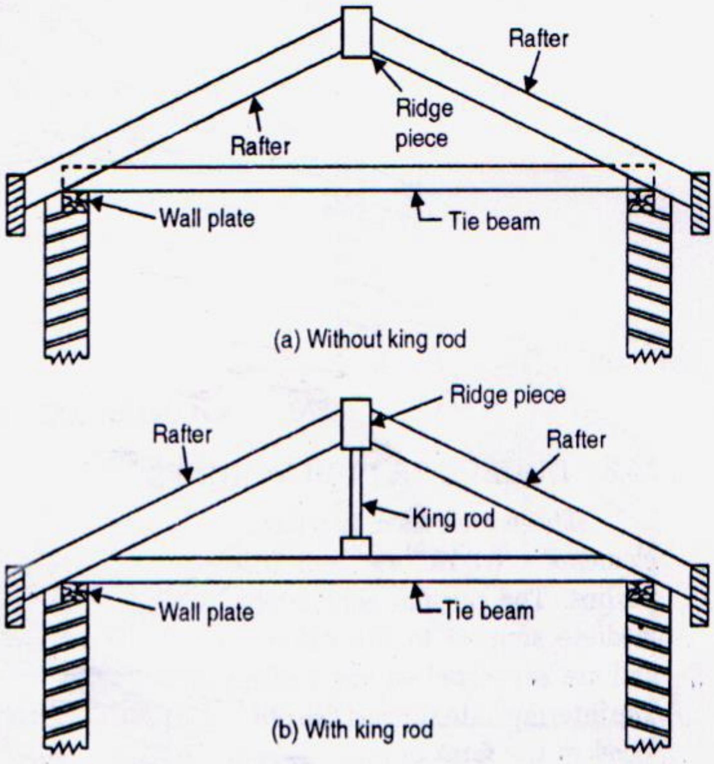



FIG. 15.6. CLOSE COUPLE ROOF.

**4. Collar beam roof**

When the span increases, or when the load is more, the rafters of the couple close roof have the tendency to bend. This is avoided by raising the tie beam and fixing it at one-third to one-half of the vertical height from wall plate to the ridge. This raised beam is known as the *collar beam* (or *collar tie*). Thus, a collar beam roof is similar to a couple close roof, except that in the latter case a tie beam is provided at the level of wall plates while in this case a collar beam is provided at the raised level (Fig. 15.7). This roof is suitable for spans upto 5 metres. A lower collar position gives stronger roof. A collar beam provides roof greater height of the room.

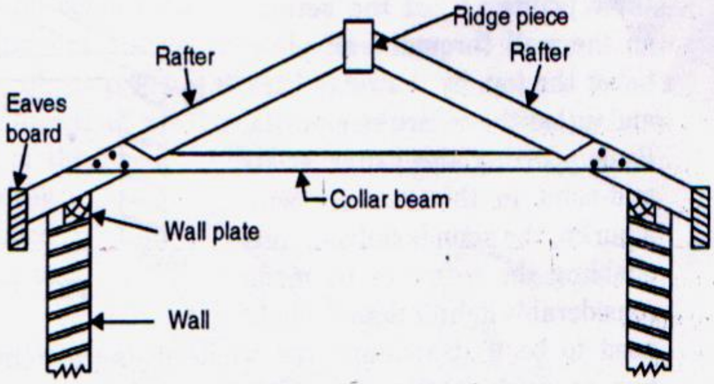



FIG. 15.7. COLLAR BEAM ROOF.

**5. Collar and scissors roof**

It is similar to the collar roof, except that two collar beams, crossing each other to have an appearance of scissors is provided as shown in Fig. 15.8.

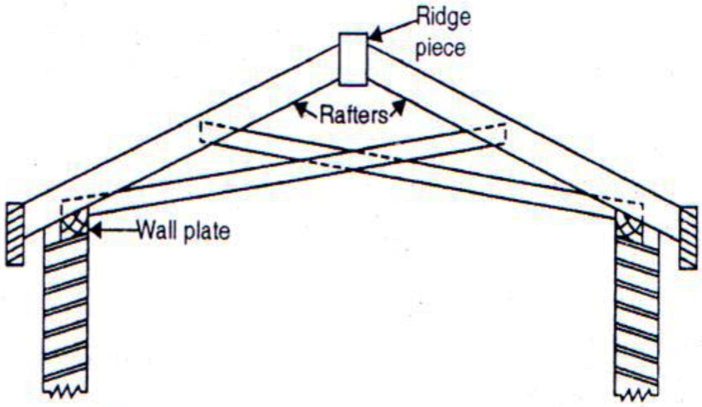
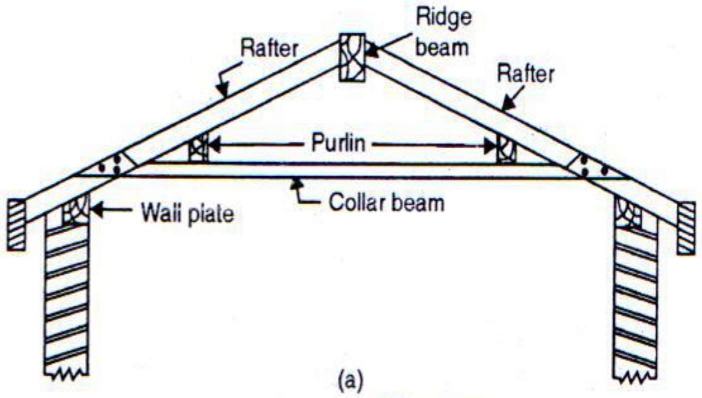



FIG. 15.8. COLLAR AND SCISSORS ROOF.

## 15.6. DOUBLE OR PURLIN ROOFS

These roofs have two basic elements : (*i*) rafters, and (*ii*) purlins. The purlins give intermediate support to the rafters, and are supported on end walls. The intermediate supports so provided in the form of purlins, reduce the size of the rafters to the economical range. Such a roof is also known as *rafter and purlin roof*. The rafters are provided fairly close (40 to 60 cm c/c). Each rafter is thus supported at three points : (*i*) at the bottom; on the wall through wall plate, (*ii*) at the top, by the ridge bam, and (*iii*) at the centre by a purlin. By supporting the rafter at its mid-point in this manner with a purlin, the span is halved, thus enabling the rafter to be made considerably lighter than it would need to be if it spanned the whole distance from eaves to the ridge. For larger roofs, two or more purlins may be provided to support each rafter. Fig. 15.9 shows two forms of this roof.



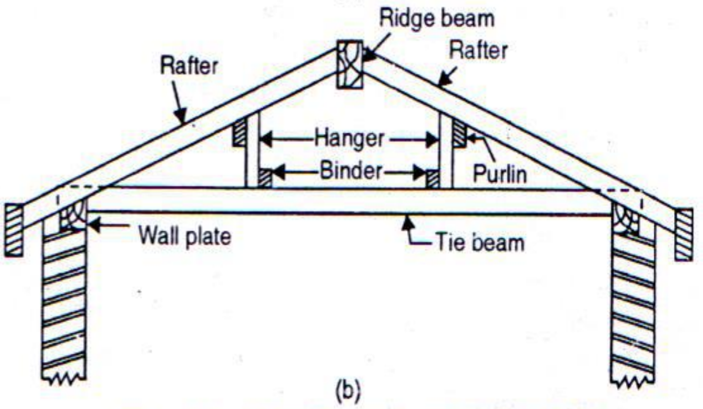




FIG. 15.9. RAFTER AND PURLIN ROOF.

## 15.7. TRUSSED ROOFS

When the span of the roof exceeds 5 m and where there are no inside walls to support the purlins, framed structures, known as *trusses* are provided at suitable interval along the length of the room. Spacing is generally limited to 3 metres for wooden trusses. In this system, the roof consists of three elements : (*i*) rafters to support the roofing material (*i.e.*. tiles etc.), (*ii*) purlins to provide intermediate support to rafters, and (*iii*) trusses to provide support to the ends of purlins. The trusses span in the same direction in which the couple of rafters run. The trusses also support the ridge piece or ridge beam. The various types of trusses in use are :

(*i*) King-post truss. (*ii*) Queen-post truss.

(*iii*) Combination of king-post and queen-post trusses.

(*iv*) Mansard truss. (*v*) Truncated truss.

(*vi*) Bel-fast truss. (*vii*) Steel trusses.

(*viii*) Composite trusses.

The first six types are essentially wooden trusses.

## 1. King-post truss

A king-post truss, shown in Fig. 15.10 consists of the following components : (*i*) lower tie beam, (*ii*) two inclined principal rafters. (*iii*) two struts, and (*iv*) a king post. The principal rafters support the *purlins*. The purlins support the closely-spaced *common rafters* which have the same slope as the principal rafters. The common rafters support the roof covering as usual.

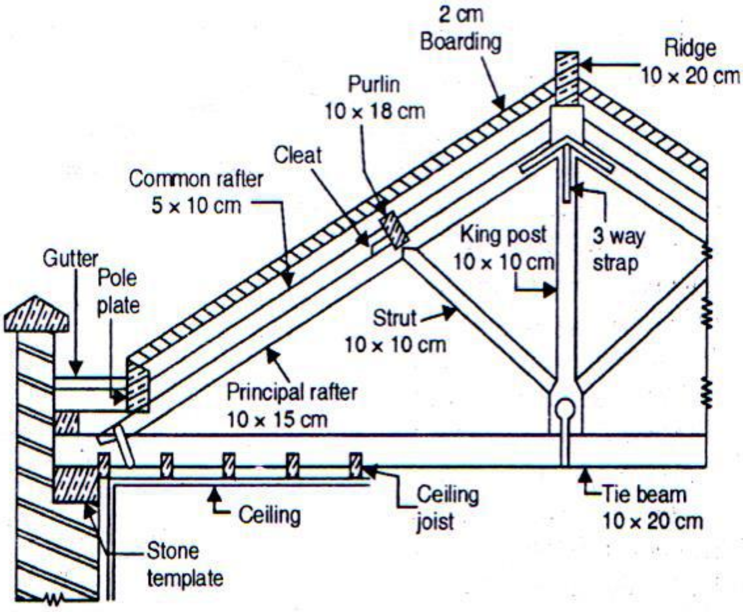



FIG. 15.10. KING-POST TRUSS ( SPAN 7 m.)

The spacing of the king-post truss is limited to 3 m centre to centre. The truss is suitable for spans varying from 5 to 8 metres. The lower, horizontal, tie beam receives the ends of the principal rafters, and prevents the wall from spreading out due to thrust. The king-post prevents the tie-beam from sagging at its centre of span. The struts connected to the tie beams and the principal rafters in inclined direction, prevent the sagging of principal rafters. *Ridge beam* is provided at the apex of the roof to provide end support to the common rafters. The trusses are supported on the bed blocks of stone or concrete, embedded in the supporting walls so that load is distributed to a greater area.

The principal rafter is jointed to the tie beam by a 'single abutment and tenon joint' or by a 'bridle joint'. The joint is further strengthened by a wrought iron heel strap, would round the joint. The head of each strut is fixed to the principal rafter by an 'oblique' mortise and tenon joint. The king-post is provided with splayed shoulders and feet, and is tenoned into the upper edge of the tie beam for a sufficient distance. It is further strength-

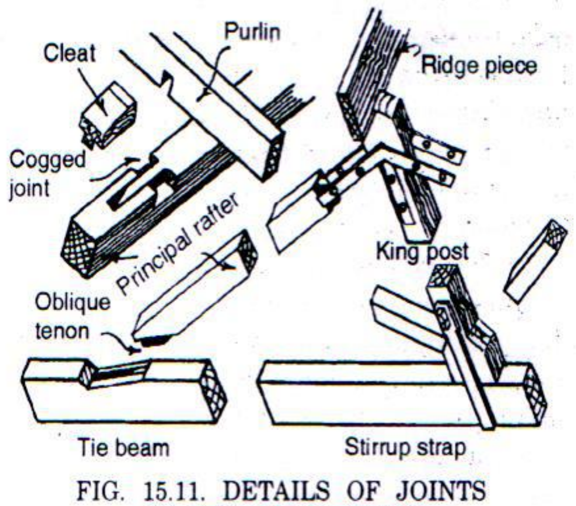



FIG. 15.11. DETAILS OF JOINTS IN KING-POST TRUSS.

is made wider, and the head of the principal rafter and the end of straining beam are tenoned into it. The joint is further strengthened by fixing a 3-way strap of wrought-iron or steel on each face as shown in Fig. 15.12 (*b*). Similarly, the feet of queen-post is widened to receive the tenon of the inclined strut, forming a 'single abutment and tenon joint'. The queen-post then tenons into the tie beam. The joint is further strengthened by stirrup straps and bolts.

**3. Combination of king-post and queen-post trusses**

Queen-post trusses are suitable for spans upto 12 metres. For greater spans, the queen-post truss can strengthened by one more upright member, called *princess-post* to each side. Fig. 15.13 (*a*) and (*b*) show the resulting combination of king-post and queen-post trusses, which are suitable upto 18 m span.

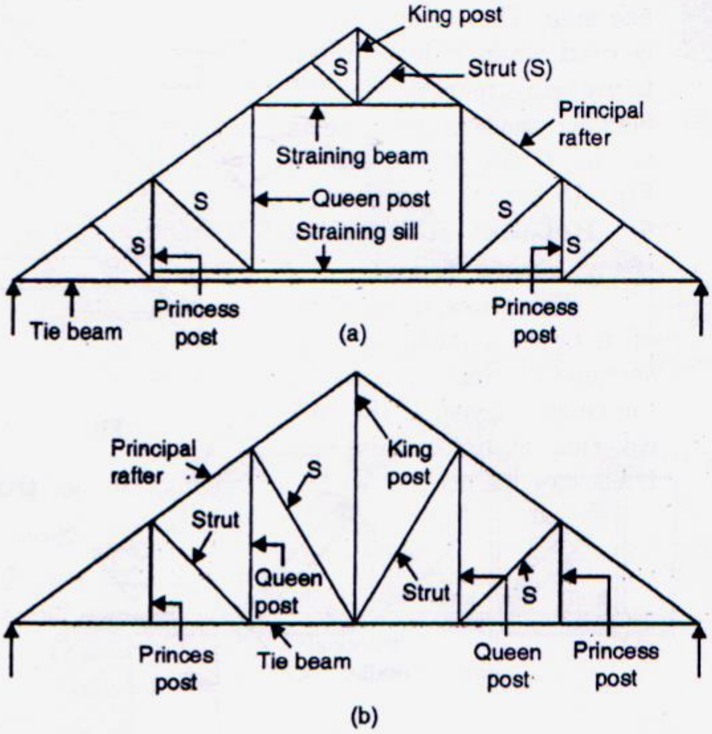



FIG. 15.13. COMBINATION OF KING-POST AND QUEEN-POST TRUSSES.

**4. Mansard roof truss**

This roof truss, named after its designer Francois Mansard, a French architect, is a combination of king-post and queen-post trusses. It is a two-storey truss, with upper portion consisting of king-post truss and the lower portion of queen-post truss. The entire truss has two pitches. The upper pitch (king-post truss) varies from 30° to 40° while two lower pitch (queen-truss) varies from 60° to 70°. The use of this truss results in economy in space, since a room may be provided between the two queen-posts. However, it has become obsolete because of odd shape. Fig. 15.14 shows two alternative forms

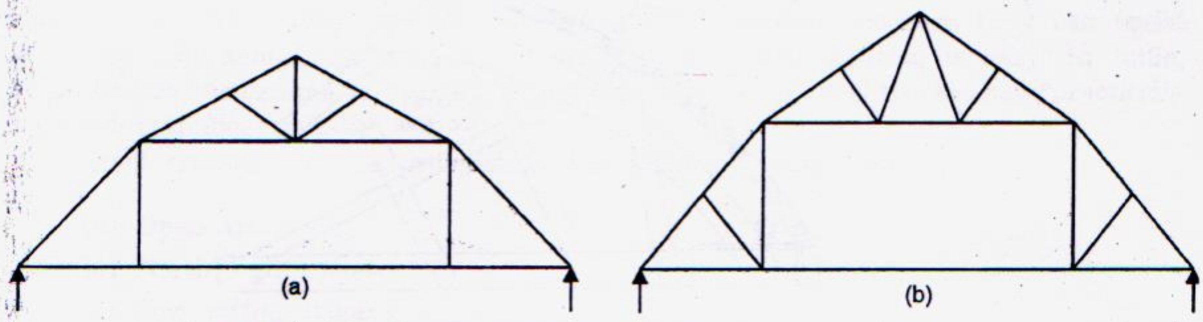



FIG. 15.14. ALTERNATIVE FORMS OF MANSARD TRUSSES.

of Mansard truss. Fig. 15.15 shows the details of the truss.

**5. Truncated truss**

A truncated truss is similar to Mansard truss, except that its top is formed flat, with a gentle slope to one side. This type of truss is used when it is required to provide a room in the roof, between the two queen-posts of the truss, as shown in Fig. 15.16.

**6. Bel-fast roof truss (Bow string truss)**

This truss, in the form of a bow, consists of thin sections of timber, with its top chord curved. If the roof covering is light, this roof truss can be used upto 30 m span. The roof truss is also known as *latticed roof truss.*

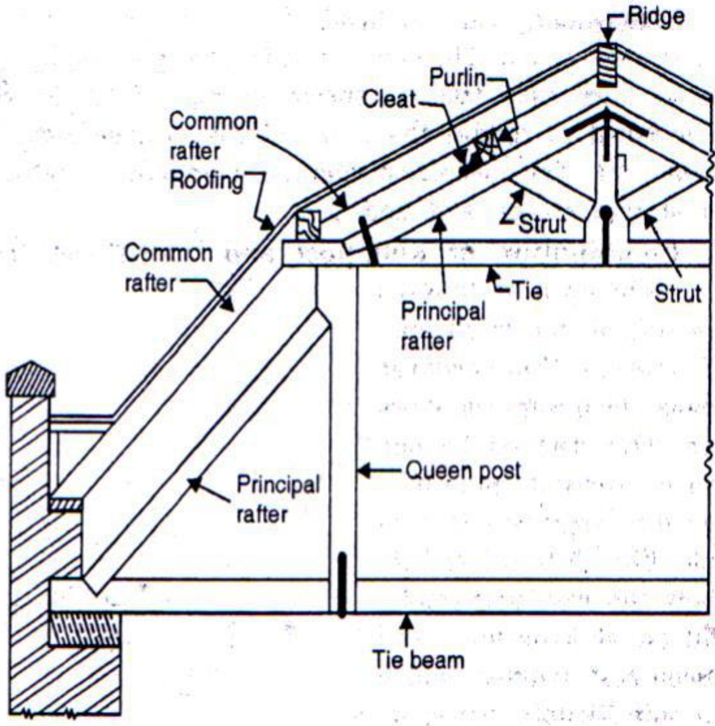



FIG. 15.15. DETAILS OF MANSARD TRUSS.

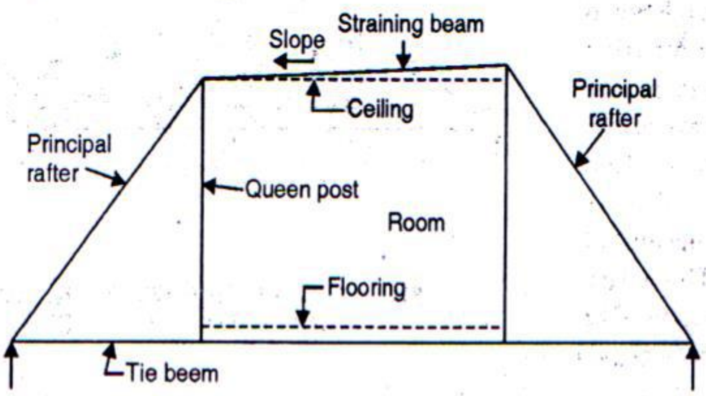



FIG. 15.16. TRUNCATED TRUSS.

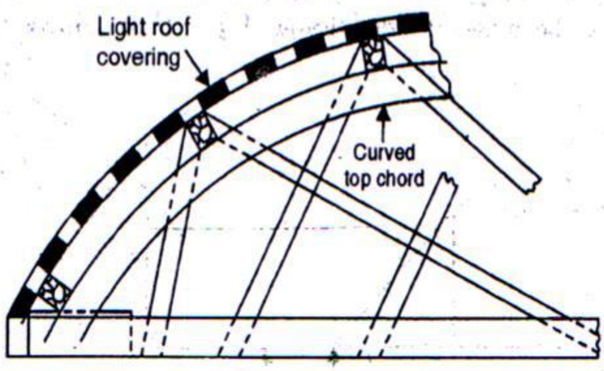



FIG. 15.17. BEL-FAST TRUSS.

**7. Composite roof trusses**

Roof trusses made of two materials, such as timber and steel, are known as *composite* roof trusses. In a composite truss, the tension members are made of steel, while compression members are made of timber. If tension members are made of timber, their section becomes very heavy because of reduction of section at the joints. Special fittings are required at the junction of steel and timber members. The joints in composite trusses should be such that cast or forged fittings can be easily used. Fig. 15.18 shows some common types of composite roof trusses, using fittings such as C.I. head, C.I. shoe, steel angle bolts and straps etc.

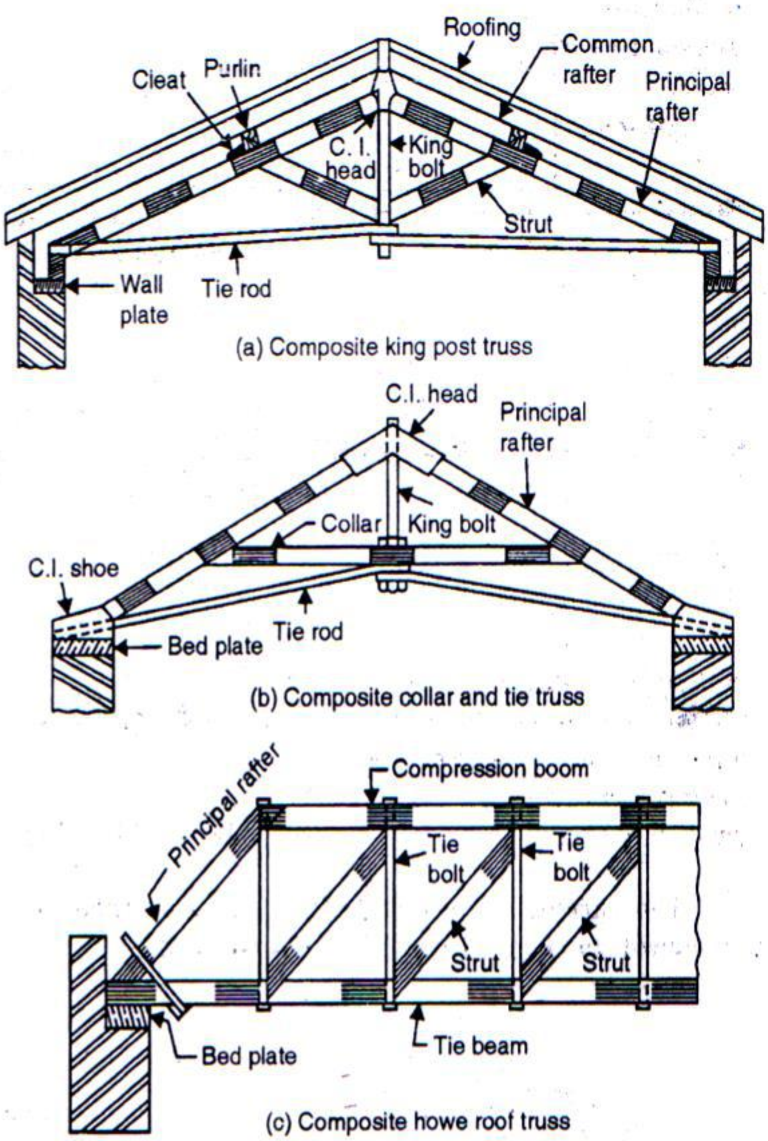



FIG. 15.18. COMPOSITE ROOF TRUSS.

## 15.8. STEEL ROOF TRUSSES

When the span exceeds 10 m, timber trusses become heavy and uneconomical. Steel trusses are more economical for larger spans. However, steel trusses are more commonly used these days, for all spans – small or large, since they are : (*i*) more economical, (*ii*) easy to construct or fabricate, (*iii*) fire-proof, (*iv*) more rigid, and (*v*) permanent. Steel trusses are fabricated from rolled steel structural members such as channels, angles, T-sections and plates. Most of the roof trusses are fabricated from angle-sections because they can resist effectively both tension as well as compression, and their jointing is easy. In India, where timber has become very costly (except in hilly regions), steel trusses have practically superseded timber trusses.

Steel trusses may be grouped in the following categories :

(*a*) Open trusses

(*b*) North light trusses

(*c*) Bow string trusses

(*d*) Arched rib trusses and solid arched ribs.

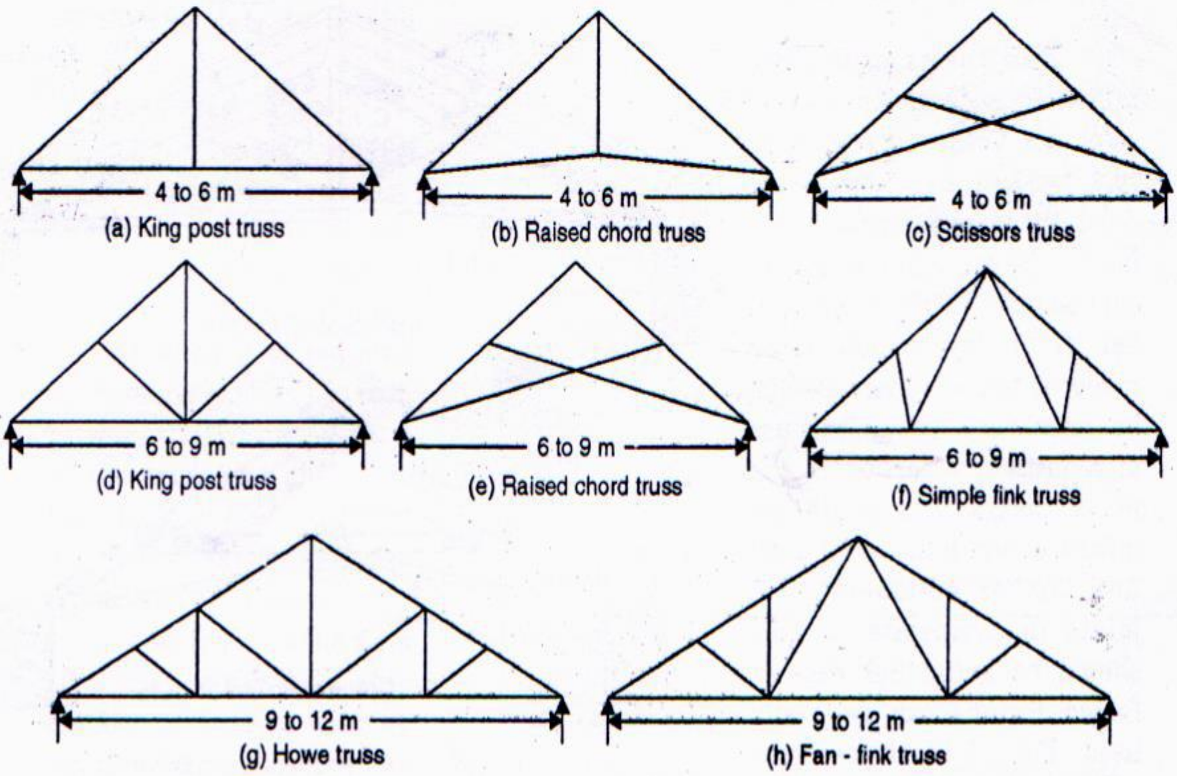



FIG. 15.19. STEEL TRUSSES.

The various shapes of these, along with their suitability for different span ranges, are shown in Figs. 15.19, 15.20, and 15.21.

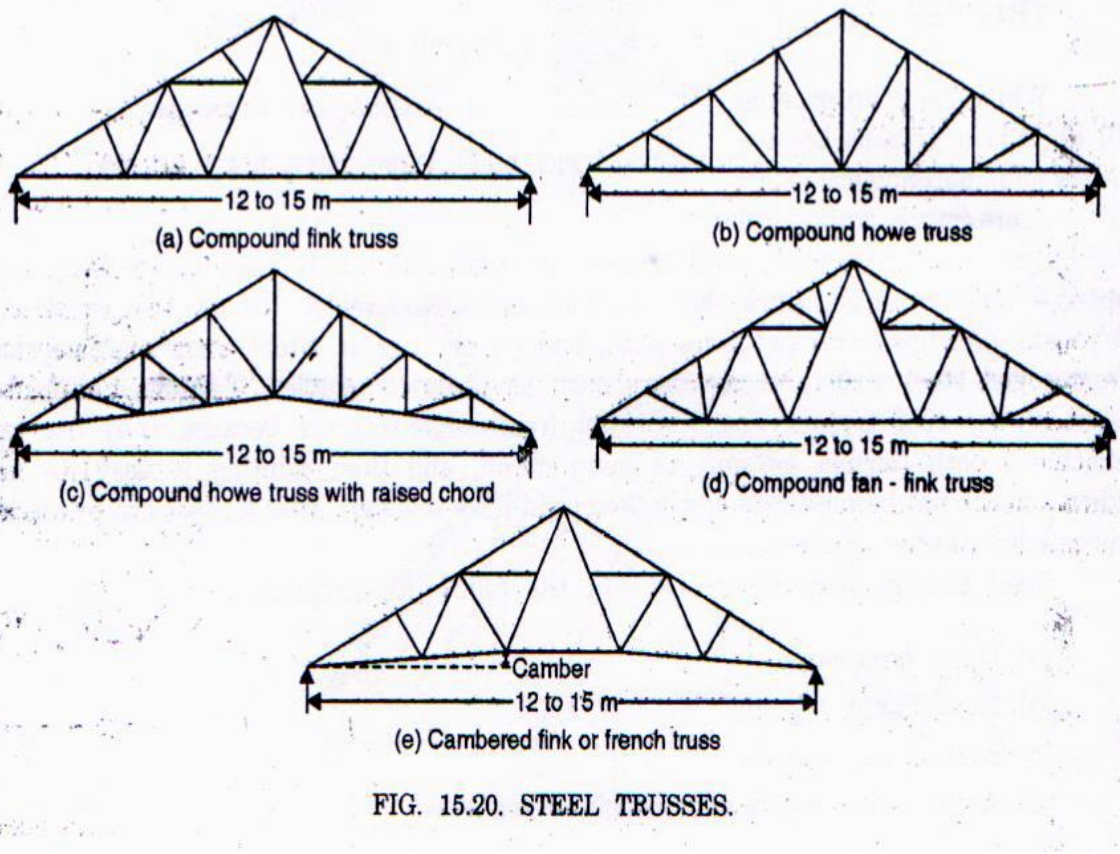



FIG. 15.20. STEEL TRUSSES.

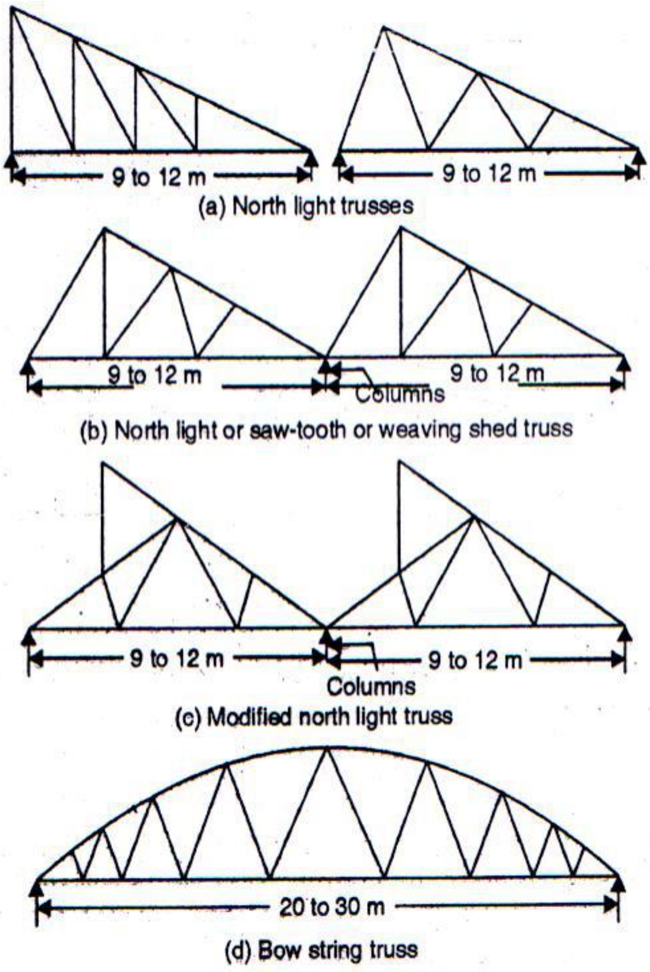



FIG. 15.21. STEEL TRUSSES.

**Industrial Building Bents** : These building bents, employed in big factories or mills, consists of a roof truss supported on steel stanchions. These bents are transversely braced. Various forms of these bents are shown in Fig. 15.22. The roof trusses supported on columns provide structural roof system for the industrial buildings. The type of roof coverings, its insulating value, acoustical properties, the appearance from inner side, the weight and the maintenance requirements are the various factors which are given consideration while designing the roof system. The asbestos corrugated and trafford cement sheets, and the galvanised corrugated sheets are commonly used as the roof covering materials.

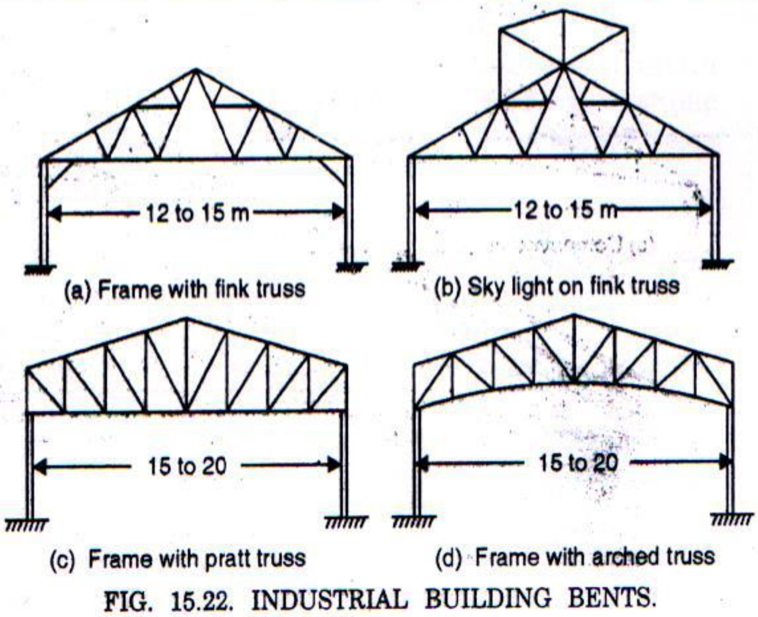



FIG. 15.22. INDUSTRIAL BUILDING BENTS.

**Details of steel roofs truss** : Steel roof trusses are commonly fabricated from angle sections and plates, though channel sections and T-sections can also be used. The roof truss is so designed that the members carry only direct stresses (*i.e.*, either compression or tension), and no bending stress are induced. The principal rafter as well as the main tie are generally made of two angle sections placed side by side, while the struts and ties are generally made of single angle sections. The members are jointed together, using a gusset plate, either through rivets or by welding. When rivets are used, the minimum pitch should not be less than three times the rivet diameter, while the maximum pitch is limited to 15 cm for compression members and 20 cm for tension members. Generally, 15 mm diameter rivets are used for small spans and 20 mm rivets are used for large spans. At least two rivets should be used at each joint. Gusset plate should not be less than 6 mm, though its thickness is designed on the basis of forces carried by members to be jointed. At the foot of the truss, short angles are fitted on both the sides of the gusset plate, which are connected to the bearing plate. The bearing plate is jointed to concrete bed through rag bolts. At the apex, suitable ridge section is fitted.

Steel trusses have the following advantages over timber trusses :

1. The sections comprising of a steel truss are readily available in the required dimensions, resulting in minimum wastage of material.

2. Steel trusses are light in weight, and can be fabricated in any shape depending upon structural and architectural requirements.

3. Steel trusses are stronger and more rigid in comparison to timber trusses. The members are equally strong in tension as well as compression.

4. Steel trusses can be used over any span, while timber trusses are suitable

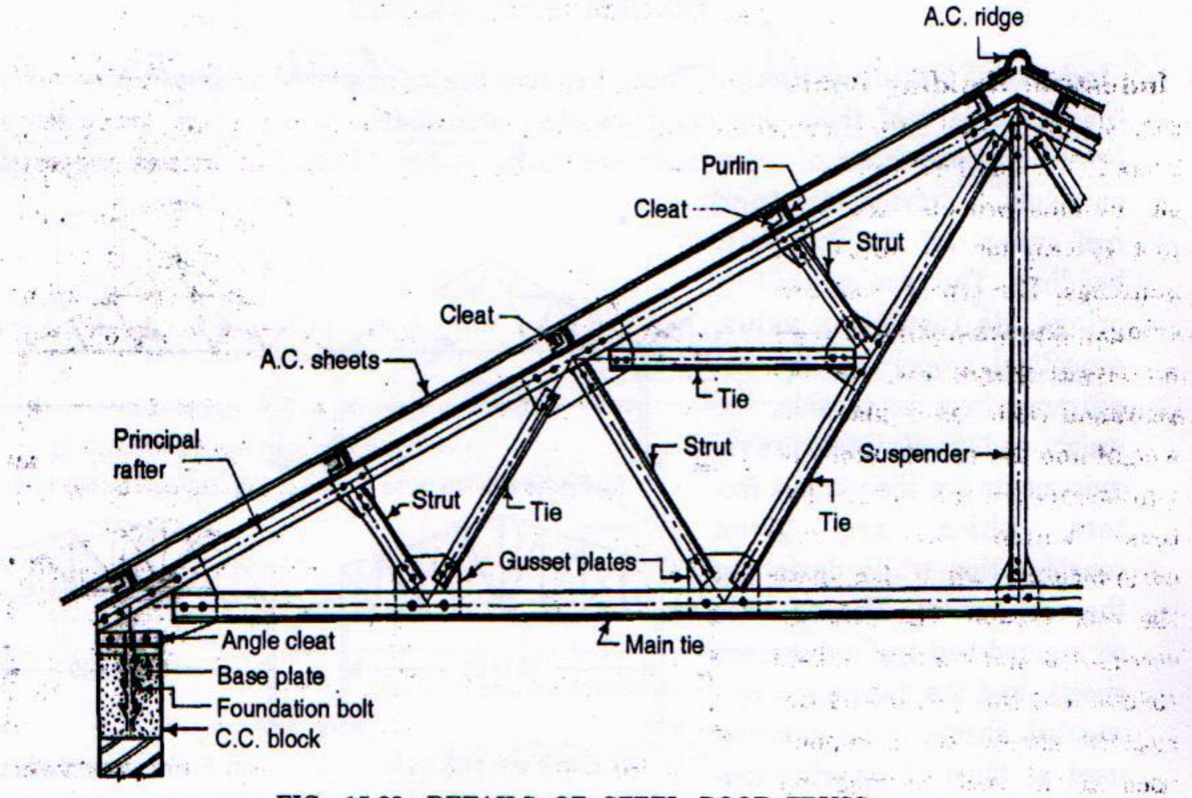



FIG. 15.23. DETAILS OF STEEL ROOF TRUSS

only upto 15 m span.

5. Steel trusses are fire-proof.

6. Steel trusses are termite proof.

7. Steel trusses are most resistant to other environmental agencies, and have longer life.

8. The fabrication of steel trusses is easier and quicker, since the sections can be machined and shaped in the workshop, and then transported to the construction site for erection.

## 15.9. ROOF COVERINGS FOR PITCHED ROOFS

Roof covering is an essential component of pitched roof, to be placed over the roof frame work, to protect it from rain, snow, sun, wind and other atmospheric agencies. Various types of roofing materials are available, and their selection depends upon (*i*) type of building, (*ii*) type of roof framework, (*iii*) initial cost, (*iv*) maintenance requirements, (*v*) fabrication facilities, (*vi*) appearance and special features of the locality, (*vii*) durability, (*viii*) availability of the material itself, and (*ix*) climate of the locality.

The following are the roof-covering materials commonly used for pitched roofs:

1. Thatch covering
2. Wood shingles
3. Tiles
4. Asbestos cement sheets
5. Galvanised corrugated iron sheets
6. Eternit slates.
7. Light weight roofing.

### (*a*) Thatch covering

This is the cheapest roof-covering, commonly used in villages. It is very light, but is highly combustible. It is unstable against high winds. It absorbs moisture and is liable to decay. It harbours rats and other burrowing animals, and gives bad smell in rainy season. Thatch roof-covering consists of bundles of reeds or straw . The frame work to support thatch consists of round bamboo rafters spaced 20 to 30 cm apart and tied with split bamboos laid at right angles to the rafters. The reed or straw must be well-soaked in water or fire-resisting solution to facilitate packing, and the bundles are laid with their butt ends pointing towards the eaves. The thatch is tightly secured to the frame work with the help of ropes or twines dipped in tar. In order to drain the roof effectively, a minimum slope of 45° is kept. The thickness of thatch covering should at least be 15 cm ; normal thickness varies from 20 to 30 cm according to its quality and pitch of roof. It is claimed that reed thatch can last about 60 years and straw thatch can last for 20 years, if properly attended to.

### (*b*) Wood shingle roofing

Shingles are thin slabs of wood used to cover roofs. The use of shingles is restricted to hilly areas where local timber is easily available at low cost. Though shingle roofing is light weight, it is not fire and termite resistant. Wood shingles are obtained from well seasoned timber, by either sawing or splitting. Sawn shingles are used chiefly. They are obtained in lengths varying from 30 to 40 cm and widths varying from 6 cm to 25 cm. They are approximately 10 mm thick at the tail or butt end and taper to 3 mm or less at the head. They are laid in a similar fashion as tiles and slates.

### (*c*) Tile roofing

Use of tiles for roofing is one of the oldest, and is still preferred for residential buildings and country houses. This is because *country tiles* are manufactured from locally vapour barrier is bonded with bitumen to the top of the top of the deck on which an insulating media like fibre board or expanded poly stryrene is bonded to be covered with two or three layers of felt roofing. The top surface is finished with a layer of white stone chipplings spread on bitumen to provide for solar reflectivity and reduce heat absorption in summer. The purlin and ridge details are shown in Fig. 15.36.

## 15.10. FLAT TERRACED ROOFING

Flat roof is the one which is either horizontal, or practically horizontal with slope less than 10°. Even a perfectly horizontal roof has to have some slope at top so that rain water can be drained off easily and rapidly. Similar to the upper floor, the flat roofs can be constructed of flag stones, R.S.J. and flag stones, reinforced cement concrete, reinforced brick work, jack arch roof or precast cement concrete units. However, the flat roof differ from the upper floor only from the point of view of top finish, commonly called terracing, to protect it from adverse effects of rain, snow, heat etc.

### Advantages of flat roofs

1. The roof can be used as terrace for playing, gardening sleeping and for celebrating functions.

2. Construction and maintenance is easier.

3. They can be easily made fire proof, in comparison to pitched roof.

4. They avoid the enclosure of the triangular space. Due to this, the architectural appearance of the building is very much improved.

5. Flat roofs have better insulating properties.

6. They require lesser area of roofing material than pitched roof.

7. They are more stable against high winds.

8. They do not require false ceiling, which is essential in pitched roofs.

9. Flat roofs are proved to be overall economical.

10. In multi-storeyed buildings, flat roof is the only choice, since overhead water tanks and other services are located on the terrace.

11. The construction of upper floors can be easily done over flat roofs, if so required in future.

### Disadvantages of flat roofs

1. The span of flat roof is restricted, unless intermediate columns are introduced. Pitched roofs can be used over large spans without any intermediate columns.

2. The self weight of flat roof is very high. Due to this, the sizes of beams, columns, foundations and other structural members are heavy.

3. They are unsuitable at places of heavy rainfall.

4. They are highly unsuitable to hilly areas or other areas where there is heavy show fall.

5. They are vulnerable to heavy temperature variations, specially in tropics, due to which cracks are developed on the surface. These cracks may lead to water penetration later, if not repaired in time.

6. It is difficult to locate and rectify leak in flat roof.

7. The speed of flat roof construction is much slower than the pitched roof.

8. The initial cost of flat roof is more than pitched roof.

9. The flat roof exposes the entire building to the weather agencies, while the projecting elements (such as eaves etc.) of pitched roof provide some protection to the building.

### Types of flat terraced roofing

Following are the commonly used terraced roofing :

1. Mud-terrace roofing.
2. Brick-jelly or Madras terrace roofing.
3. Mud-phaska terracing with tile paving.
4. Lime concrete terracing.
5. Lime concrete terracing with tile paving.
6. Bengal terrace roofing.
7. Light weight flat roofing.

### 1. Mud-terrace roofing

This type of terracing is suitable where rainfall is less. It can be provided either on tiles (Punjab type terracing) or on wood boards (Maharastra and Madhya Pradesh practice). In both the cases, terracing is made with white earth mud containing large percentage of sodium salt.

The mud-terracing in Punjab is provided over roof which consists of 50 mm × 50 mm × 6 mm T-sections spaced at 32 cm centre to centre over R.S.J. Well-burnt tiles of size 30 cm × 30 cm × 5 cm or 30 cm × 15 cm × 5 cm are placed between the flanges of the T-sections ; using lime mortar. Over the tiles, a 15 cm thick layer of stiff mud, white in colour and containing sodium salts, is spread and beaten with sticks till the surface becomes hard and the beater rebounds. The surface is then plastered with mud and cow-dung mix plaster. Finally, the surface is finished with 1 : 4 cement-cowdung plaster.

In the Maharastra and Madhya Pradesh practice, mud terracing is done on teak wood boards (4 to 5 cm thick) nailed to the wooden joists. On the boards, a 2.5 cm thick layer of wood shaving is spread, over which bricks are laid on edge, in lime or mud mortar. On the bricks, a 8 to 10 cm thick layer of mud is spread and beaten hard. Finally, a 2.5 cm thick layer of white earth containing high percentage of sodium salts is applied. This top layer has to be renewed once in a year. Such roofs do not leak, provide insulation against heat and thus keep the building cool and comfortable.

### 2. Brick jelly roofing or Madras terrace roofing

Fig. 15.37 shows the section through the roofing, which is constructed in the following steps :

(*i*) Wooden joists are placed on R.S.J. with a furring piece in-between. The furring piece height at the centre is so adjusted that the required slope of the roof is obtained.

(*ii*) A course of specially prepared bricks of size 15 cm × 5 cm × 12 mm is placed on edge in lime mortar (1 : 1.5) laid diagonally across the joists.

(*iii*) After the brick course is set, a 10 cm thick layer of brick-bat concrete is laid, consisting of 3 parts of brick-bats, 1 part of gravel and sand, and 50 percent of of lime mortar by volume. The concrete is well-rammed for 3 days, so that the thickness reduces to 7.5 cm, by wooden hand beaters. The surface is cured for 3 days, by sprinking lime water.

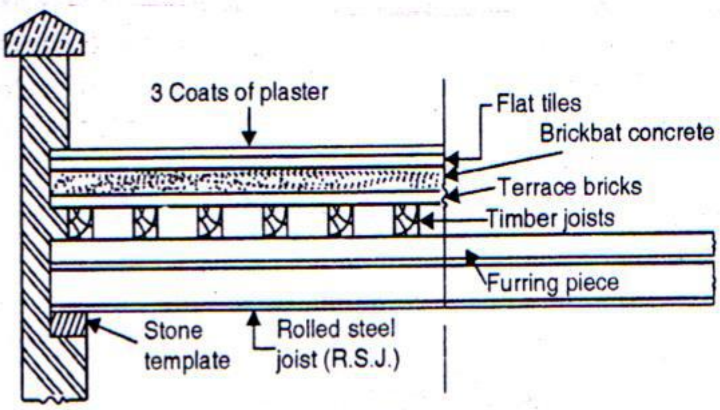



FIG. 15.37. MADRAS TERRACE ROOF.

(*iv*) When the brick-bat concrete has set, three courses of Madras flat tiles (15 cm × 10 cm × 12 mm) are laid in lime mortar ($1 : 1\frac{1}{2}$), making a total thickness of 50 mm. The vertical joints of the tiles in successive layers should be broken. The joints of tiles in top layer are left open to provide key for top plaster. Alternatively, China mosaic tiles may be used.

(*v*) Finally, the top surface is plastered with three coats of lime mortar. The surface is rubbed and polished.

**3. Mud-phuska terracing with tile paving**

This method of terracing is equally suitable to hot as well as arid regions, and is commonly used over R.C.C. roofing. The section of roofing is shown in Fig. 15.38. The work is carried out in the following steps :

1. The R.C.C. slab is cleaned off dust and loose material. A layer of hot bitumen is spread over it at the rate of 1.70 kg of bitumen per square metre of roof surface.

2. A layer of coarse sand is immediately spread over the hot coat of bitumen, at the rate of 0.6 $m^3$ of sand per 100 $m^3$ of roof surface.

3. Mud-phuska is prepared from puddled clay mixed with bhusa at the rate of about 8 kg of bhusa per $m^3$ of clay. A 10 cm thick layer of this mud-phuska is applied over the sand-bitumen layer. Proper slope (usually 1 in 40) is given in mud-phuska layer. Alternatively, slope may be given in R.C.C. slab itself.

4. The mud-phuska layer is consolidated properly. It is then plastered with 13 mm coat of mud-cow-dung mortar (3 : 1).

5. Tile bricks are laid flat on plastered surface. The joints are grouted in 1 : 3 cement mortar.

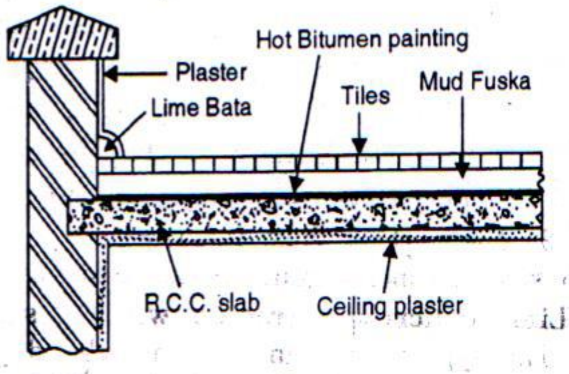



FIG. 15.38. MUD-PHUSKA AND TILE TERRACING

**4. Lime concrete terracing : Jodhpur type roofing**

This type of terracing is commonly used over flag stone roofing, though it can also be used over R.C.C. slab. The procedure of lime terracing varies from place to place. The one adopted for Jodhpur stone slab roofing is described below, in steps:

1. The longitudinal joints between the stone slabs are first pointed in cement mortar. The joints should be V-shaped, not exceeding 25 mm at the top and 10 mm at the bottom. This joint is filled with cement mortar (mix 1 : 2 to 1 : 4) and picked with stone chips of wedge shape and top finish rounded with cement mortar so as to project little above the slabs. Before filling mortar in the joints, flat strips of timber (or 3 inch dia. bamboos) should be kept along the joint on the other face of the stone slabs so that mortar does not fall down. Similarly, the space left over the walls at the ends of the slabs, and also the space on walls between the slabs where roof is continuous should be filled with 1 : 2 : 4 cement concrete. These joints should properly cured, at least for 7 days.

2. In order to provide proper slope to the roof, *ralthal* is laid. This is done by laying stone spawls in 1 : 2 lime mortar over the surface of the slabs in the required thickness. Hydraulic lime (kankar lime) should be used. *Ralthal* so laid should be cured for 7 days.

3. Laying of the *lime chhat* is done in four consecutive days. On the *first day,* unslaked *kankar lime* (hydraulic lime) 10 cm in thickness is spread over the roof slabs. The lime is then slaked in situ, by adding water. It is then beaten with conical stones by hand, so that no particles of lime remain unslaked to cause blisters.

4. On the *second day,* the lime is watered, raked up and again the process of first day is repeated.

5. On the *third day,* 250 gm of hemp (finely choped) and methi 750 gm finely powdered per 10 sq. metre is evenly and thoroughly mixed with the lime. Then coarse stone aggregate duly washed should be spread over this lime in a thickness not less than 10 cm.

The coarse aggregate is thoroughly beaten with conical stones by hand so that this stone aggregate gets well-embedded in lime mass.

6. On the fourth day, stone grit or screening is spread in a layer of 40 mm and beaten with stone beaters till they are well set. This process of beating should continue with wooden thapies and by sprinkling water till the whole mass becomes stiff and offers resistance to penetration. Thickness of lime chhat should not be less than 15 cm at any place.

7. The above work should be cured at least for 7 days.

8. After seven days, *sandala coat* consisting of cream of lime is laid over the lime chhat in thin layers and rubbed for full four hours or more, using rounded pebbles for rubbing and polishing. During the process of rubbing, solution of 65 gm of Gur and 250 gm of Gugal per 10 square metres is sprinkled every now and then.

9. The surface thus prepared is cured with water at least for 15 days using damp sand or moist gunny bags so as to keep the surface constantly wet.

**5. Lime concrete terracing with tiles**

This type of terracing is commonly adopted over R.C.C. roofing. Fig. 15.39 shows a typical section of roofing, which is laid in the following steps :

1. The R.C. slab is cleaned off dust etc., land layer of hot bitumen is applied at the rate of 1.7 kg per sq. m. of roof surface.

2. A layer of coarse sand is immediately spread over the hot layer of bitumen, at the rate of 0.6 cubic metre of sand per 100 sq. m. of roof surface.

3. A 10 cm thick (average) layer of lime concrete is laid, in proper slope. The entire slope is given in lime concrete itself. The lime concrete may consist of 2 parts of lime, 2 parts of surkhi and 7 parts of brick ballast of 25 mm gauge. The concrete is well beaten.

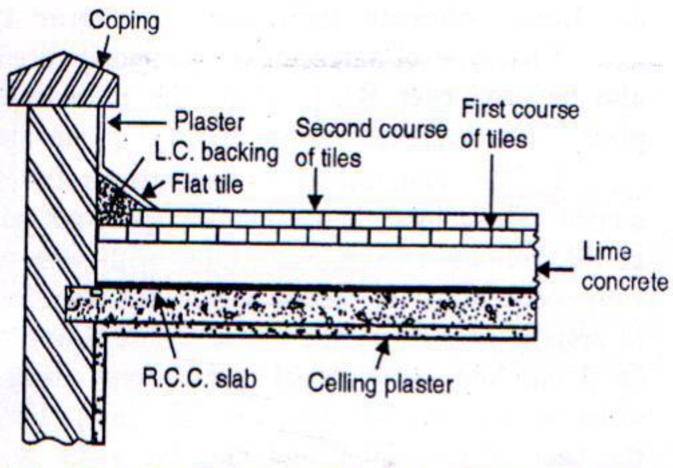


FIG. 15.39. LIME CONCRETE AND TILES ROOFING.

4. Two courses of flat brick tiles are laid in 1 : 3 cement mortar. The joints of top course are pointed with 1 : 3 cement mortar. The vertical joints in the two courses are broken.

**6. Bengal terrace roofing**

This type of roofing is adopted for timber roofs of verandah etc. Fig. 15.40 shows the section of such roofing, which is constructed in the following steps :

(*i*) Wooden rafters are placed at 30 to 50 cm c/c, on some slope.

(*ii*) Wooden battens (5 × 1 cm) are placed across the rafters, at 15 c/c.

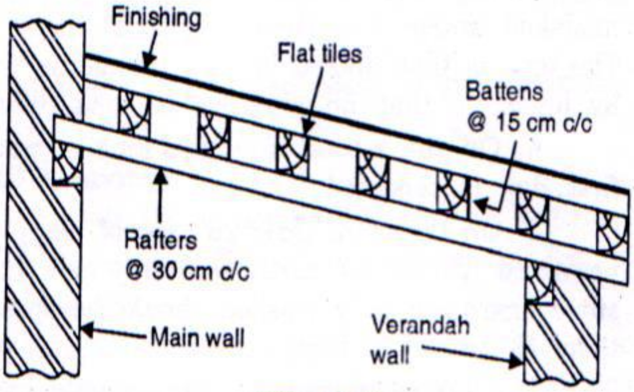


FIG. 15.40

(*iii*) A course of flat tiles (15 cm × 8 cm × 2 cm), well-soaked in white wash, is laid in lime or cement mortar, over the battens.

(*iv*) The roof is then finished with one of the following two methods :

***Method* (*a*)**. Two or more courses of flat tiles are laid in mortar. Two to three coats of lime plaster are applied. The final course of lime plaster is rubbed smooth and polished.

***Method* (*b*)**. A 4 to 5 thick layer of fine jelly concrete is laid over the tiles. Over this concrete, a course of flat tiles is laid. The surface is then finally finished with two or three coats of lime plaster, the final coat being rubbed smooth and polished.

**7. Light weight flat roof**

This consists of aluminium alloy and steel decking, described earlier under pitched roofing. The section of roof with aluminium alloy and steel decking is shown in Fig. 15.41. The decking shown has an additional soffit sheet. The decking sheet is suitably supported on steel beams. Table 15.2 gives the maximum span over which these can be used, for an imposed load of 0.75 $kN/m^2$.

TABLE 15.2. METAL DECKING

| Depth of corrugation (mm) | Thickness of metal (mm) | Maximum span (m) | | | |
|---|---|---|---|---|---|
| | | Aluminium | | Steel | |
| | | Single span | Double span | Single span | Double span |
| 25 | 0.7 | | | 1.42 | 1.71 |
| 45 | 0.7 | | | 2.1 | 2.54 |
| 25 | 0.9 | 0.99 | 1.19 | 1.95 | 2.31 |
| 45 | 0.9 | 1.99 | 2.38 | 2.82 | 3.34 |
| 25 | 1.2 | 1.54 | 1.85 | | |
| 45 | 1.2 | 2.25 | 2.67 | | |
| 85 | 1.2 | 3.60 | 3.98 | | |

On the top of decking, a felt vapour barrier is bonded with bitumen. Over it, fibre board or expanded polystyrene is bonded, for insulation. This is then covered with two or three layers of felt roofing. Finally, the top surface is finished with a layer of white stone chipping spread on bitumen to provide for solar reflectivity and reduce heat absorption.

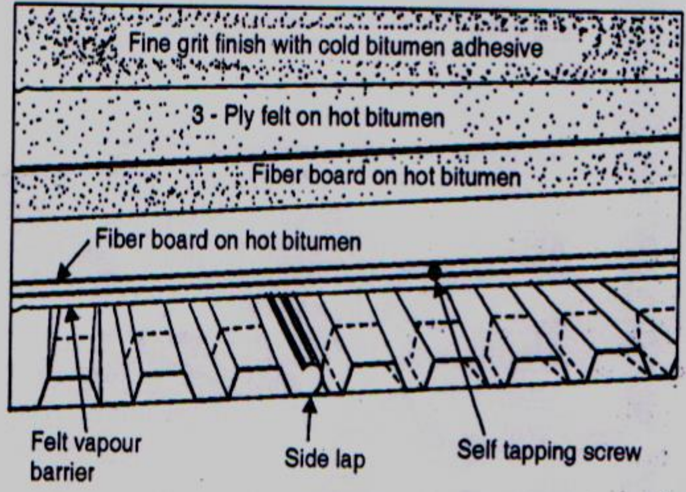



FIG. 15.41. LIGHT WEIGHT FLAT ROOF WITH METAL DECKING

## PROBLEMS

1. (*a*) State briefly the essential requirements of a good roof.
   (*b*) Compare merits and demerits of flat and pitched roofs.
2. Explain, in brief, but with sketches, various basic forms of pitched roofs.
3. Define the following terms :
   Pitch ; Hip ; Eaves ; Verge ; Jack rafters ; Common rafters ; Cleat ; Boarding ; Template.
4. Write notes on :
   (*a*) Lean to roof.
   (*b*) Couple close roof.
   (*c*) Mansard roof truss.
   (*d*) Couple roof.

# FOUNDATIONS

Every structure consists of two parts. (1) Foundation and (2) Super structure. The lowest artificially prepared parts of the structure which are in direct contact with the ground and which transmit the loads of the structure to the ground are known as Foundation or Substructure. The solid ground on which the foundation rest is called the "foundation bed" or foundation soil and it ultimately bears the load and interacts with the foundations of buildings.

**Objects of foundations:**

Foundations are provided for the following purposes

1) To distribute the total load coming on the structure on large area.
2) To support the structure
3) To give enough stability to the structures against various distributing forces such as wind, rain etc.
4) To prepare a level surface for concreting and masonry work. The general inspection of site of work serves as a good for determine the type of foundation, to be adopted for the proposed work and in addition, it helps in getting the data w.r.to the following items.

i) Behavior of ground due to variations in depth of water table
ii) Disposal of storm water at site
iii) Nature of soil by visual examination
iv) Movement of ground due to any reason etc.

**Bearing capacity:** The ability of the foundation material, weather soil or rock to carry loads safely.

**Methods of determine the bearing capacity of soil:**

The bearing capacity of soil is determined by any one of the following methods

(i) Method of loading
(ii) Method of dropping a weight

**I. Method of loading**

**Procedure to carry out the test:**

1. A square pit of required size is excavated upto 5 times the side of steel plate to be used. At the centre of pit, square hole is dig, which is same ratio to that of breadth to depth of pit.
2. The bottom of the hole is made level

3. The steel plate is put up in the hole and then platform is prepared as shown in fig 10.1.

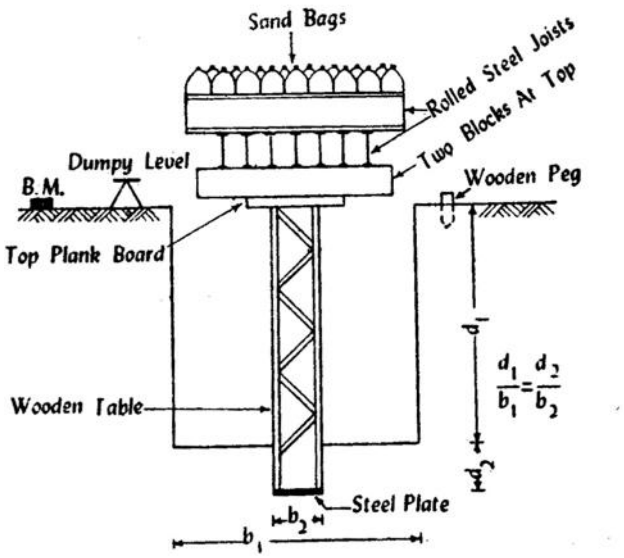



**Fig 10.1 Method of loading**

4. The amount of initial load is decided according to the type of the soil to be tested
5. A level is planted to note the setting of steel plate w.r.to the permanent benchmark.
6. The load is to be kept on platform till the settlement of the ground ceases or stops
7. The load is increased by a suitable amount, usually 0.5 tonnes and the procedure is continued
8. The recording of results is carried out in the following proforma.

| Date time taking readir | Lo | Increa in settler nt | Total settlement | Rema |
|---|---|---|---|---|
| | 0.5 ton | a b c - | a a+b a+b+c - | |
| | | a1 b1 | a+b+c+a1 a+b+c+a1+b a+b+c+a1+b c1 | settle nt cea |
| | 1.0 ton | | | settle nt cea |

9. The settlement of the ground will be fairly is proportion to the load upto a certain limit, when the bearing power of soil exceeded, the settlement will be out of the proportion.

10. The bearing capacity and safe bearing capacity of soil are calculated by using the following

Bearing capacity of soil in tones/m$^2$

Maximum load

= --------------------------------

Area of steel plate Safe bearing capacity of soil in tones/m$^2$

Bearing capacity of soil

= ---------------------------------------

Factor of safety

**Note**:

1) This method can also be used for confirming the known bearing power of a soil

2) The loading should applied without shock

3) Dial gauges or deflect meters to record the settlement instead of level & staff for the accuracy upto 0.02mm

4) The zero corrections should be deducted from the observed settlement to get actual settlements zero correction is the settlement due to adjustment of soil particles under the action of loading

5) The bearing capacity of sandy soil and gravelly soil is affected to the extent of 50% by presence of water table. Water should be pumped out before placing the steel plate

6) The results obtained by this method are fairly accurate and reliable.

**II. Method of dropping a weight:**

In this method, a substance of known weight is dropped from a known height as shown in 10.2. The depth of impression made by the weight on the soil is noted. Then the bearing capacity of the soil is worked out as follows.

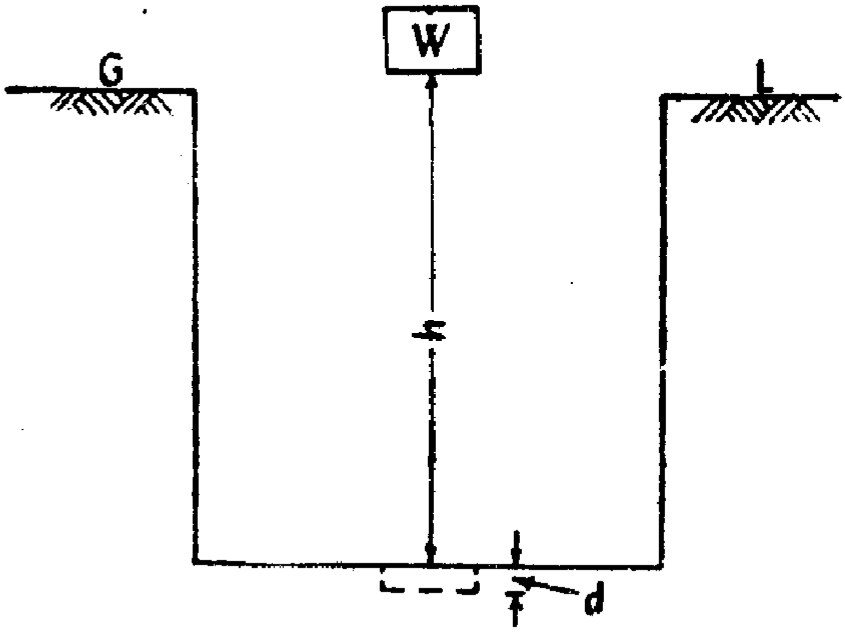



**Fig 10.2 Method of Dropping Weight**

Ultimate resistance of soil

w x h R= -------------
d

where R – Resistance of soil

A – cross section area of the substance h - Height
w - weight of substance

 Safe bearing capacity of soil per unit are

= R / A x f

Where f – factor of safety

The results obtained by this method are approximate and hence, this method is used for minor engineering structures or at places where first method would be impractible.

**Types of soils – Bearing Capacity:** Ultimately the load of the structure is coming on the soil and hence, it is of utmost importance to know the strength and behavior of the soil. The term bearing power or bearing capacity of soil is used to indicate the maximum load per unit area, which the soils resist safely without displacement. Dividing the ultimate bearing capacity of a soil by a factor of safety, the safe bearing capacity of a soil is obtained. Max. safe bearing capacity of different types of soils are given in table 10.1.

| **S.No.** | **Type of Soil** | **Max. safe bearing capacity t/m$^2$** |
|---|---|---|
| 1. | Soft, wet clay or muddy clay | 5 |
| 2. | Black cotton soil | 15 |
| 3. | Soft clay | 10 |
| 4. | Moist clay, and sand clay Mixture | 15 |
| 5. | Medium clay | 25 |
| 6. | Compact clay | 45 |
| 7. | Fine, loose and dry sand | 10 |
| 8. | Medium, compact and dry sand | 25 |
| 11. | Compact gravel | 45 |
| 12. | Soft rocks | 45 |
| 13. | Laminated rock such as sand stone & Lime stone | 165 |
| 14. | Hard rocks such as granite, diorite, trap | 330 |

**Table 10.1**

**Types of foundations:**

Depending upon their nature and depth, foundations have been categorized as follows

(i) Open foundations or shallow foundations

(ii) Deep foundations

I. **Open foundations or shallow foundations:** This is most common type of foundation and can be laid using open excavation by allowing natural slopes on all sides. This type of foundation is practicable for a depth of about 5m and is normally convenient above the water table. The base of the structure is enlarged or spread to provide individual support. Since the spread foundations are constructed in open excavations, therefore they are termed as open foundations. This type of foundation is provided for structure of moderate height built on sufficiently firm dry ground. The various types of spread footings are:

1. Wall footing
2. Isolated footing
3. Combined footing

4. Inverted arch footing

5. Continuous footing

6. Cantilever footing

7. Grillage footing

1. **Wall Footing:** These footings can be either simple or stepped. The base course of these footings can be concrete or entirely of one material simple footing are used for light structures. They have only one projection beyond the width of the wall. The base width of the concrete base course should be equal to twice the width of wall. The depth of concrete bed is atleast twice the projection as shown in fig 10.3. The depth of concrete bed is calculated by

$T = m\sqrt{\frac{p}{f}}$ where t – depth of concrete bed

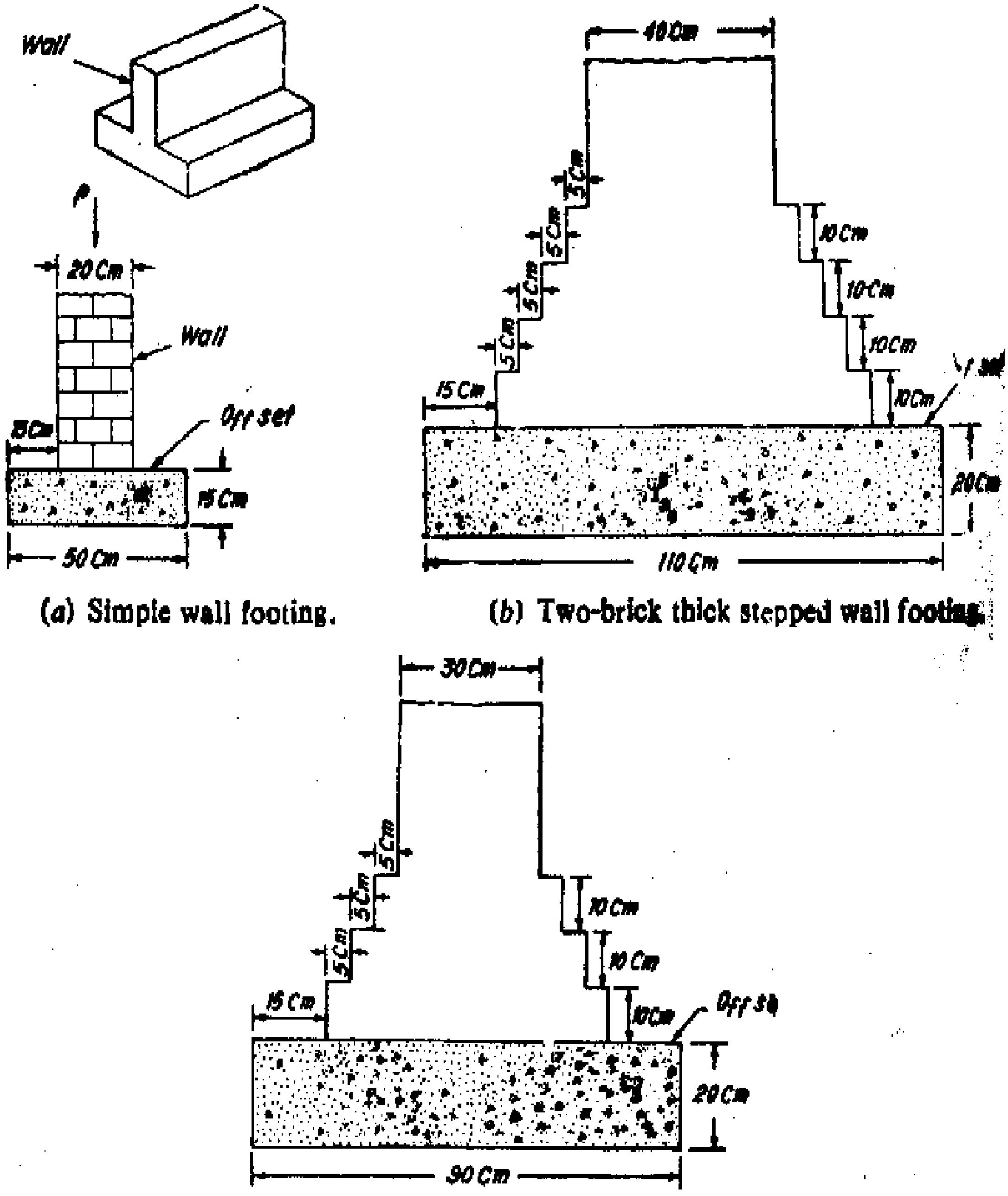
m – offset of concrete bed in cm p – Load coming on soil kg/cm$^2$
f – 0.03 x ultimate crushing strength of concrete in 28 days The depth of the footing is calculated by the following formula

$$H = \frac{p}{w}\left(\frac{1 - \sin\phi}{1 + \sin\phi}\right)^2$$ where

H - Minimum depth of footing in metre

p - Safe bearing capacity of soil in kg/m$^2$ w - Unit wt. Of soil in kg/m$^3$
$\phi$ - Angle of repose of the soil

the depth of footing is generally limited to 0.9m the width of footing should be calculated by divided the total load in kg/m run by the allowable bearing capacity of soil in kg/m2.




(*a*) Simple wall footing. (*b*) Two-brick thick stepped wall footing.

(*c*) One and half brick thick stepped wall footing.

Simple and stepped wall footings.

**Fig 10.3**

2. **Isolated Footings:** These are used to support individided columns. They can be of stepped type or have projections in the concrete base. In case of heavy loaded columns steel reinforcement is provided in both directions in concrete with 15cm offsets as shown in the fig10.4.

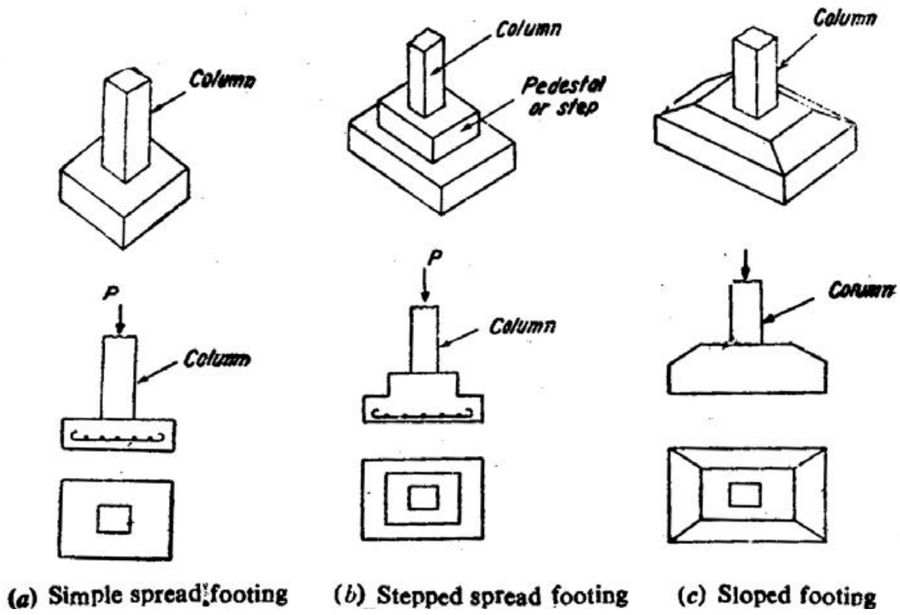



**Fig 10.4 Types of Isolated Footings**

3. **Combined Footing:** A combined footing supports two or more columns in a row A Combined footing may be rectangular or trapezoidal constructed with reinforced concrete. The location of centre of gravity of column loads and centroid of the footing should coincide. The combined footing is as shown in fig10.5.

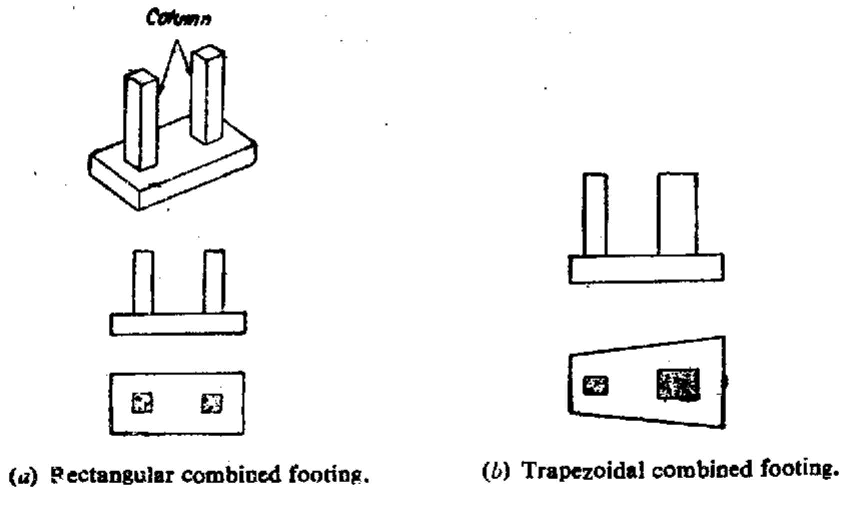



**Fig 10.5 Combined Footings**

4. **Inverted Arch Footing**: This type of construction is used on soft soils to reduce the depth of foundation loads above an opening are transmitted from supporting walls through inverted arches to the soil. In this type the end columns must be stable

enough to resist the outward pressure caused by arch actions. The inverted arch footing is as shown in fig10.6.

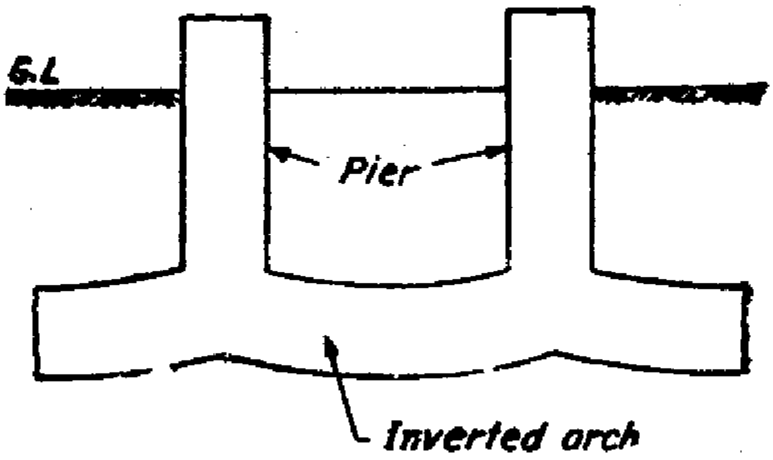



**Fig 10.6 Inverted Footing**

5. **Continuous Footing:** In this type of footing a single continuous R.C slab is produced as foundation of two or three or more columns in a row. This type of footing is suitable at locations liable to earthquake activities. This also prevents differential settlement in the structure. In order to have better stability a deeper beam is constructed in between the columns as shown in fig10.7.

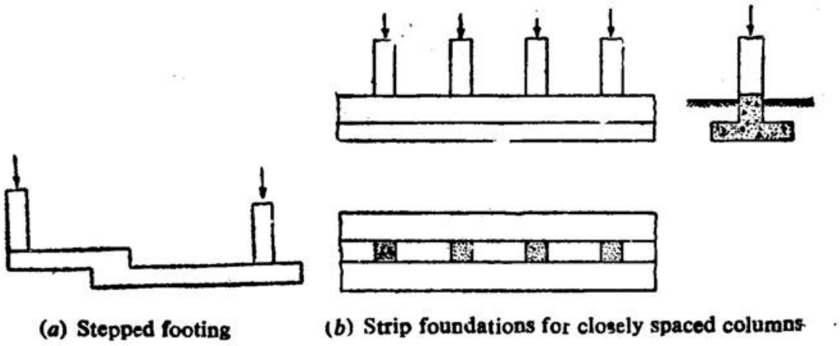
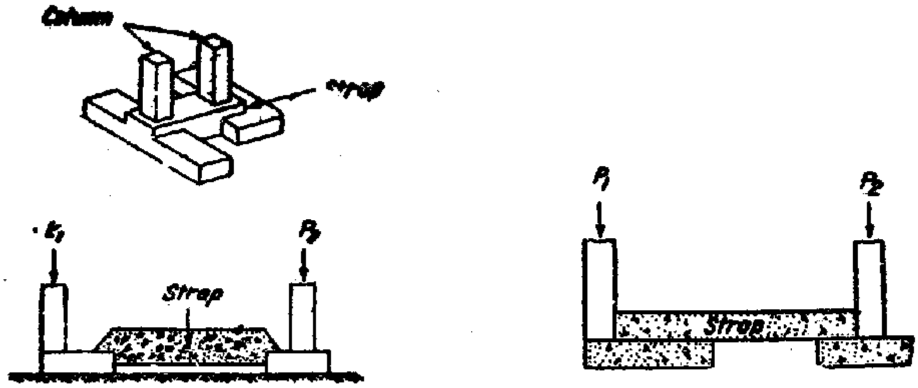



**Fig 10.7 Continuous Footing**

6. **Strap or cantilever footing**: Strap footing consists of two or more individual footings connected by a beam called strap or cantilever footing or pump handle foundation. This type of foundation may be used where the distance between the columns is so great that combined trapezoidal footing becomes quite narrow with high bending moments strap or cantiliver footing is as shown in fig 10.8.




(a) Strap footing with non-uniform strap.

(b) Cantilever footing with uniform strap.

**Fig 10.8 Strap or cantilever footing**

7. **Grillage footing :** This type of footing is used to transmit heavy loads from steel columns to foundation soils having low bearing power. This type of foundation avoids deep excavation and provides necessary area at the base to reduce the intensity of pressure of the foundation soil is not stiff and there is a plenty of water with spring, the sides are protected by sharing. The grillage footing is a s shown in fig 10.9.

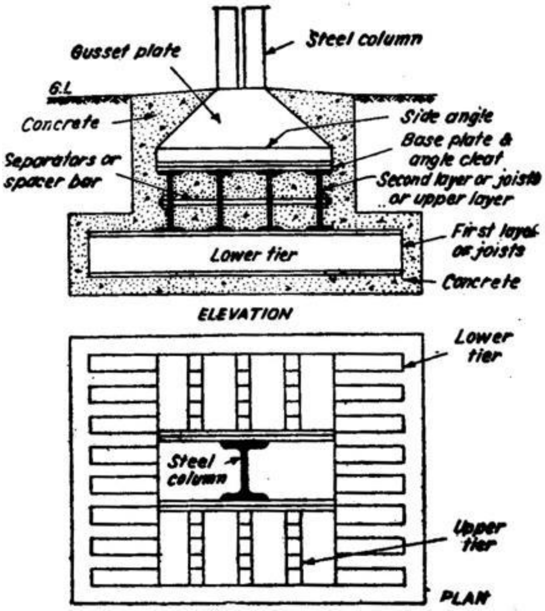



**Fig 10.9 Grillage Footing**

8. **Raft Foundation:** A raft or mat is a combined footing that covers the entire area beneath a structure and supports all the columns. When the allowable soil pressure is low or the structure loads are heavy the use of spread footings would cover more than one half of the area and it may be prove more economical to use raft foundation. There are

also used where the soil mass contains compressible lenses so that the differential settlement would be difficult to control usually when the hard soil is not available within 1.5 to 2.5m, a raft foundation is adopted. The raft is composed of reinforced. Concrete beam with relatively thin slab underneath fig 10.10 shows different types of raft.

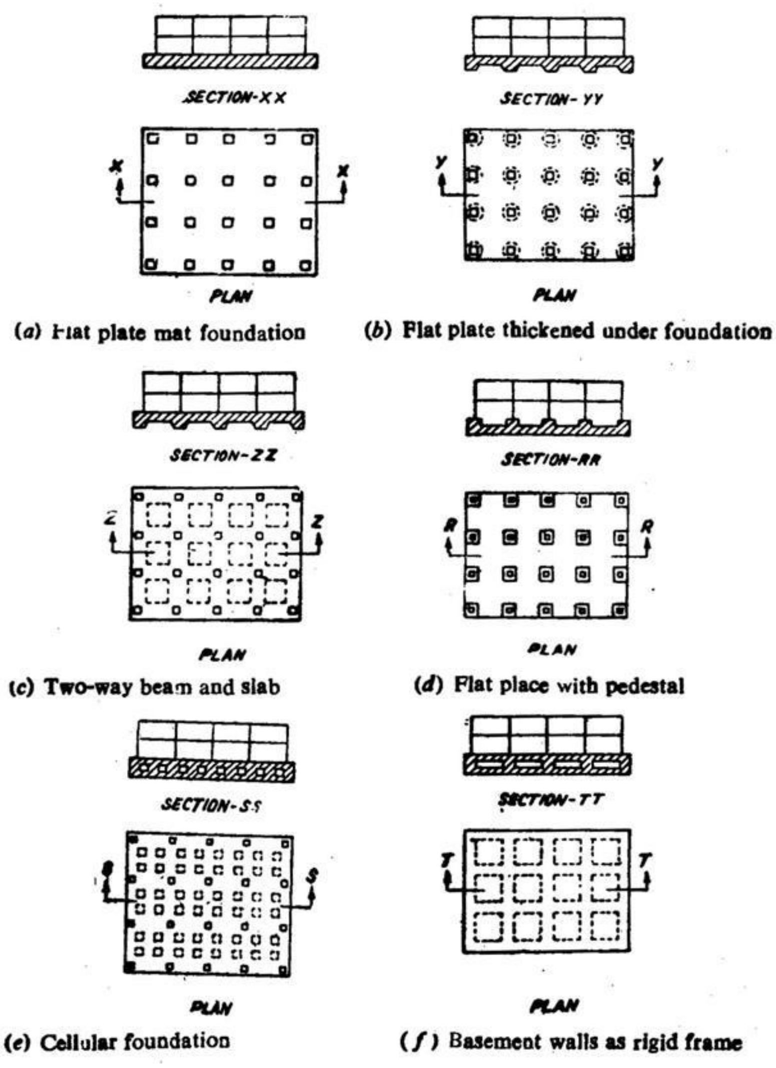



**Fig 10.10 Different types of Raft Foundations II Deep foundations:**

These foundations carry loads from a structure through weak compressible soil or fills onto the stronger and less compressible soils or rocks at depth. These foundations are in general used as basements, buoyancy rofts, eaissions, cylinders, shaft and piles.

a) **Basements**: There are constructed in place in an open excavation. They are hallow slab structure designed to provide working or storage space below ground level. The structural design is governed by their functional requirements.

b) **Buoyancy rafts:** They are hallow substructures designed to provide a buoyant substructure beneath with the net loading on the soil reduce to the desired low intensity.

c) **Coissions**: They are hallow substructures designed to be constructed on or near the surface and then sunk as single units to their required level.

d) **Cylinders**: They are small single cell coissions

e) **Shaft foundations**: They are constructed within deep excavation supported by lining constructed in place subsequently filled with concrete.

f) **Pile foundations**: Pile foundation is a construction for the foundation supported on piles. A pile is an element of construction composed of timber, concrete, or steel or a combination of them. Pile foundation may be defined as a column support type of a foundation, which may be cast in-situ or **Pre-cast**. This type of construction is adopted when the loose soil extends to a great depth. The load of the structure is transmitted by the piles to hard stratum below or it is resisted by the friction developed on the sides of pipes.

**(i) Classification based on the function**

a) **Bearing piles**- Penetrate through soft soil and their bottom rest on a hard stratum

b) **Friction piles-** The frictional resistance is equal to load coming on the piles as shown in the fig 10.11.

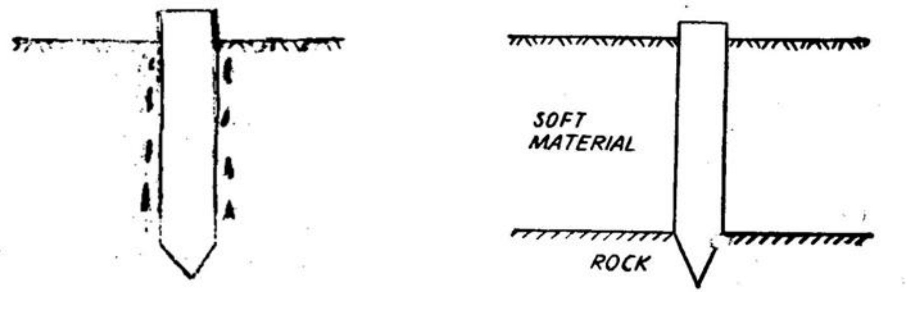



**Fig 10.11 Friction file & Bearing Pile**

c) **Screw piles**-Used for gravely ground sand, mixed gravel ground etc as shown in fig 10.12.

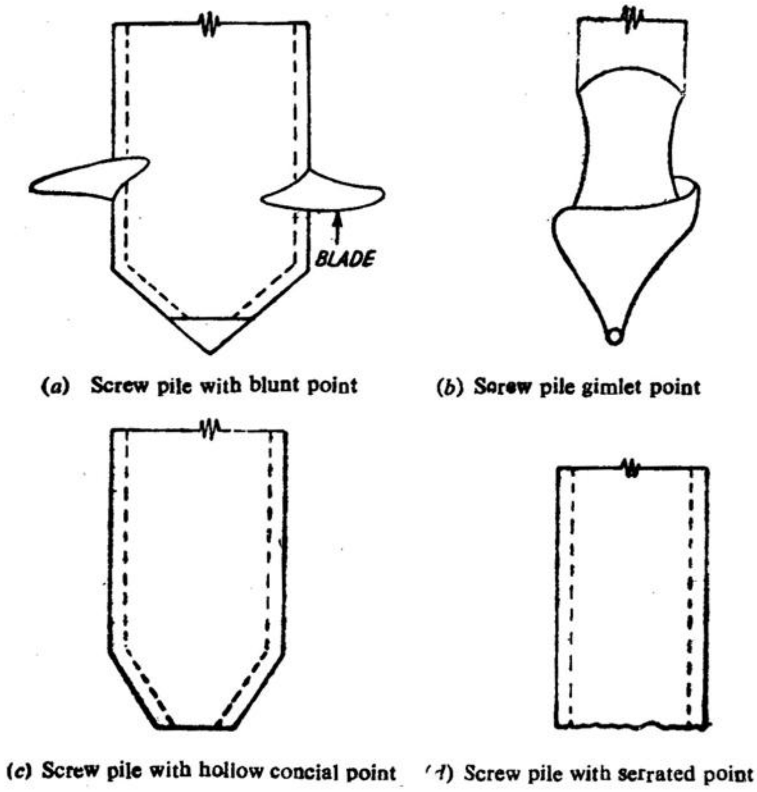



**Fig 10.12 Different types of screw piles**

d) **Uplift piles-** when the structure subjected to uplift pressure.

e) **Butter pile –** To resist large horizontal or inclined forces

f) **Sheet pile**-used as bulk heads or a impervious cutoff

**(ii) Classification based on materials and composition**

a) **Cement concrete piles**-Posses excellent compressive strength

1) Precast

2) Cast-in-site

a) Under reamed piles

b) Bored compaction piles as shown in fig 10.13.

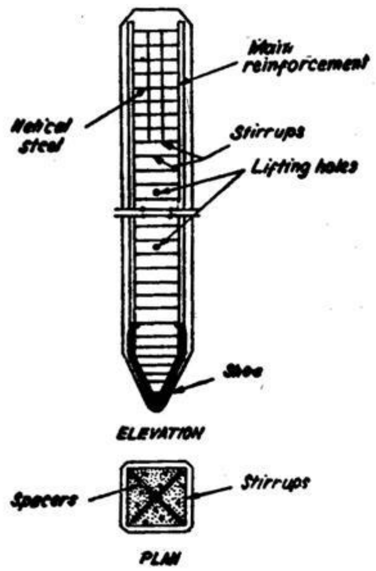


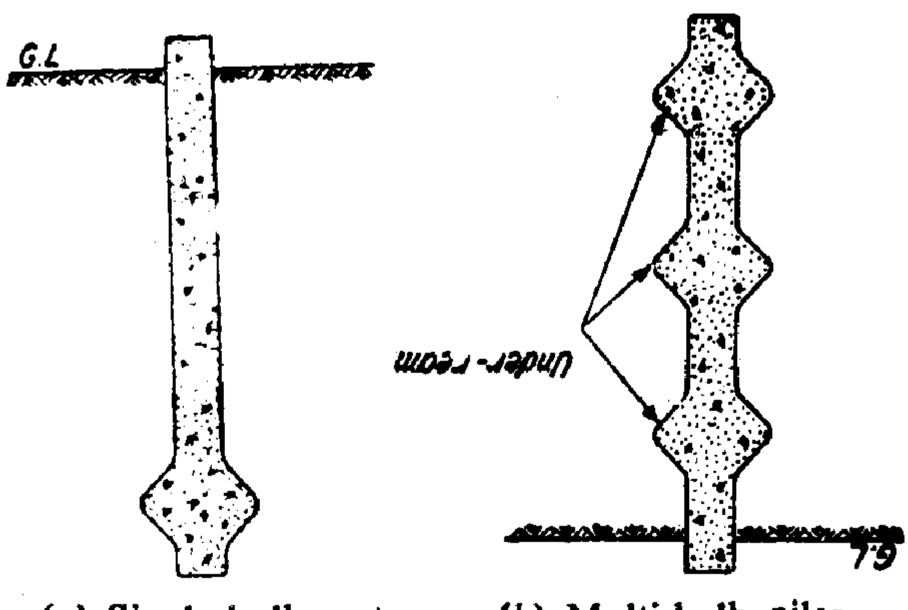

**Fig 10.13. Pre-cast concrete Pile**

b) **Timber piles**-Small bearing capacity, not suitable for hard soil and economical

c) **Steel piles-**With stand impact stresses and resist lateral forces

d) **Sand piles**-Not suitable for loose or wet soils or where is a danger of scour. Easy to construct and irrespective of water table.

e) **Composite piles-** combination of two different materials are used to form composite file and suitable where the upper part of pile to project above the water table. Economical and easy to construct as shown in fig 10.14




**(*a*) Single-bulb cast *in-situ* pile** **(*b*) Multi-bulb piles**

**Fig 10.14 Under-reamed Piles 10.5Requirements of a good foundation:**

Following are the three basic requirements to be fulfilled by a foundation to be satisfactory

1) **Location :** The foundation should be located that it is able to resist any unexpected future influence which may adversely affect its performance. This aspect requires careful engineering judgement.

2) **Stability**: The foundation structure should be stable or safe against any possible failure

3) **Settlement**: The foundation structure should not settle or deflect to such an extent so as to impair its usefulness.

**Causes of failure of good foundation:**

The different causes for foundation failure are given below

1. Non uniform settlement of sub soil and masonry

2. Horizontal movement of the soil adjacent to structure

3. Alternate swelling and shrinkage in wet and dry cycles of the season

4. Lateral pressure due to lateral movement of earth tending to over turn the structure

5. Action of weathering agencies like sun, wind or rain

6. Lateral escape of the soil beneath the foundation of the structure

7. Roots trees and shrubs which penetrate the foundation

* * *

**SYNOPYSIS**

1. Foundations is the lowest – artificially prepared parts of structure which are in direct contact with ground and which transmit the loads of the structure to the ground

2. The object of providing the foundation is

(i) To distribute the total load coming onto the structure on large area

(ii) To support the structure

(iii) To give stability to the structure

(iv) To prepare a level surface for concreting and masonry work

3. The bearing capacity of soil is used to indicate maximum load per unit area which the soil will resist safely without displacement

4. Depending upon their nature and depth, the foundations are

(i) Shallow foundation

(ii) Deep foundation

5. The shallow or open foundation are the following types usually about 5m and above water table

(i) Wall footing

(ii) Isolated footing

(iii) Combined footing

(iv) Inverted footing

(v) Continuous footing

(vi) Cantilever footing

(vii) Grillage footing

6. Deep foundations carry loads from a structure through weak compressible soils or fills are classified as

(i) Basements

(ii) Buoyancy rafts

(iii) Caissons

(iv) Shaft foundations

(v) Pile foundations

7. Classification based on the function

(i) Bearing piles
(ii) Friction piles
(iii) Screw piles
(iv) Uplift piles
(v) Batter piles
(vi) Sheet piles

8. Classification based on materials and composition

(i) Cement concrete piles a. Pre-cast b. Cast-in-site

(ii) Timber piles

(iii) Steel piles

(iv) Sand piles

(v) Composite piles

9. A good foundation should have the basic requirements

(i) Location

(ii) Stability

(iii) Settlement

10. The causes for the failure of foundations

(i) Non uniform settlement

(ii) Horizontal movement of the soil

(iii) Alternate swelling and shrinkage

(iv) Lateral pressure due to lateral movement of earth

(v) Action of weathering agencies

(vi) Lateral escape of the soil beneath the foundation of structure
(vii) Roofs of trees and shrubs

**SHORT ANSWER QUESTIONS**

1. What are the main types of foundations?
2. What is the purpose of foundation?
3. What is meant by bearing capacity of soil?
4. Name the methods of determining the bearing capacity of soil?
5. Define safe bearing capacity.
6. Name any two causes of failure of foundations.
7. Name any two requirements of a good foundation
8. What is shallow foundation?
9. What is meant by deep foundation?
10. Name any four types of shallow foundations.
11. What is the purpose of raft foundation?
12. What is the grillage footing?

**ESSAY TYPE QUESTIONS**

1. Explain the requirements of good foundation.
2. What is bearing capacity and explain any one method to find the bearing capacity of soil?
3. Explain the causes for the foundation failures.
4. Explain the types of shallow foundations in brief.
5. What are deep foundations? Name the types.
6. Explain the functions of foundation.

*** * ***

# Damp Proofing

## 21.1. INTRODUCTION : CAUSES OF DAMPNESS

One of the basic requirement of a building is that it should remain dry or free from moisture travelling through walls, roofs or floors. *Dampness* is the presence of hygroscopic or gravitational moisture. Dampness gives rise to unhygienic conditions, apart from reduction in strength of structural components of the building. Damp prevention is therefore one of the important items of building design. Every building should be *damp proof*. Provision of *damp proof courses* prevent the entry of moisture in the building.

Following are various causes of dampness in buildings :

**1. *Moisture rising up the walls from ground***

All the structures are founded on soils, and the sub-structure is embedded into it. If the soil is pervious, moisture constantly travels through it. Even in the case if impervious soils, lot of soil moisture may be present. This moisture may rise up into the wall and the floor through capillary action. Ground water rise will also result in moisture entry into the building through walls and floor.

**2. *Rain travel from wall tops***

If the wall tops are not properly protected from rain penetration, rain will enter the wall and will travel down. Leaking roofs will also permit water to enter.

**3. *Rain beating against external walls***

Heavy showers of rain may beat against the external faces of walls and if the walls are not properly treated, moisture will enter the wall, causing dampness in the interior. If balconies and chajja projections do not have proper outward slope, water will accumulate on these and could ultimately enter the walls through their junction. This moisture travel would completely deface interior decoration of the wall.

**4. *Condensation***

Due to condensation of atmospheric moisture, water is deposited on the walls, floors and ceilings. This moisture may cause dampness.

**5. *Miscellaneous causes***

Moisture may also enter due to the following miscellaneous causes :

(*i*) *Poor drainage* at the building site.

(*ii*) *Imperfect orientation* : Walls getting less sunlight and heavy showers may remain damp.

(*iii*) *Imperfect roof slope* : Specially in the case of flat roofs.

(*iv*) *Defective construction* : Imperfect wall jointings, joints in roofs, defective throating etc.

(*v*) *Absorption of water* from defective rain water pipes.

## 21.2. EFFECTS OF DAMPNESS

The following are the ill effects of entry of dampness :

1. Dampness gives rise to breeding of mosquitoes and create unhealthy living conditions.

2. Travel of moisture through walls and ceiling may cause unsighty patches.

3. Moisture travel may cause softening and crumbling of plaster, specially lime plaster.

4. The wall decoration (*i.e.*. painting etc.) is damaged, which is very difficult and costly to repair.

5. Continuous presence of moisture in the walls may cause efflorescence resulting in disintegration of bricks, stones, tiles, etc., and consequent reduction in strength.

6. The flooring gets loosened because of reduction in the adhesion when moisture enters through the floor.

7. Timber fittings, such as doors, windows, almirahs, wardrobes etc., coming in contact with damp walls, damp floors etc., get deteriorated because of warping, buckling, dry-rotting etc. of timber.

8. Electrical fittings get deteriorated, giving rise to leakage of electricity and consequent danger of short circuiting.

9. Floor coverings are damaged. On damp floors, one can not use floor coverings

10. Dampness promotes and accelerates growth of termites.

11. Dampness along with warmth and darkness breeds germs of dangerous diseases such as tuberculosis, neuralgia, rheumatism etc. Occupants may even be asthamatic.

12. Moisture causes rusting and corrosion of metal fittings attached to walls, floors and ceilings.

## 21.3. METHODS OF DAMP PROOFING

Following methods are adopted to make a building damp proof :

(1) Use of damp proofing course (D.P.C.) : membrane damp proofing.
(2) Integral damp proofing.
(3) Surface treatment.
(4) Cavity wall construction.
(5) Guniting.
(6) Pressure grouting.

### 1. Membrane damp proofing : Use of D.P.C.

This consists of introducing a water repellent membrane or *damp proof course* (D.P.C.) between the source of dampness and the part of building adjacent to it. Damp proofing course may consist of flexible materials such as bitumen, mastic asphalt, bituminous felts, plastic or polythene sheets, metal sheets, cement concrete etc. Damp proofing course may be provided either horizontally or vertically in floors, walls etc. The following *general principles* should be kept in mind while providing D.P.C. :

(*i*) The damp proofing course should cover the full thickness of walls, excluding rendering.

(*ii*) The mortar bed supporting D.P.C. should be levelled and even, and should be free from projections, so that D.P.C. is not damaged.

(*iii*) D.P.C. should be so laid that of a continuous projection is provided.

(*iv*) At junctions and corners of walls, the horizontal D.P.C. should be laid continuous.

(*v*) When a horizontal D.P.C. (*i.e.*. that of a floor) is continued to a vertical face, a cement concrete fillet of 7.5 cm radius should be provided at the junction.

(*vi*) D.P.C. should not be kept exposed on the wall surface otherwise it may get damaged during finishing work.

**2. Integral damp proofing**

This consists of adding certain water proofing compounds of materials to the concrete mix, so that it becomes impermeable. These water proofing compounds may be in three forms :

(*i*) Compounds made from chalk, talc, fullers earth, which may fill the voids of concrete under the mechanical action principle.

(*ii*) Compounds like alkaline silicates, aluminium sulphate, calcium chlorides, etc. which react chemically with concrete to produce water proof concrete.

(*iii*) Compounds, like soap, petroleum, oils, fatty acid compounds such as stearates of calcium, sodium, ammonia etc. work on water repulsion principle. When these are mixed with concrete, the concrete becomes water repellent.

(*iv*) Commercially available compounds like Publo, Permo, Silka etc.

**3. Surface treatment**

The surface treatment consists of application of layer of water repellent substances or compounds on these surfaces through which moisture enters. The use of water repellent metallic soaps such as calcium and aluminium oletes and stearates are much effective against rain water penetration. Pointing and plastering of the exposed surfaces must be done carefully, using water proofing agents like sodium or potassium silicates, aluminium or zinc sulphates, barium hydroxide and magnesium sulphates etc. It should be noted that surface treatment is effective only when the moisture is superficial and is not under pressure. Sometimes, exposed stone or brick wall face may be sprayed with water repellent solutions.

**4. Cavity wall construction**

This is an effective method of damp prevention, in which the main wall of a building is shielded by an outer skin wall, leaving a cavity between the two. For details about cavity wall construction, reference may be made to Chapter 9.

**5. Guniting**

This consists of depositing under pressure, an impervious layer of rich cement mortar over the exposed surfaces for water proofing or over pipes, cisterns etc. for resisting the water pressure. Cement mortar consists of 1 : 3 cement sand mix, which is shot on the cleaned surface with the help of a cement gun, under a pressure of 2 to 3 kg/cm$^2$. The nozzle of the machine is kept at a distance about 75 to 90 cm from the surface to be gunited. The mortar mix of desired consistency and thickness can be deposited to get an impervious layer. The layer should be properly cured atleast for 10 days.

**6. Pressure grouting**

This consists of forcing cement grout, under pressure, into cracks, voids, fissures etc. present in the structural components of the building, or in the ground. Thus the structural components and the foundations which are liable to moisture penetration are consolidated and are thus made water-penetration-resistant. This method is quite effective in checking the seepage of raised ground water through foundations and sub-structure of a building.

## 21.4. MATERIALS USED FOR DAMP PROOFING COURSE

An ideal damp proofing material should have the following *characteristics*:

(1) The material should be perfectly impervious and it should not permit any moisture penetration or travel through it.

(2) The material should be durable, and should have the same life as that of the building.

(3) The material should be strong, capable of resisting super- imposed loads/pressure on it.

(4) Material should be flexible, so that it can accommodate the structural movements without any fracture.

(5) The material should not be costly.

(6) The material should be such that leak-proof jointing is possible.

(7) The material should remain steady in its position when once applied. It should not allow any movement in itself.

Following materials are commonly used for damp-proofing course :

**1. Hot bitumen**

This is highly flexible material, which can be applied with a minimum thickness of 3 mm. It is placed on the bedding of concrete or mortar, while in hot condition.

**2. Mastic asphalt**

Mastic asphalt is semi-rigid material which is quite durable and completely impervious. It is obtained by heating asphalt with sand and mineral fillers. However, it should be laid very carefully, by experienced persons. It can withstand only very slight distortion. It is also liable to squeeze out in very hot climate or under heavy pressure.

**3. Bituminous or asphaltic felts**

This is a flexible material which is available in rolls of various wall thicknesses. It is laid on a levelled flat layer of cement mortar. An overlap of 10 cm is provided at joints and full width overlap is provided at angles, junctions and crossings. The laps should be sealed with bitumen. Bituminous felts cannot withstand heavy loads, through they can accommodate slight movements.

**4. Metal sheets**

Sheets of lead, copper aluminium can be used as D.P.C. These sheets are of flexible type. *Lead sheets* are quite flexible. Their thickness should be such that its weight is not less than 20 $kg/m^2$. They are laid similar to the bituminous felts. Lead sheets have the advantages of being completely impervious to moisture, resistant to ordinary atmospheric corrosion, capability of taking complex shapes without fracture and resistant to sliding action. It does not squeeze out under ordinary pressure. However, it may be corroded when in contact with lime or cement. It should, therefore, be protected by a coating of bitumen. *Copper sheets*, of minimum 3 mm thickness, are embedded in lime or cement mortar It has high durability, high resistance to dampness, high resistance to sliding and reasonable resistance to ordinary pressure. *Aluminium sheets*, if used, should be protected with a layer of bitumen. It is not as good as lead or copper sheets.

**5. Combination of sheets and bituminous felts**

*Lead foil* sand wiched between asphaltic or bituminous felts can be effectively used as D.P.C. The combination, known as *lead core* possesses characteristics of easy laying, durability, efficiency, economy and resistance to cracking.

**6. Bricks**

Special bricks, having water absorption not less than $4\frac{1}{2}$ % of their weight may be used as D.P.C. in locations where damp is not excessive. These bricks are laid in two to four courses in cement mortar. The joints of bricks are kept open.

**7. Stones**

Dense and sound stones, such as granite, trap, slates, etc. are laid in cement mortar (1: 3 ) in two courses or layers to form effective D.P.C. The stones should extend to the full width of the wall.

**8. Mortar**

Cement mortar (1 : 3) is used as bedding layer for housing other D.P.C. materials. A small quantity of lime may be added to increase workability of the mortar. In water used for mixing, 75 gm of soft soap is dissolved per litre of water. This mortar may also be used for plaster work on external walls.

**9. Cement concrete**

Cement concrete of 1 : 2 : 4 mix or 1 : $1\frac{1}{2}$ : 3 mix is generally provided at plinth level to work as D.P.C. The thickness may vary from 4 cm to 15 cm. Such a layer can effectively check the water rise due to capillary action. Where dampness is more, two coats of hot bitumen paint may be applied on it.

**10. Plastic sheets**

This is relatively a new type D.P.C. material, made of black polythene, 0.5 to 1 mm thick in the usual walling width and roll lengths of 30 m. C.B.R.I. Roorkee has recently suggested a new D.P.C. which comprises a 400 gauge thick alkathene laid over 12 mm thick 1 : 4 cement mortar. The treatment is cheaper but is not permanent.

## 21.5 D.P.C. TREATMENT IN BUILDINGS

**1. Treatment to foundations against gravitational water**

Foundation may receive water percolating from adjacent ground, and this moisture may rise in the wall. This can be checked by providing *air drain* parallel to the external wall. The width of air drain may be about 20 to 30 cm. The outer wall of the drain is kept above the ground to check the entry of surface water. A R.C.C. roof slab is provided. Openings with gratings are provided at regular interval, for the passage of air. Usual D.P.C. are also provided horizontally and vertically, as shown in Fig. 21.1.

**2. Treatment to basements**: When basements in damp soils are constructed, three methods may be adopted:

(*i*) Provision of foundation drains and D.P.C.

(*ii*) Provision of R.C.C. raft and wall slab.

(*iii*) Asphalt tanking.

***(a) Provision of foundation drains and D.P.C.*** : When basement rests on soils which are not properly drained, (such as peat soil etc.) great hydrostatic pressure

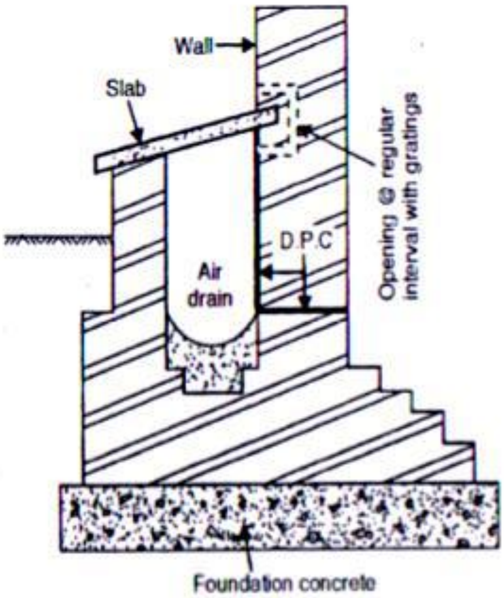



FIG. 21.1. AIR DRAIN.

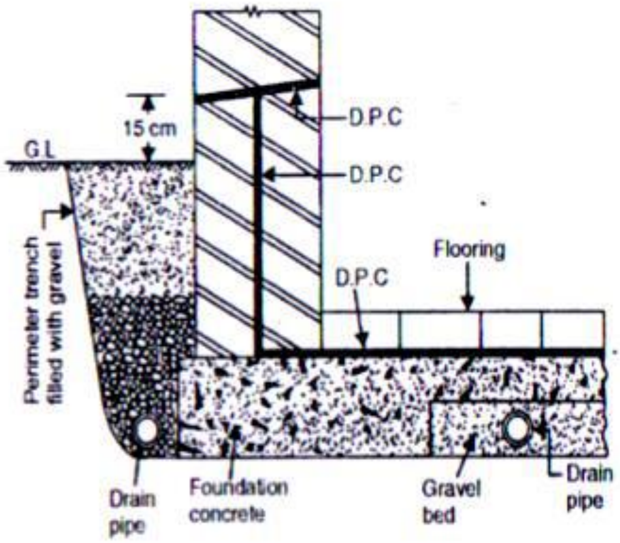



FIG. 21.2. D.P.C. TREATMENT FOR BASEMENT ON UNDRAINED SOILS.

is exerted and the floor as well as wall receive water continuously oozing out. In such a case it becomes necessary to make a trench all round, upto foundation level and fill it with gravel, coke and other pervious materials. Open jointed drains may be provided to collect the underground water. Drainage pipes, embedded in gravel bed, may also be provided before foundation concrete, as shown in Fig. 21.2. Horizontal and vertical D.P.C. are provided in wall as well as foundation concrete.

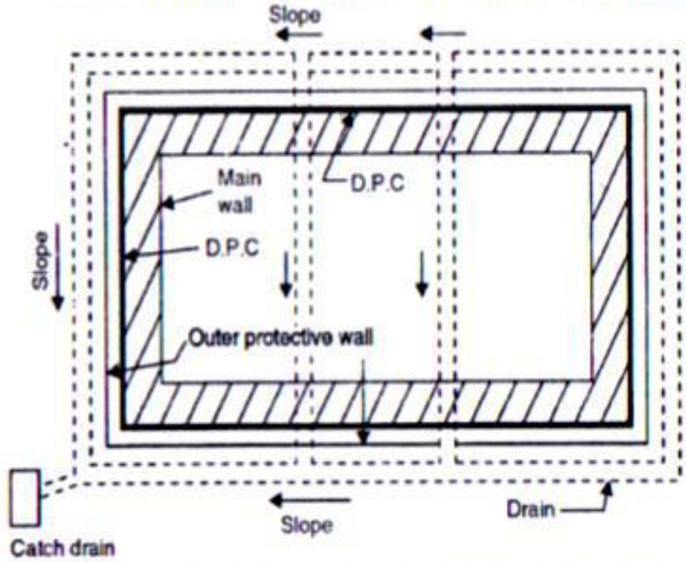



FIG. 21.3. PLAN SHOWING LAYOUT OF DRAINS.

The drain may have suitable longitudinal slope, ultimately draining the water into a catch drain. Drain pipes under the basement slab may be provided at some suitable interval, as shown in Fig. 21.3.

**(b) *Provision of R.C.C. raft and wall slab***: Where underground water pressure is severe, the drainage system may not solve the problem effectively. Also, constant pumping out water may be costly. In such a case, floor slab as well as walls may be constructed in rigid R.C.C. structure. Horizontal and vertical D.P.C. treatment is also provided as shown in Fig. 21.4. Atleast 3 layers of bituminous felts are used as D.P.C. Half- brick thick outer protecting wall is provided at the outer face of R.C.C. wall slab.

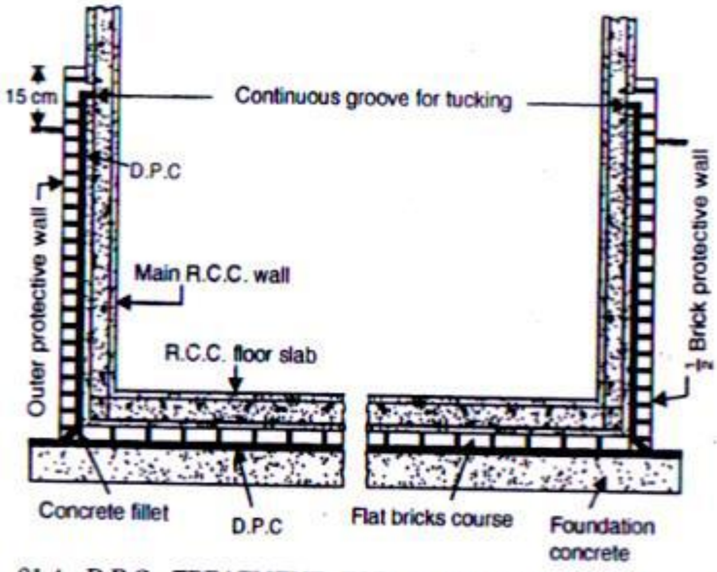



FIG. 21.4. D.P.C. TREATMENT FOR BASEMENT IN DAMP SOIL.

(c) ***Asphalt tanking*** **(Fig. 21.5)** : This is adopted when the subsoil water table is not very high. The treatment consists of horizontal D.P.C. in the form of asphaltic layer of 30 mm thick in three coats over the entire area of basement floor and then extending it in the form of vertical D.P.C. on the external faces of the basement walls. The thickness of vertical asphaltic layer may be 20 mm, applied in three coats. The D.P.C. thus functions like a water proof tank on the external faces of the basement, thus keeping it dry. A $1\frac{1}{2}$ -brick thick outer protective wall is constructed. The vertical D.P.C. is taken atleast 15 cm above ground level. A protective flooring of flat bricks on foundation concrete (1 : 3 : 6) is provided to protect the D.P.C. from damage during the construction of floor slab.

### 3. Treatment to floors

For locations where ground moisture is not present, subsoil is rammed well and

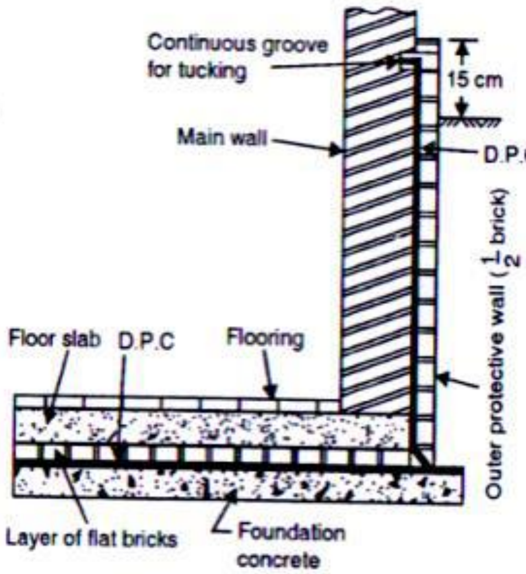



FIG. 21.5. ASPHALT TANKING FOR BASEMENT.

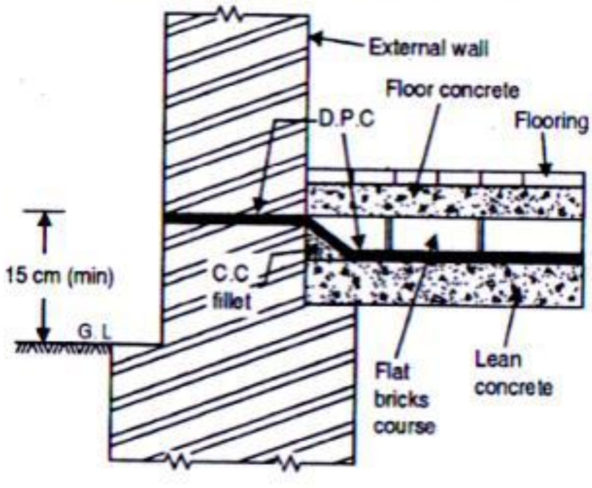



FIG. 21.6. D.P.C. FOR FLOORING.

a 7.5 to 10 cm thick layer of coarse sand is spread over the entire area under flooring. Alternatively, stone soling may first be provided and then 7.5 cm to 10 cm thick layer of lean cement concrete (1 : 3 : 6 or 1 : 4 : 8) may be provided under it. Over this base, flooring may be laid. However, in damp soils, where water table is near ground surface, it is essential to provide membrane D.P.C. over the entire area, as shown in Fig. 21.6. The membrane may be in the form of mastic asphalt or fibrous asphalt felt. A layer of flat bricks is laid on a cushion of find sand over D.P.C. to protect it from damage during the construction of floor slab. Before laying bituminous felt, a coat of hot bitumen, at the rate of 1.5 kg/m$^2$ is applied over the foundation concrete, to serve as primer coat. After laying bituminous felt over it, a finishing coat of hot bitumen is applied at the rate of 1.5 kg/m$^2$ over the felt.

**4. Treatment to walls**: For basement walls, a vertical D.P.C. is laid over the external face of wall, as shown in Figs 21.3 and 21.4. This vertical layer of D.P.C. is laid over the base of water-cement plaster grounted on the external face of the wall. This vertical D.P.C. is further protected by external protective wall of half-brick thickness. The vertical D.P.C. should be carried atleast upto a level 15 cm above G.L. Similarly, horizontal D.P.C. in external wall, extending from the floor, is provided atleast 15 cm above G.L., as shown in Fig. 21.5. In the internal walls, D.P.C. is provided in level with the upper surface of concrete floor. If two ground floors are at different levels and are connected by an internal wall, the D.P.C. is provided as shown in Fig. 21.6. The provision of D.P.C. for cavity walls has been expiained in Chapter 9.

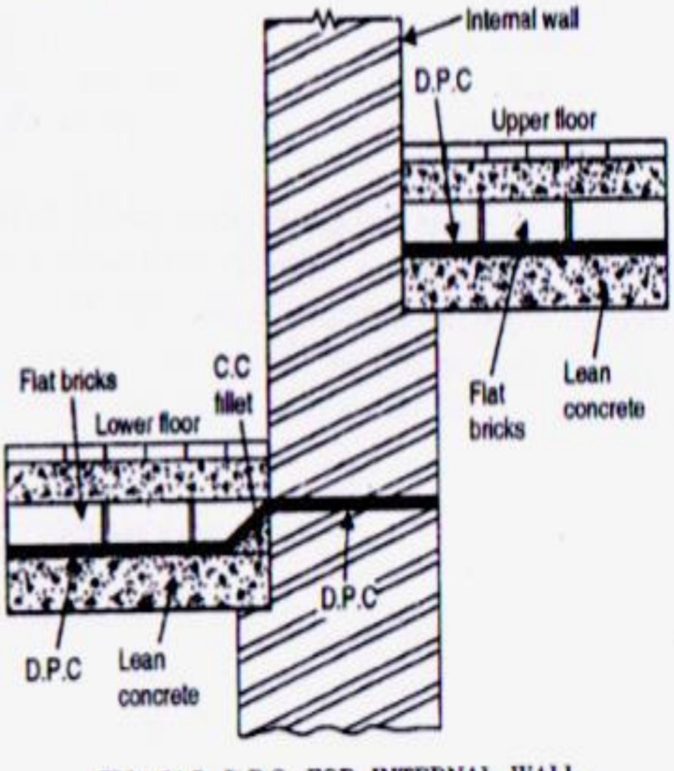



FIG. 21.7. D.P.C. FOR INTERNAL WALL.

**5. Treatment of roofs** : The methods of providing D.P.C. for flat roofs, parapets, copings and pitched roofs have been illustrated in Chapter 15.

# DOORS & WINDOWS

(i) Single angle iron

(ii) Double angle iron

(iii) T-section

(iv) Channel sections formed from pressing steel plates.

These sections, along with the position of door shutters are shown in Fig. 17.5.

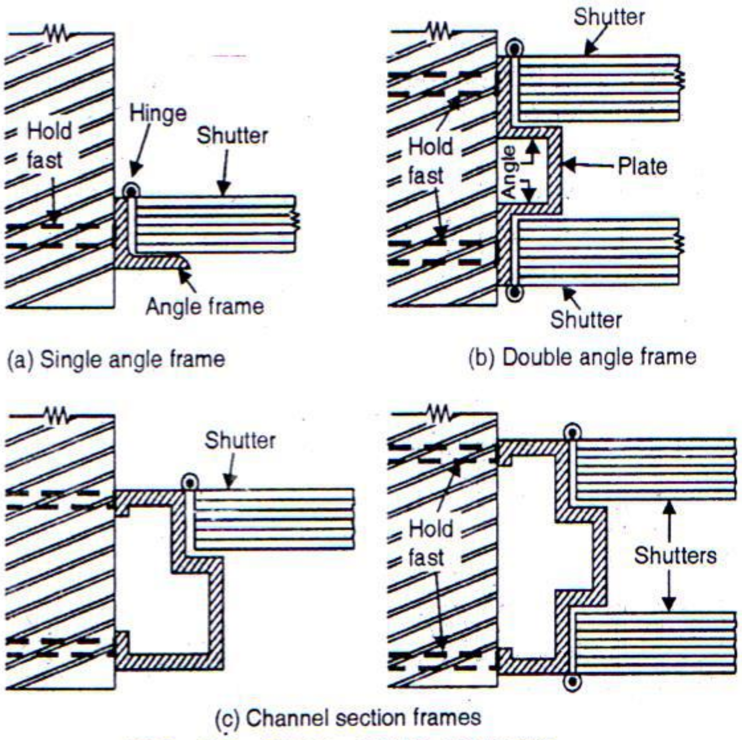



FIG. 17.5. STEEL DOOR FRAMES.

Steel hold fasts or lugs are welded to the frame. Steel frames are generally fixed in prepared door opening. Chases are cut in brick masonry for accommodating hold fasts or lugs which are then grouted with cement mortar. The vertical jambs and the head of the frame are welded together. The hinges of the shutters are also welded to the frame. In the case of stone masonry or R.C.C. where it is difficult to cut chases, wooden plugs are embedded at appropriate places in the jamb during the construction of wall. The steel frame is fixed with plugs with the help of galvanised iron wood screws of big size.

## 17.6. TYPES OF DOORS

Doors commonly used in building are classified into the following types, depending upon (i) type of materials used (ii) arrangement of different components of the door, (iii) method of construction, and (iv) nature of working operations :

| | | |
|---|---|---|
| 1. | Battened and ledged doors | *Classification on the basis of arrangement of components* |
| 2. | Battened, ledged and braced doors | |
| 3. | Battened, ledged and framed doors | |
| 4. | Battened, ledged, braced and framed doors | |
| 5. | Framed and panelled doors | *Classification on the basis of method or manner of construction* |
| 6. | Glazed or sash doors | |
| 7. | Flush doors | |
| 8. | Louvered doors | |
| 9. | Wire-gauged doors | |
| 10. | Revolving doors | *Classification on the basis of working operations* |
| 11. | Sliding doors | |
| 12. | Swing doors | |
| 13. | Collapsible steel doors | |
| 14. | Rolling steel shutter doors | |
| 15. | Mild steel sheet doors | *Metal doors.* |
| 16. | Corrugated steel sheet doors | |
| 17. | Hollow metal doors | |
| 18. | Metal covered plywood doors. | |

## 1. BATTENED AND LEDGED DOORS

This is the simplest type of door, specially suitable for narrow openings. The door, shown in Fig. 17.6 is formed of vertical bonds, known as *battens*, which are usually tongued and grooved, and are fixed together by horizontal supports known as *ledges*. Battens are 100 to 150 mm wide and 20 to 30 mm thick. Ledges are 100 to 200 mm wide and 25 to 30 mm thick. Three ledges are generally provided — top, middle and bottom. The door is hung to the frame by means of T-hinges of iron.

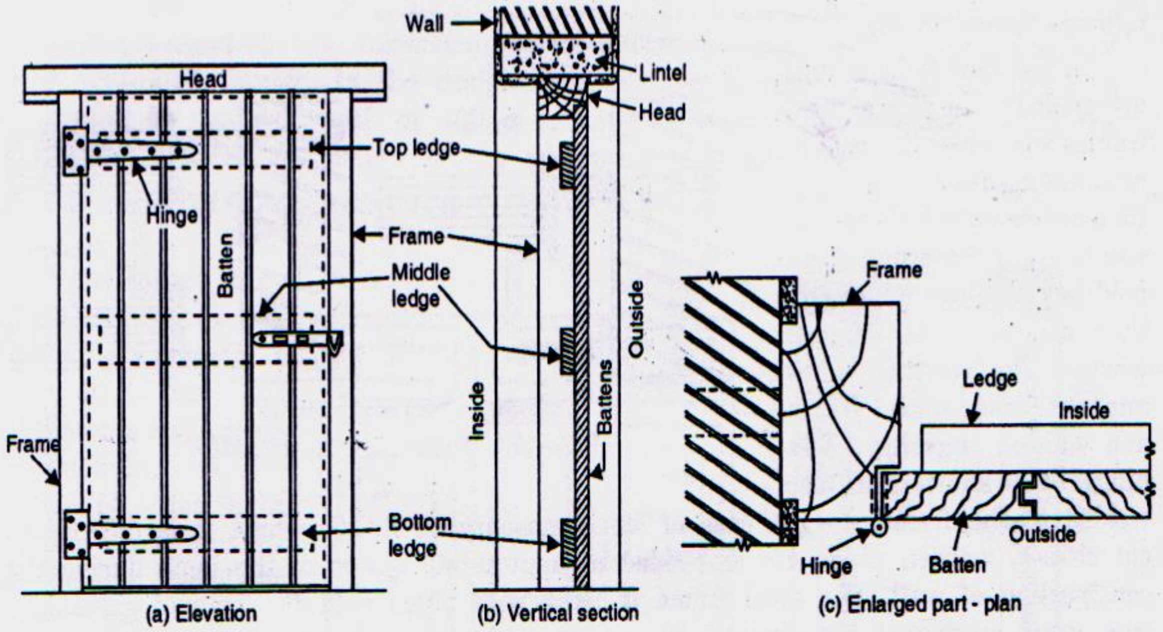



FIG. 17.6. BATTENED AND LEDGED DOOR.

## 2. BATTENED, LEDGED, AND BRACED DOORS

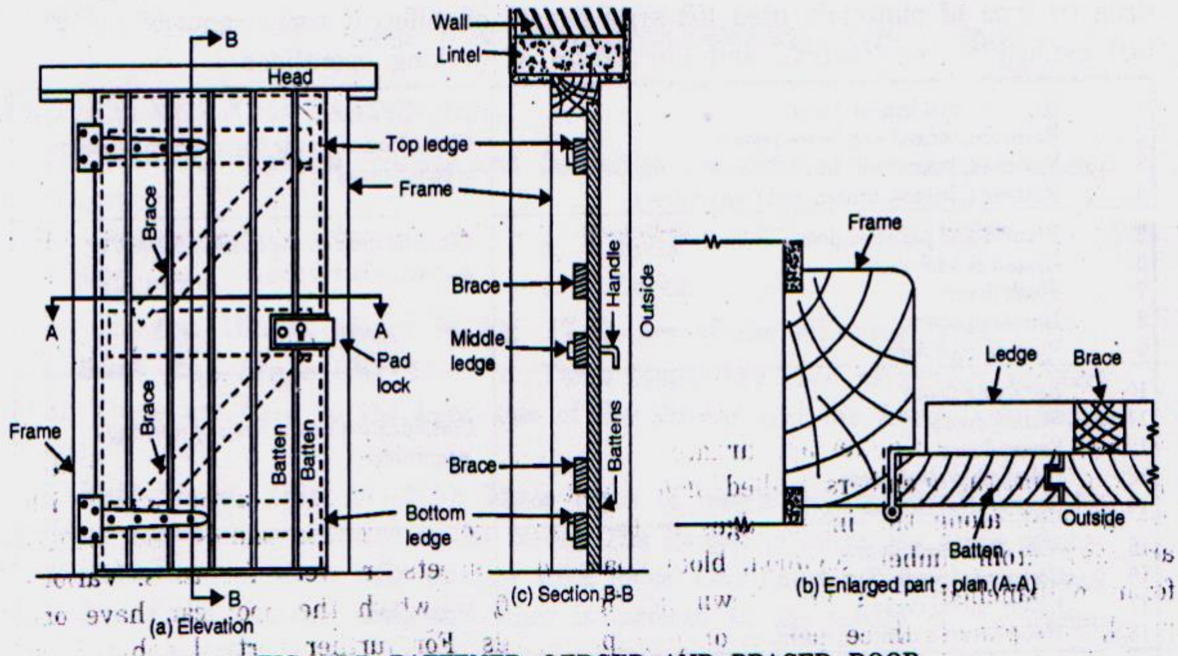



FIG. 17.7. BATTENED, LEDGED AND BRACED DOOR.

These doors are improved versions of battened and ledged doors, in which additional inclined (or diagonal) members, called *races* are provided, as shown in Fig. 17.7, to give more rigidity. Hence these doors can be used for wider openings. The braces, 100 to 150 mm wide have the same thickness as the ledges, and are simply housed in the ledges. It is essential that the braces slope upwards from the handing side since they have to work as struts, to take compression.

### 3. BATTENED, LEDGED AND FRAMED DOORS

This door is also an improved form of simple battened and ledged door, in which frame work for the shutter is provided in the form of two verticals, known as *styles*. Styles are generally 100 mm wide and 40 mm thick. Three ledges are provided as usual. The total thickness of *style* is adjusted equal to the thickness of ledges plus the thickness of battens.

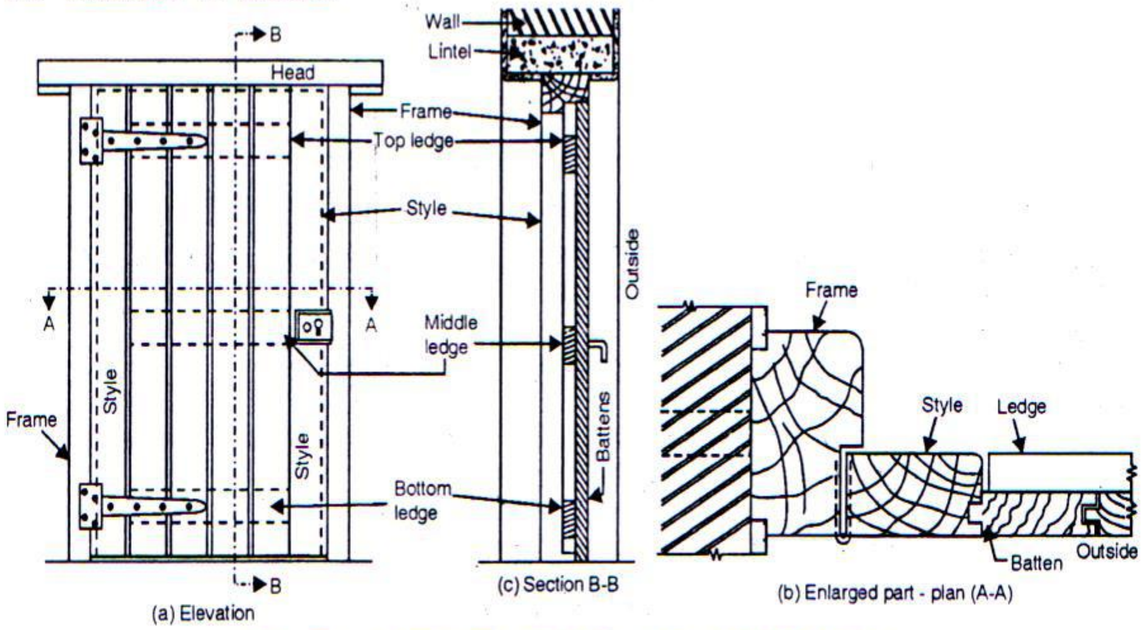



FIG. 17.8. BATTENED, LEDGED AND FRAMED DOOR.

### 4. BATTENED, LEDGED, BRACED AND FRAMED DOORS

This door is the modification over type 3 door described above, with the provision of additional braces, provided diagonally between the ledges, to increase its strength, durability, and appearance. This door, thus, consists of battens, two vertical members (styles), three ledges, and two braces. The battens are generally tongued, grooved and V-jointed. The braces are housed into the ledges, at about 40 mm from the styles.

### 5. FRAMED AND PANELLED DOORS

These types of doors are widely used in almost all types of building since they are strong and give better appearance than batten doors. This door consists of a frame work of vertical members (called *styles*) and horizontal members, called *rails* which are grooved along the inner edges of the frame, to receive the panels. The panels are made from timber, plywood, block board, A.C. sheets or even of glasses. Various forms of panelled doors are shown in Fig. 17.10, in which the door can have one panel, two panels, three panels or multiple panels. For further vertical sub-division of panels, vertical pieces, known as *mullions* can be provided. Panelled doors may contain

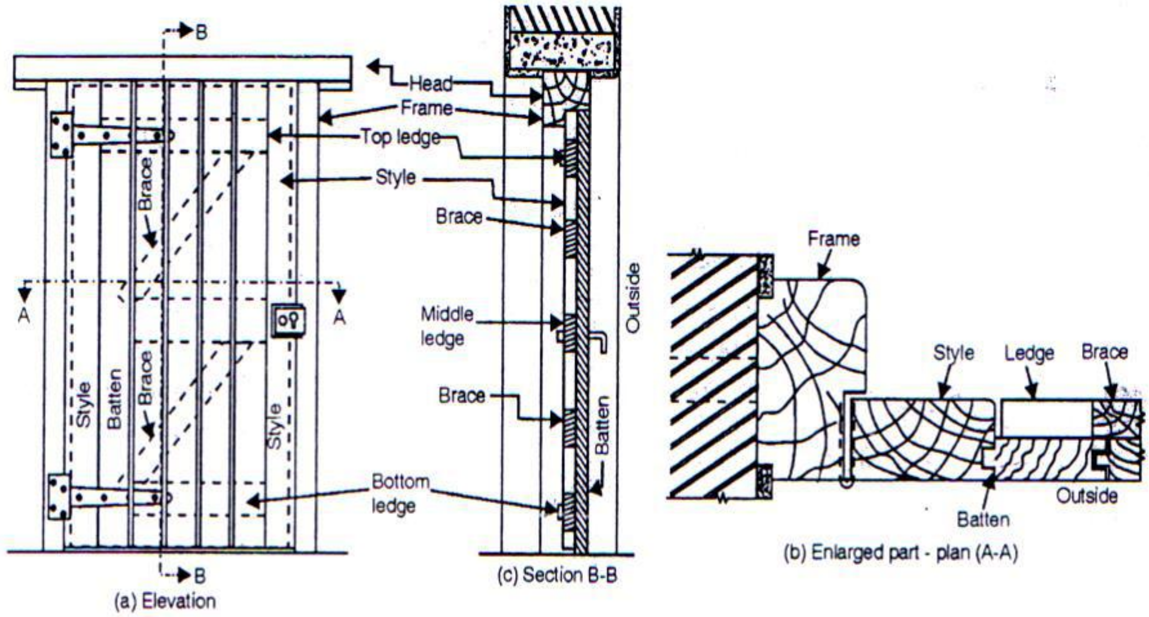



FIG. 17.9. BATTENED, LEDGED, BRACED AND FRAMED DOOR.

single leaf (such as those shown in Fig. 17.10) for small openings or may contain two leafs (as shown in Fig. 17.11) for wider openings. In double leafed door, each leaf has separate frames, each hinged to the corresponding jamb-post of the door.

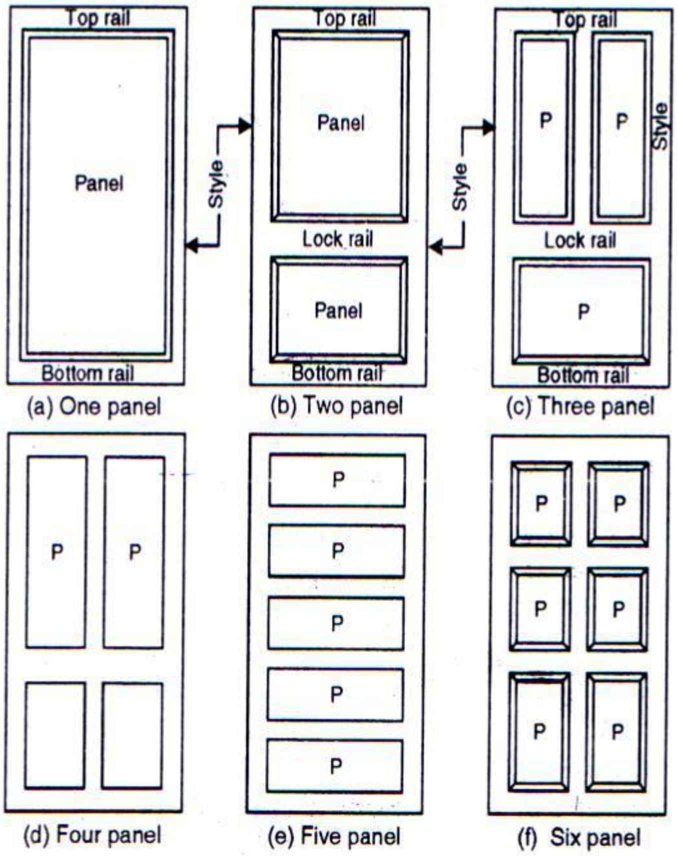



FIG. 17.10. VARIOUS FORMS OF SINGLE-LEAF PANELLED DOORS.

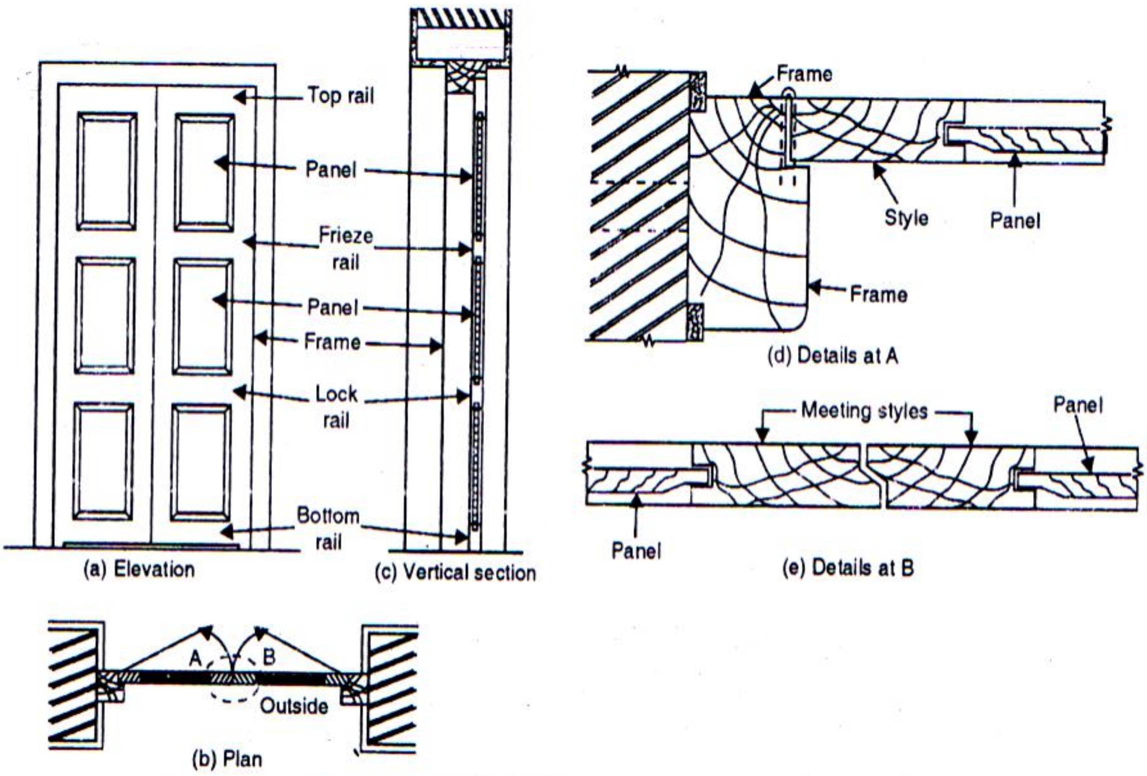



FIG. 17.11. DETAILS OF A DOUBLE--LEAF SIX PANELLED DOOR.

**Salient features of framed and panelled doors**

1. The styles are continuous from top to bottom, *i.e.* they are in single piece.

2. Various rails (*i.e.* top rail, bottom rail and intermediate rails) are jointed to the styles at both the ends.

3. The styles and the rails are jointed by tenon and mortised joints.

4. Mullions or mutines, if provided, are jointed to the adjacent rails between which it is fixed.

5. The bottom and lock rails are made wider than top and frieze rails.

6. The entire frame is grooved on all the inside faces to receive the panels.

7. Additional timber *beading* is provided either on one or on both the sides to improve the elevation of the door.

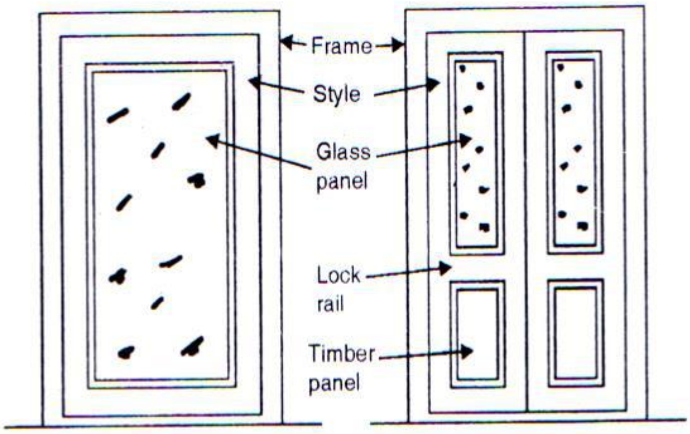
8. The lock rail elevation is so adjusted that its centre line is at a height of about 800 mm from the bottom of the shutter.

9. The minimum width of style is kept as 100 mm. The minimum width of bottom rail and lock rail is kept as 150 mm.

10. If panels are made of timber, its minimum width should be 150 mm, and minimum thickness should be 15 mm. However, the maximum area of single panel of timber should not be more than 0.5 $m^2$. These restrictions do not apply to panels of plywood, particle board or hard board.

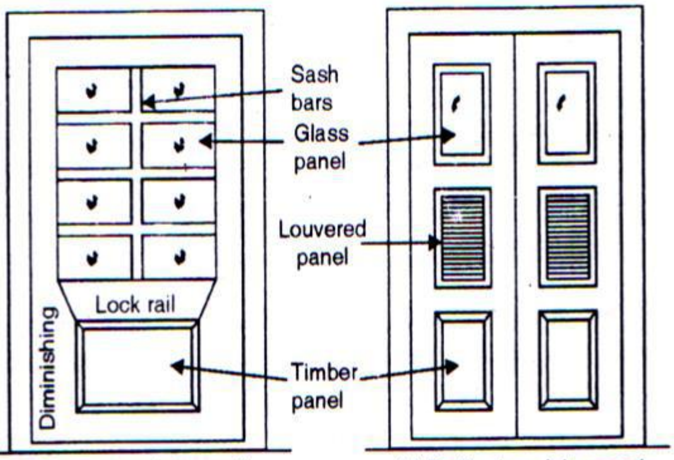
**6. GLAZED OR SASH DOORS**

Glazed or sash doors are provided where additional light is required to be admitted to the room through the door, or where the visibility of the interior of the room is




(a) Fully glazed single-leaf door (b) Partly glazed, partly panelled double leaf door

FIG. 17.12. FULLY AND PARTLY GLAZED DOORS.




(a) Party glazed door with diminishing style (b) Partly glazed, louvered and panelled door

FIG 17.13. FULLY AND PARTLY GLAZED DOORS.

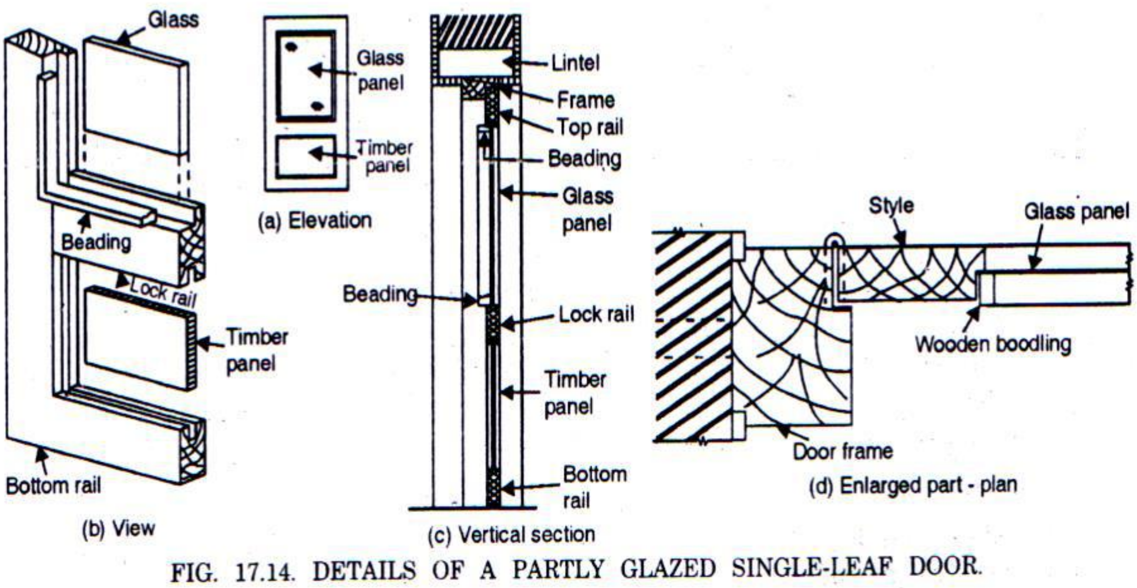



FIG. 17.14. DETAILS OF A PARTLY GLAZED SINGLE-LEAF DOOR.

required from the adjacent room. Such doors are commonly used in residential as well as public buildings like hospitals, schools, colleges etc. The doors may be either fully glazed, or they be partly glazed and partly panelled. In the latter case, the ratio of glazed portion to panelled portion is kept 2 : 1 ; the bottom one-third height is panelled and the top two-thirds height is glazed. Figs. 17.12 and 17.13 show some common forms of glazed doors, and partly glazed doors The glass is received into rebates provided in the wooden sash bars and secured by 'rails putty' or by wooden beads fixed to the frame. Partly glazed doors are sometimes provided with stiles which gradually diminish at lock rail, to improve the elevation and to permit more area for the glazed panels. Such a door is shown in Fig. 17.13(*a*). Such types, which decrease in width at the lock-rail level are called '*diminishing stiles*' or '*gun stock stiles*'. Fig. 17.13 (*b*) shows a partly glazed, louvered and panelled door. The louvers permit natural ventilation even when the door is closed.

### 7. FLUSH DOORS

Flush doors are becoming increasingly popular these days because of their pleasing appearance, simplicity of construction, less cost, better strength and greater durability. They are used both for residential as well as public and commercial buildings. These doors consist of solid or semi-solid skeleton or core covered on both sides with plywood, face veneers etc., presenting flush and jointless surface which can be neatly polished.

Flushed doors are of two types :

(*i*) Solid core flush door or laminated core flush door.

(*ii*) Hollow and cellular core flush door.

**(*i*) Solid core flush door or laminated core flush door** (Fig. 17.15)

Such a door consists of the wooden frame consisting of styles, and top and bottom rails is used for holding the core. The core consists either of core-strips of timber glued together under great pressure and faced on each side by plywood sheets, or of block board, particle board or a combination of particle board and block board, faced

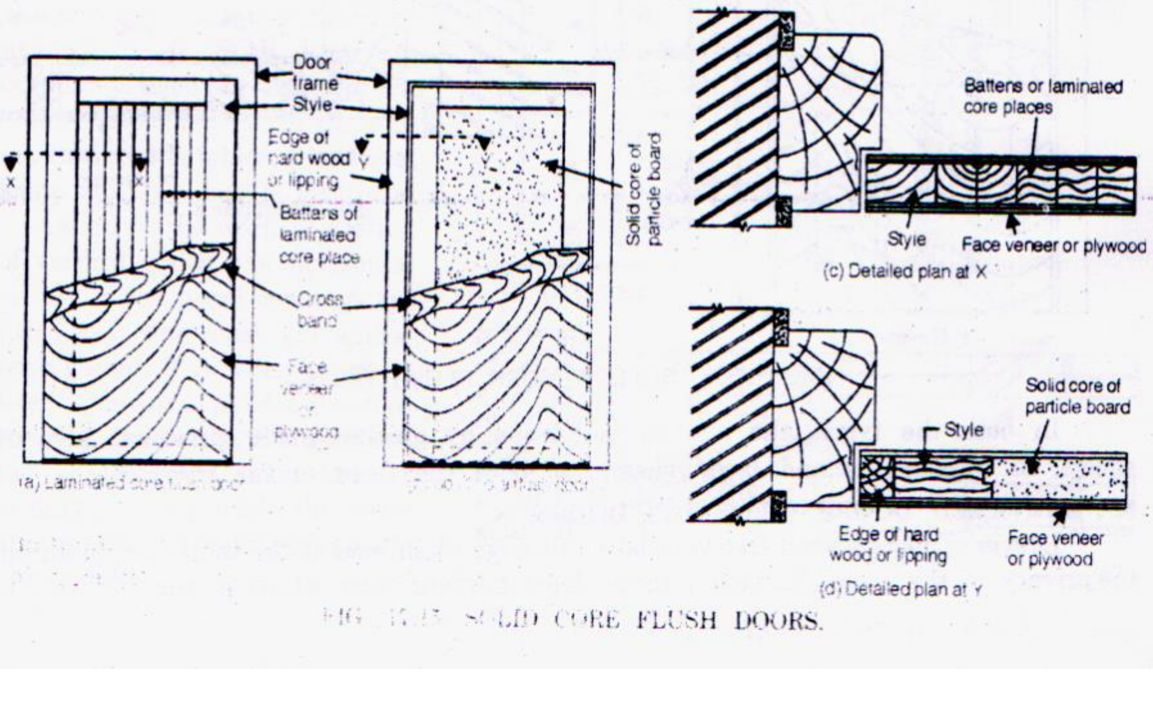



FIG. 17.15 SOLID CORE FLUSH DOORS.

with plywood sheets. In the laminated core, the wooden strips are of maximum width of 25 mm glued together, and the length of each strip is equal to the length of the laminated core. In each type of core, plywood sheets are glued under pressure to the assembly of core housed in the frame on both faces. Alternatively, separate cross-bands and face veneers can be glued on both the faces, with the grains of crossband at right angles to the core and grain of veneer at right angles to that of the cross-band. The core is housed in the outer frame having stiles, top and bottom rails each of not less than 75 mm width. Such doors are quite strong, but are heavy and require more material.

**(ii) Hollow core and cellular core flush door** (Fig. 17.16)

A *hollow core flush door* consists of frame made up of styles, top rail, bottom rail and minimum two intermediate rails, each of a minimum of 75 mm width. The inner space of the frame is provided with equally spaced battens each of minimum 25 mm width, such that the area of voids is limited to 500 sq. cm. A *cellular core flush door* consists of a frame of styles, top rail and bottom rail, each of a minimum of 75 mm width, with the void space, filled with equidistant battens of wood or plywood, each of a minimum of 25 mm in width. The battens are so arranged that the void space between adjacent vertical and horizontal battens does not exceed 25 $cm^2$ in area, and that the total area of voids does not exceed 40% of the area of the shutter.

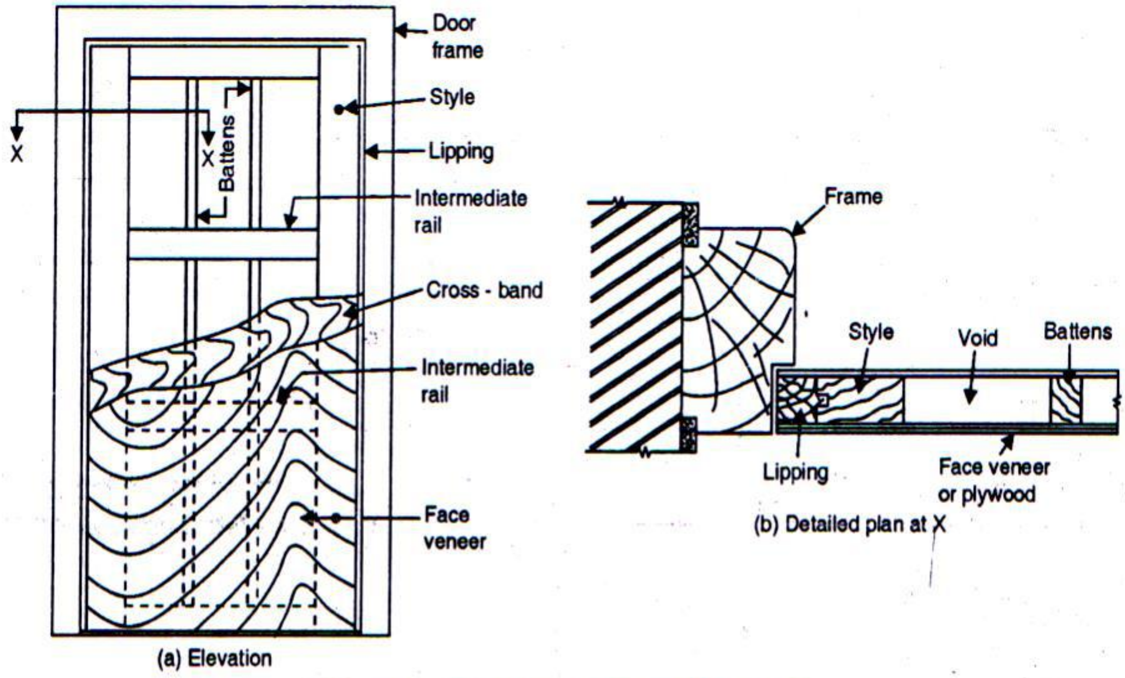



FIG. 17.16. HOLLOW CORE FLUSH DOOR.

In both the types, the shutter is formed by glueing under pressure, plywood sheets, or cross-bands and face veneers, to both the faces of the core.

## 8. LOUVERED DOORS (VENETIAN DOORS)

Louvered doors permit free ventilation through them, and at the same time maintain the privacy of the room. However, these doors harbour dust which is very difficult to be cleaned. These doors are generally used for latrines and bath rooms of residential and public buildings. The door may either be louvered to its full height, or it may be partly louvered and partly panelled such as the one shown in Fig. 17.17 (*a*). The louvers are arranged at such an inclination that vision is obstructed while they permit free passage of air. This is achieved by fixing the upper back edge of a louver higher than the lower front edge of the louver just above it. Louvers may be either fixed or movable. In the case of movable louvers, a vertical piece of timber is provided to which the louvers are attached through hinges. The movement of louvers is actuated by the vertical piece of timber. Louvers may be made of either timber or glass or plywood.

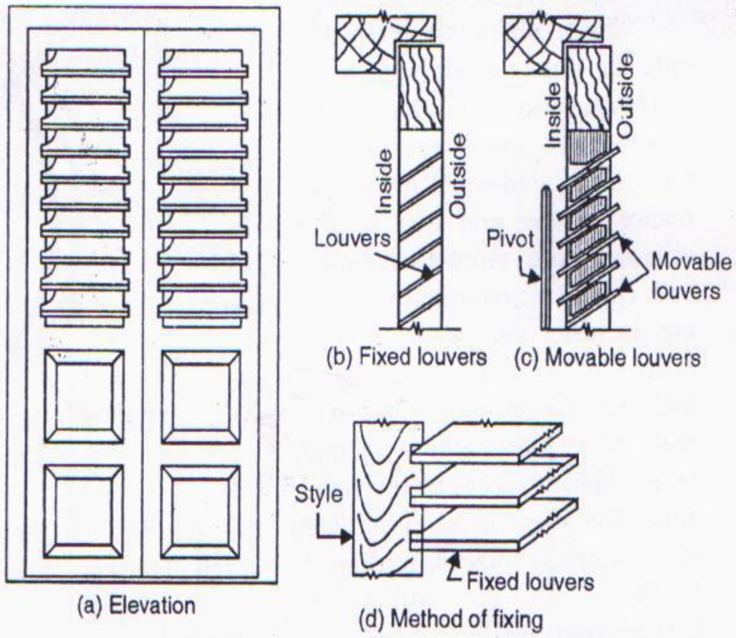



FIG. 17.17. LOUVERED DOORS.

**9. WIRE-GAUGED DOORS**

These types of doors are provided to check the entry of flies, mosquitoes, insects etc. Wire mesh is provided in the panels, and therefore they permit free passage of air. Such doors are commonly used for refreshment rooms, hotels, cupboards containing food and eatables, and sweet shops etc. The door is formed of a wooden frame work consisting of vertical styles and horizontal rails, and the panel openings are fitted with fine mesh galvanized wire-gauge. The wire-gauge is fixed by means of nails and timber beading. Generally, the door has two shutters the inner shutter is fully panelled while the outer shutter has wire-gauged panels (Fig. 17.18).

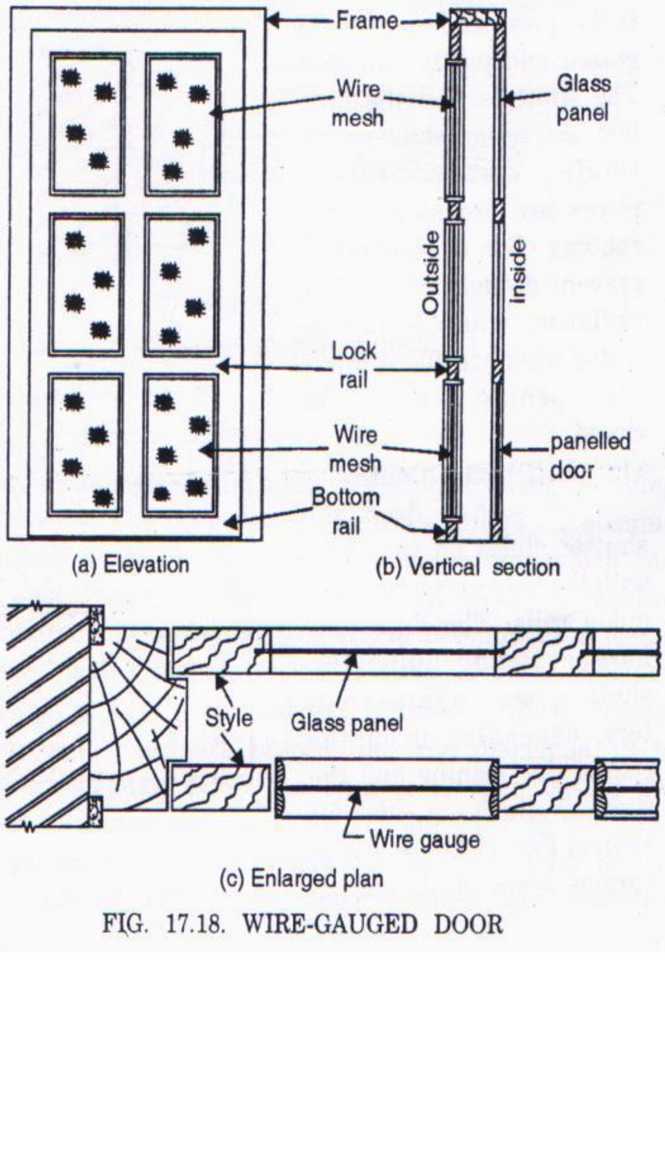



FIG. 17.18. WIRE-GAUGED DOOR

## 10. REVOLVING DOORS

Such doors are provided only in public buildings, such as libraries museums, banks etc. where there are constant visitors. Such a door provide entrance to one and exit to the other person simultaneously, and closes automatically when not in use. This door is also suitable for air-conditioned buildings or for buildings situated at a place where strong breeze blow throughout the year, since the door is so assembled that it excludes the wind drought. The door consists of a centrally placed mullion to which four radiating shutters are attached, as shown in Fig. 17.19. The mullion or vertical member is supported on ball bearings at the bottom, and has bush bearing at the top, so that its rotation is without any jerk, friction and noise. the shutters may be fully glazed, fully panelled or partly glazed and partly panelled The shutters and the mullion are enclosed in a vestibule. Vertical rubber pieces are provided at the rubbing ends of shutters to prevent drought of air. The radiating shutters can be folded where traffic is more. The opening can also be closed.

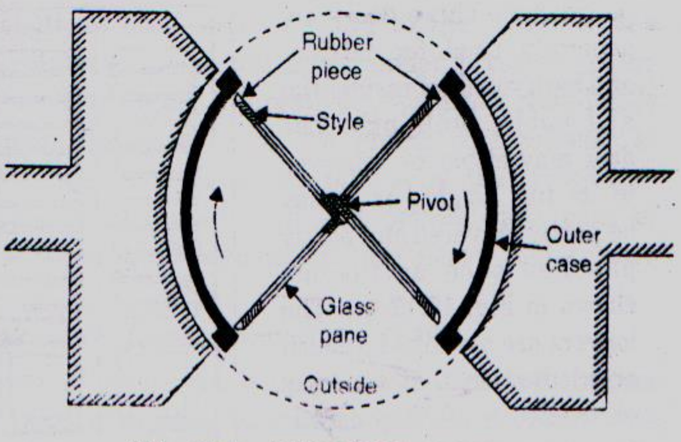



FIG. 17.19. REVOLVING DOOR.

## 11. SLIDING DOORS.

In such a door, the shutter slides on the sides with the help of runners and guide rails. The door may have one sliding shutter, two shutters or even three shutters, depending upon the size of the opening and the space available on sides for sliding. Fig 17.20 (*a*) shows various types of sliding ar-

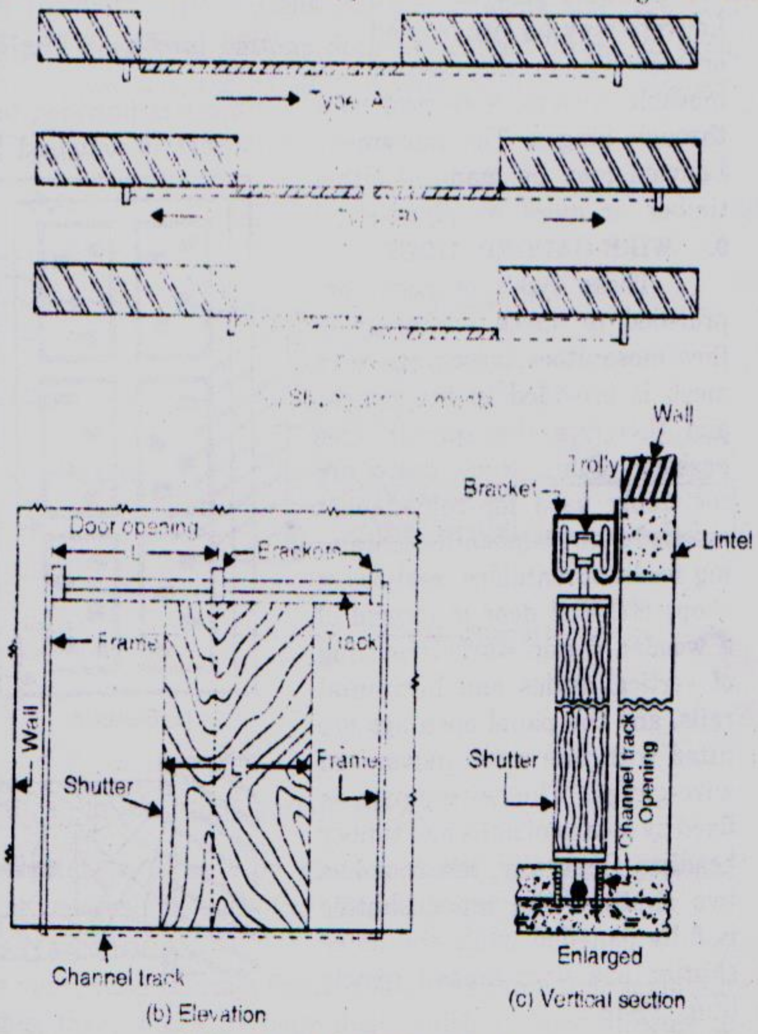



FIG. 17.20. SLIDING DOOR.

rangements. Fig. 17.20 (*b*) shows the front view of a sliding door with single shutter, while Fig. 17.20 (*c*) shows its vertical section.

## 12. SWING DOORS

A Swing door has its leaf attached to the door frame by means of special *double action spring hinge,* so that the shutter can move both inward or outward as desired. Generally, such doors have single leaf, but two leafs can also be provided. Such doors are not rebated at the meeting styles , the closing edges of which should be segmental. When the door is to be used, a slight push is made and then the action of spring brings the shutter in closed position . The return of the shutter is with force, and hence in order to avoid accident, either the door should be fully glazed or a peep hole should be provided at the eye level, as shown in Fig. 17.21.

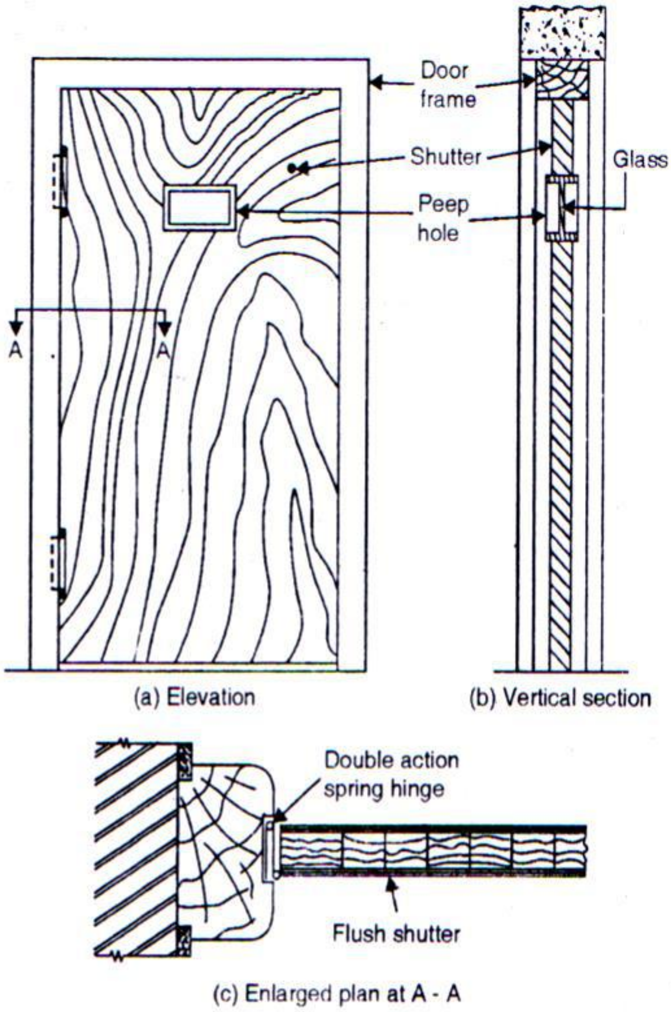



FIG. 17.21. SWING DOOR.

## 13. COLLAPSIBLE STEEL DOORS

Such doors are used in godowns, workshops, sheds, public buildings etc., for providing increased safety and protection to property. The door neither requires hinges for opening and closing, nor any frame for hanging them. It acts like a steel curtain which can be opened or closed by horizontal push. Such a door is even provided in residential buildings where opening is large but there is not enough space to accommodate leafed shutters. The door is fabricated from vertical double channels (20 × 10 × 2 mm) joined together with the hollows on the inside, so that a vertical gap is created. Such channel units are spaced at 100 to 120 mm apart and are braced flat iron diagonals 10 to 20 mm wide and 5 mm thick. These diagonals allow the shutter to open out or get closed. The shutters operate between two iron rails of T-shape, one fixed to the floor and other to the lintel. Rollers mounted on horizontal piece are provided both at the top and the bottom ends of vertical pieces. The door is also provided with handles, locking arrangements, stoppers etc.

Metal windows, made of mild steel is becoming increasingly popular in private as well as public buildings, because of their strength and less cost. However, windows made of other metals, such as aluminium, bronze, stainless steel etc. are also used for those buildings where high degree of elegance finishing etc. is required. Aluminium windows are rust-proof, durable and require no maintenance and painting; they are therefore increasingly becoming popular for domestic buildings.

Fig. 17.31 shows a mild steel window. Mild steel windows are the cheapest, and are therefore extensively used in all types of buildings. Mild steel sections, used for the fabrication of metal windows, are manufactured in wide range of standard sizes. The commonly used sections are angle sections, Z-sections, T-sections and channel sections, all of which are slightly modified in shape to meet various requirements of window functioning. Steel windows can be fixed either directly to the masonry opening, or it may be fitted into wooden frame already fixed in the opening. Generally, the first alternative is adopted since it is cheaper. However, it should be ensured that no load of the wall etc., is transferred to the window frame. For this, it is usual practice to keep the size of window-opening slightly more than the window frame. Also, the frame may be fixed in the formed opening, after the masonry work is over.

**Method of fixing steel windows**

1. The prepared opening, in which steel window frame is to be fixed is cleared, and exact position of the window frame is marked by drawing chalk-lines along the verticals and head and sill of the window frame.

2. The distances of fixing holes are measured on the frame, and these positions are marked on the chalk lines drawn in the joints of the opening.

3. Holes are cut in the brick masonry, of size 5 cm square and 5 to 10 cm deep, to accommodate hold fasts or *lugs*.

4. The frame is placed in the opening and its position is adjusted in correct alignment by striking wooden wedges in correct position. Since there is little gap between the opening and the window frame, temporary wooden wedges can be easily driven. After adjusting the window in correct alignment, the lugs are screwed tight to the frame.

5. The lugs are grouted into the holes with cement mortar.

6. After the grout has set, wooden wedges are removed, and the space between the opening and the frame (known as *surrounds*) is filled with cement mortar.

7. In the case of stone masonry or R.C.C. work, where it is difficult to cut holes for lugs, wooden plugs are embedded at appropriate places during the construction itself. the window frame is then fixed to these plugs with the help of galvanised iron wood screws.

**Advantages of Steel windows**

Steel windows have following advantages over timber windows:

1. Steel windows are generally manufactured in factories, with greater precision and better quality control.

2. They exhibit elegant appearance and stream lined-finishing.

3. Steel windows are stronger and more durable than wooden windows.

4. There is no contraction or expansion due to weather effects in the steel windows. Wooden windows have this defect.

5. They are rot proof and termite proof.

6. They are highly fire resistant.

7. Since steel windows are fabricated from thin sections, they provide more effective area for light and ventilation.

8. They grant better facilities for providing different types of openable parts.

9. They are easy to maintain, and the cost of maintenance is almost negligible.

**9. BAY WINDOWS**

Bay windows project outside the external wall of the room. This projection may be triangular, circular, rectangular or polygonal in plan. Such a window, shown in Fig. 17.32, is provided to get an increased area of opening for admitting greater light and air. They also provide extra space in the room, and improve the overall appearance of the building.

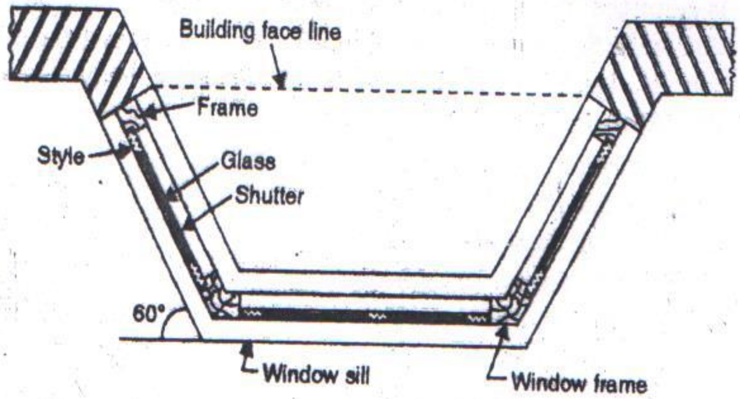



FIG. 17.32. BAY WINDOW.

**10. CLERE-STOREY WINDOW** (Fig. 17.33)

These windows are provided in a room which has greater ceiling height than the surrounding rooms, or when a lean-to-roof of low height is there adjacent to the room. It is generally provided near the top of the main roof, and they open above the lean-to-roof, or roof slab of adjoining rooms. The window shutter is made to swing on two horizontal shutters provided on side styles. It can be opened or closed by means

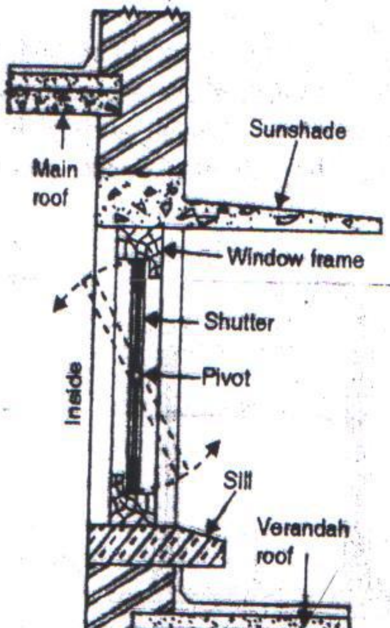



FIG. 17.33. CLERE-STOREY WINDOW.

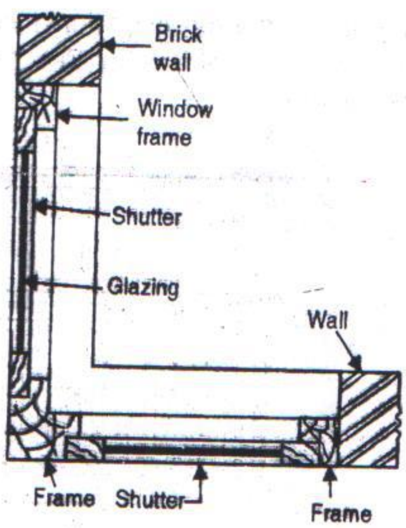



FIG. 17.34. CORNER WINDOW.

of two cords, one attached to the top rail and other to the bottom rail of the shutter. The shutter swings in such a way that upper part opens inside the room and the lower part opens outside, to exclude rain water. Such a window increases the appearance of the building. It is essential to provided a rain-shed or chhajah over the window.

## 11. CORNER WINDOWS

This is a special type of window which is provided in the corner of a room. This window has two faces in two perpendicular directions. Due to this, light and air is admitted from two directions. Such a window very much improves the elevation of the building. However, special lintel has to be cast over the window-opening. The jamb post of the window, at the corner, is made of heavy section, as shown in Fig. 17.34.

## 12. DORMER WINDOWS

A dormer window is a vertical window provided on the sloping roof, as shown in Fig. 17.35. Such a window provides ventilation and lighting to the enclosed space below the roof, and at the same time, very much improve the appearance of the building.

## 13. GABLE WINDOWS

It is a vertical window provided in the gable end of a pitched roof, as shown in Fig. 17.35.

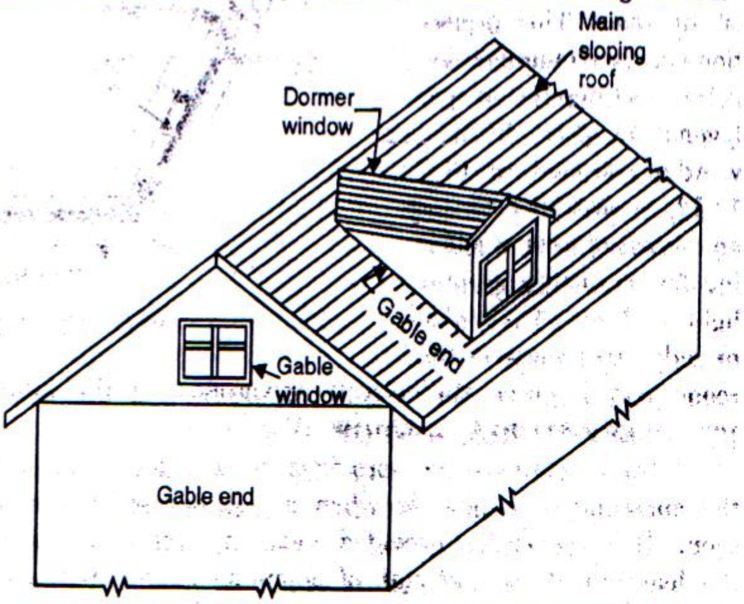


FIG. 17.35. DORMER WINDOW AND GABLE WINDOW

## 14. LANTERN WINDOWS

Such windows are provided over the flat roofs, to provide more light and air to the inner apartments/rooms of a building. The windows project above the roof level. They may be of several shapes in plan. They admit light either through vertical faces or inclined faces, as shown in Fig. 17.36 . The roof slab has an appropriate opening below the window.

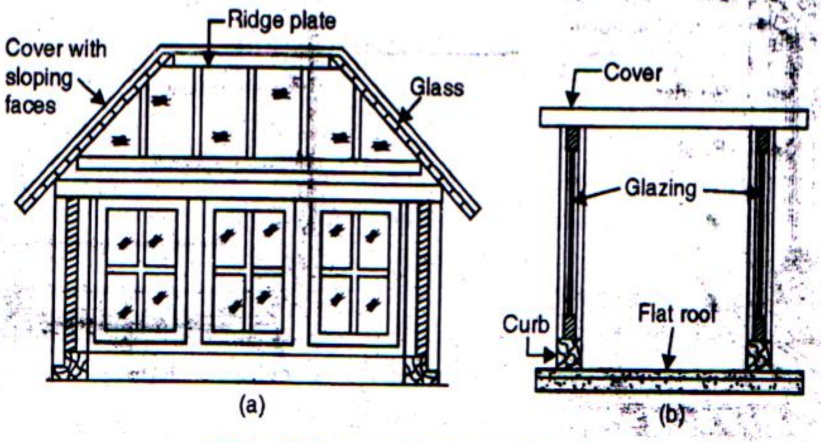


FIG. 17.36. LANTERN WINDOWS.

## 15. SKY LIGHTS

A sky light is provided on a sloping roof, to admit light. The window projects above the top, sloping surface. They run parallel to the sloping surface. The common rafters are suitably trimmed and the sky light is erected on a curb frame shown in Fig. 17.37. The opening so made is properly treated by lead flashing to make the roof, surrounding the opening, water-proof.

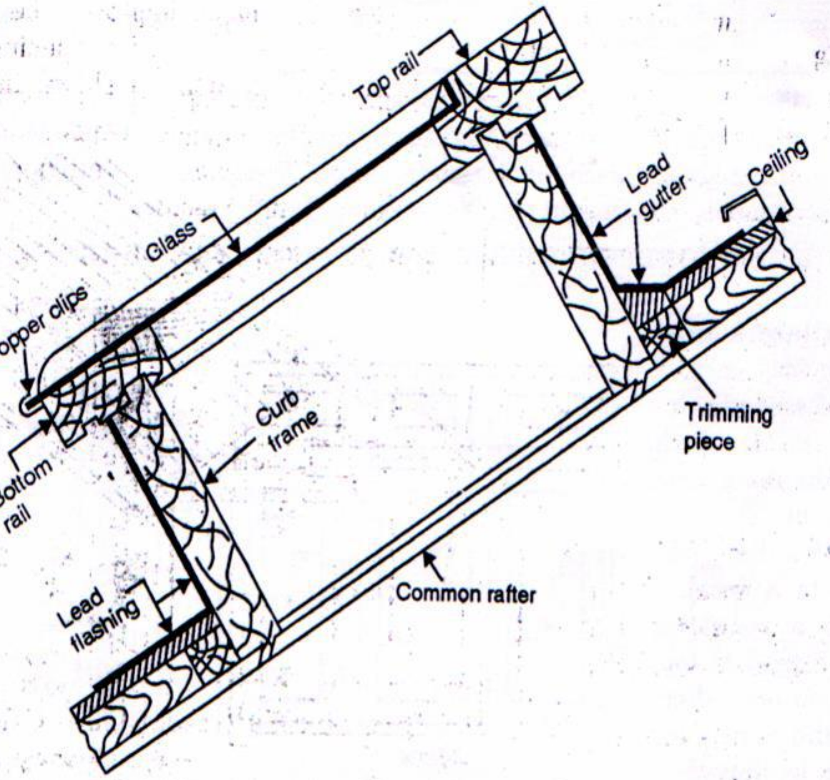



FIG. 17.37. SKY LIGHT.

## 16. VENTILATORS

Ventilators are small windows, fixed at a greater height than the window, generally about 30 to 50 cm below roof level. The ventilator has a frame and a shutter, generally glazed, which is horizontally pivoted. The shutter can be opened or closed by means of two cords, one attached to the top rail and other to the bottom rail of the shutter. The top edge of the shutter opens inside and bottom edge opens outside, so that rain water is excluded.

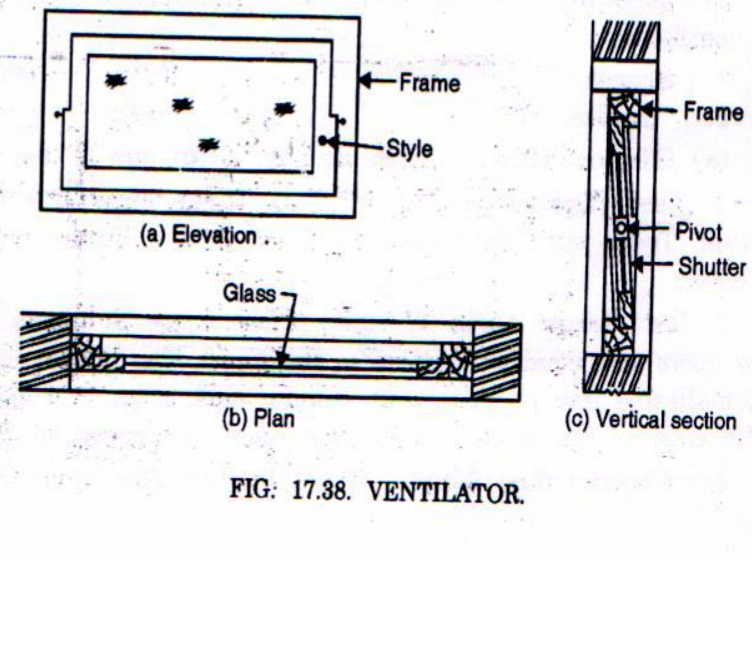



FIG. 17.38. VENTILATOR.

TABLE 17.3 DIMENSIONS OF VENTILATORS

| S.No. | Designation | Size of opening (mm) | Size of ventilator frame (mm) | Size of ventilator shutter (mm) |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
| 1. | 6 V 6 | 600 × 600 | 590 × 590 | 500 × 500 |
| 2. | 10 V 6 | 1000 × 600 | 990 × 590 | 900 × 500 |
| 3. | 12 V 6 | 1200 × 600 | 1190 × 590 | 1100 × 500 |

Table 17.3 gives the dimensions of ventilator openings, size of ventilator and size of ventilator shutter. In the designation, the first number denotes the width of the opening in modules, each of 100 mm, letter V denotes a ventilator, while the last number denotes the height of the opening in the modules.

## 17.9. VENTILATOR COMBINED WITH WINDOW OR DOOR : FAN LIGHT (Fig. 17.39)

Ventilators may also be provided in continuation of a window or a door, at its top. Such a ventilator is also known as a fan light. The construction of a fan light is similar to a window sash. Such a ventilator is usually hinged at top, and can open out. Alternatively, the ventilator shutter can be hinged at the bottom.

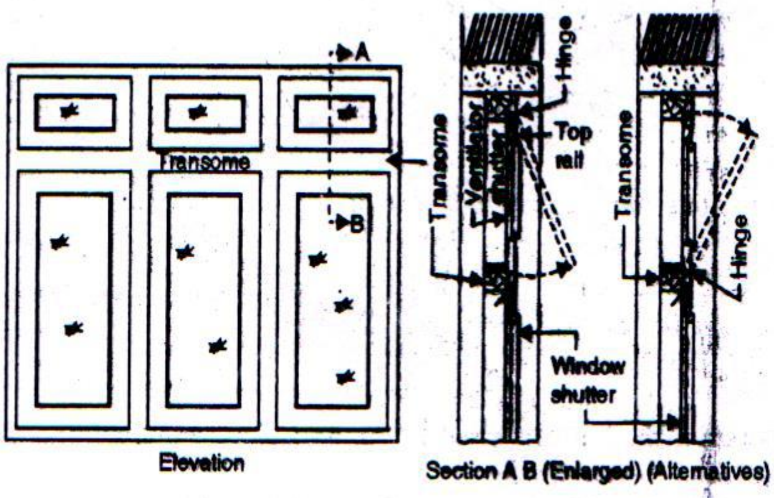



FIG. 17.39. VENTILATOR COMBINED WITH WINDOW.

## 17.10. FIXTURES AND FASTENINGS

The following types of fixtures and fastenings are required for doors, windows and ventilators :

1. Hinges.
2. Bolts.
3. Handles.
4. Locks.

(*a*) **Hinges.** Hinges, shown in Fig. 17.40, are of the following types :

1. ***Back flap hinge*** (Fig. 17.40 *a*). These hinges are used where the shutters are thin. These are fixed to the back side of the shutter and the frame, and hence the name.

2. ***Butt hinge*** (Fig. 17.40 *b*). These types of hinges are commonly used for fixing doors and window shutters to the frame. The flanges of hinge are made of cast iron, malleable iron or steel, with counter sunk holes. One flange of hinge is screwed to the edge of the shutter while the other is screwed to the rebate of the frame.

3. ***Counter-flap hinge*** (Fig. 17.40 *c*). This hinge is formed in three parts

## BUILDING SERVICES

**PLUMBING SERVICES (WATER DISTRIBUTION, SANITARY)**

How best a building might have been planned and built; it is incomplete till adequate building services are not provided to it. Building / Plumbing services include:

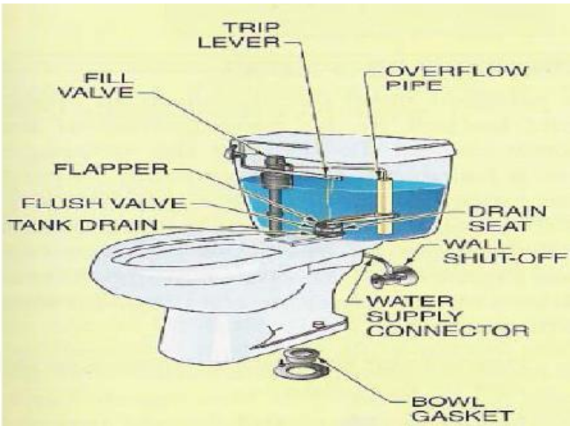
- Water distribution system
- Sanitary fittings and
- Effective drainage system

Sufficient quantity of water is provided to the building for the needs such as drinking, bathing, washing of cloths and washing of floors. More quantity of water is used through sanitary fittings like water closets, wash basins, sinks, bath rooms etc.. After use of whole water, some quantity of water gets polluted and has to be drained off through the underground drains. In addition, telephone services and electric fittings are also come under the preview of building services.

**WATER DISTRIBUTION SYSTEM / WATER SUPPLY**:

Water supply to water closets; bath rooms, wash basins, kitchens etc of a building is provided through water supply pipes from municipal water mains which run along the streets. Over head water storage tanks are also connected to municipal mains through pipes with the help of ferrule.

Ferrule




Water closet

Requirement of water for residences should be assumed as 135 liters per head per day whereas the requirement varies from 45 to 70 litres per day for schools / restaurants / offices per seat.

For water supply to the buildings / offices, always galvanized iron pipe of 15 mm dia is used. From municipal mains to house, the pipe line may be buried underground by arranging elbows, nipples, clamps, sockets, bends, bib-taps, check nut/ unions, gate valves/ball valves etc.. and finally connected to bath rooms, kitchens, wash basins, sinks. A water meter is also provided to the municipal mains at the entry level of water mains to a building.

**SANITARY LINES & FITTINGS:**

For collection of water, various types of sanitary fittings are required and to be fitted in the building. All these fittings should be as far as possible be fitted against an external wall. Following are some of the examples for sanitary fittings:

WASH BASINS: These are used for washing hands, tooth brushing, face washing etc and usually fixed that the height from the floor to the top of the basin is 78.5 cm.

SINKS: These are used cleaning of utensils in kitchens or glassware items in laboratories. Sinks are rectangular basins made from glazed earthen ware or stone-ware with flat bottom and all their internal angles are made round for easy cleaning.. Sinks are fixed in such a way that height of the top of the sink from floor is 90 cm.

BATH TUBS: These are made from enameled iron, plastic, Cast Iron, porcelain, marble. Normal dimensions of bath tubs are as follows:

| | | | |
|---|---|---|---|
| Length | ……… | 1.7 - 1.85 | mtr |
| Width | ……… | 70– 75 | cm |
| Overall height | ……... | 58– 60 | cm |

The bath tub is provided with a tap to fill it with water and an outlet to drain the water. In some tubs two taps are provided, one for hot and another for cold water supply. Bath tub should also be provided with one over-flow pipe to take away excessive spilling water.

WATER CLOSET (W.C.): It is used to receive human excreta directly from persons using it. The appliance is connected to the porcelain pipe by means of a trap. The water closets may be Indian type or European type. Both these WC’s have an arrangement of flushing the discharged excreta by the persons with the help of water.

| | |
|---|---|
|  |  |
| Indian W C | European W C |

URINAL SYSTEMS: Urinal systems are used to discharge urine. They may be bowl type or stack type.. Urinals are discharged into the pipe through a nehani trap. Urinals should be designed to allow a minimum clear width of 60 cm between partition. The number of stack urinals draining into any one outlet should preferably be not more than 5 in case of public buildings.

| | |
|---|---|
|  |  |
| Bowl type urinals | Stack type urinals |

**DRAINAGE SYSTEM:** Drainage of a locality can be divided into public drainage and private drainage systems.

Under public drainage category, municipal sewers/drains are laid along the roads and are properly maintained by municipal / corporation authorities. Houses and buildings are constructed along both the sides of the roads by laying own sewer lines inside the house / building premises under the category of private drainage system. These sewer lines collect sewage / waste water from bathrooms, kitchens, water closets etc fitted in the building and convey it to the municipal sewers.

So, the system of sewer lines or drains laid in the premises of a building is called the house drainage.

Principles of house drainage:

- House sewers / drains should be laid as far as possible by the side of a building rather than below the building..

- The size of drain should be adequate for maximum discharge from the house.

- Drains should be laid at proper gradient so that the lowest level of the building may drain in it.

- Drain should be laid on good foundation and protected against external loads.

- As far as possible, drains should be laid in straight lines with successive inspection chambers.
- The house drain should be connected to the public sewer line which is always lower than the level of house sewer else, the flow in reverse direction may take place.

# Plumbing for Buildings

## 30.1. INTRODUCTION : PLUMBING SERVICES

Public water supply systems follow the sequence of water collection from source of supply, conveyance to treatment plants, treatment including disinfection and, finally, its distribution. Ultimately, water is distributed for various consumption purposes in a building through internal water distribution system. In every building, adequate quantity of water should be available at required locations, to meet various needs of the occupants. Before designing a building, water needs must be properly computed. The transmission of water within the building is carried through pipes which may run either underground or above ground. The water so supplied ultimately gets converted into *waste water*, which has to be properly *drained*. Various fittings used for use of water, and for drainge of used water are commonly known as *sanitary fittings*.

The services like water supply, drainage, sanitation etc. are sometimes known as *plumbing services*. *Plumbing* is a general term indicating the practice, materials and fixtures used in the installation or maintenance of all piping, fixtures, appliances and other appertenances used in connection with water supply system as well as sanitary and storm water drainage system within a building and its connection with any point of public disposal. The *plumbing system* comprises the entire system of pipings fixtures and appliances etc. used for water supply and drainage. Thus a *plumbing water supply system* comprises of water supply and distribution pipes, taps, valves, storage tanks etc., while *plumbing drainage system* consists of wash basins, water closets, urinals, traps, soil waste pipes, vent pipes, septic tanks etc. etc.

## 30.2 WATER DISTRIBUTION SYSTEM

Water is collected from the water main through a service connection. The layout of water distribution piping may be basically a horizontal or vertical arrangement of limited height and in which underground mains *under pressure* supply water to the fixture inlets. Such a system is known as unfeed system. Alternatively, water is first collected in underground tank (known as suction tank) and then it is pumped to elevated storage tanks, usually situated at the top of the building. From these elevated storage tanks, water can flow down and feed the fixtures.

### General considerations

While laying out the pipe lines, the following considerations should be kept in mind :

1. The lines should be so laid that there is no risk involved in the contaminating of water supply. For this, following three things are necessary :

(*a*) There is no cross-connection any where between a pipe carrying possible water and the pipe carrying used or waste water.

(*b*) There should be no back flow from any cistern or appliance towards the source of supply.

(*c*) Water supply pipes and waste water pipes (drainage pipes) should not be laid very close to each other.

2. The pipe line should be properly protected against any damage. To achieve this, underground pipe line should be enclosed in a cement mortar *bata* so that its rusting by soil bacteria is prevented, and also it should have earth cover of atleast 60 cm. When pipe line is laid above ground, it should run clear of water. Also, when it crosses a wall, it should be contained in suitable sleeve for the entire length of the crossing.

3. In the unfeed system, pipe should carry water under adequate pressure. For this, lay out of pipe should be simple and direct as far as possible. The pipes should be laid out as straight as possible.

**Estimation of water requirements** : For *residential buildings*, Indian Standard recommends that a water requirement of 135 litres per head per day may be assumed. Out of this, 90 litres may be taken for domestic purposes while the balance 45 litres are taken for flushing requirements. The requirements of water for buildings other than residence may be found from Table 30.1.

**TABLE. 30.1. WATER REQUIREMENTS FOR BUILDINGS OTHER THAN RESIDENCES**

| *Type of building* | *Rate per head per day in litres* |
|---|---|
| 1. Factories, where bath rooms are required to be provided. | 45 |
| 2. Factories where no bath rooms are required to be provided. | 30 |
| 3. Hospital (including laundry) per bed.<br>(*i*) Number of beds not exceeding 100<br>(*ii*) Number of beds exceeding 100 | <br>340<br>450 |
| 4. Nurses homes and medical quarters. | 135 |
| 5. Hostels | 135 |
| 6. Hotels (per bed) | 180 |
| 7. Offices | 45 |
| 8. Restaurants (per seat) | 70 |
| 9. Cinemas, concert halls and theatres (per seat). | 15 |
| 10 Schools<br>(*a*) Day Schools<br>(*b*) Boarding Schools | <br>45<br>135 |

## 30.3. MATERIAL FOR SERVICE PIPES

The pipe leading from the distribution main of the municipal water supply to the plumbing system of the house is known as the *service main*. The following materials are commonly used for service pipes :

(*i*) Copper pipe or brass pipe

(*ii*) Galvanised iron, either lined or unlined (*iii*) Lead pipe, either lined or unlined

(*iv*) Polythene pipe.

**1. Copper tubing**. Copper tubing is non-corrosive with most waters. It is used extensively in better grade houses and where ground water is highly corrosive to steel pipe. It has considerable strength, reasonable ductility, and is obtainable in long lengths. There are two types of copper water service pipes : *heavy gauge* and *light guage*. The former can be threaded and is used for high pressure work in industrial layouts. For general purpose work where pressure does not exceed 0.15 N/mm$^2$, and for interval domestic work, light gauge tube is used. For underground work, as for the pipe from the main to the building, special copper tube is used having a heavier guage. The copper tube can be attached to the main without the use of conventional goose neck, the flared end of the tubing being connected directly to the corporation cock without threading.

**2. G.I. pipes.** These are used where water is suitable. In India, these are extensively used because of their low cost in comparison to copper tubes. Galvanised iron or steel tubes corrode more readily in soft and acid waters and are not so easily manipulated as copper, although they are stronger and can be used in hard water area where they withstand the hammering needed to remove the scale.

**3. Lead pipe.** Lead pipe has the following advantages (*i*) highly resistant to corrosion (*ii*) highly flexible and (*iii*) high hydraulic coefficient of flow. However, lead has cumulative poisoning effect, specially when it goes into solution. Due to this, it is not preferred.

**4. Polythene tube**. These are being increasingly used internally and externally for cold water service pipes only. Plastic pipe has the following advantages over metal piping. (*i*) it is lower in cost (*ii*) it is non corrosive (*iii*) it is light in weight (*iv*) it can be installed with ordinary tools, (*v*) it does not require threading (*iv*) it is more resistant to bacterial scale and (*vii*) it has some insulating value. However, these are not useful where temperature is high.

## 30.4. SERVICE CONNECTION

A service connection is primarily a connection from the distribution system to the consumer. A consumer may be a single house, an apartment house, a planned block development or a water district buying water 'wholesale'. A connection for a single house will normally involve tapping the main while it is under pressure and installing a corporation cock. A domestic service connection includes the following components:

**1. Brass or bronze ferrule**. Ferrule is a right angled sleeve made of brass or bronze. For a typical service connection to a house, a ferrule is inserted in the main, most usually an 'under pressure' connection which can be inserted without shutting down the main.

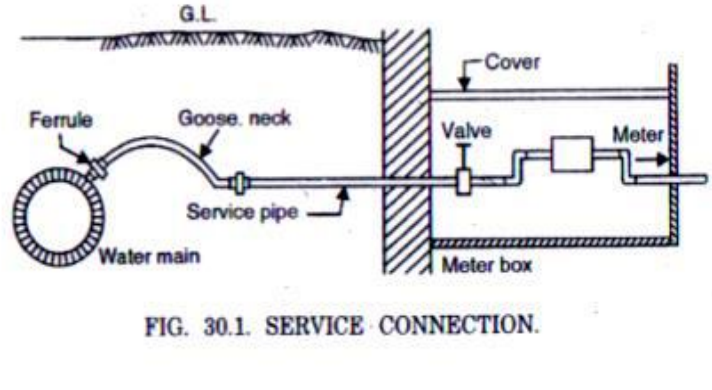



FIG. 30.1. SERVICE CONNECTION.

**2. Goose neck.** This consists of a 40 to 50 cm long curved piece of flexible pipe made of brass, copper or lead. The goose neck prevents the breaking of the main service pipe due to movement that takes place between the water main and the service pipe, thus providing flexibility of the junction.

**3. Stop cock or curb valve.** It is installed in a suitable chamber with cover, to close down the supply, for repairs of the plumbing system.

**4. Main service pipe.** It may be of various materials discussed in Sec. 30.3. Its diameter may very from 12 mm to 40 mm.

**5. Water meter.** It is also installed in a suitable chamber with cover. It measures the quantity of water used by the consumer.

## 30.5. SIZE OF SERVICE PIPES

The size of the service pipes are determined on the basis of the following : (*i*) the minimum pressure in the distribution main at the proposed point of connection, (*ii*) length of service pipe required, (*iii*) elevation of the highest point of delivery above the distribution mains, (*iv*) number and types of plumbing fixtures in the building, and (*v*) maximum rate of flow required. The maximum rate of flow may be estimated by considering what the average householder expects at his plumbing fixtures. Guidance may be taken from Table 30.2.

**TABLE 30.2**

| *Plumbing Fixture* | *Flow Required (litres/min.)* | |
|---|---|---|
| | *Good* | *Reasonable* |
| Kitchen Tap | 10 | 7 |
| Bath Tap (cold) | 25 | 15 |
| W.C. flushing cistern | 10 | 7 |

If it is assumed that one of each of these is in operation simultaneously, a maximum demand rate of 29 to 45 litres/min. is obtained. Knowing the rate of flow and the desired velocity, pipe diameter can be found. Alternatively, the diameter of service pipe can also be fixed on the basis of occupants in the house, as given in Table 30.3.

**TABLE 30.3**

| *No. of occupants* | *4* | *8* | *24* | *60* |
|---|---|---|---|---|
| Dia. of service pipe (mm) | 12.5 | 20 | 25 | 30 |

## 30.6. WATER METER

Water meter is normally used for measuring flows to domestic buildings. A water meter should possess the following characteristics:

1. It should accurately measure and register both small and large flows.
2. It should be easy to maintain and repair. Spare parts should be readily available.
3. It should have good capacity with reasonable head loss.
4. It should be capable of working at all pressures efficiently.
5. It should be durable. Its parts should not be affected by chemicals used for purification and the impurities in water.
6. It should be rugged.
7. It should prevent back flow passing through it and should not be liable to clogging.
8. It should have low cost.

Meters used on water distribution systems may be of two types :

(a) Inferential or velocity meters, and

(b) Positive or displacement meters.

**Inferential meter**. It measures the velocity of flow across a cross-section whose area is known. They are used only for high flows. Common examples of this type of meters are the rotary and the turbine meters.

**Displacement meter.** These are primarily used for relatively low flows as for the residential buildings. In this meter, the quantity of water actually passing through it is measured by filling and emptying the chamber of known capacity. Types of displacement meters in use include resiprocating, rotary, oscillating and nutating disc meters, depending upon the motion of the moving part in the measuring device.

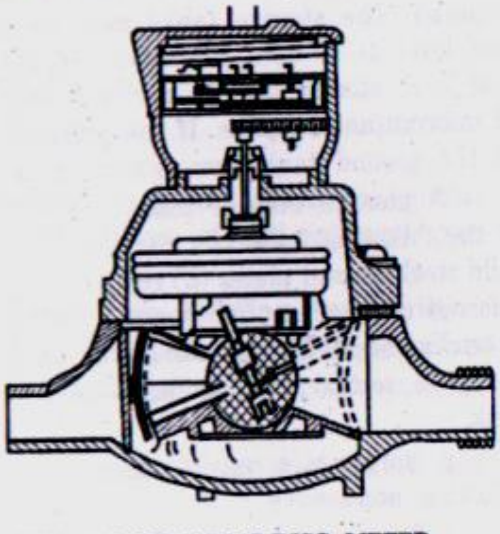


FIG. 30.2 NUTATING-DISC METER.

Disc meter, shown in Fig. 30.2 consists of a disc of hard rubber placed inside a chamber which is provided with inlets and outlets. The water entering the chamber oscillates the disc about its centre with a spiral motion. The oscillations imparted by one complete filling and emptying are recorded by the disc meter in terms of volume of water.

## 30.7. VALVES

For domestic water supply, two types of valves are commonly used :

(a) Globe valve, and (b) Gate valve.

**Globe valve**. It is used in pipe lines for convenience in manually closing the pipes to control the flow of water. Fig. 30.3 shows the section of a globe valve. It should be installed with water pressure under the valve seat as shown. The globe valve has advantage of quicker opening and closing, of longer life and of being more easily repaired.

**Gate valve.** Gate valve is used in pipe lines for convenience in manually closing the pipes. The gate valve has an advantage over the globe valve in that it offers less resistance to flow. It is therefore

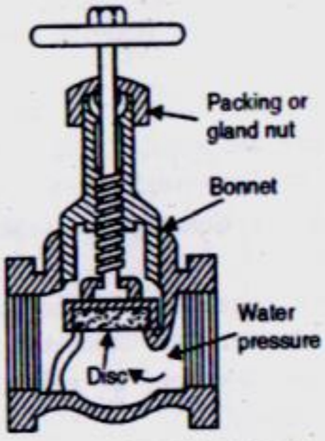



FIG. 30.3. GLOBE VALVE.

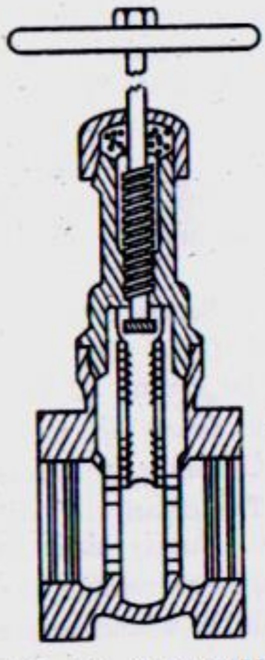


FIG. 30.4 GATE VALVE.

used in preference to the globe valve where resistance to the flow of water is to be kept at a minimum. It also controls the flow equally well from either direction.

## 30.8 STORAGE TANKS

The water supply to a building may either be continuous or intermittant. Even in the case of continuous supply in the mains, the pressure of water may not be sufficient to rise to all the floors of the building. In either case, storage tanks are required. The storage tanks may be situated either at the ground level, or at the roof level or at both the levels. If the pressure of water is sufficient to rise to the roof level, storage tank is provided only at the roof level, so as to store water because of intermittant supplies. If the pressure of water is not sufficient, water is first stored at the ground tank from where it is pumped to the top storage tank.

A storage tank is made of the following materials : (*i*) mild steel pressed plates (*ii*) reinforced concrete, or (*iii*) stone or brick masonry. Fig. 30.5 shows a typical section of a storage tank.

A storage tank consists of following accessories :

1. *Top cover* made of mild steel, aluminium or other suitable material, light in weight and tight fitting so that mosquitoes do not enter. It may have locking arrangement.

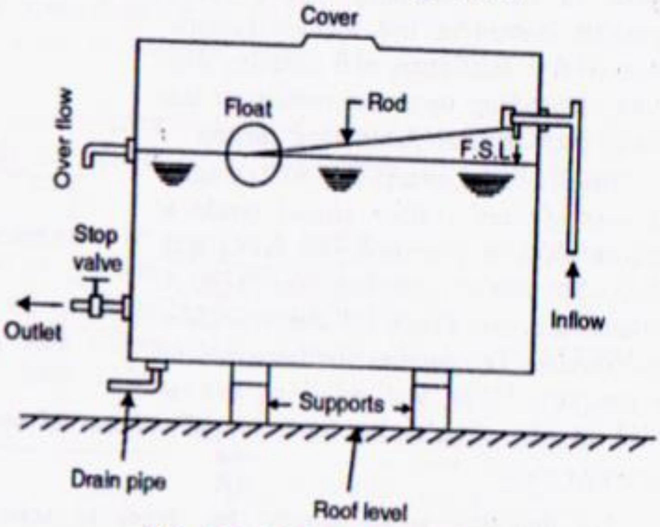



FIG. 30.5. STORAGE TANK.

2. *Ball valve with float* which is provided near the inlet to the tank, so as to control the inflow of water. The float assembly works automatically, thus maintaining a constant water level in the tank. When the water level falls down, the float moves down thus opening the inlet valve. When the level in tank reaches the desired full supply level (F.S.L.), the float rises up thus closing the inlet valve.

3. *Over flow pipe* which is set about 2.5 cm above F.S.L. In case the float assembly fails, the inflow is not cutoff and the water entering the tank overflows through this pipe.

4. *Supply pipe or inlet pipe*, admitting water into the tank.

5. *Outlet pipe with stop valve* set about 2.5 to 5 cm above the bottom of the tank, for cutting off the supply to down tank pipes.

6. *Drain pipe or scour pipe* for cleaning the tank periodically.

**Capacity of storage tank**

The capacity of storage tank depends upon the following factors:

(*i*) Supply hours from the mains, with sufficient pressure.

(*ii*) Frequency with which the tank can be refilled during 24 hours.

(*iii*) Rate and regularity of supply.

In the case of multi storeyed building, the first two or three storeys may be fed directly from the water mains while upper storeys are fed directly from the storage tanks. However, if the supply is either intermittant or irregular, storage may be provided for all the storeys. Table 30.4 give Indian Standard Recommendations for domestic storage capacities.

**TABLE 30.4. DOMESTIC STORAGE CAPACITIES**

| | |
|---|---|
| (*A*) For premises occupied as tenements with common convenience | |
| 1. Ground floor | No storage required, provided no down take fittings are installed. |
| 2. 1 st, 2nd, 3rd, 4th and upper floors | 500 litres per tenement. |
| (*B*) For premises occupied as flats or blocks : | |
| 1. Ground floor | No storage required, provided no down take fittings are installed |
| 1. 1 st, 2nd, 3rd, 4th and upper floors | 800 litres per tenement |

**Flushing storage tank**. These tanks are required to supply water to the various flushing cisterns through down tank pipes. The supply pipes of a building do not directly feed water to these cisterns. The storage capacities for flushing purposes depend upon the number of water closets (W.C.) and urinals in a building. Table 30.5 gives I.S. code recommendations for flushing storage capacities for various types of buildings.

**TABLE 30.5. FLUSHING STORAGE CAPACITIES**

| *Classification of building* | *Storage Capacity* |
|---|---|
| 1. For tenements having common conveniences. | 900 litres net per W.C. seat. |
| 2. For residential premises other than tenements having common conveniences. | 270 litres net for each W.C. seat and 180 litres for each additional seat in the same flat. |
| 3. For factories and workshops. | 900 litres per W.C. seat and 180 litres per urinal seat. |
| 4. For cinemas, public assembly hall etc. | 900 litres per W.C. seat and 360 litres per urinal seat. |

## 30.9. HOUSE DRAINAGE : GENERAL PRINCIPLES

The arrangement provided in a house or building, for collecting and conveying waste water through drain pipes, by gravity, to join either a public sewer or a domestic septic tank, is termed as *house drainage* or building drainage.

### Aims of house drainage

House drainage is provided

(*i*) to maintain healthy conditions in the building

(*ii*) to dispose off waste water as early and quickly as possible

(*iii*) to avoid the entry of foul gases from the sewer or the septic tank

(*iv*) to facilitate quick removal of foul matter (*e.g.* human excreta)

(*v*) to collect and remove waste matters systematically

### Principles of house drainage

The following principles are adopted for the efficient drainage system :

1. The lavatory blocks should be so located that the length of drainage line is minimum. In the case of multistoreyed building they should be located one above the other. At least one wall of the lavatory block should be an outside wall, to facilitate the fixing of soil and vent pipes.

2. The drainage pipes should be laid by the side of the building rather than below the building.

3. All the drains should be aligned straight between successive inspection chambers. All sharp bends and junctions should be avoided except through chambers.

4. The slope of the drains should be sufficient to develop self cleansing velocity.

5. The size of drain should be sufficient, so that flooding of the drain does not take place while handling the maximum discharge.

6. The drainage system should contain enough number of traps at suitable locations.

7. The house drain should be disconnected to the public sewer by the provision of an intercepting trap. This will avoid the entry of foul gases from entering the house drainage system. It should be seen that the public sewer is deeper than the housedrain.

8. Rain water pipes should drain out rain water directly into the street gutters from where it is carried to the storm water drain.

9. All the connections should be water tight.

10. The entire drainage system should be properly ventilated from the starting point to the final point of disposal. It should permit free circulation of air.

11. All the materials and fittings of the drainage system should be hard, strong and resistant to corrossove action. They should be non-absorbent type.

12. The entire system should be so designed that the possibilities of formation of air locks, siphonage, under deposits etc. are minimised.

## 30.10. PIPES AND TRAPS

**Pipes.** In a house drainage system, a pipe may have the following designations, depending upon the function it carries :

1. ***Soil pipe.*** A soil pipe is a pipe through which human excreta flows.

2. ***Waste pipe.*** It is a pipe which carries only the liquid waste. It does not carry human excreta.

3. ***Vent pipe.*** It is a pipe which is provided for the purpose of the ventilation of the system. A vent pipe is open at top and bottom, to facilitate exit of foul gases. It is carried at least 1 m higher than the roof level.

4. ***Rain water pipe.*** It is a pipe which carries only the rain water.

5. ***Anti-siphonage pipe.*** It is pipe which is installed in the house drainage to preserve the water seal of traps.

The following sizes of pipes are commonly used in house drainage :

| | |
|---|---|
| Soil pipe | : 100 mm |
| Waste pipe : horizontal | : 30 to 50 mm |
| Waste pipe : vertical | : 75 mm |
| Rain water pipe | : 75 mm |
| Vent pipe | : 50 mm |
| Anti-siphonage pipe : | |
| (*i*) Connecting soil pipe | : 50 mm |
| (*ii*) Connecting waste pipe | : 40 mm |

**Traps**

A traps is a depressed or bent fitting which, when provided in a drainage system, always remains full of water, thus maintaining a *water seal*. It prevents the passage of foul air or gas through it, though it allows the sewage or waste water to flow through it. The depth of water seal is the vertical distance between the crown and dip of a trap (Fig. 30.6). The depth of water seal represents its *strength* or effectiveness. Greater the depth of water seal, more effective is the trap. The depth of water seal varies from 25 mm to 75 mm.

***Causes of breaking of seal*** . Water seal may break due to the following reasons:

(*i*) faulty joints

(*ii*) crack in the bottom of seal

(*iii*) creation of partial vacuum in the sewer fittings

(*iv*) increase in the pressure of sewer gases, and

(*v*) non-use for a prolonged period.

The breaking of the water seal can be prevented by (*i*) connecting the portion between the soil pipe and trap by a vent pipe, and (*ii*) use of anti-siphonage pipe in the building.

**Characteristics of traps** . A trap should possess the following characteristics:

1. It should possess adequate water seal at all times, to fulfill the purpose of its installation. However, it should retain minimum quantity of water for this purpose.

2. It should be of non-absorbent material.

3. It should be free from any inside projections, angles or contractions, so that flow is not obstructed or retarded.

4. It should be simple in construction, cheap and readily available.

5. It should be self cleansing.

6. It should be provided with suitable access for cleaning.

7. Its internal and external surfaces should have smooth finish so that dirt etc. does not stick to it.

**Classification of traps** : Traps are classified as follows :

(*a*) **Classification according to shape** (Fig. 30.6)

(*i*) ***P-Trap*** (Fig. 30.6 *a*). This resembles the shape of letter *P*, in which the legs are at right angles to each other.

(*ii*) ***Q-trap* or *half-S-trap*** (Fig. 30.6 *b*). This resembles the shape of letter *Q*, in which the two legs meet at an angle other than a right angle.

(*iii*) ***S-trap*** (Fig. 30.6 *c*). This resembles letter-*S*, in which both the legs are parallel to each other, discharging in the same direction. Fig. 30.6 (*d*) shows the development of all the three types of traps.

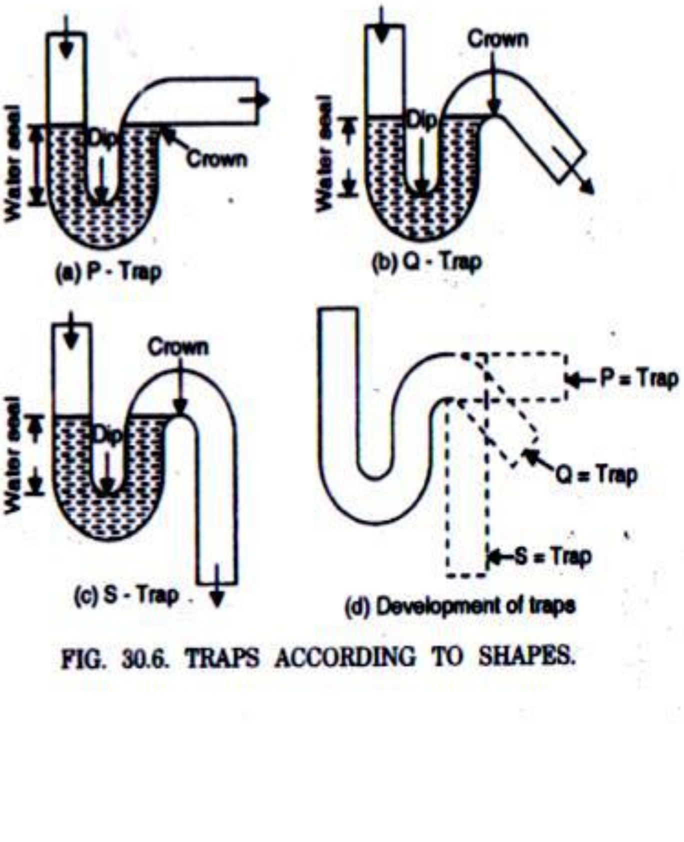



FIG. 30.6. TRAPS ACCORDING TO SHAPES.

**(b) Classification according to use :**

(i) Floor trap or nahni trap

(ii) Gully trap

(iii) Intercepting trap.

***Floor trap or Nahni trap***

A floor trap, commonly known as a *nahni trap* is used to collect wash water from floors, kitchens and bath rooms. It forms the starting point of waste water floor. It is made of cast iron, with a gravity at top, to exclude entry of solid matter of big size. This cover can be removed to do frequent cleaning of the trap. These traps have small water seal.

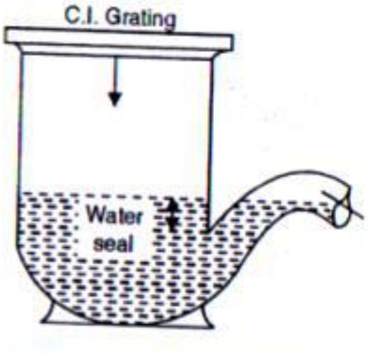



FIG. 30.7. FLOOR TRAP.

***Gully trap*** (Fig. 30.8)

These are special types of traps which disconnect sullage drain (collected from baths, kitchen etc.) from the main drainage system. It is either made of stone-ware or of cast iron. Stone ware gully trap is of square section at the top on which C.I. grating is fitted. Fig. 30.8 (*a*) shows such a gully along with its variations. A C.I. gully is circular in section, as shown in Fig. 30.8 (*b*), along with its variations. It can also be fitted in a masonry chamber as shown in Fig. 30.8 (*c*). A water seal of 60 to 70 mm is usually provided. It may have either a *S* trap and *P*-trap. A gully trap, is provided at the external face of a wall. It thus receives waste water from baths, kitchens etc. and pass it on to the house drain carrying excremental discharge from water closets etc. A well designed gully trap may serve two or three connections from nahni traps.

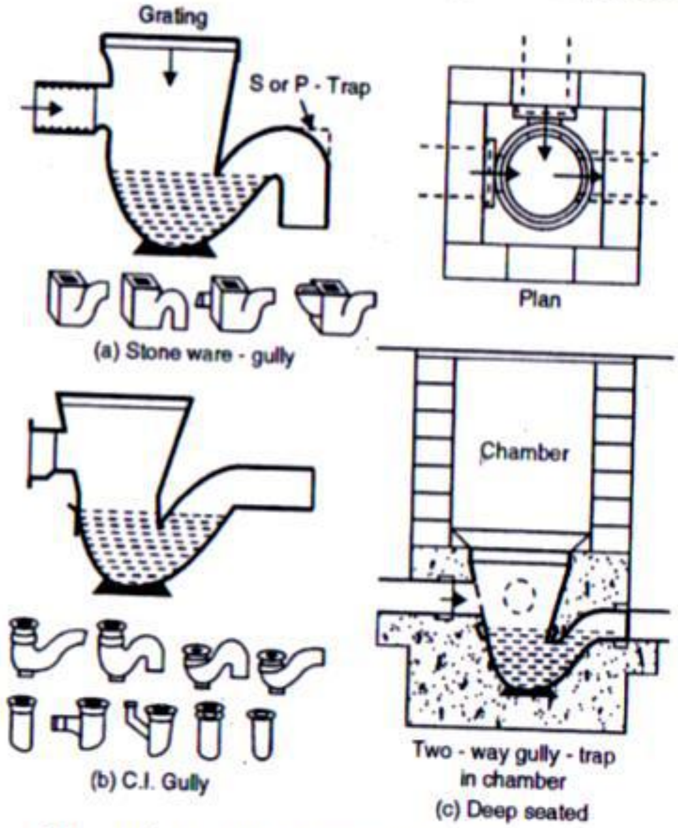



FIG. 30.8. VARIOUS FORMS OF GULLY TRAPS.

***Intercepting traps***

This is a special type of trap provided at the junction of house drain with the public sewer or septic tank. It is thus provided in the last manhole of the house drainage system. It has a deep water seal of 100 mm, so as to effectively prevent the entry of sewer gases from public sewer line into the house drain.

The trap has an opening at the top, called the *cleaning eye* or *rodding arm*, having a tight fitting plug, for frequent cleaning of the trap.

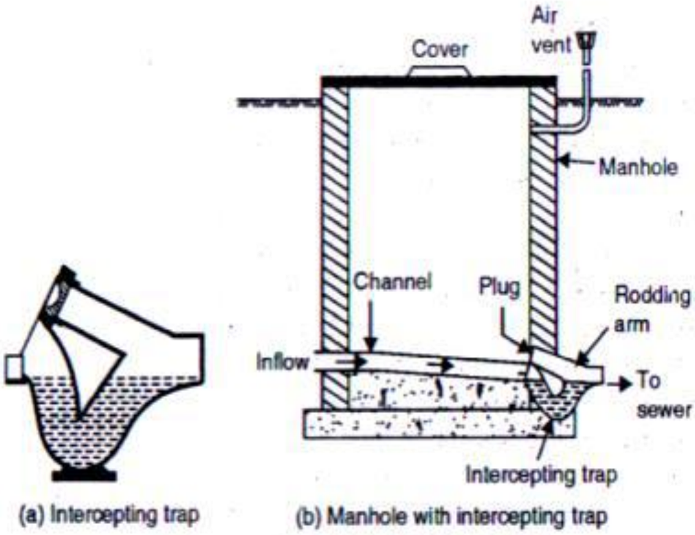



FIG. 30.9 INTERCEPTING TRAPS.

### *Grease traps*

Such traps are used only in large hotels, restaurants or industries where large quantities of oily wastes are expected to enter the water flow. If the oily or greasy matter is not separated, it will stick to the building drainage system resulting in the formation of ugly scum and consequent obstruction to reaeration. A grease trap is either a masonry or cast iron chamber, with a bent pipe or Tee-pipe at the outlet end. Because of sudden increase in the area of flow at entry, the velocity of flow is reduced, resulting in the separation of oily and greasy matter from the waste water. This greasy matter, floating on the top can be removed later.

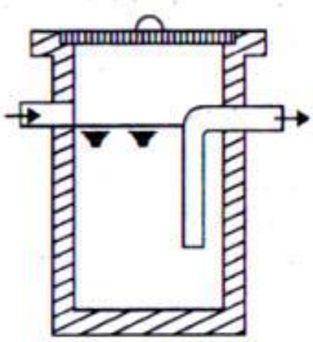


FIG. 30.10 GREASE TRAP

### *Silt traps*

If the water carries a lot of coarse particles of silt, sand etc., it is better to remove these before entering into the building drain. The silt particles normally enter the drain because of its use in washing the utensils. A silt trap is just similar to a grit chamber. Fig. 30.11 shows a combined silt and grease trap.

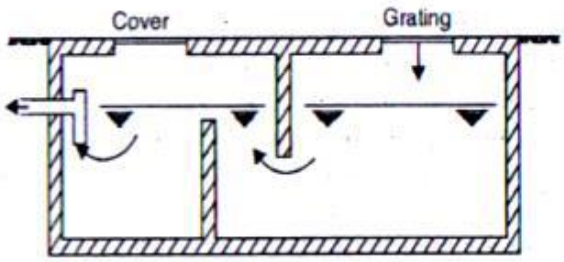



FIG. 30.11. COMBINED SILT AND GREASE TRAP.

## 30.11. SANITARY FITTINGS

The following fittings are commonly used in buildings, for efficient collection and removal of waste water to the house drain:

(*i*) Wash basins (*ii*) Sinks

(*iii*) Bath tubs (*iv*) Water closets

(*v*) Urinals (*vi*) Flushing cisterns.

**1. Wash Basin**

Wash basins are usually made of pottery or porcelain ware. Sometimes, they are also made of porcelain enamelled cast iron, pressed steel or plastic, specially where number of users are more. An ordinary wash basin is mounted on brackets fixed on wall, while a padestal type basin is mounted on padestal rising from wall. They are available in different shapes and sizes. Normally, a wash basin is provided with two taps- one for hot water and the other for cold water mounted at its top. It has an oval shaped bowl, with an overflow slot at the top. The waste pipe with a mettallic strainer is provided at the bottom of the bowl. The waste pipe has a trap at its bottom. Fig. 30.12 shows a flat bottom wash basin.

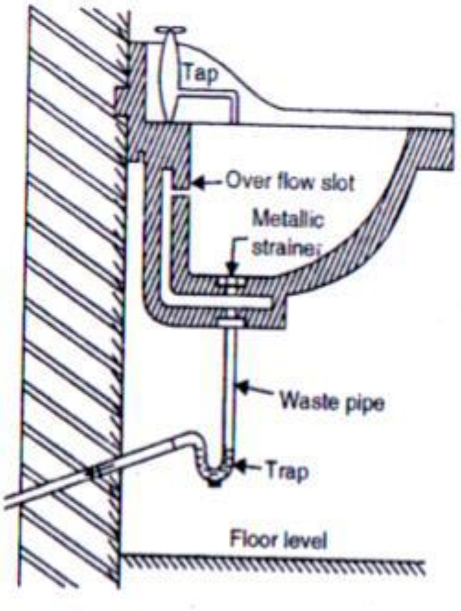



FIG. 30.12. WASH BASIN.

**2. Sink.**

While a wash basin is used for washing hands, face etc. a sink is used in kitchen or laboratory. These may be made of glazed fire clay, stainless steel, metal, porcelain or enamelled pressed steel. They are manufactured in various sizes and shapes, though rectangular shape is quite common in kitchens. It may also have a drain board attached to it. A sink may also be constructed of cast-in-situ concrete, with suitable finishing surface such as marble, terrazo etc. The out-let pipe, provided with a grating of brass or nickel, may discharge over a floor trap or nahni trap.

**3. Bath tub**

Bath tubs, are usually made of iron or steel coated with enamel, enamelled porcelain or of plastic material. They may also be made of cast-in-situ concrete finished with marble chips or terrazzo, or else may be made of marble slabs properly jointed at the side. It has a length varying from 1.7 to 1.85 m, width between 0.7 m to 0.75 m and depth near waste pipe varying from 0.43 m to 0.45 m. The overall height may vary between 0.58 to 0.6 m. It is provided with outlet and overflow pipes, usually of 40 mm diameter. A trap with proper waterseal is used at the outlet.

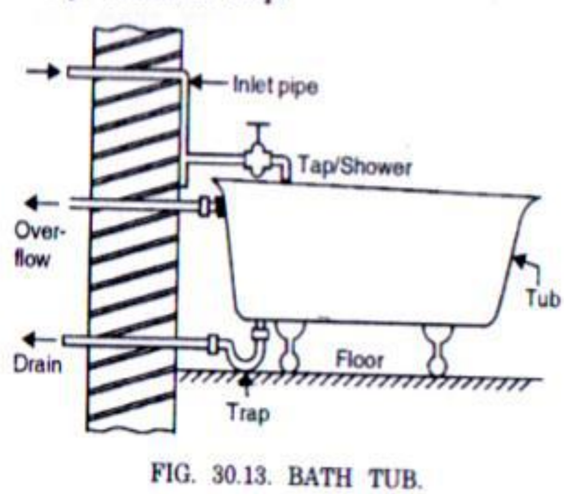



FIG. 30.13. BATH TUB.

**4. Water closets**

Water closets are designed to receive and discharge human excreta directly from the person using it. The appliance is connected to the soil pipe by means of a suitable trap. It is usually connected to a flushing cistern to flush the closet and discharge the human excreta to the soil pipe. Water closets are of three types.

(*i*) Indian-type

(*ii*) European type

(*iii*) Anglo-Indian type.

**1. Indian type W.C.** (Fig. 30.14 *b*)

The Indian style water closet (W.C.), shown in Fig. 30.14 (*b*) is simple in construction and working, but is used in squatting position. It is usually made of porcelain. The pan and trap are available in two different pieces. The trap has an opening for antisiphonage pipe. The W.C. is fixed in squatting (or siting) position just at floor level. Since the excreta does not directly fall into the trap, therefore, there are chances for excreta to become foul. The excreta may stick to the surface of the pan if the flushing is not proper. The flush water enters the rim of the pan through the opening provided in the front of the pan. The flushing cistern is normally kept 2 m above the closet. Indian type closet requires greater quantity of water (atleast 10 litres) for flushing.

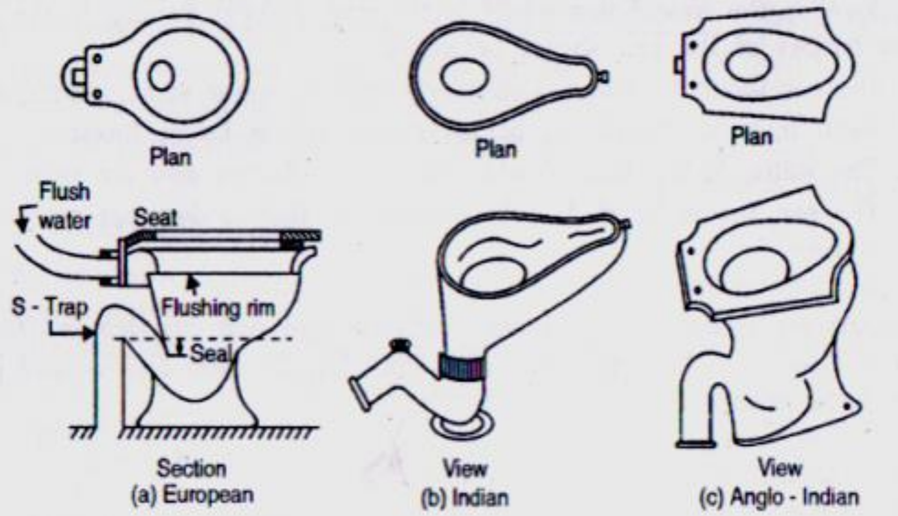



FIG. 30.14. WATE CLOSETS

**2. European type W.C.**

Fig. 30.14 (*a*) shows a typical European type water closet. It is usually made of porcelain. It is a wash down water closet, provide with a seat and a cover. The pan has flushing rim to spread the flush water. The excreta directly falls in the trap, and therefore there are less chances of excreta becoming foul. The padestal type European W.C. also known as *commode* is commonly used. The closet is fitted with either a P-trap or S-trap. It can also be used at upper floors, while in case of Indian type W.C., the upper floor has to be depressed to receive the pan fixed at floor level. Generally, a low level flushing cistern is used with the European ltype W.C.

**3. Anglo-Indian W.C.** [Fig. 30.14 (*c*)]

The main advantage of Indian type W.C. is that it can be used in squatting position since it is fixed at floor level, while an European type W.C., which is fixed at about 40 cm higher than the floor level, cannot be conveniently used in squatting position since the legs of the user cannot rest on thin rim conveniently. However, the defect with Indian W.C. is that the excreta does not fall directly in the trap. An Anglo-Indian W.C. removes both these defects. As shown in Fig. 30.14 (c), the closet is fixed about 40 cm above the floor level. However, the upper rim of the pan is properly enlarged so that legs can rest on it while using in squatting position. The inner shape of the pan is intermediate between the two types, with wider top area of the trap. The excreta directly falls in the water contained by the trap. The top flushing rim and seat etc. are similar to the European type.

**Requirements of a water closet**

The following are the requirements of a good water closet:

1. It should be convenient in use by persons of all age–both old as well as children.

2. The size of the pan should be such that the urine as well as the fecal material does not fall outside the pan.

3. The trap should be such that water does not splash when the excreta falls in water.

4. Urine should not splash outside the pan.

5. Fecal matter should flow easily in the trap, without sticking to the pan. For that the, surface of the pan should be smooth.

6. Flushing should be achieved effectively with the use of small quantity of water.

7. Fecal material should not be too plainly visible before flushing.

8. The water in the trap should provide an effective and air tight seal.

9. The pan should be of durable material, so that it does not crack with the passage of time.

**5. Urinals**

Urinals are usually of two types : (*i*) *bowl type and* (*ii*) *slab* or *stall type* . The former type in used in residential buildings while the later type is used in public buildings. A stall urinal normally has more than one units, with a centre to centre spacing of 0.6 to 0.7 m. Fig. 30.15 shows the two types of urinals. The best types of urinals are made of enamelled fire-clay, others of salt glazed stoneware, marble, slate and in cement. The contents of urinals are collected and discharged into the soil pipe through floor trap (nahni trap). Automatic flushing cisterns are generally provided for stall type urinals, which operates, at regular interval of 10 to 15 minutes.

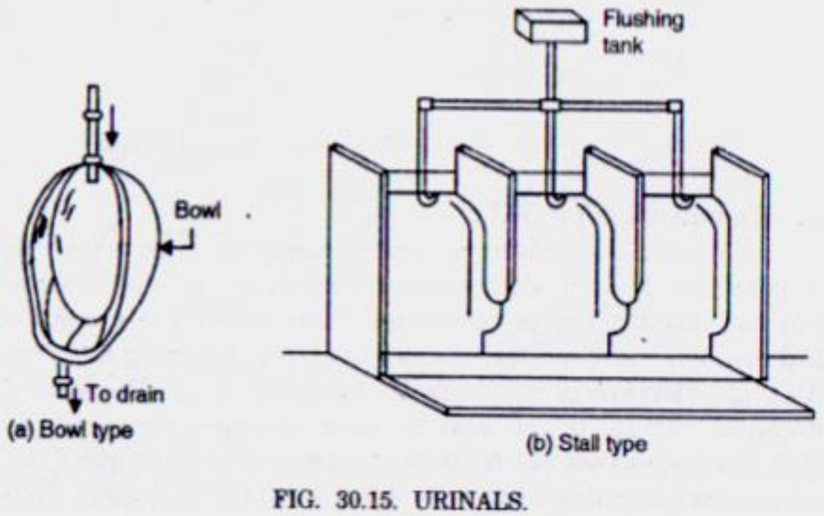



FIG. 30.15. URINALS.

**6. Flushing cisterns**

Flushing cisterns are used for flushing out water closets and urinals. These are made of either cast iron or of porcelain. For Indian type W.C., cast iron flushing cistern is normally used, fixed at about 2 m above the floor level. For European type and Anglo-Indian type closets, porcelain cisterns are normally used, fixed at about 60 cm above floor levels. The low level flushing cisterns, made of porcelain, are decent in look, and operate very easily by simply turning a handle.

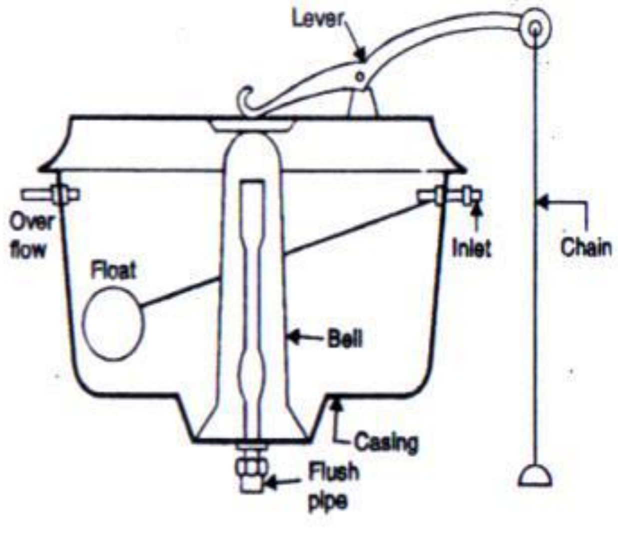



FIG. 30.16. BELL TYPE FLUSHING CISTERN

Flushing cisterns are of two types : (*i*) *valveless* siphonic type and (*ii*) *valve fitted* siphonic type. *Bell type* flushing cistern, commonly used with Indian type closets, is the typical example of valveless siphonic cistern, shown in Fig. 30.16.

A bell type flushing cistern consists of the following parts:

1. A bell or dome
2. A float
3. A lever with a chain
4. Inlet, outlet and overflow pipes and
5. Cast iron casing.

The bell is connected to flushing chain through a lever. The float is so set that when the discharge level is reached, the float rod closes the inlet cock. When the chain is pulled, the bell is lifted up, thus splashing the water. The splashing of water takes away some air with it, causing partial vacuum in the top of the bell. Siphonic action thus starts, and water in the cistern enters the bell through holes provided at its bottom. When the tank is emptied, air enters from the bottom and siphonic action is broken. The lowering of the float results in the opening of the inlet cock, and water thus enters the cistern. It should be noted that the chain should be released immediately after the pull, otherwise the partial vacuum caused by splashing water may be destroyed by the entry of air from the flush pipe. The capacity of a bell type flushing cistern may vary between 5 to 15 litres.

## 30.12. SYSTEMS OF PLUMBING

There are four principal systems of plumbing for drainage of buildings :

(*i*) Single stack system

(*ii*) One pipe system

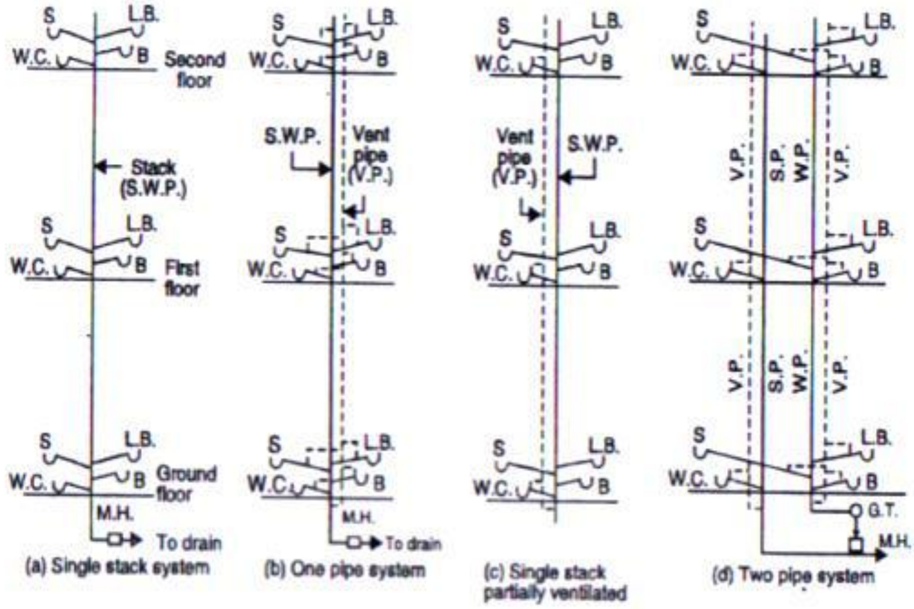
(*iii*) Partially ventilated single stack system and

(*iv*) Two pipe system.

All the four systems are shown diagrammatically in Fig. 30.15.

**1. Single stack system** (Fig. 30.17 *a*)

This is the simplest system, in which the waste matter from baths, sinks, etc., as well as foul matter from the W.C. are discharged in one single pipe, called the soil and waste pipe (S.W.P.). This pipe terminates as the vent pipe at its top, and no separate vent pipe is provided. The single stack system is effective only if the traps are filled with water seal of depth not less than 75 mm. Gulley traps and waste pipes are completely dispensed with. The system is simple and economical since only one pipe is used.




W.C. = Water Closet ; B = Basin ; L.B. = Lavatory Basin ; S = Sink ;
V.P. = Ventilating Pipe ; S.W.P. = Soil Pipe and Waste Water ; S.P. = Soil Pipe
W.P. = Waste Pipe ; M.H. = Man Hole ; G.T. = Gulley Trap.
**Note.** All pipes terminate as vent pipes at the top.

FIG. 30.17. PLUMBING SYSTEMS.

**2. One pipe system** (Fig. 30.17 *b*) : In this system, a separate vent pipe is provided, and the traps of all water closets, basins etc. are completely ventilated. In a multistoreyed building, the lavatory blocks of different floors are situated one above the other, so that the waste water discharged from various units at different floors can be carried through common soil and waste pipe (S.W.P.). The system is costlier than the single stack system.

**3. Single stack system partially ventilated** (Fig. 30.17 *c*) : This is modified form of the single stack system and one pipe system. In this system, the waste from W.C., basins, sinks etc. is discharged into one common soil and waste pipe (S.W.P.) However, in addition, a relief vent pipe is also provided which provides ventilation to the traps of water closets. The traps of basins etc. are not directly connected to the vent pipe.

**4. Two pipe system** (Fig 30.17 *d*)

In this system, separate soil pipe (S.P.) and waste pipe (W.P.) are provided. The discharge from W.C. is connected to the soil pipe (S.P.) while the discharge from baths, sinks, lavatory basin etc. are connected to the waste pipe (W.P.). All the traps are competely ventilated by providing separate ventilating pipes. Thus, four pipes are required. The discharge from waste pipe is disconnected from the drain by means of a gully trap.

**Anti-siphonage pipe**

It is a pipe provided to preserve the water seal of traps. It maintains proper ventilation and does not allow the water seal to get broken due to siphonic action. In the case of a multi-storeyed building, the sudden flush of water in the upper storey results in the sucking of air from the short branch of the pipe connecting the W.C. to the soil pipe of lower storey. This sucking of air causes partial vacuum on the downstream side of the water seal of the lower W.C. The pressure at the upstream side of the water seal is more (atmospheric), which forces the water up the trap and siphons it out in the branch. This results in breaking of the water seal. This can be avoided by connecting the crown of the trap to the atmosphere through an anti-siphonage pipe (Fig. 30.18). A ventilating pipe can therefore be used as an anti-siphonage pipe.

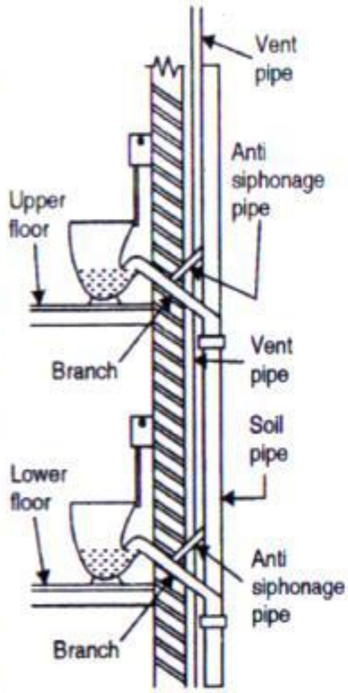
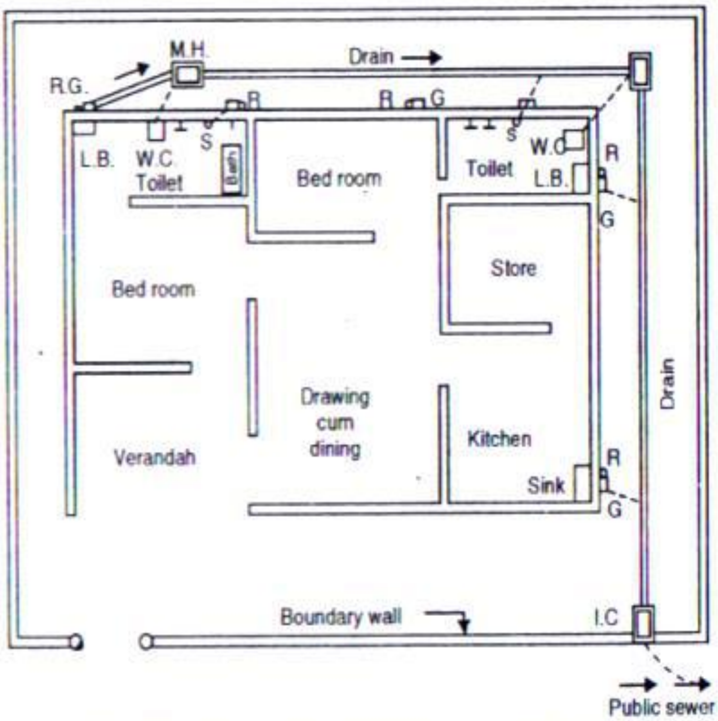



FIG. 30.18. ANTI-SIPHONAGE PIPE.

## 30.13. HOUSE DRAINAGE PLANS

For efficient drainage, it is always better to prepare house drainage plan. In some cities, it is statuatory to submit such plans. Fig. 30.19 shows a typical plan for drainage of a small house.

The site plan is drawn to a suitable scale, showing onto it the position of baths, W.C., urinals, wash basins and other units, along with the position of gully traps and floor traps. The longitudinal section of the drain is also drawn, showing distances, invert levels, size and levels of inspection chambers and man holes, gradient of pipes and the position and level of the public sewer.




R = RAINWATER PIPE ; G = GULLEY TRAP ; L.B. = LAVATORY BASIN ; W.C. = WATER CLOSET ; S = SINK M.H. = MANHOLE ; I.C. = INTERCEPTING CHAMBER

FIG. 30.19. DRAINAGE PLAN OF A BUILDING.

## 30.14. SEPTIC TANK

A septic tank is used to treat sewage from isolated group of country houses, where a piped sewage system (*i.e.*, a public sewer) is not available. It is a horizontal continuous flow sedimentation tank in which sewage moves very slowly. Septic tank serves two purposes : (*i*) deposition of the settling solids in sewage by sedimentation, and (*ii*) partial or complete digestion of the sludge prior to its disposal. A septic tank produces septic action by anaerobic bacteria, wherein proteins, carbohydrates, cellulose and fatty matter present in sewage are broken to simpler compounds. The nitrogen is converted to ammonia, while the colloidal matter is flocculated, then liquified and finally digested. The effluent from the septic tank is discharged either into soak pit or below ground level through open jointed agricultural drains, so that the effluent gets absorbed in the soil. The aerobic bacteria in the soil bring about necessary changes in the organic matter and make it stable. The effluent from the septic tank should not be discharged in open drains.

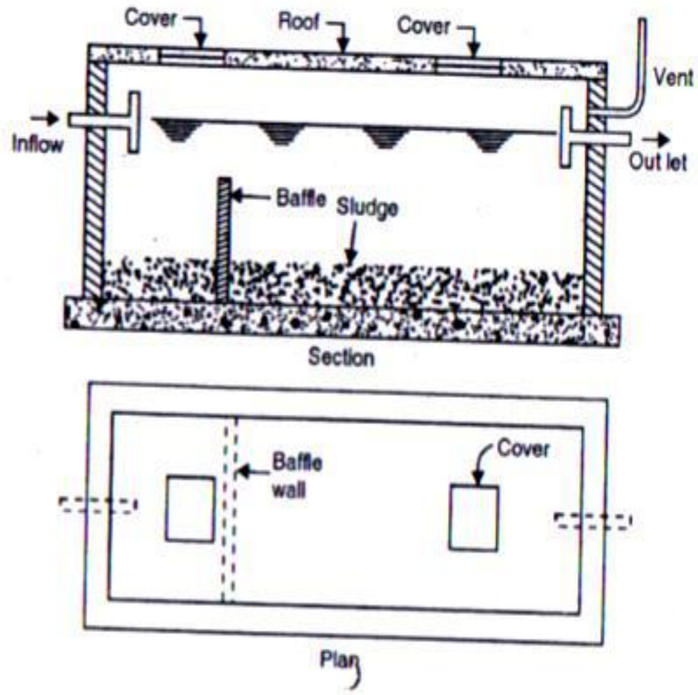



FIG. 30.20. SEPTIC TANK.

Fig. 30.20 shows a simple septic tank. It is so constructed that direct current between inlet and outlet is prevented. This is achieved by using pipe-tees at inlet and outlet. A baffle wall with openings is constructed at some distance away from the outlet. The outlet pipe is kept about 15 cm lower than the inlet pipe. The sludge, which is deposited in the bottom is cleaned periodically, say once in 6 to 12 months. A vent pipe is provided for the escape of gases.

## 30.15. SOAK PIT (SEEPAGE PIT)

A soak pit is a covered pit dug in the ground, in which effluent from the septic tank is discharged. It is generally dug in the pervious soil which can absorb the effluent. Fig. 30.21 shows two forms of soak pits : (*a*) lined, and (*b*) unlined.

Lined soak pits are used when the inner volume is kept empty. The lining may be of bricks, stone or concrete blocks, with dry open joints, and with atleast 7.5 cm backing of coarse aggregate. However, if the inner volume is filled with stone and brick aggregates, no lining is required, except for the masonry ring provided at the top.

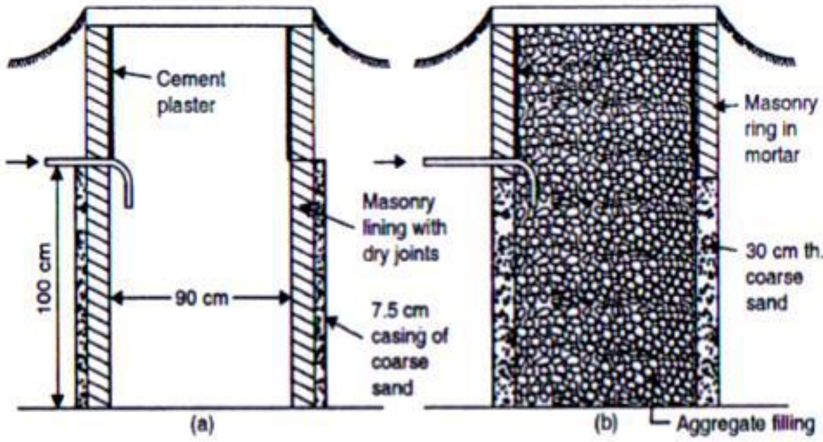



FIG. 30.21. SOAK-PITS.

## Sludge soak pit

A sludge soak pit is the one in which the sewage effluent from the house drain is directly discharged. The water in the accummulated sewage is soacked by adjoining pervious soil while the sludge is digested in the pit. Such soak pits are quite common in areas where subsoil is highly pervious. Fig. 30.22 shows a typical section of such a soak pit. It is lined with masonry with open joints. The top is covered with a rigid slab. The diameter of such a tank varies from 2 m to 3 m, while the depth varies from 2.5 m to 4 m. Each individual house has one such soak pit which has a life of about 20 years for a family of 6 persons. When the soakpit gets filled up, the top cover is removed and the tank is emptied.

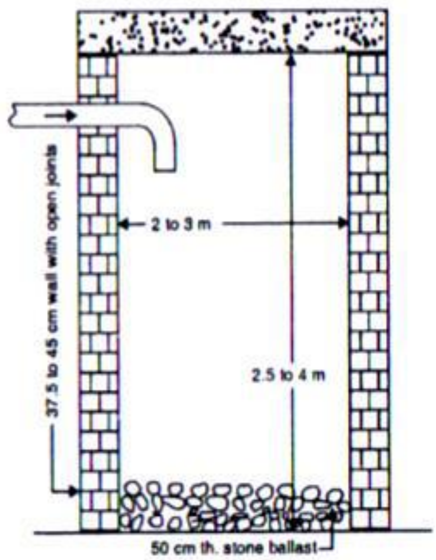



FIG. 30.22. SLUDGE SOAK PIT.

## PROBLEMS

1. Describe, with the help of a neat sketch, the method of taking a house connection for water supply.

2. Write notes on the following :

   (a) Materials for service pipe

   (b) Storage tanks

# VENTILATIONS AND AIR-CONDITIONING OF BUILDINGS

The process of supplying fresh air and removing contaminated air by natural / mechanical process is termed as **ventilation.** To provide excellent conditions to live and work air movement, temperature, humidity conditions etc are important. The simultaneous control of temperature, humidity, air motion and air purity is known as air-conditioning.

SYSTEMS OF VENTILLATION: A good ventilating system should fulfill the following requirements:

- It should admit required amount of fresh air in the room.
- All the corners of the room should get proper ventilation.
- Desired humidity should be maintained.
- Effective temperature should be maintained
- The ventilating air should be free from impurities such as dust, odour etc

The systems of ventilation may be divided into two categories:

NATURAL VENTILATION: Natural system of ventilation is considered suitable for small houses and not for big buildings such as government offices, assembly halls, theatres, auditoriums and factories.

This natural ventilation system largely depends upon the scientific location of doors, windows, ventilators and other openings. Fresh air inside the building is cool and heavy. After sometime, the air becomes hot and lifted up in due course of time. The heated air is driven out through ventilators provided near the ceiling. For proper ventilation the top of this opening area should be not more than 45 cm below the ceiling.

Fresh air again comes in the building gets lifted up by heating and again escapes through openings provided near the ceiling. This effect cause flow of wind in upward direction and is known as **stack effect.**

General considerations for natural ventilation:

- Inlet openings should be located that all parts of the room are uniformly ventilated.
- Inlet openings should not be obstructed by trees, partitions, adjoining buildings etc.
- Outlet openings ( ventilators) should be located near the ceiling.
- Outlet openings should be just opposite to inlets. This ensures better cross-ventilation.
- More height of the room gives better ventilation due to stack effect.
- If wind direction is variable , then openings should be provided in all the walls.

- In sloping or pitched roofs, ventilators are to be fixed at the ridge.

MECHANICAL VENTILATION: The system of ventilation in which some mechanical arrangements are made to provide adequate ventilation in the room is termed as mechanical ventilation.
Though the mechanical ventilation provides better comfortable conditions than natural ventilation, it is costlier method but it results in considerable increase in the efficiency of the persons working under such conditions. Mechanical ventilation can be classified broadly under the following headings:

(a) Extract or exhaust system: By fixing the blowers / fans, fresh air flow inside the room can be maintained.
(b) Supply or plenum system: Fresh air is forced with the help of input fans or blowers into the room and polluted air is allowed to leave the room by itself. The fresh air may be cooled or heated where required by installing cooling and or heating systems at the inlets. In this case, better control on humidity and temperature of incoming air can be exercised.

- Balanced system: This system uses fans to supply air. In this case entry of hot air is prevented by closing the doors or openings.

Air conditioning: The simultaneous control of temperature, humidity, air motion and air purity is known as air-conditioning.

**AIR CONDITIONING** is one type of mechanical arrangement. This process consists of conditioning air w. r. t. humidity, temperature, odour, bacteria content, dust content and air movement so that comfortable conditions are maintained inside the room.

Types of air-conditionings:

- Comfort air-conditioning creates such conditions of the air inside the room, as would give maximum human comfort.
- Industrial air-conditioning creates and maintains the air to the needs of the industry during the material processing, manufacturing process, storage etc.
- Summer air-conditioning cools and control the inside temperature of the room.
- Winter air-conditioning is just the reverse of summer air-conditioning.
- Composite air-conditioning required to be done for the whole year irrespective of the temperature variation.

Principles of air-conditioning:

The temperature range which is liked by majority of the people is called the comfortable zone. A temperature of 21ºC to 22.5ºC is regarded as most likely comfort temperature in a room.

The air movement or velocity of air is important factor in air-conditioning. The velocity of air should be between 6 to 9 mts per minitue. It is remembered that the increase in air velocity decreases the inside effective temperature.

Humidity control of air is also important. An average value of relative humidity between 40 – 60% is considered desirable.

ROOM AIR-CONDITIONERS: These are self-contained air-conditioning units comprising a compressor, evaporator fan, and air-cooled condenser.
This unit is used for single rooms having limited occupancy. These are suited for bed rooms, office cabins, hotel rooms and hospitals. Room air-conditioners are available in the normal range of 1.0; 1.5; 3.0, 4.5 tons capacity.

CENTRAL SYSTEM OF AIR-conditioning: In this system, various processes such as filtering; cooling or heating; humidification etc are all installed at a central place and conditioned air is distributed in all the parts of the building through system of ducts. This system is economical than other systems and better control on conditions inside the hall can be maintained.. However, this system requires an elaborate system of ducts which occupy considerable space.

**ACOUSTICS**

Acoustics is a science of sound that deals with the origin and propagation of sound waves. Hence, vibrations cause sound waves.

Vibrations causing sound, develop series of compressions and refractions in the medium and cause waves. These waves propagate the sound in all the directions from the source. Medium through which sound waves travel may be in solid, liquid or gaseous state. Sound waves cannot travel in vacuum as there is no medium for sound waves to travel. The speed with which sound waves travel through the medium, is known as velocity of sound .

Acoustics is used as a knowledge for the design and construction of theatres, cinemas etc with proper acoustical conditions.

For obtaining better acoustical conditions, some materials which could absorb all excess of sound energy are required to be incorporated on the surfaces of the room. Such materials are known as sound absorbing materials.

Sound absorbing material should be water-proof, fire-proof, quite strong ; good looking and economical in construction and maintenance. Sound absorbing capacity of the materials depends on the thickness, density,
softness and porosity of the materials. Less density, more thickness, and more of softness of the materials are the favourable properties for any sound absorbing material. Some of the sound absorbing materials are: Straw board with 12 mm thickness has sound absorption coefficient of 0.30.
Pulp boards are quite cheap and can be fixed by ordinary paneling. Its coefficient of absorption is 0.17.

Acoustic plaster with 20 mm thick having density of 0.11 gm / $cm^3$ has sound absorbing coefficient of 0.3 at 500 cycles / sec. It is also known as fibrous plaster.

Perforated plywood has the absorption coefficient value may be as high as 0.95 when made with mineral wool and cement asbestos

Wood wool boards with 2.5 cm thick has its absorption coefficient is 0.20 Quilts and mats are made from wool or glass wool and are mostly used as sound absorbing materials.

| | | |
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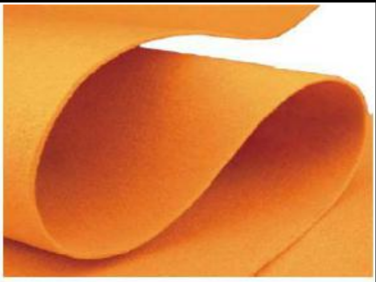
|  |  |  |
| Straw board | Pulp material | Acoustic plaster board |

| | |
|---|---|
|  |  |
| Quilts and mats | Wood wool |

FACTORS TO BE CONSIDERED IN THE ACOUSTIC DESIGN OF A HALL:

**Volume:** The volume of the hall should be in a relation to the intensity of the sound likely to be produced in the hall and also on the capacity of the hall. In fixing the volume of the hall, its height plays a more significant role than length and breadth.
Eg: cinema halls ---- 3.7 to 4.2 cum per seat.

**Shape:** Echoes and other defects generated due to sound wave reflections can be eliminated by scientifically shaping the hall. Concave walls are considered not good from the acoustic point of view due to the formation of focal points where sound waves get concentrated and thus acoustic behavior of the hall is disturbed. Plain walls are considered good but convex walls are considered excellent. Height of the ceiling should be about ½ to 2/3$^{rd}$ of the width of the hall. However, the radius of curvature of the ceiling should be studied properly.

**Sound Absorption material:** while making the selection of sound absorbing material, cost, durability, appearance, fire resisting properties etc should be considered along with about absorbing properties.

## DAMP PROOF AND FIRE PROOF CONSTRUCTION

Damp prevention and fire protection are the chief requirements to ensure the safety of buildings against dampness and fire respectively. The sources, effects, techniques and methods of damp prevention, materials used for damp-proofing (D.P.C) damp-proofing treatments in buildings, treatment of dampness are discussed under damp proof chapter.

**Sources of dampness(causes)**

Dampness in building in generally due to one or more of the following causes

(i) Faulty design of structure

(ii) Faulty construction or poor workmanship

(iii) Use of poor materials in construction

These cause give rise to an easy access to moisture to enter the building from different points, such as rising of moisture from ground, rain penetration through walls, roofs and floors etc. The moisture entering the building from foundation and roofs, travels in different directions further under the effects of capillary action and gravity respectively. The entry of water and its movements, in different parts of the building are positively due to the one or more of the causes listed above.

**Effects of dampness:**

The various effects caused due to dampness in buildings mainly results in poor functional performance, ugly appearance and structural weakness of the buildings.

1. A damp building creates unhealthy living and working conditions for the occupants
2. Presence of damp condition causes efflorescence on building surfaces which ultimately results in the disintegration of bricks stones, tiles etc and hence reduction of strength
3. It may result in softening and crumbling of plaster
4. It may cause bleaching and flaking of the paint which results in the formation of coloured patches on the wall surfaces and ceilings
5. It may result in the corrosion of metals used in the construction of buildings
6. The materials used as floor coverings such as tiles are damaged because they lose adhesion with the floor bases
7. Timber when in contact with damp condition, gets deteriorated due to the effect of warping, buckling and rolling of timber
8. All the electrical fittings gets deteriorated, causing leakage of electric current

with the potential danger of a short circuit

9. Dampness promotes the growth of termites and hence creates unhygienic conditions in buildings

10. Dampness when accompanied by the warmth and darkness, breeds the germs of tuberculosis, neuralgia, aute and chronis neumatism etc which some times result in fatal diseases

**Techniques and methods of damp prevention:**

The following are the precautions to be taken to prevent dampness in buildings, before applying the various techniques.

1. The site should be located on high ground and well drained soil to safe guard against foundation dampness

2. All the exposed walls should be of sufficient thickness to safeguard against rain protection (minimum 30cm)

3. Bricks of superior quality free from defects should be used

4. Good quality cement mortar (1:3) should be used to produce definite pattern and perfect bond in the building

5. Cornices and string courses should be provided to through rain water away from the walls

6. All the exposed surfaces like top of walls, compound walls etc should be covered with water proofing cement plaster

7. Cavity walls are more reliable than solid walls in preventing the dampness

**Techniques:**

1. Use of damp proof courses

2. Water proof or damp proof treatments

3. Cavity walls or hallow walls

4. Guniting or shot concrete or shotcrete

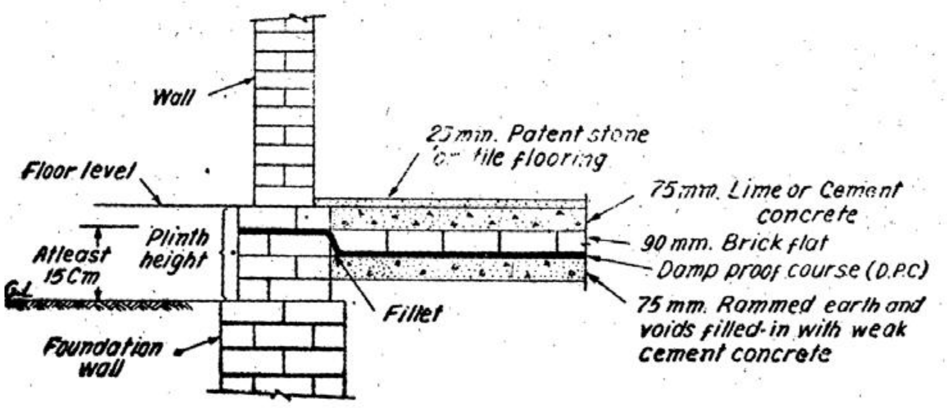
5. Pressure grouting or cementation

**1. Use of damp-proof courses (D.P.C.)**

These are layers or membranes of water repellent materials such as bituminuous felts, mastic asphalt, plastic sheets, cement concrete, mortar, metal sheets, stones etc which are interposed in the building structure at all locations wherever water entry is anticipated or suspected. The best location or position of D.P.C. in the case of building without basement lies at plinth level or structures without any plinth level, it should be laid at least 15cm above ground level. The damp proof course provided horizontally and vertically in floors, walls etc. In the case of basements, laying of D.P.C. is known as taking Fig 14.1 shows the D.P.C. treatment above ground level.

**Fig 14.1 D.P.C. above ground level for new buildings**

**2. Water proof surface treatments:** The surface treatment consists in filing up the pores of the material exposed to moisture by




providing a thin film of water repellent material over the surface (internal / external ) . External treatment is effective in preventing dampness

Many surface treatments, like pointing, plastering, painting, distempering etc are given to the exposed surfaces and also to the internal surface . The most commonly used treatment to protect the walls against dampness is lime cement plaster (1:6) (1- cement, 6-lime) mix proportion. Generally employed as water proofing agent in surface treatments are sodium or potassium silicate. Aluminium or zinc sulphate, Barium Hydroxide and magnesium sulphate in alternate applications. Soft soap and alum also in alternate applications, unie and unseed oil; coal tar, bitumen, waxes and fats; resins and gums

Waxes and fats are not suitable in tropics as they melt with rise in temperatures

**3. Integral damp-proofing treatments :**

The integral treatment consists of adding certain compounds to the concrete or mortar during the process of mixing, which when used in construction acts as barriers to moisture penetration under different principles

i) **Compounds like chalk**, talc, fallers earth etc have mechanical action principle (i.e.,) they fill the pores present in the concrete or mortar and make them dense and water proof

ii) **Compounds like denser** and water proof sulphates, calcium chlorides etc work on chemical action principle (i.e.) they react chemically and fill the pores to act as water-resistant

iii) **The compounds like soaps**, petroleum, oils fatty acids compounds such as sterates of calcium, sodium ammonium etc work on the repulsion principle i.e., they are used as admixture in concrete to react with it and become water repellent

**4. Cavity walls or hallow walls:** A cavity wall consists of two parallel walls or leaves or skins of masonary separated by a continuous air space or cavity. The provision of continuous cavity in the wall per effectively prevent the transmission or percolation of dampness from outer walls or leaf to inner wall or leaf. The following are the advantages of cavity wall.

(i) As there is no contact between outer and inner walls of cavity wall, possibility of moisture penetration is reduced to a minimum.

(ii) A cavity wall prevents the transmission of heat through wall.

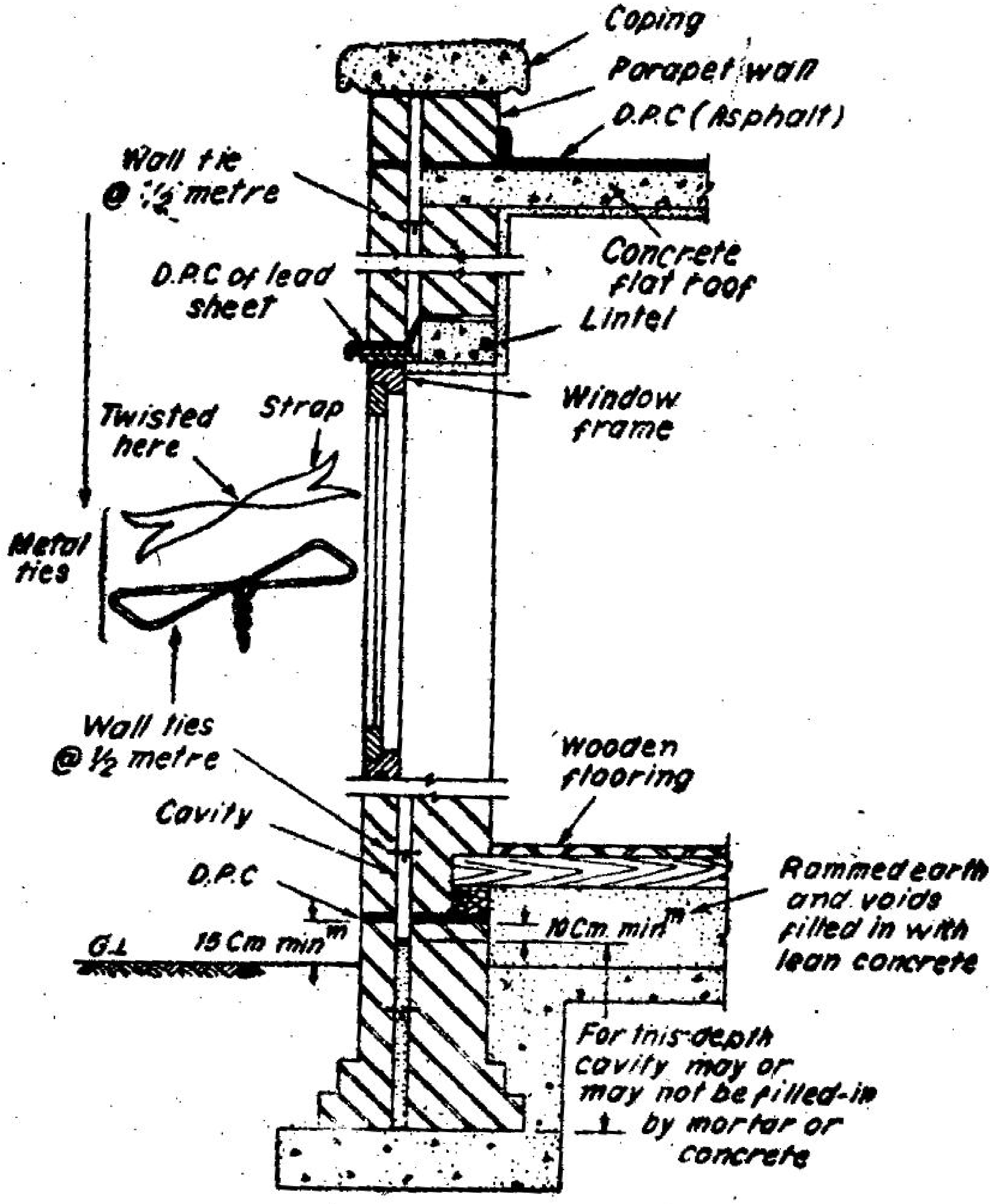
(iii) A cavity wall offer good insulation against sound.

(iv) The cavity wall tends to reduce the nuisance of efflorescence.

**(v)** The cavity wall also provides benefits such as economy, better comfort and hygienic conditions in buildings

The cavity wall construction and D.P.C. details for flat roofs is as shown in fig no 14.2

**Fig 14.2 Cavity wall construction and D.P.C. details for flat roofs**



**5. Guniting: (or shot concrete) :** The technique of guniting consists in forming an imperious layer of rich cement mortar (1:3) or fine aggregate mix for water proofing over the exposed concrete surface or over the pipes, cisterns etc for resisting the water pressure. By this technique, an impervious layer of high compressive strength (600 to 700 kg/cm$^2$) is obtained and hence this is also very useful for reconditioning or repairing old concrete works

**6. Pressure grouting or (cementation).** The mixture of cement, sand and water under pressure into the cracks, voids or fissures present in the structural component or the ground. In general, the foundations are given this treatment to avoid the moisture penetration. This technique also used for repairing structures, consolidating ground to improve bearing capacity, forming water cut-offs to prevent seepage etc.

**Fire protection:**

It is defined as the protection of the occupants of the building, contents and structure of the building and adjacent buildings from the risks of fire and spread of fire. The objective is achieved by using fire- resistive materials in the construction. By suitable planning of the building internally and in relation to adjacent building internally and in relation to adjacent building and by providing suitable means of quick escape for the occupants. These measures are essential to minimize the spread of fire and limit the total damage to a minimum

**Important considerations in fire protection:**

1. It should be the objective of every engineer and architect while planning and designing the building that the structure offer sufficient resistance against fire so as to afford protection to the occupants, use of fire-resisting materials and construction techniques and providing quick and safe means of escape in the building.

2. All the structural elements such as floors, walls, columns, beams etc should be made of fire resisting materials

3. The construction of structural elements such as walls, floors, columns, lintels, arches etc should be made in such a way that they should continue to function atleast for the time, which may be sufficient for occupants to escape safely in times of fire.

4. The building should be so planned or oriented that the elements of construction or building components can with stand fire for a given time depending upon the size and use of building, to isolate various compartments so as to minimize the spread of fire suitable separation is necessary to prevent fire, gases, and smoke from spreading rapidly

through corridors, staircases left shafts etc.

5. Adequate means of escape are provided for occupants to leave the building quickly and safely in terms of outbreak of fire.

6. In multi-storeyed office buildings suitable equipment for detecting, extinguishing and warning of fire should be installed in the niches.

**Fire-resistant construction:**

National building code classifies the construction into four classes, namely type 1, type 2, type 3 and type 4 on the basis of fire-resistance offered by building components for 4-hours, 3- hours, 2-hours and 1-hour respectively. To achieve the objective of fire-resistance, due considerations should be made in design and construction of the structural members and use of combustible material should be avoided as far as possible in the construction

a) Walls and columns

b) Floor and roofs

c) Wall openings

d) Building fire escape elements (i.e.,) stair, staircase, corridors, entrances etc.

a) **Walls and columns:** The load-bearing non-load bearing walls should be plastered with fire resistive mortar to improve fire resistance. Normally 20cm thick common wall is sufficient from fire resistance point of view. Bricks should be preferred to stones if the construction is solid bearing wall. If it happens to be a framed structure then R.C.C. frames are preferred to those of steel frame. Partition walls, should also be fire resistant materials. In case of wooden partitions are employed, they should be covered with metal lath and plaster. Sufficient cover to R.C.C. members like beams or columns should be to enable them to function satisfactorily, under the fire maximum time. It has been recommended that a cover of atleast 5cm inside the main reinforcement of structural members, like columns, girders, trusses etc, 38mm for ordinary beam, long span slabs, arches etc, 25mm for partition walls, short spans should be provided. The fire proofing treatments, which can possibly to concrete and steel column construction are as shown in the fig 14.3.

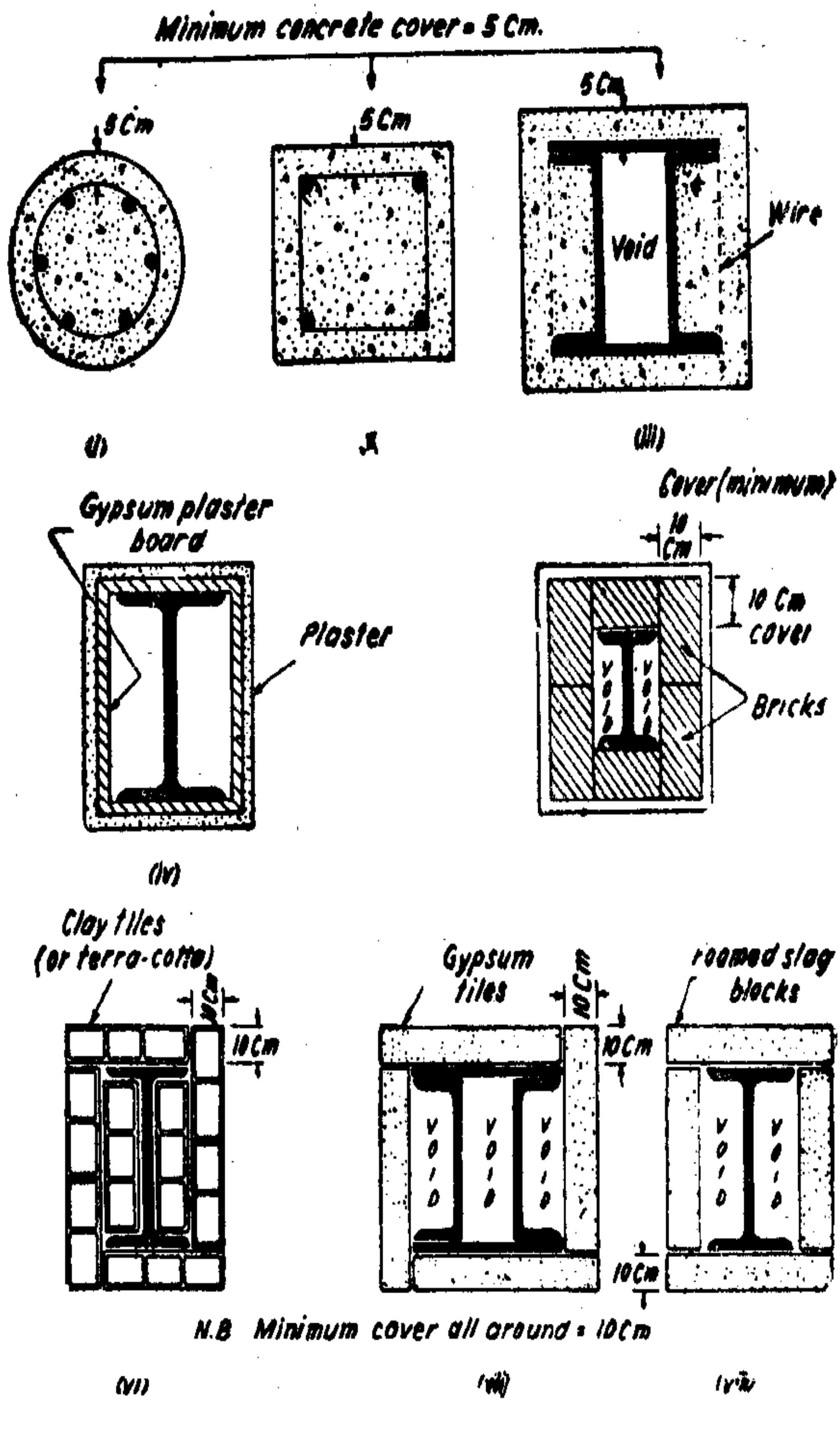
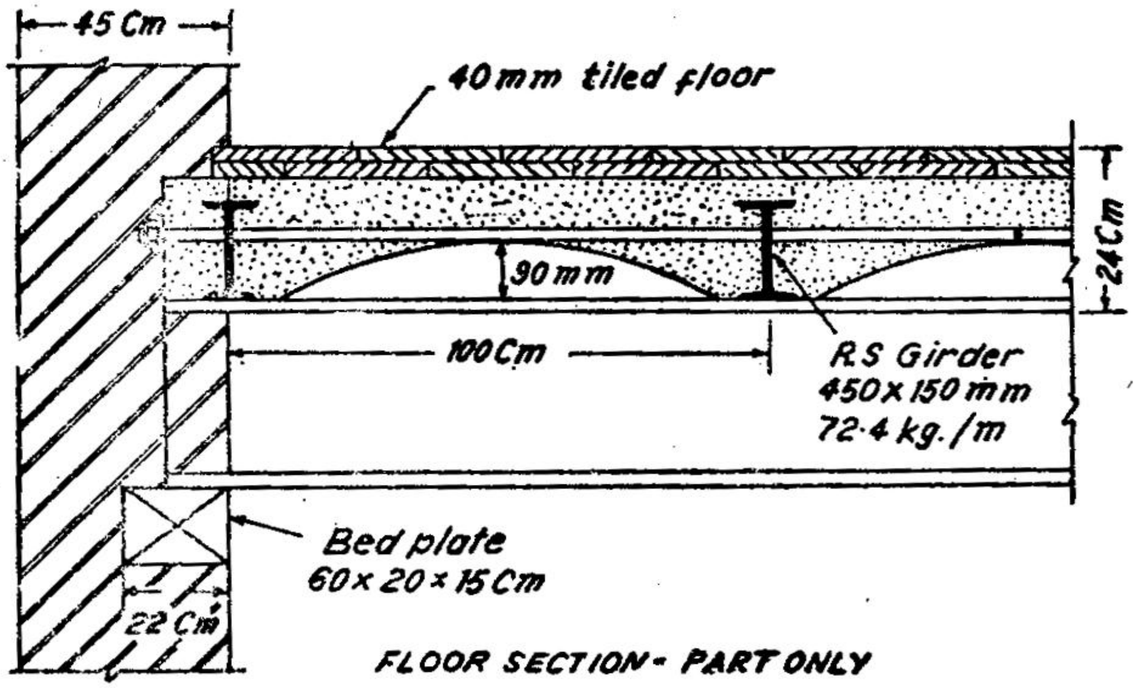


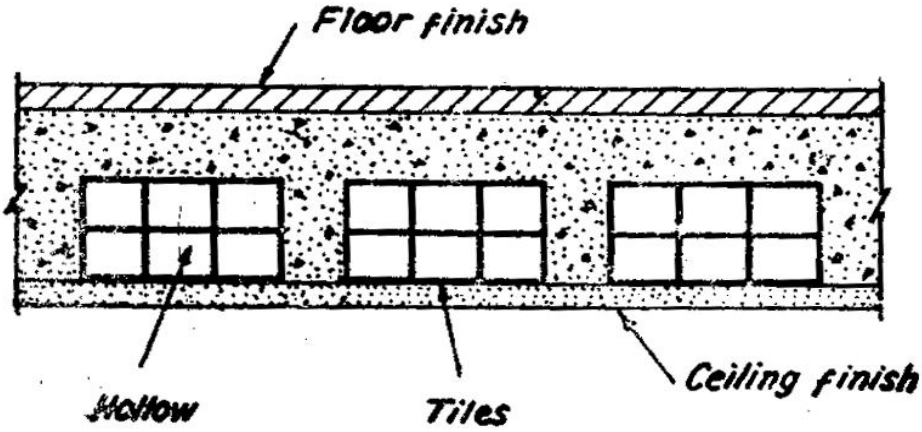

**Fig 14.3 Fire proofing treatments to concrete and steel columns**

b) **Floors and roofs:** The floors and roofs should be made of fire-resisting material as they act as horizontal barriers to spread of heat and fire in vertical direction. For fire- resistant construction, the floor such as concrete jack arch floor with steel joists embedded in concrete or hallow tiled ribbed floor, R.C.C. floor etc should be used as shown in fig. 14.4.

**Fig 14.4 Fire-resisting in floors**




**Fire-resisting concrete Jack Arch floor.**




**Fire-resisting—Hollow tiled Ribbed floor.**

c) **Wall openings**: From fire resistance point of view, firstly the openings in the walls should be restricted to a minimum and secondly they should be protected by suitable arrangements in case of fire. These days, wire- glass panels are preferred for windows, where as steel rolling shutters are becoming popular for door ways and window openings in garages, godowns, shops etc due to their ability in preventing the spread of fire

d) **Building fire escape element:** Staircases, corridors, Lobbies, entrances etc are the fire escape elements should be constructed out of fire-resistant materials and be well separated from the rest of the building. Doors to the staircase, corridors and lefts should be made of fire- proofing materials. Staircase should be created next to the outerwalls and should be accessible from any floor in the direction of flow towards the exits from the building.

**General measures of fire safety in building**:

In important buildings, in addition to the fire-resisting materials and adopting fire resistant construction, the following general measures of fire-safety have been recommended

(i) Alaram system

(ii) Fire extinguishing arrangements

(iii) Escape routes for public buildings

**SYNOPYSIS**

1. Damp prevention and fire protection are the chief requirements

to ensure the safety of buildings against dampness and fire respectively

2. The sources of dampness are

(i) Faulty design of structure

(ii) Faulty construction or poor workmanship

(iii) Use of poor materials inc construction

3. The effects of dampness are

(i) Unhealthy living and working conditions for occupants

(ii) Disintegration of bricks results decreasing in strength

(iii) Crumbling of plaster

(iv) Formation of colour patches on the wall

(v) Corrosion of metals

(vi) Timber get deteriorated

(vii) Electrical fittings gets deteriorated causing short circuit

(viii) Growth termites creates unhygienic conditions

4. The techniques used for damp roofing

(i) Use of damp proof courses

(ii) Water proof or damp proof treatments

(iii) Cavity wall or hallow walls

(iv) Gunitins or shot concrete

(v) Pressure grouting or cementation

5. Five protection is defined as the protection occupants of the building, contents and structure of the building and adjacent buildings from the risks of fire and spread of fire. This is achieved by using fire resistive materials in the construction by suitable planning

6. The general measures of fire safety in building are

(i) Alaram system

(ii) Fire extinguish arrangements

(iii) Escape routes for public buildings

**SHORT ANSWER QUESTIONS**

1. Define damp prevention
2. What is D.P.C. ? Give examples.
3. What are the important sources of dampness?
4. Name any four effects of dampness
5. Name any four methods of preventing dampness
6. Define fire protection
7. What are the general methods of fire safety in buildings?
8. What are the properties of ideal fire resisting material?

**ESSAY TYPE QUESTIONS**

1. Explain the sources of dampness.
2. Explain the effects of dampness.
3. Explain the methods of preventing dampness
4. Explain the fire-resisting properties of the following material

a. Timber

b. Stone

c. Bricks

d. Concrete

5. Explain fire-resistance construction
6. Explain the general measures of fire safety in buildings.

* * *

# Fire Protection

## 23.1. INTRODUCTION

No building material is perfectly fire proof. Every building contains some materials (such as furniture, clothing, eatables etc.) which can either easily catch fire or which are vulnerable to fire. However, the endeavor of the architects and engineers should be to plan, design and construct the building in such a way that safety of occupants may be ensured to the maximum possible extent in the event of outbreak of fire in the building due to any reason whatsoever. The technical interpretation of *fire safety* of building is to convey the *fire resistance* of buildings *in terms of hours* when subjected to fire of known intensity. It should have structural time interval so that adequate protection to the occupants is afforded. A wider interpretation of fire safety may be deemed to cover the following aspects :

(*a*) Fire prevention and reduction of number of outbreaks of fire,

(*b*) Spread of fire, both internally and externally,

(*c*) Safe exit of any and all occupants in the event of an out-break of fire,

and (*d*) Fire extinguishing apparatus.

### *Causes of fire*

Most fires are *caused* by carelessness. Common instances of carelessness are : (*i*) careless discarding of lighted ends of cigarettes, cigars, matches and tobacco, (*ii*) smoking in unauthorised places. (*iii*) indifferent maintenance of machinery including overloading and under or over lubricating of bearings, (*iv*) general indifference to cleanliness, (*v*) incorrect storage of materials, (*vi*) faulty workmanship and inattention to electrical installations (this is particularly evident by the fires which occur during the monsoon), (*vii*) un-approved equipment and layout, (*viii*) inattention of persons concerned with inspection and patrol of the premises under their jurisdiction, and (*ix*) inattention of fire safety regulations, etc., etc.

In case of an outbreak of fire, the danger is from fire, smoke and panic. The provision of suitable means of escape should be in relation to these dangers and the number of persons affected. The chances of damage due to panic can be reduced ; the *escapes* should be located in such a way that they remain unobstructed by smoke or fumes. The means of escapes from fire should be easily accessible, unobstructed and clearly defined.

## 23.2 FIRE HAZARDS

Fire safety of buildings should be considered from three aspects and protection should accordingly be provided against the following three types of fire hazards.

(a) Possibility of loss or damage to life, referred to as *personal hazard*.

(b) Possibility of fire occurring and spreading inside the building itself, referred to as *'internal hazard'* and

(c) Possibility of fire spreading from an adjoining building or buildings or from across a street or road, referred to as *'exposure hazard'*.

The consideration of *personal hazard* is naturally of permanent importance and requires the provision of liberally designed and safe fire proof exits and escapes in all buildings and particularly those having more than one storey.

*Internal hazard* concerns damage or destruction of the building and influences directly personal hazard. The internal hazard is directly related to *fire load* which, in turn, enables the building to be graded when considered along with the duration of fire.

*'Exposure hazard'* deals with the risk of fire spreading into a building through the open air from fire in other buildings, from stocks of combustible material etc., or into a division or compartment of a building through the open air from a fire in other division or compartment of the same building.

A small building containing highly inflammable material may constitute a high internal hazard ; a large building containing quantities of combustible material, for example, a godown, would also be described as high internal hazard even though the actual outbreaks are likely to be few, because when a fire does occur, the destruction of contents and structural damage might be considerable. Theatres, cinemas and other places of public assembly, even though their combustible contents may be low, are considered to present a high internal hazard primarily because of the large number of people and the extent of personal hazard, involved. On the other hand, from stand point of high combustible content, would constitute low personal hazard because of few people likely to be in such a building.

## 23.3. FIRE LOAD

Fire load is the amount of heat in Kilocalories (kcal) which is liberated per square metre of floor area of any compartment by the combustion of the contents of the building and any combustible part of the building itself. This amount of heat is used as the basis of grading of occupancies.

The fire load is determined by multiplying the weight of all combustible materials by their calorific value, and dividing the floor area under consideration. For example, if a section of a building, having an area of 80 sq. metre has 1200 kg of combustible material having a calorific value of 4000 kcal/kg,

$$\text{Fire load} = \frac{1200 \times 4000}{80} = 60000\,\text{kcal/m}^2.$$

Indian Standard (IS : 1641 – 1960) grades the fire loads into the following three *classes* :

(a) ***Low fire load*** : Not exceeding 275000 $\text{kcal/m}^2$ and as applying generally to domestic buildings, hotels and offices and similar buildings.

(*b*) ***Moderate fire load*** : Exceeding 275000 $kcal/m^2$ but not exceeding 550000 $kcal/m^2$ applying generally to trading establishment and factories.

(c) ***High fire load*** : Where the value exceeds 550000 but does not exceed 1100000 $kcal/m^2$ applying to fire load grading to godowns and similar structures.

Fire load of any building is classed as of normal or of abnormal fire risk depending on susceptibility of the occupancy of the building to fire. The occupancy of the building may consist of materials in store or manufacturing processes.

Different materials having the same weight and the same calorific value may present different hazards on account of their other properties, such as rate of ignition, speed of burning and liberation of dangerous fumes. Materials are classified for purpose of assessing fire grading under the heading Non-Hazardous (NH), Hazardous (H) and Extra Hazardous (EH) based on the following characteristics : (*i*) explosive tendencies, (*ii*) high inflammability, (*iii*) liability to intensify a fire. (*iv*) generation of intense heat when burning, (*v*) liability to extend the fire zone, (*vi*) difficulty to extinguish, and (*viii*) spontaneous combustion tendencies.

**Grading of occupancies by fire load**

Based on fire load, occupancies are graded into the following three classes :

1. ***Occupancies of low fire load*** : Under this fall those occupancies whose the fire load does not exceed an average of 275000 $kcal/m^2$ of net floor area of any compartment, nor an average of 550000 $kcal/m^2$ on limited isolated areas. Domestic buildings, hotels, boarding houses, restaurants, schools, hospitals, temples, mosques, commercial offices come under this category. Also, the factories and workshops in which materials and processes are of a recognised non-hazardous nature (such as an engineering workshop) come under this.

2. ***Occupancies of moderate fire load*** : Under this fall those occupancies whose the fire load exceeds an average of 275000 $kcal/m^2$ of net floor area of any compartment but does not exceed an average of 550000 $kcal/m^2$ nor on average of 1100000 $kcal/m^2$ on limited isolated areas. Examples of occupancies that fall under this category are retail shops, emporium, bazars, factories and workshops generally.

3. ***Occupancies of high fire load*** : Under this fall those occupancies whose fire load exceeds an average of 550000 $kcal/m^2$ of net floor area of any compartment but does not exceed an average of 1100000 $kcal/m^2$ of net floor area, nor an average of 2200000 $kcal/m^2$ on limited isolated areas. Examples of occupancies that fall under this category are godowns and similar buildings used for bulk storage of non-hazardous materials and goods.

## 23.4. GRADING OF STRUCTURAL ELEMENTS

Structural elements of buildings are graded, for fire resistance, by the time for which they resist a standard fire of given time temperature grading. The time-temperature grading is based on, observations in actual fires. The relationship between the actual fire expressed as fire load and the standard fire is established by burning down weights of combustible material corresponding to different classes of fire loads, so as to match the time temperature grading of the standard fire. From the results it follows that the different grades of fire resisting structural elements will resist the corresponding fire loads shown against them in Table 23.1 (IS : 1641-1960).

Thus, a structural element classified as of grade 4 will successfully withstand the standard fire severity and comply with other conditions for an hour. If that structural element is incorporated in a building of which the fire load gives rise to a fire, equivalent in severity to one hour severity in the test, then the structural element should resist the building fire without failure.

**TABLE 23.1. CLASSIFICATION OF STRUCTURAL ELEMENTS**

| *Grade No* | *Time-in-hours (min.resistance against standard fire* | *Fire load and class of fire which the structural element can withstand* | |
|---|---|---|---|
| | | *Fire load in k cal /m²* | *Class of fire* |
| 1 | 6 | 1100000 and over | Very high |
| 2 | 4 | 500000 to 1100000 | High |
| 3 | 2 | 275000 to 500000 | Medium |
| 4 | 1 | Less than 275000 | Low |
| 5 | $\frac{1}{2}$ | – | Very low |

## 23.5. GRADING OF BUILDINGS ACCORDING TO FIRE RESISTANCE

Structural precautions aid in giving a building the necessary resistance to a complete burn and restrict any spread of fire and also minimize the personal hazard. In grading building according to fire resistance and structural precautions provided, it has been assumed that no assistance will be forthcoming from municipal fire brigade and that no fire fighting apparatus has been provided or attached to building. National Building Code of India (SP : 7-1970) divides buildings into the following *four* types according to the *fire load* the building is designed to resist :

(*i*) *Type 1 construction.* All structural components have 4-hours fire resistance.

(*ii*) *Type 2 construction.* All structural components have 3-hours fire resistance.

(*iii*) *Type 3 construction.* All structural components have 2-hours fire resistance.

(*iv*) *Type 4 construction.* All structural components have 1-hour fire resistance.

Experience shows that with fire fighting equipment installed in the premises, the duration of fire in buildings having a fire load between 500000 to 1100000 kcal/m² is usually less than 3 hours. Hence type 1 construction prescribed for this class of buildings generally ensures sufficient protection. However, in buildings covered under type 1, proper ventilation and provision for escape of hot gases should be made. Also, when fire fighting equipment or the services of a fire brigade are available in the premises, the design should provide for immediate access from several positions.

*The most satisfactory condition of a building is when it is constructed to resist a complete burn out of combustible contents, without failure or collapse.*

## 23.6. CHARACTERISTICS OF FIRE RESISTING MATERIALS

An ideal fire resisting material should possess the following characteristics :

1. The material should not disintegrate under the effect of great heat.

2. The expansion of the material due to heat should not be such that it leads to instability of the structure of which it forms a part.

3. The contraction of the material due to sudden cooling with water (during fire

extinguition process) after it has been heated to a high temperature should not be rapid.

In relation to fire, building materials can be divided into two types : (*i*) *non-combustible materials*, and (*ii*) *combustible materials*. *Non-combustible materials* are those which if decomposed by heat will do so with absorption of heat (*i.e.* endothermically) or if they oxidise, do so with negligible evolution of heat. These materials do not contribute to the growth or spread of fire, but are damaged and decomposed when high temperatures are reached. Examples of non-combustible materials are : stones and bricks, concrete, clay products, metal, glass etc. *Combustible materials* are those which, during fire, combine exothermically with oxygen, resulting in evolution of lot of heat and giving rise to flame or glow. Such materials burn and also contribute to the growth of fire. Examples of these materials are : wood and wood products, fibre board, straw board etc.

## 23.7. FIRE-RESISTING PROPERTIES OF COMMON BUILDING MATERIALS

### 1. Stone

Stone is a non-combustible building material and also a bad conductor of heat and does not contribute to the spread of fire. However, it is a *bad* fire-resisting material since it is liable to disintegrate into small pieces when heated and suddenly cooled, giving rise to failure of structure. Granite, on exposure to severe heat, explodes and disintegrates. Lime stone is the worst, since it is easily crumbled even under ordinary fire. Sand stone of compact composition (fine grained) can, however, stand the exposure to moderate fire without serious cracks. *In general, the use of stone in a fire-resisting construction should be restricted to a minimum.*

### 2. Bricks

Brick is a poor conductor of heat. First class bricks moulded from good clay can stand exposure to fire for a considerable length of time, upto temperatures of about 1200°C. Brick masonry construction, with good mortar and better workmanship, is the most suitable for safeguarding the structure against fire hazards.

### 3. Concrete

The behavior of concrete during exposure to heat varies with the nature of coarse aggregate and its density, and the quality of cement. It also depends upon the position of steel in concrete. Aggregates expand on heating while ordinary cement shrinks on heating. These two opposite actions may lead to spalling of the concrete surface. Aggregates obtained from igneous rocks containing higher calcareous content, tend to crack more while the aggregates like foamed slag, cinder and bricks are better. The cracks formed in concrete generally extend to a depth of about 25 mm. Hence reinforced concrete fire-resistant construction should have greater cover. *In general, concrete offers a much higher resistance to fire than any other building material.* Reinforced concrete structures can withstand fire lasting for several hours with a temperature of 1000°C without serious damage.

### 4. Steel

Though steel is non-combustible, it has very low fire resistance, since it is a good conductor of heat. During fire, it gets heated very soon, its modulus of elasticity reduces and it looses its tensile strength rapidly. It is found that yield stress of mild steel at 600° C is about $\frac{1}{2}$ of its value at normal temperatures. Hence unprotected steel beam sags and unprotected columns or struts buckle, resulting in the collapse of structures. If the surface paint on these steel components is not fire resistant, it is essential to protect structural steel members with some coverings of insulating materials like brick, terra-cotta, concrete etc. Fixing of steel in plate or sheet form to the structural steel frame work is also effective in resisting the passage of flame. Such construction is widely used in making fire-resisting doors and windows.

**5. Glass**

Glass is poor conductor of heat, and its thermal expansion is also less. When it is heated and then suddenly cooled, cracks are formed. These cracks can be minimised if glass is reinforced with steel wire netting. Thus, *reinforced glass* is more fire resistant, and can resist variations in temperature without serious cracks. Reinforced glass has higher melting point. Even if cracks are formed, the embedded wires hold the cracked portion in position. Reinforced glass is therefore commonly used for fire-resisting doors, windows, done sky-lights, etc.

**6. Timber**

Timber is a combustible material. It ignites and gets rapidly destroyed during fire, if the section is small. However, if timber is used in *thick* sections, it possesses the properties of self-insulation and slow burning. During exposure to fire, timber surface gets charred ; this charred portion acts as protective coating to the inner portion. However, if the temperatures are higher than 500°C, timber gets dehydrated under continued exposure, giving rise to combustible volatile gases which readily catch fire. In order to make timber fire-resistant, the following measures are adopted :

(*i*) use of thicker sections at wider spacing than thinner sections at closer spacing, specially in case of floor joints. (*ii*) reducing number of corners and area of exposed surfaces to a minimum. (*iii*) coating timber surface with chemicals like ammonium phosphate and sulphate, borax and boric acid, zinc chloride, (*iv*) painting timber surfaces with asbestos or ferrous oxide paints, if painting is necessary. Painting these with oil paints or varnish should not be done since these paints catch fire.

**7. Cast-iron and wrought iron**

Cast iron behaves very badly in the event of fire. On sudden cooling, it gets contracted and breaks down into pieces or fragments, giving rise to sudden failure. Hence it is rarely used in fire-resistant building unless suitably covered by bricks, concrete etc. Wrought iron behaves practically in the same way as mild steel.

**8. Asbestos cement**

It is formed by combining fibrous asbestos with Portland cement. It has low coefficient of expansion and has property of incombustibility. It has, therefore, great fire-resistance. Asbestos cement products are largely used for construction of fire-resistant partition walls, roofs, etc. It is also used as protective covering to other structural members.

**9. Aluminium**

It is very good conductor of heat. It has very poor fire-resistant properties. Its use should be restricted to only those structures which have very low fire risks.

**10. Plaster or mortar**

Plaster is non-combustible. Hence it should be used to protect walls and ceilings against fire risks. Cement plaster is better than lime plaster since the latter is likely to be calcined during fire. The fire-resistance of plaster can be increased by using it in thick layers or reinforcing it with metal laths. Gypsum plaster, when used over structural steel members, make them better fire-resistant.

## 23.8. GENERAL FIRE SAFETY REQUIREMENTS FOR BUILDINGS

In order that the fire hazards (i.e. personal hazard, internal hazard and exposure hazards) are minimised, IS : 1641-1960 recommends that the buildings shall conform to the following general requirements :

1. All buildings and particularly buildings having more than one storey shall be provided with liberally designed and safe fire-proof exits or escapes.

2. The exits shall be so placed that they are *always* immediately accessible and each is capable of taking all the persons on that floor as alternative escape routes may be rendered unusable and/or unsafe due to fire.

3. Escape routes shall be well-ventilated as persons using the escapes are likely to be overcome by smoke and/or fumes which may enter from the fire.

4. Fire-proof doors shall conform rigidly to the fire safety requirements.

5. Where fire-resisting doors are employed as cut-offs or fire breaks, they shall be maintained in good working order so that they may be readily opened to allow quick escape of persons trapped in that section of the building, and also, when necessary, prompt rescue work can be expeditiously carried out.

6. Electrical and/or mechanical lifts, while reliable under normal conditions may not always be relied on for escape purposes in the event of a fire, as the electrical supply to the building itself may be cut-off or otherwise interrupted, or those relying on mechanical drive may not have the driving powder available.

7. Lift shafts and stairways invariably serve as flues or tunnels thus increasing the fire by increased drought and their design shall be such as to reduce or avoid this possibility and consequent spread of fire.

8. False ceiling, either for sound effects or air-conditioning or other similar purpose shall be so constructed as to prevent either total or early collapse in the event of fire so that persons underneath are not fatally trapped before they have the time to reach the exits ; this shall apply to cinemas, and other public or private buildings where many people congregate.

9. To a lesser extent, the provisions of clause (8) above shall apply to single-storey buildings which may be used for residence or an equivalent occupancy. Whatever be the class or purpose of the building, the design and construction shall embody the fire retardent features for ceilings and/or roofs.

10. ***Floors***. Floors are required to withstand the effects of fire for the full period stated for the particular grading. The design and construction of floors shall be of such a standard that shall obviate any replacement, partial or otherwise, because experience shows that certain types of construction stand up satisfactorily against collapse and suffer when may first be considered as negligible damage, but in practice later involves complete stripping down and either total or major replacement. This consideration shall also be applied to other elements of structure where necessary.

11. ***Roofs.*** Roof for the various fire-grades of the buildings shall be designed and constructed to withstand the effect of fire for the maximum period for the particular grading, and this requires concrete or equivalent construction. It is, however, important

that maximum endurance is provided for as stated in para 9.

12. ***Basements.*** Where basements are necessary for a building and where such basements are used for storage, provision shall be made for the escape of any heat arising due to fire and for liberating and smoke which may be caused. It is essential that fire resistance of the basement shall conform to the highest order and all columns for supporting the upper structures shall have a grading not less than laid down in types 1 to 3.

13. ***Smoke extraction from basements***. The following requirements shall be provided for smoke extraction :

(*a*) Unobstructed smoke extracts having direct communication with the open air shall be provided in or adjoining the external walls and in positions easily accessible for firemen in an emergency.

(*b*) The area of smoke extracts shall be distributed, as far as possible, around the perimeter to encourage flow of smoke and gases where it is impracticable to provide a few large extracts, for example, not less than 3 $m^2$ in area, a number of small extracts having the same gross area shall be provided.

(*c*) Covers to the smoke extracts shall, where practicable, be provided in the stall board and/or pavement lights at pavement level, and be constructed of light cast iron frame or other construction which may be readily broken by fire-men in emergency. The covers shall be suitably marked.

(*d*) Where they pass through fire resisting separations, smoke extracts shall in all cases be completely separated from other compartments in the building by enclosures of the appropriate grade of fire resistance. In other cases, steel metal ducts may be provided.

(*e*) Where these are sub-basements, the position of the smoke extracts from sub-basements and basements shall be suitably indicated and distinguished on the external faces of the building.

## 23.9 FIRE RESISTANT CONSTRUCTION

In a fire resistant construction, the design should be such that the components can withstand fire as an integral member of structure, for the desired period. We shall consider the construction of the following components :

1. Walls and columns.
2. Floors and roofs.
3. Wall openings.
4. Escape elements.
5. Strong room construction.

**1. Walls and columns** : The following points should be observed for making walls and columns fire-resistant:

(*i*) Masonry walls and columns should be made of thicker section so that these can resist fire for a longer time, and can also act as barrier against spread of fire to the adjoining areas.

(*ii*) In the case of solid load-bearing walls, bricks should be preferred to stones.

(*iii*) If walls are to be made of stones, granite and lime stone should be avoided.

(*iv*) In the case of building with framed structure, R.C.C. should be preferred to steel.

(*v*) If steel is used for the framed structure, the steel structural components should be properly enclosed or embedded into concrete, terracotta, brick, gypsum plaster board, or any other suitable material, as illustrated in Fig. 23.1.

(*iv*) If the frame work is of R.C.C., thicker cover should be used so that the members can resist fire for a longer time. It is recommended to use 40 to 50 mm cover for columns, 35 to 40 mm cover for beams and long span slabs and 25 mm for short span slabs.

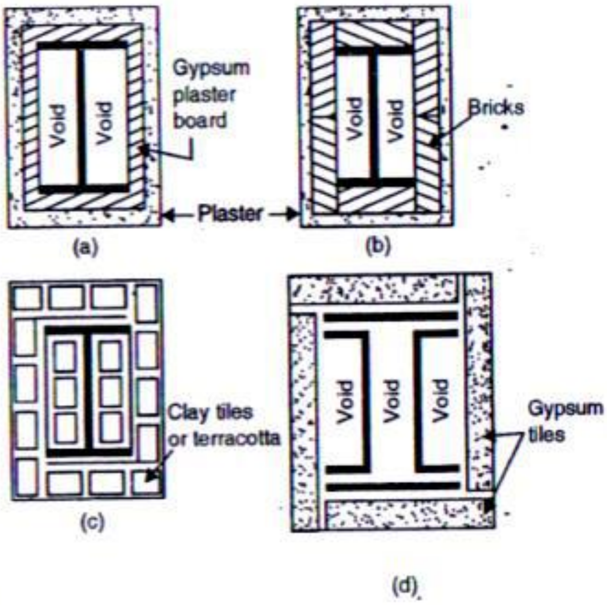



FIG. 23.1. PROTECTION OF STEEL COMPONENTS.

(*vii*) Partition walls should be of fire-resistant materials such as R.C.C., reinforced brick work, hollow concrete blocks, burnt clay tiles, reinforced glass, asbestos cement boards or metal laths covered with cement plaster.

(*viii*) Cavity wall construction has better fire resistance.

(*ix*) All walls, whether load bearing or non-load bearing, should be plastered with fire-resistive mortar.

**2. Floors and roofs**

The following points are note-worthy for fire-resistant floors and roofs :

(*i*) For better fire resistance, slab roof is preferred to sloping or pitched roofs.

(*ii*) If it is essential to provide sloping roof, trusses should either be of R.C.C. or of protected rigid steel with fire proof covering.

(*iii*) For better fire resistance, the floor should be either of R.C.C. or of hollow tiled ribbed floor or of concrete jack arch floor with steel joists embedded in concrete.

(*iv*) If floor is made of timber, thicker joists at a greater spacing should be used, and fire stops or barriers should be provided at suitable interval.

(*v*) The flooring materials like concrete tiles, ceramic tiles, bricks etc. are more suitable for fire resistance.

(*vi*) If cast iron, wrought iron, cork carpet, rubber tiles etc. are to be used, these should be protected by a covering of insulating materials like ceramic tiles, plaster, terracotta, bricks etc.

(*vii*) Ceiling, directly suspended from floor joists should be of fire resistant materials like asbestos cement boards, fibre boards, metal lath with plaster etc.

**3. Wall Openings**

(*i*) From the point of view of fire spread, openings in the walls should be a bare minimum.

(*ii*) Openings serve means of escape. Hence these should be properly protected by suitable arrangements, in case of fire.

(*iii*) Doors and windows should be made of steel. Fire-resistant doors can be obtained by fixing steel plates to both the sides of the door.

(*iv*) Wire-glass panels are preferred for windows.

(*v*) Rolling shutter doors should be used for garages, godowns, shops etc.

(*vi*) In case of timber doors, minimum thickness of door leaf should be 4 cm. and that of door frame as 8 to 10 cm.

(*vii*) All escape doors should be such as to provide free circulation to the persons in passages, lobbies, corridors, stairs etc., and should be made of fire proofing material.

**4. Escape Elements**

(*i*) All escape elements, such as stair cases, corridors, lobbies, entrances etc. should be constructed of fire-resistant materials.

(*ii*) These escape elements should be well separated from the rest of the building.

(*iii*) Doors to these escapes should be fire proof.

(*iv*) Staircases should be located next to the outer wall and should be accessible from any floor in the direction of flow towards the exits from the building.

(*v*) Fire proof doors to the emergency stair cases should be fixed in such a way as to make them close from inside only.

(*vi*) The lift shafts connecting various floors should be surrounded with the enclosure walls of fire-resisting materials.

(*vii*) Lift shafts should be vented from top to permit escape of smoke and hot gases.

(*viii*) An emergency ladder should be provided in the fire-resisting building. This ladder should be atleast 90 cm wide, constructed of fire-resistant materials.

(*ix*) All escape routes over roofs should be protected with railings, balustrades or parapets not less than one metre in height.

**5. Strong room construction**

A strong room construction is found to be useful in case of safe deposit vaults in banks. Following are the important features of construction :

(*i*) The walls, floors and ceilings of a strong room are made of atleast 30 cm thick cement concrete. If thin R.C.C. walls are used, they should be have covering of bricks or terra-cotta and then suitably plastered with fire-resistant plaster.

(*ii*) Doors and windows are well anchored to concrete walls by large number of steel hold fasts longer in length.

(*iii*) Doors and windows should be fire-proof. It is preferable to have double fire-proof door.

(*iv*) Windows and ventilators should be covered by special grills made of 20 mm steel square bars. These grills should be well fixed to concrete walls by means of long steel hold fasts.

## 23.10. FIRE ALARMS

Fire alarms are installed to give an alarm and to call for assistance in event of fire. The fire alarms give enough time to the occupants to reach to a safe place.

Fire alarms can be either manual or automatic.

**1. Manual alarms**

These are of a hand-bell type or similar other sounding device, which can emit distinctive sound when struck. These are sounded by watchmen and the occupants are thereby warned to have safe exit in shortest possible time. Manually operated alarms shall be provided near all main exits and in the natural path of escape from fire, at readily accessible points which are not likely to be obstructed.

**2. Automatic alarms**

These alarms start sounding automatically in the event of fire. It is used in large industrial buildings which may remain unoccupied during night. The automatic fire alarm sends alarm to the nearest control point. The system can also perform the function of sending message to the nearest fire brigade station.

## 23.11. FIRE EXTINGUISHING EQUIPMENTS

Each building should have suitable fire extinguishing arrangements, depending upon the importance of the building and the associated fire hazards. Following are usual equipments required for fire extinction.

**1. Manual fire extinguishing equipment**

These devices are useful for extinguishing fire as soon as it starts. They are not so useful when once the fire has spread. Under this category comes the portable extinguishers of carbon-dioxide type or foam generation type etc. The discharge from a portable fire extinguisher lasts only for a short duration of 20 to 120 seconds. In some cases, specially in small buildings buckets of water, sand and asbestos blanket may be kept ready at all times to extinguish fire. These buckets are installed at convenient locations for taking care of fire of minor size.

**2. Fire hydrants**

These fire hydrants are provided on a ring main of 150 mm dia. in the ground around the building periphery. The ring main gets water from underground tank with pressure, so that available pressure at each hydrants is of the order of about 3.5 to 4 $kg/cm^2$.

**3. Wet riser system**

The system consists of providing 100 to 150 mm dia. vertical G.I. pipes (risers) at suitable locations in the building. A fire pump is used to feed water from underground tank to these pipes, to ensure a pressure of 3 $kg/cm^2$ at uppermost outlet.

**4. Automatic sprinkler system**

This arrangement is adopted for important structures like textile mills, paper mills etc. The system consists of a net work of pipes 20 mm dia. fixed to the ceiling of the room. These pipes are spaced at 3 m centre to centre. Heat actuated *sprinkler heads* are fixed to these pipes at regular interval. The pipes get supply from a header. Each sprinkler head is provided with fusible plug. In the event of fire, the fusible plug in the sprinkler nearest to the wire melts due to rise of temperature, and water gushes out of the sprinkler head. The fire is thus brought under control in a short period.

# MASONRY

Masonry is defined as the art of construction in which building units, such as clay bricks, sand-lime, bricks, stones, Pre-cast hallow concrete blocks, concrete slabs, glass bricks, combination of some of these building units etc are arranged systematically and bonded together to form a homogeneous mass in such a manner that they can with stand point to other loads and transmit then through the mass without fail or disintegration.
Masonry can be classified into the following categories.

1. Stone masonry
2. Brick masonry
3. Hallow block concrete masonry
4. Reinforced masonry
5. Composite masonry

These can be further sub-divided into varies types depending upon workmanship and type of materials used.

**Definitions of terms:**

1. **Course**: A course is a horizontal layer of bricks stones

2. **Bed**: the surface of a stone perpendicular to the line of pressure of (lower surface of bricks or stones in each course)

3. **Back**: The inner surface of wall not exposed is called back. The material forming back is known as backing

4. **Face**: The exterior of the wall exposed to weather is known as face. The material used in the facing of wall is known as facing'

5. **Hearting**: It is the interior portion of a wall between facing and backing

6. **Head**: It is a brick or stone, which lies with its greatest length at right angles to the face of the work.

7. **Stretcher**: It is a brick or a stone which lies with its congest side parallel to the face of the work

8. **Bond**: The method of arranging bricks so that the individual units are tied together

9. **Spalls**: The chips of stones used for filling the interstics in stone masonry

10. **Quoins**: The stones used for the corners of walls of structure

11. **Bat**: It is a portion of a brick cut across the width.

12. **Closer**: It is the portion of a brickcut in such a manner that its one long face remains uncut

13. **Queen closer**: it is the portion of a brick obtained by cutting a brick length-wise into two portions

14. **King closer**: It is the portion of brick obtained by cutting off the triangular piece between the centre of one end and the centre of one side.

15. **Bevelled closer**: It is the portion of a brick in which the whole length of the brick is bevelled for maintaining half width at one end and full width at the other

16. **Frog**: It is an indentation or depression on the top face of a brick made with the object of forming a key for the mortar.

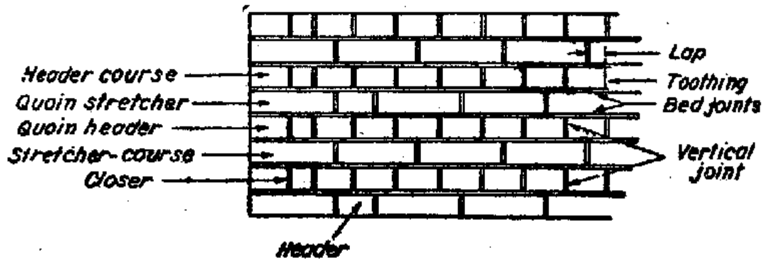
17. **Sill**: It is a horizontal stone, concrete or wood, employed for the purpose of shedding off rain water from the face of wall immediately below the window opening

18. **Corbel**: It is the extension of one or more course of stone or brick from the face of a wall to serve as a support for wall plates

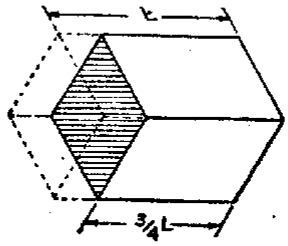
19. **Templates**: Pieces of stones placed under the end of a beam to distribute load over a greater area.

20. **Coping**: It is the course placed upon the exposed top of an external wall to prevent the seepage of water

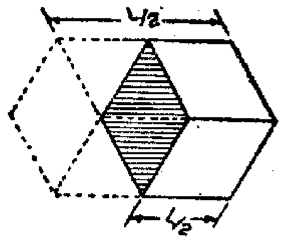
21. **Buttress**: It is a sloping or stepped masonry projection from a tall wall intended to strengthen the wall against the thrust of a roof as shown in fig 11.1



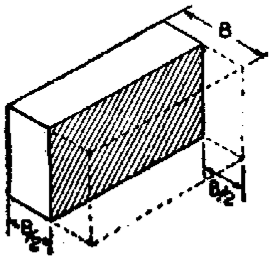

Masonry wall



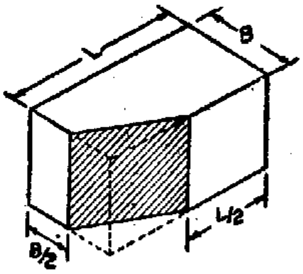

Three quarter Bat



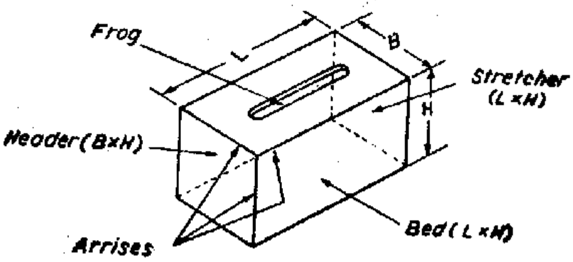

Half bat




Queen closer




King closer




Full brick

**Fig 11.1 Definitions of terms**

**Stone masonry:** The construction of stones bonded together with mortar is termed as stone masonry where the stones are available in a abundance in nature, on cutting and dressing to the proper shape, they provide an economical material for the construction of various building components such as walls, columns, footings, arches, lintels, beams etc.

**Uses of stone masonry:**

Stone masonry construction is used in

(i) Building foundations, dams, monumental structures
(ii) Building walls, piers, columns, pillars, light houses and architectural works.
(iii) Arches, domes, lintels and beams
(iv) Roofs, flems, paving jobs
(v) Railway, bullest, black boards and electrical switch boards

**Selection of stone for stone masonry:**

The selection of stones for stone masonry depends upon

a. Availability
b. Ease of working
c. Appearance
d. Strength and stability
e. Polishing characteristics
f. Economy
g. Durability

The table 11.1 given broadly outlines the different types of stones used for different purposes

| S<br>N | **Purpose** | **Stones used** |
|---|---|---|
| 1 | Heavy engineering works<br>Ex: stocks, break waters, light hou<br>bridges, piers | Granite, gneiss |
| 2 | Buildings situated in industrial tow | Granite<br>compact<br><br>sandstone |
| 3 | Pavements, railway ballast, door and<br><br>steps | Gr<br>te<br><br>sla |
| 4 | Electrical switch board | Ma<br>le<br><br>sla |
| 5 | Fire resistance works | Compact sandsto |
| 6 | Carving and ornamental works | Marble and later |
| 7 | Face work and architectural purpos | Marble, gra<br>closer<br><br>gained sand ston |

**Tools required for stone masonry construction:**

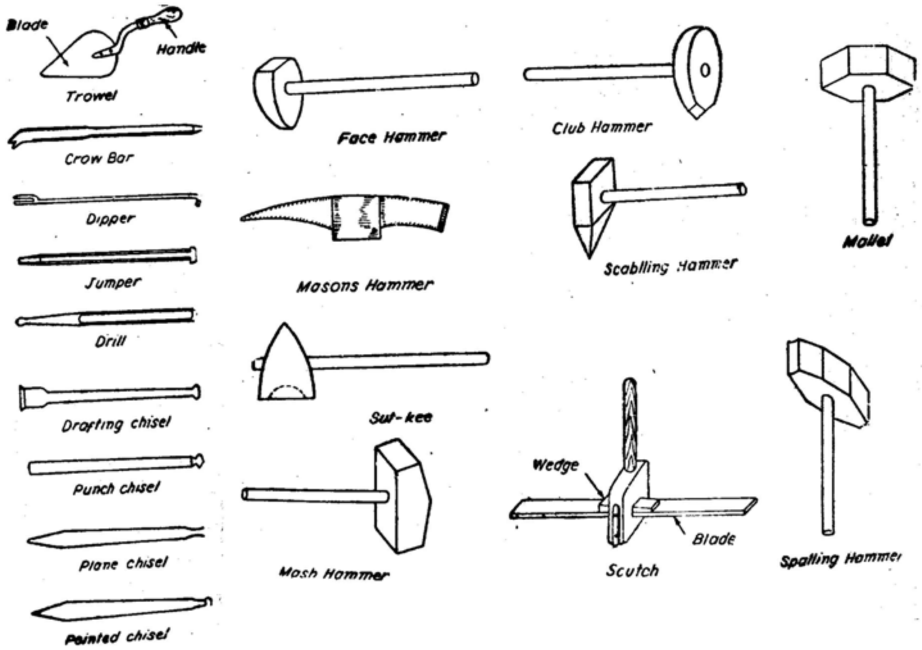



**Fig 11.2 Tools for Stone Masonry**

a) **Trowel** : This is used to lift and spread mortar

b) **Square**: This is made of flat steel having each arm about 0.5m long

c) **Plumb rule and bob**: This is used to check the vertically of walls

d) **Spirit level:** this is used to chick the horizontality of walls

e) **Line and pin**: This is used to maintain the alignment of the work in progress

f) **Bevel**: The instrument used to set right angles

g) **Pick axe**: This is employed for dressing of rough stone and split the stones in the quarry

h) **Crowbar**: This is used to make stones in query

i) **Chisels**: They are used to dress stones

j) **Spall hammer**: This is heavy hammer used for rough dressing of stones

k) **Mallet**: The wooden hammer used for driving of wooded headed chisels

l) **Iron hammer**: This is used for carving of stones

m) **Scabbling hammer**: This is used to break small projections of stones

n) **Pitching tool**: This is used to make the stones of required size

o) **Gauge**: this is employed to dress stones for spring course, comice, coping etc

p) **Claw tool:** This is employed for dressing the surface of stones

q) **Nicker**: This is employed to draw fine chisel lines on the stone surface

r) **Jumper**: They are used for boring holes

s) **Wedge and feathers**: They are employed for cutting the stones after they have been bored with jumper.

t) **Gad**: A small steel wedge used for splitting of stones

u) **Drag**: This is employed to level a stone surface

v) **Punch**: This is employed to dress roughly the stones

w) **Handsaw**: This is used to cut soft stones

x) **Cross-cut saw:** This is used to cut hard stones

y) **Frame saw**: This is used to cut large blocks of stones.

**Types of Stone Masonry:**

Based on the arrangement of the stone in the construction and degree of refinement in the surface finish, the stone masonry can be classified broadly in the following two categories

1. Rubble masonry
2. Ashlar masonry

**General principles in the stone masonry construction**

1. The stones to be used for stone masonry should be hard, tough and durable.
2. The pressure acting on stones should be vertical
3. The stones should be perfectly dressed as per the requirements
4. The heads and bond stones should not be of a dumb bell shape.
5. In order to obtain uniform distribution of load, under the ends of griders, roof trusses etc large flat stones should be used
6. The beds of the stones and plan of the course should be at right angles to the slope in the case of sloping retaining wall
7. Wood boxing should be filled into walls having fine dressed stone work to protect it during further construction
8. The mortar to be used should be good quality and in the specified faces.
9. The instruction work of stone masonry should be raised uniformly.
10. The plumb bob should be used to check the vertically of erected wall
11. The stone masonry section should always be designed to take compression and not the tensile stresses
12. The masonry work should be properly cured after the completion of work for a period of 2 to 3 weeks
13. As per as possible broken stones or small stones chips should not used

14. Double scaffolding should be used for working at higher level

15. The masonry hearting should be properly packed with mortar and chips if necessary to avoid hallows

16. The properly wetted stones should be used to avoid mortar moisture being sucked

**1) Rubble masonry:** In this category, the stones used are either undressed or roughly dressed having wider joints. This can be further subdivided as uncoursed, coursed, random, dry, polygonal and bint.

(i) **Uncoursed rubble masonry**: This is the cheapest, roughest and poorest form of stone masonry. The stones used in this type of masonry very much vary in their shape and size and are directly obtained from quarry. Uncoursed rubble masonry can be divided into the following.

a) Uncoursed random rubble

b) Uncoursed squared rubble

a) **Uncoursed random rubble masonry:** The weak corners and edges are removed with mason's hammer. Generally, bigger stone blocks are employed at quoins and jambs to increase the strength of masonry.

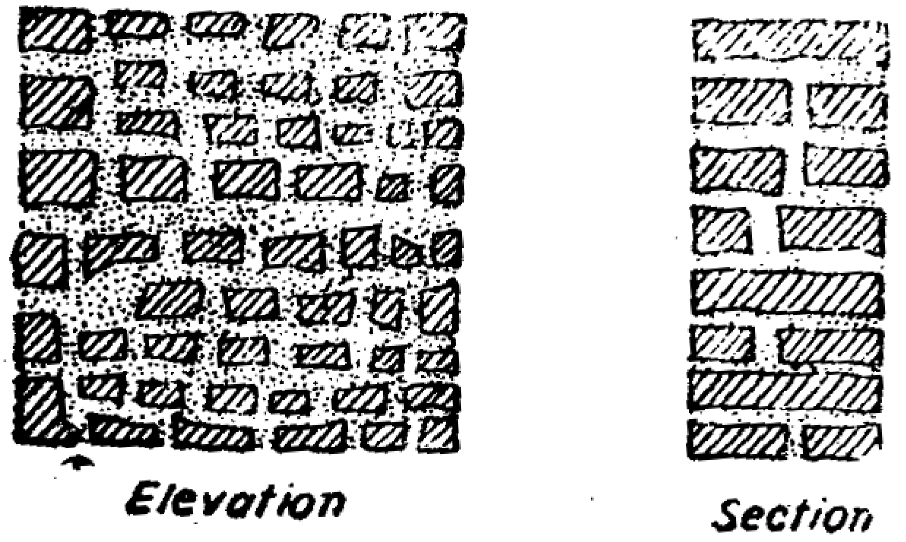
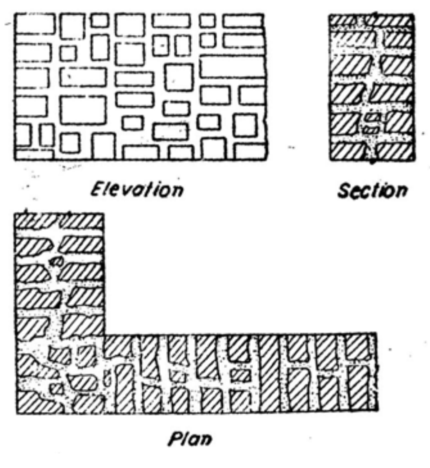



**Fig 11.3 Uncoursed random rubble masonry**

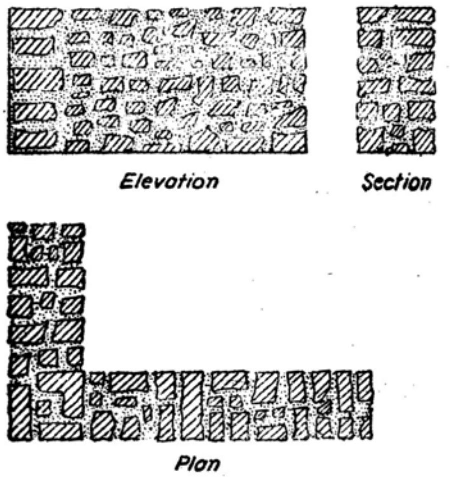
b) **Uncoursed squared rubble:** In this type the stone blocks are made roughly square with hammer. Generally the facing stones are given hammer-dressed finish. Large stones are used as quoins. As far as possible the use of chips in bedding is avoided as shown in 11.4.

**Fig 11.4 Uncoursed squared rubble masonry**



(ii) **Coursed random rubble:** This type of masonry is commonly used in the construction of low height walls of public buildings, residential buildings, abutment and piers of ordinary bridges. The stones of 5 to 20cm size are used in each course as shown in fig 11.5.

**Fig 11.5 Coursed Random Rubble**




(iii) **Coursed squared rubble:** This type of masonry is made up of hammer squared stones facing with bonded backing of uncoursed random rubble masonry. The stones employed in each course are of equal height. The backing and facing construction, should be carried simultaneously. In order to avoid thick mortar joints, small chips may be used as shown in the fig 11.6.

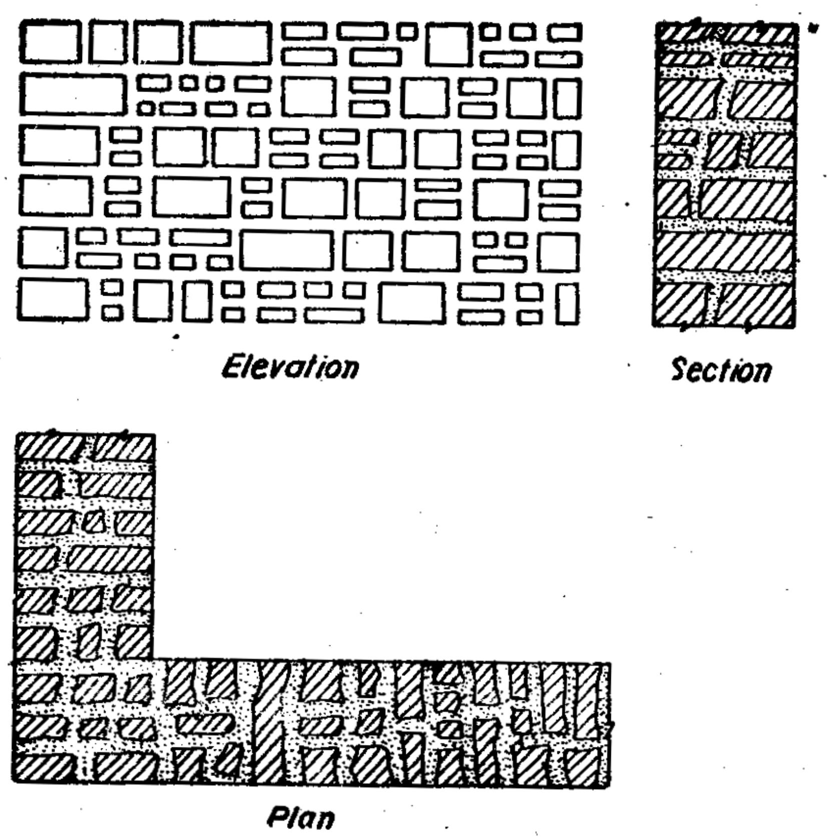



**Fig 11.6 Coursed Squared Rubble Masonry**

(iv) **Built to regular course:** In this type of stone masonry the uniform height stones are used in horizontal layers not less than 13cm in height. Generally, the stone beds are hammered or chisel dressed to a depth of atleast 10cm from the face. The stones are arranged in such a manner so that the vertical joints of two consecutive curse donot coincide with each other as shown in fig 11.7.

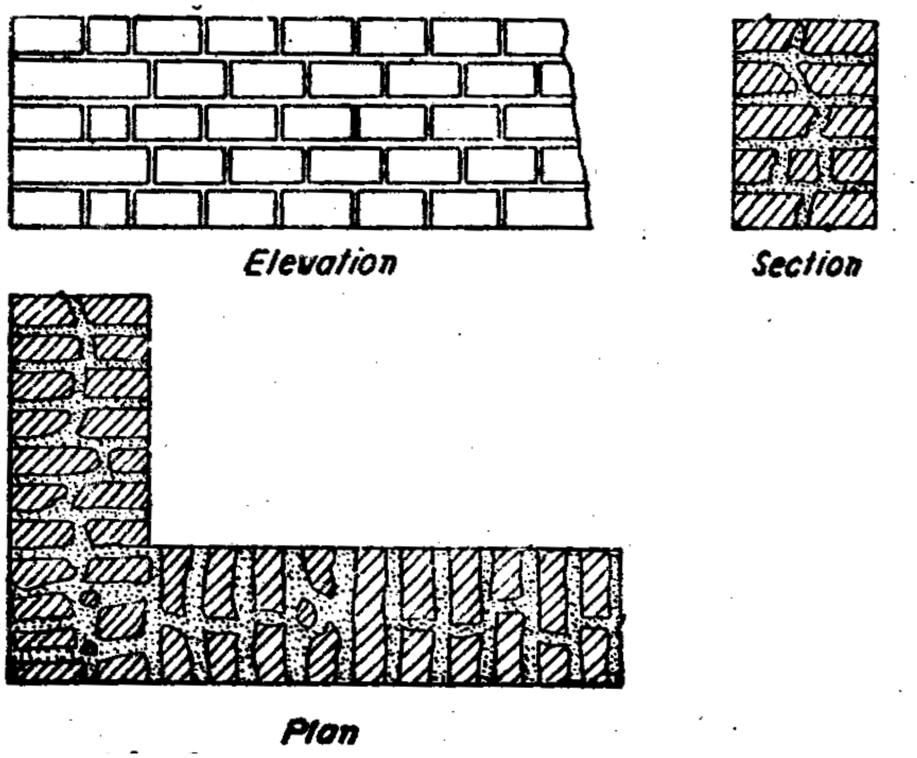



**Fig 11.7 Built to regular courses**

(v) **Polygonal rubble masonry:** In this type of masonry the stones are roughly dressed to an irregular polygonal shape. The stones should be so arranged as to avoid long vertical joints in face work and to break joints as much as possible. Small stone chips should not be used to support the stones on the facing as shown in fig 11.8.

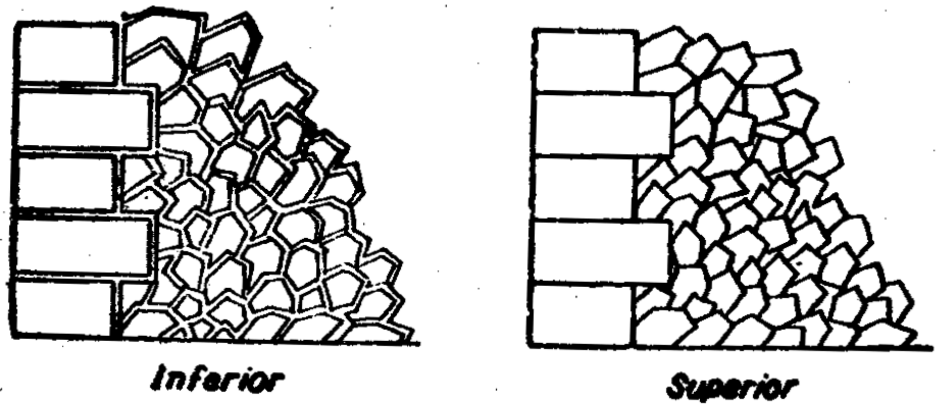



**Fig. 11.8 Polygonal rubble masonry**

(vi) **Plint rubble masonry:** This type of masonry is used in the areas where the flint is available in plenty. The flint stones varying in thickness from 8 to 15cm and in length from 15 to 30cm are arranged in the facing in the form of coursed or uncoursed masonry as shown in fig 11.9.

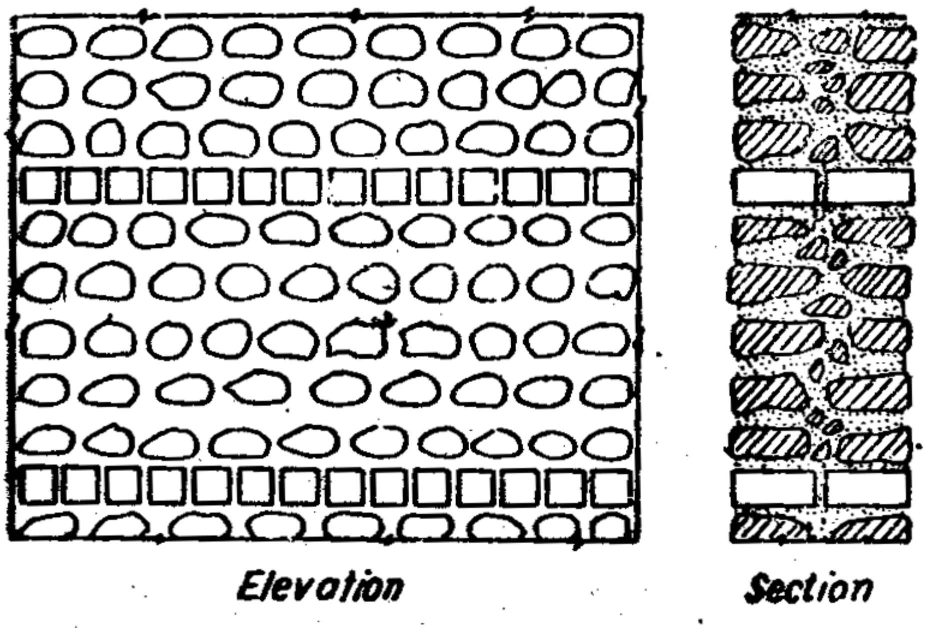



**Fig 11.9 Plint Rubble Masonry**

(vii) **Dry rubble masonry:** This type of masonry is used in the construction of retaining walls pitching earthen dams and canal slopes in the form of random rubble masonry without any mortar. The hallow spaces left around stones should be tightly packed with smaller stone pieces as shown in fig 11.10.

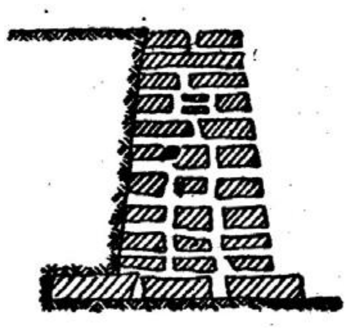


**Fig 11.10 Dry Rubble Masonry**

2. **Ashlar Masonry:** This type of masonry is built from accurately dressed stones with uniform and fine joints of about 3mm thickness by arranging the stone blocks in various patterns. The backing of ashlar masonry walls may be built of ashlar masonry or rubble masonry. The size of stones blocks should be in proportion to wall thickness. The various types of masonry can be classified under the following categories as shown in fig 11.11 to fig 11.13 .

(i) Ashlar fine

(ii) Ashlar rough

(iii) Ashlar rock or quarry faced

(iv) Ashlar facing

(v) Ashlar chamfered

(vi) Ashlar block in course

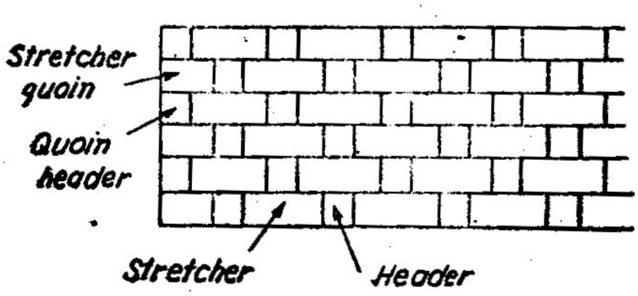



**Fig 11.11 Ashlar Fine Masonry**

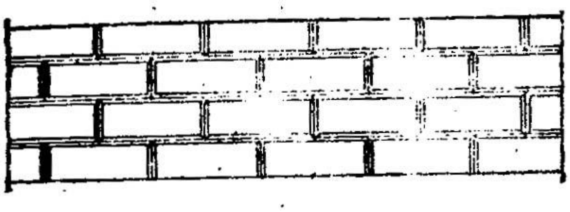


**Fig 11.12 Ashlar chamfered Masonry**

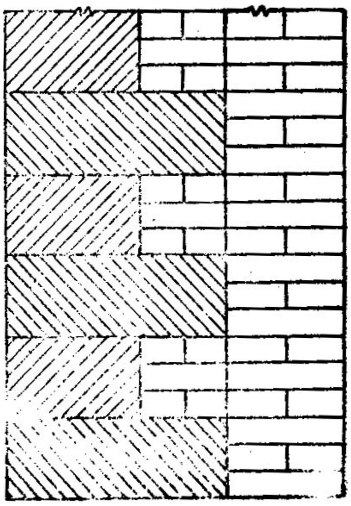


**Fig 11.13 Ashlar Facing**

**Brick masonry:**

Brick masonry is a unified mass obtained by systematic arrangement of laying bricks and bonding together with mortar. Brick is a building unit of hard inorganic clay material of size which can be conviently handled. The brick masonry is used in foundations, walls, columns, buttresses, retaining structures window sells, jambs, corbels, copings ornamental brickwork, circular brickwork, fire places, flumes, tall chimneys, cavity walls, thresholds, culverts, steps, floors, arches etc. The strength of brick masonry works depends upon the quality of bricks and type of mortar used.

Generally mortars are following types used for brick masonry

(i) Mud mortar

(ii) Cement mortar

(iii) Cement lime mortar

(iv) Lime surkhe mortar

**General principles in brick masonry construction:**

1. A good brick masonry should utilize bricks, which are sound, hard, well burnt and tough with uniform colour, shape and size.

2. The bricks should be compact, homogenious, free form holes, cracks, flaws, air-bubbles and stone lumps and soaked in water for atleast two hours before use

3. In the brickwork, the bricks should be laid on their beds with the frogs pointing upwards

4. The brick courses should be laid truly horizontal and should have truly vertical joints

5. As far as possible the use of brick – bats should be discouraged

6. As far as possible the brick wall should be raised uniformly less than 1.5m in day with proper bond.

7. When the mortar is green the face joints should be racked to a depth of 12 to 19mm in order to have a proper key for plastering or pointing.

8. In order to ensure continuous bond between the old and the new, the wall should be stopped with a toothed end.

9. Finished brickwork should be cured for a period of 2 to 3 weeks for lime mortar and 1 to 2 weeks for cement mortar

10. In order to carryout the brickwork at higher level, a single scaffolding is used.

**Types of brick bonds:**

Bonding is a process of arranging bricks and mortars to tie them together in a mass of brickwork. It should have a minimum of vertical joints in any part of the work.

**Characteristics of brick bond or rules for bonding:**

1. The brick masonry should have bricks of uniform shape and size

2. For satisfactory bondage the lap should be one-fourth of the brick along the length of the wall and half brick across thickness of the wall

3. The brick bats use should be discouraged

4. The vertical joints in the alternate courses should coincides with the centre line of the stretcher

5. The alternate courses the centre line of header should coincide with the centre line of stretcher, in course below or above it.

6. The stretcher should be used only in the facing while hearting should be done in the headers only

**Classifications of bonds:** The bonds can be classified as follows:

(i) Stretcher bond

(ii) Header bond

(iii) English bond

(iv) Double Flemish bond

(v) Single Flemish bond

(vi) Garden wall bond

(vii) Facing bond

(viii) Dutch bond

(ix) Raking bond

(x) Zigzag bond

(xi) English cross bond

(xii) Bonds in columns

(xiii) Brick on edge bond or soldier course

(xiv) Bonds at junction and squint junction

**Stretcher bond:** In this type of bond all the bricks are laid with their lengths in the direction of the wall. This pattern is used only for wall having thickness of 9cm only as shown in fig 11.14.

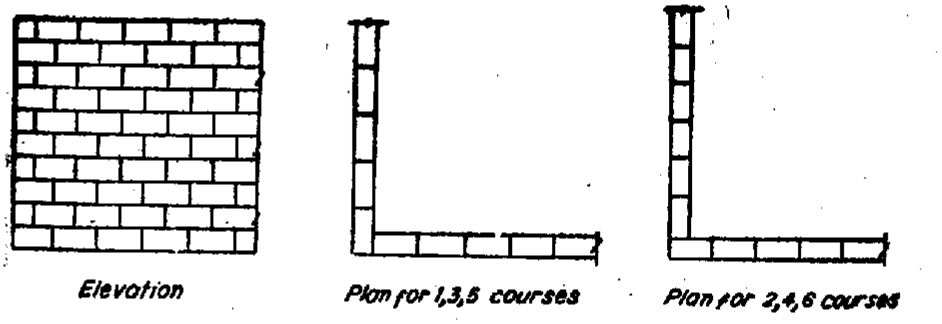



**Fig 11.14 Stretcher Bond**

**Header bond:** In this type of bond all the bricks are laid with their ends towards the face of the wall. This arrangement is suitable for one brickwall of curved wall and footings for better load distribution as shown in fig 11.15.

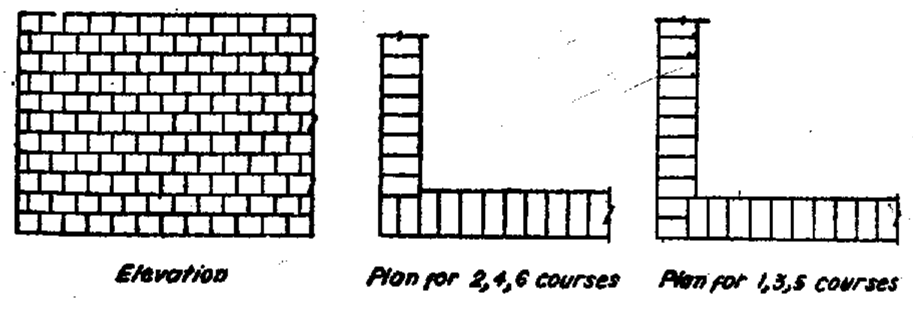
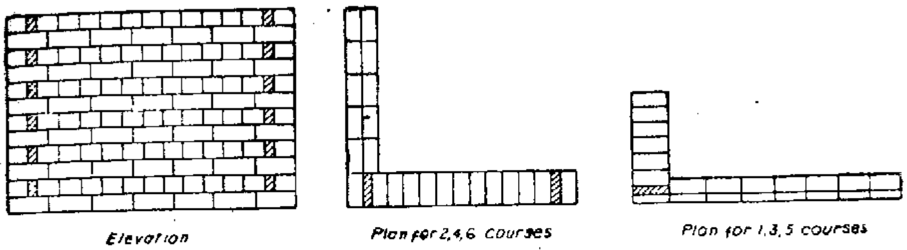
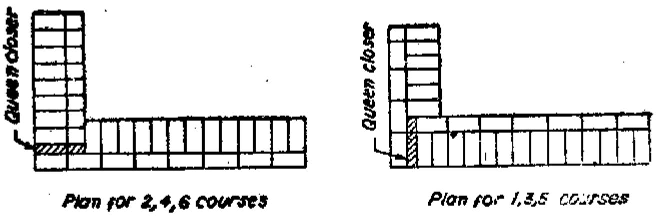



**Fig 11.15 Header Bond**

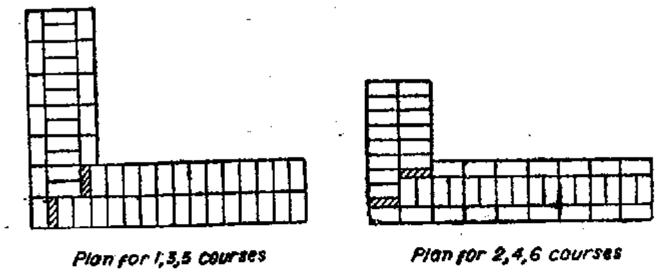
**English bond**: In this type of bond alternate course of headers and stretchers are laid. It is necessary to place queen closer in the heading course for breaking the joints vertically. The different english bonds are as shown in fig 11.16 and 11.17.



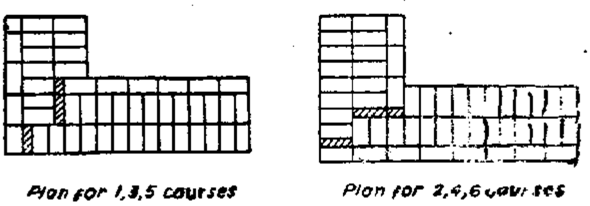

**One-brick wall English bond**




**One-and-a-half-bricks wall English bond.**




**Two-bricks wall English bond.**




**Two-and-a-half-bricks wall English bond.**

**Fig 11.16 English Bond**

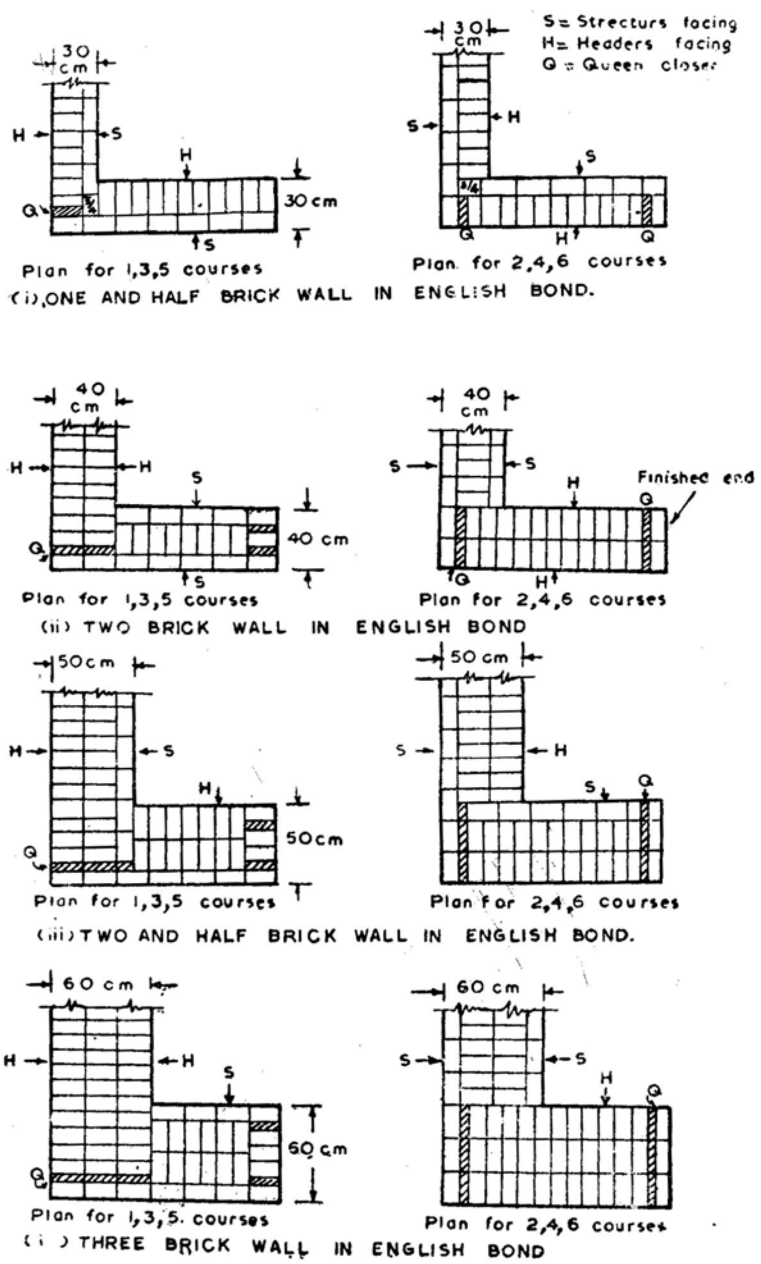
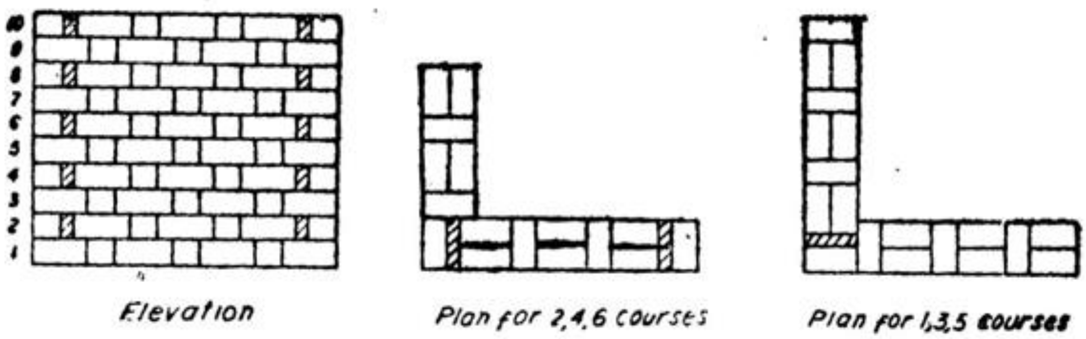
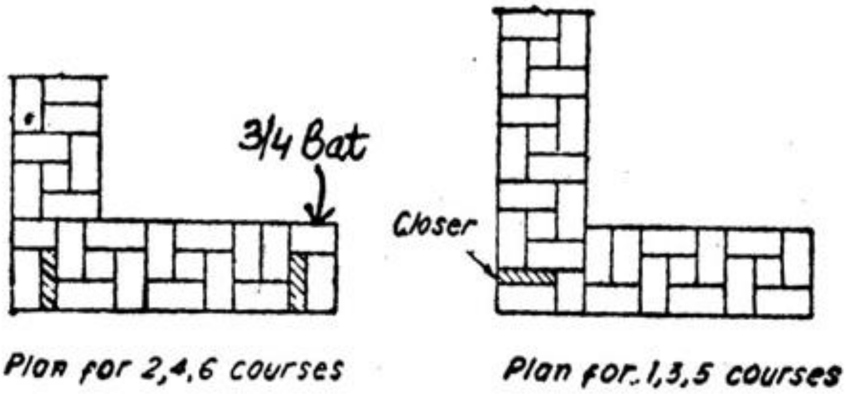



**Fig 11.17 Alternate arrangements for various wall thicknessess in English Bond**

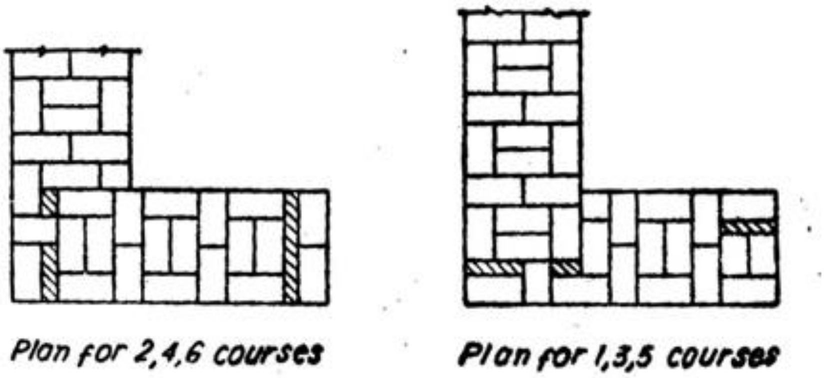
Double Flemish bond: In this type, alternate heads and stretchers are laid in each course. The facing and backing are of the same appearance brickbats and queen closers are used. The double Flemish bond is as shown in fig 11.18.




One-brick wall double flemish bond.




One-and-a-half-bricks double flemish bond.




Two-bricks double flemish bond.

**Fig 11.18 Double Flemish Bond**

**Single Flemish bond:** This type of bond is comprised of double Flemish bond facing and English bond backing in each course. This type of construction partially possesses the strength of English bond, and appearance of Flemish bond. As this type of bond requires minimum thickness of 1 ½ bricks so it cannot be used for walls having thickness less than 1½ bricks. The fig 11.19 shows the single Flemish bond.

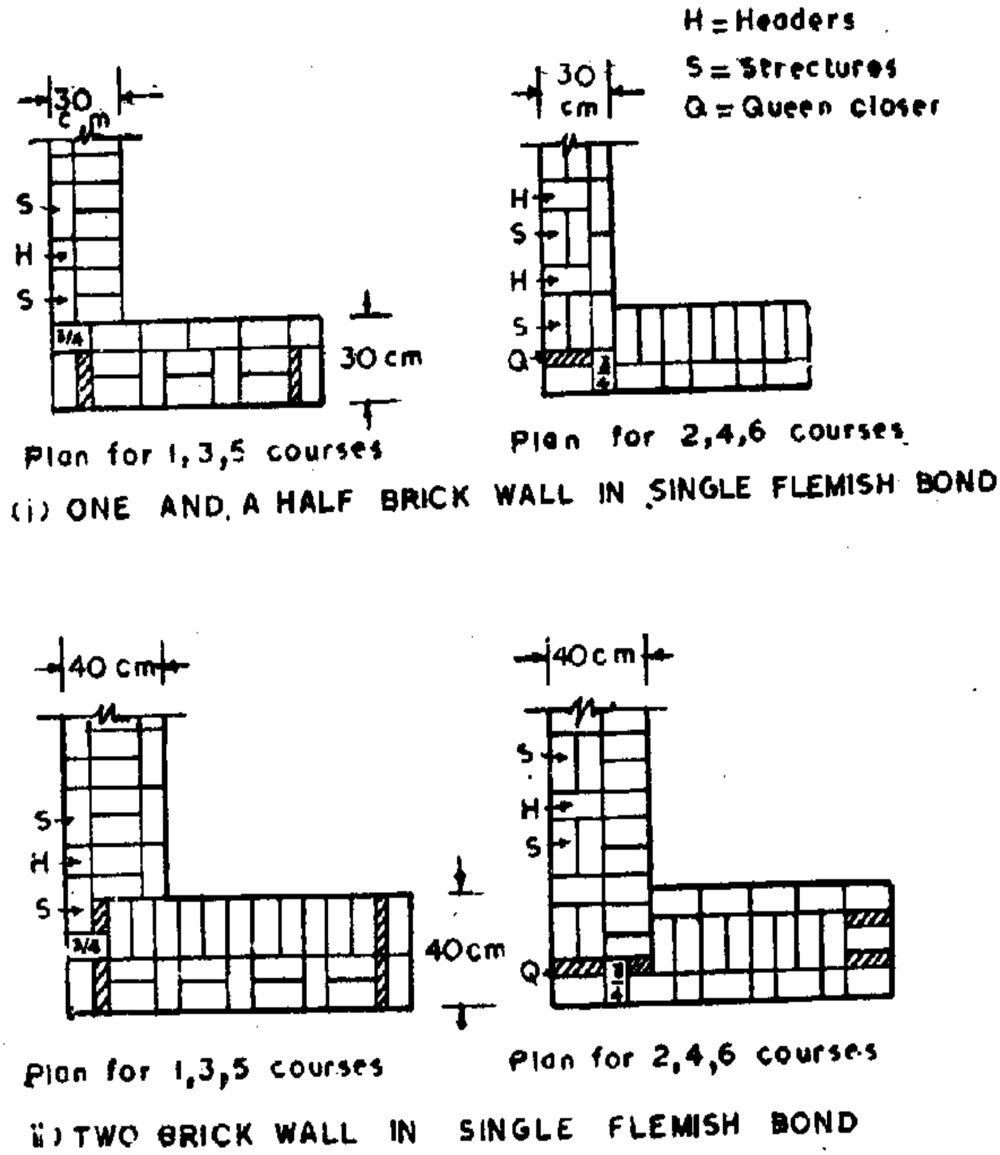



**Fig 11.19 Single Flemish Bond**

**Garden wall bond:** This type of bond is employed for the construction of garden walls, compound walls, boundary walls etc. This wall bond can be both English as well as Flemish as shown in the fig 11.20 & 11.21.

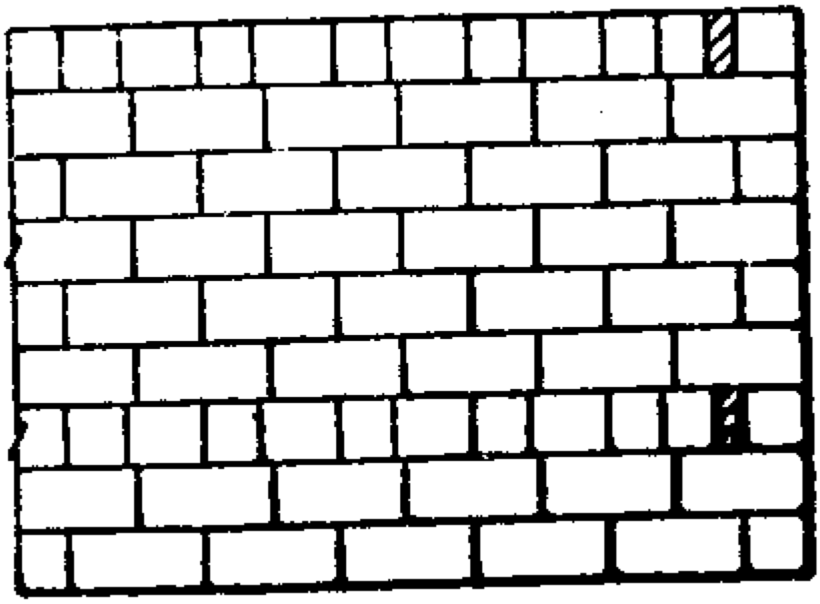


**Fig 11.20 English Garden Wall Bond**

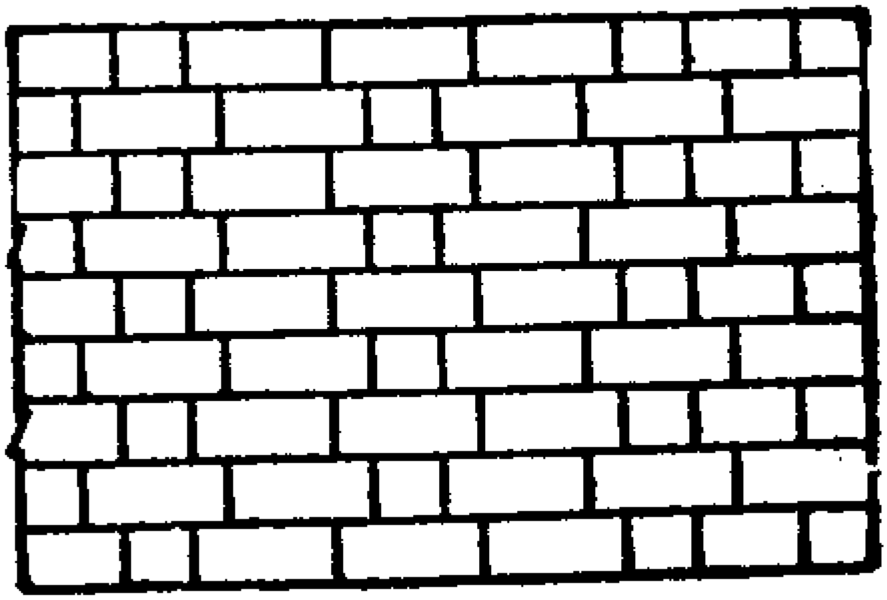


**Fig 11.21 Flemish Garden Wall Bond**

**Facing bond:** In this type of bond bricks of different thickness are used in the facing and backing of the wall. In this case, a header course is placed after several stretcher courses. In this type of bond, the distance between the successive heading courses is equal to common multiple of thickness of backing and facing bricks.

**Dutch bond:** This is the modified form of English bond. The corners of the wall provided with dutch bond are quite strong. The alternate courses in this type of bond are headers and stretchers. In stretcher course ¾ bat is used as quoin. A header is placed next to the ¾ bat in every alternate stretcher course as shown in the fig 11.22.

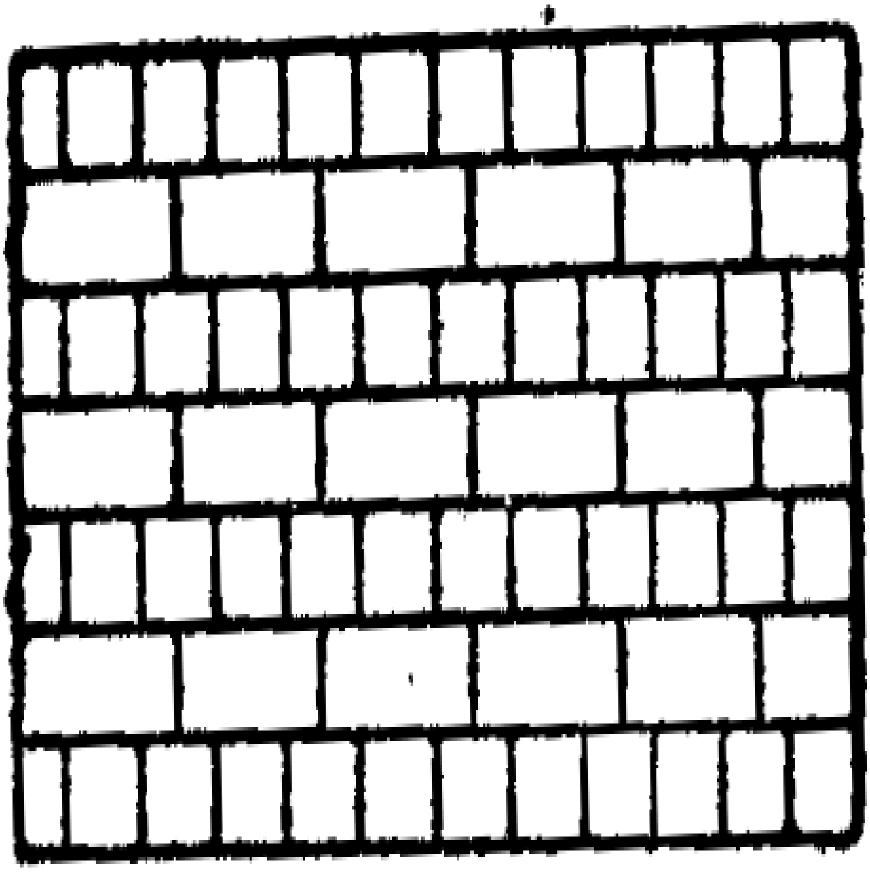
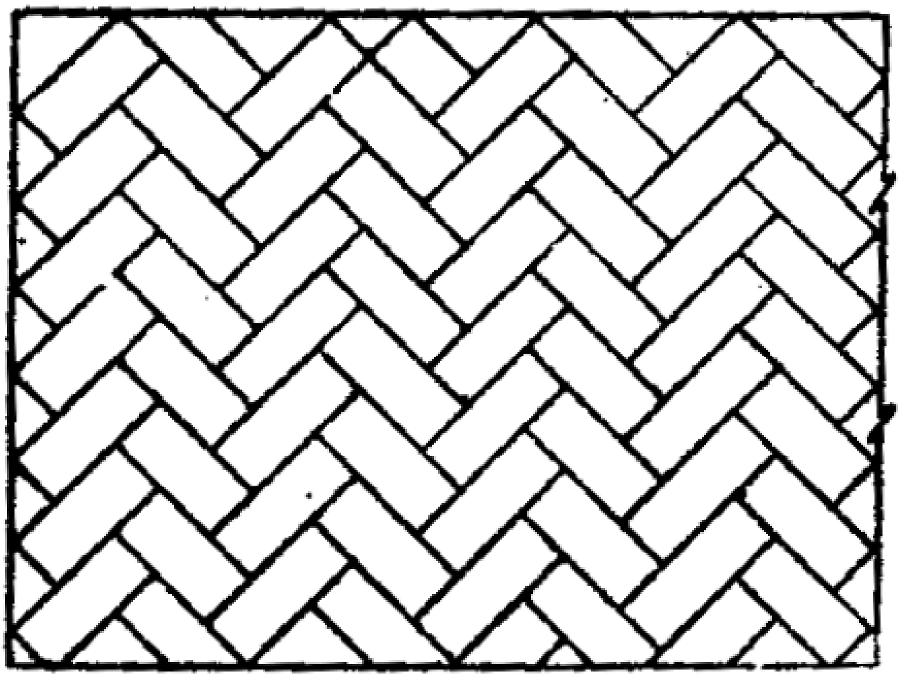


**Fig 11.22 Dutch Bond**

**Raking bond:** In this type of bond alternate courses are placed in different directions to get maximum strength in the wall. The racking courses are laid to certain interval along the height of the wall in very thick wall having number of headers more than the no.

of stretchers between the facing and backing. Thus the raking course rectifies the defect of low longitudinal, stiffness in thick wall. This is of two types a. Herring bone bond (placed at $45^0$ in both direction) b. Diagonal bond as shown in fig 11.23.

**Fig 11.23 Herring Bone Bond**



**Zigzag bond:** This type of bond very much similar to herring bone bond. The only difference is that bricks are laid in zigzag way and used for paving the brick floor as shown in fig 11.24

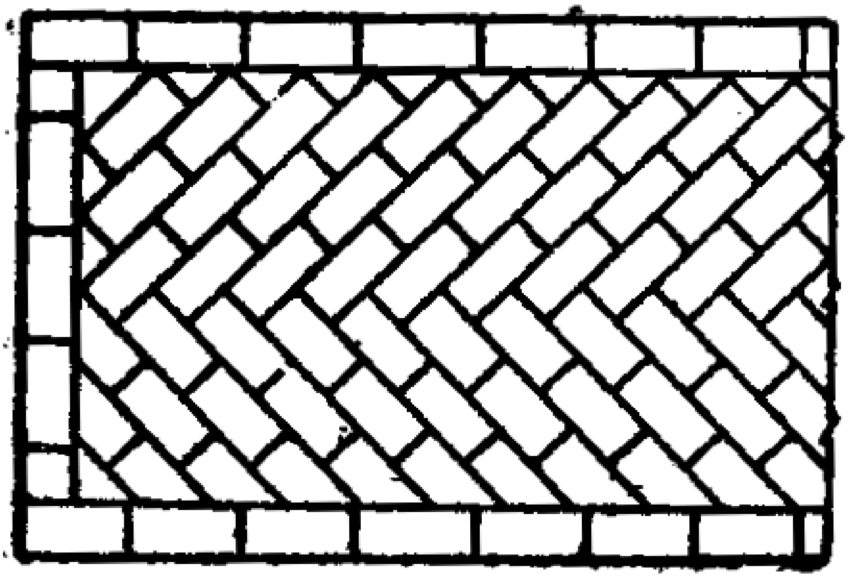


**Fig 11.24 Zigzag Bond**

**English cross bond:** This type of bond is aesthetically more sound and posses greater strength than English bond. In this bond every alternate stretcher course has a header placed next to the quolin stretcher and rest of the details are similar to English bond as shown in fig 11.25

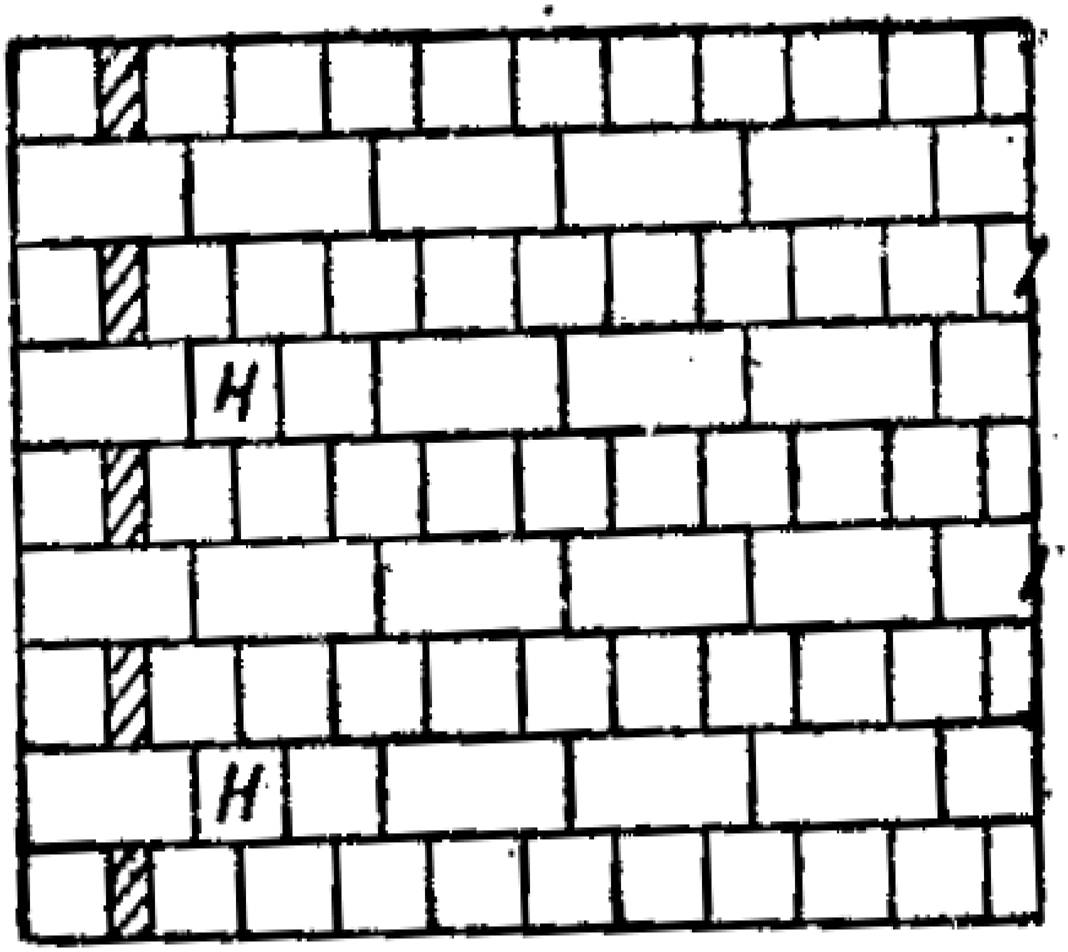



**Fig 11.25 English Cross Bond**

**Brick on edge bond or soldier course:** In this type of bond, the bricks are laid on edge. The bricks are placed as headers and stretchers in alternate courses in such a manner that headers are placed on bed and the stretchers are placed an edge forming a continuous cavity. This bond is weak in strength but economical.

Bonds in columns: Generally English bond or double Flemish bond are used for column construction. In case of circular or octagonal construction moulded bricks are used. The various arrangements of bricks in different columns shapes are as shown in fig 11.26.

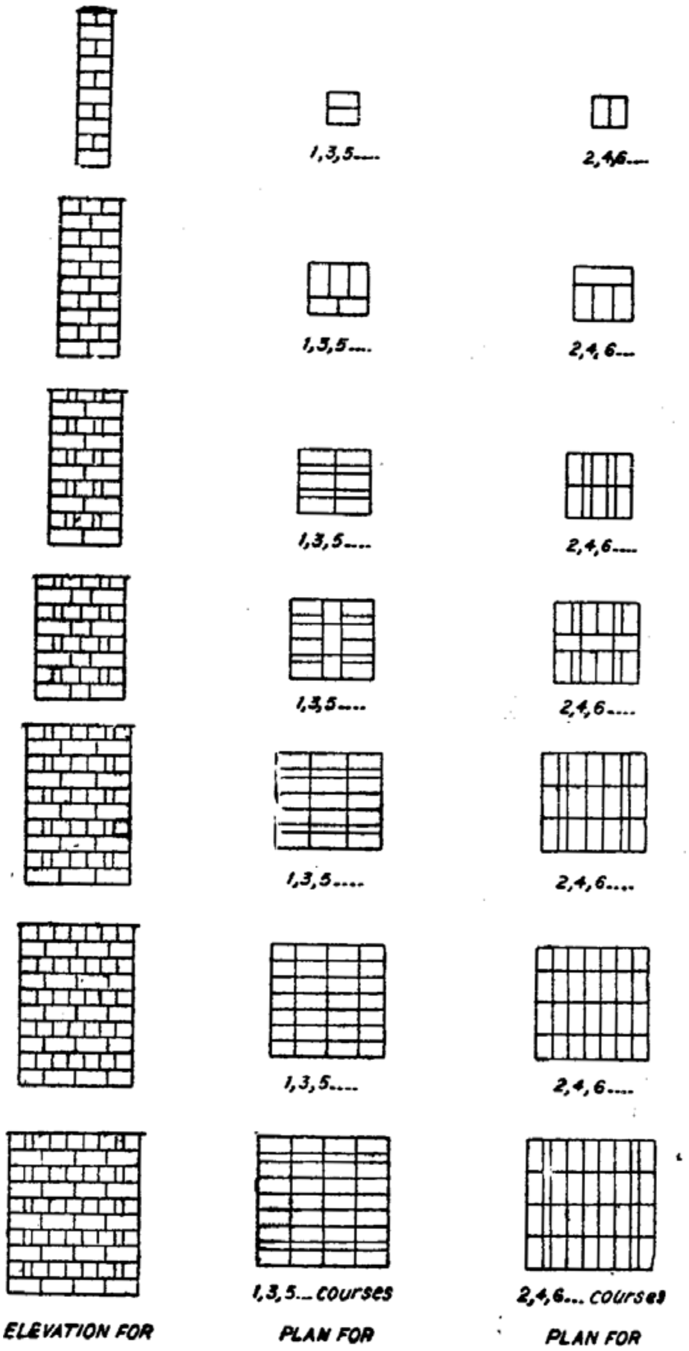



**fig 11.26 Bonds in columns**

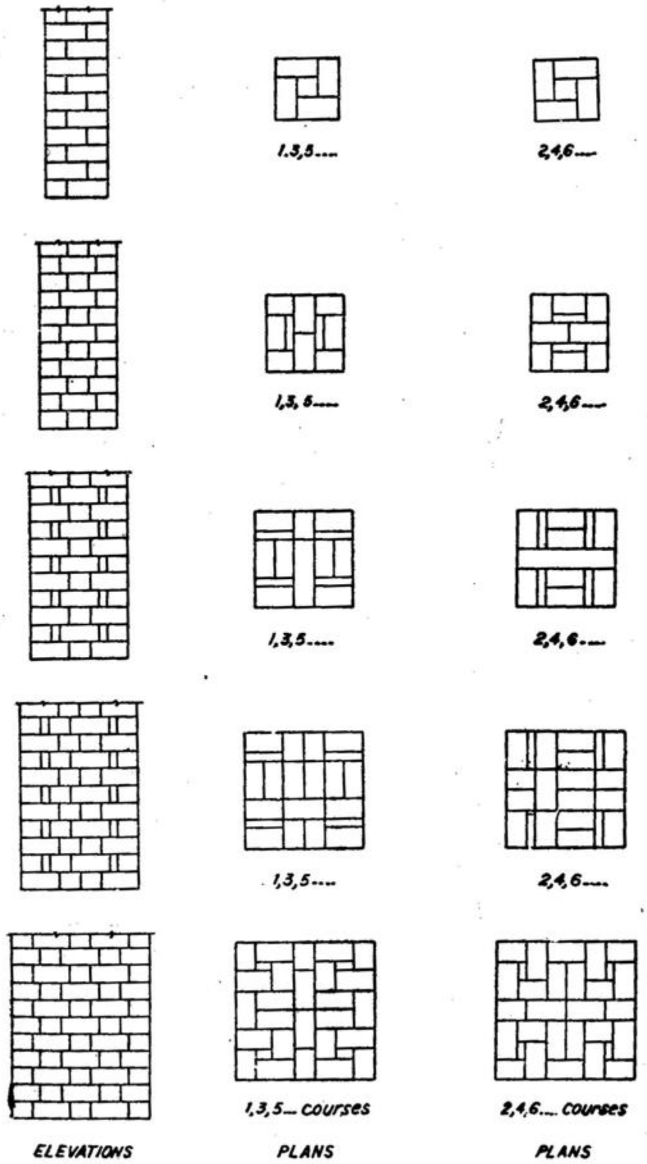
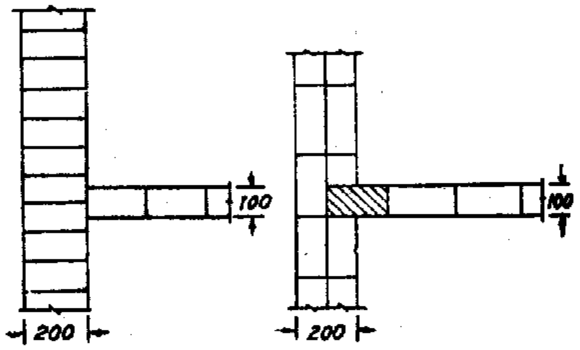


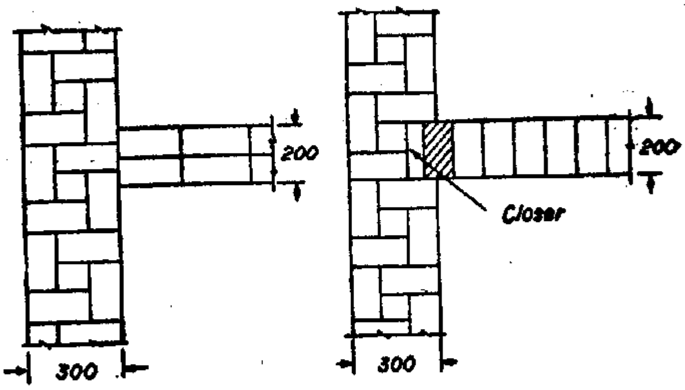

**Fig 11.27 Columns in Double Flemish bond**

**Bonds at junction:** When two walls meet or intersect each other, the meeting point is known as junction

(i) **For tee junction-** English or double Flemish is used as shown in fig 11.28.




Plans for one-brick Tee-Junction.




Plans for one-and-a-half brick Tee-Junction.

Fig. 8·39. Tee-Junction in English Bond.

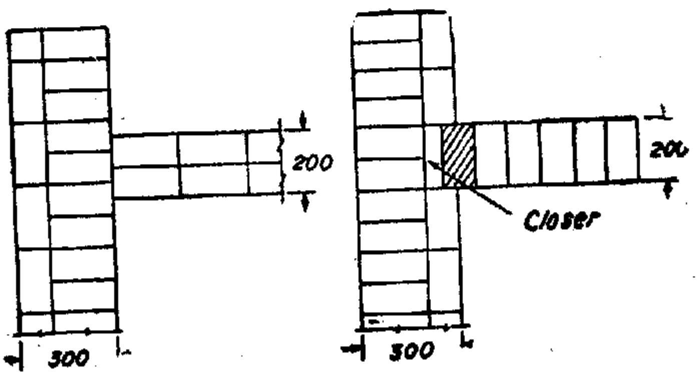



**Fig 11.28 Bonds in Tee-Junction**

(ii) **For cross junctions** – English bond is used as shown in fig. 11.29

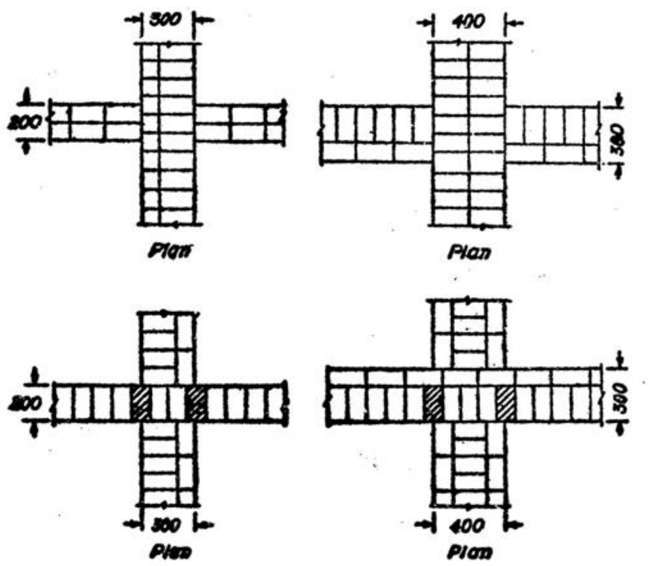



**Fig 11.29 Cross Junctions in english bond**

**SYNOPYSIS**

1. Masonry is art of construction in which buildings units bricks, stones etc are arranged systematically and binded with cement & sand mixture

2. The masonry is classified as

(i) Stone masonry

(ii) Brick masonry (iii)Hallow Masonry (iv)Re-forced masonry

(v) Composite Masonry

3. The stone masonry is useful for foundations, dams, walls, piers, columns, arches, domes, lintels, beams, roofs, floors, railway ballest, black boards and electrical switch boards

4. Stone masonry is divided

(i) Rubble masonry

(ii) Ashlar masonry

5. The brick masonry is a unified mass obtained by systematically arrangement of laying brick and bonded together with mortar.

6. The brick mortar generally the following types

(i) Mud mortar

(ii) Cement mortar (iii)Cement lime mortar (iv)Lime surkhi mortar

7. Bonding is a process of arranging bricks and mortars to tie them together in a mass of brickwork

8. The bonds can be classified as

(i) Stretcher bond

(ii) Header bond

(iii) English bond

(iv) Double flemish bond

(v) Single flemish bond

(vi) Garden wall bond

(vii) Faving bond

(viii) Dutch bond

(ix) Raking bond

(x) Zig zag bond

(xi) English cross bond

(xii) Bonds in columns

(xiii) Brick on edge bond or soldier course

(xiv) Bonds at junction and squint junction

**SHORT ANSWER QUESTIONS**

1. What is masonry?
2. Name the types of masonry 3.Define the following

a. Strecher

b. Quoins

c. Queen closer

d. King closer

e. Frog

f. Sill

4. Define stone masonry
5. What are the uses of stone masonry?
6. Name the import stones used in the construction of stone masonry 7.What is the use of following tools in the construction of stone masonry

a. Plumb rule

b. Spirit level

c. Line and pin

d. Bevel

e. Mallet

f. Chisel

g. Scabbling hammer

h. Jumper

i. Gauge

8. Define brick masonry
9. What are the uses of brick masonry
10. Name the important types of stone masonry

**ESSAY TYPE QUESTIONS**

1. What is stone masonry? Explain the uses of stone masonry
2. Explain the following with neat sketch a) king closer b) queen closer.
3. What are factors to be considered for the selection of stone for stone masoanry?
4. Explain different types of stones used for various purposes
5. Explain the types of tools and their uses for stone masonry construction
6. What are the general principles adopted in the stone masonry construction
7. Explain the types of stone masonry
8. Explain the types of brick masonry
9. What are principles adopted in brick masonry construction?
10. Compare the merits and demerits of stone masonry and brick masonry.

* * *

# Masonry-2 : Brick Masonry

## 6.1. INTRODUCTION

Brick masonry is made of brick units bonded together with mortar. Two essential components of brick masonry are therefore :

(*i*) Bricks (*ii*) Mortar

The mortar used for brick masonry should have the same characteristics as discussed in Chapter 5 for stone masonry. Mortar acts as a cementing material and unites the individual brick units together to act as a homogeneous mass. Following types of mortar may be used in brick masonry :

1. Cement mortar
2. Lime mortar
3. Cement-lime mortar
4. Lime-surkhi mortar and
5. Mud mortar

Mud mortar is used only for low-rise buildings which carry light loads. Cement mortars are used for high-rise buildings, where strength is of prime importance. Lime mortar and lime-surkhi mortars are used for all types of construction.

Bricks are manufactured by moulding clay in rectangular blocks of uniform predetermined size, drying them and then burning them in a kiln. Clay is a plastic earth, constituted largely of sand and alumina with traces of chalk, iron, manganese dioxide etc. Good bricks should be thoroughly burnt so that they become hard and durable. Satisfactory burning of bricks is ascertained by a hard ringing sound emitted when two bricks are struck together. The bricks should be free from cracks, chips, and large particles of lime. The strength of brick masonry chiefly depends upon: (*i*) quality of bricks, (*ii*) quality of mortar and (*iii*) method of bonding used. Unbonded wall, even constructed with good quality bricks and good quality mortar has little strength and stability.

Brick masonry is sometimes preferred over other types of masonry due to the following reasons :

1. All the bricks are of uniform size and shape, and hence they can be laid in any definite pattern.

2. Brick units are light in weight and small in size. Hence these can be easily handled by brick layers by hand.

3. Bricks do not need any dressing.

4. The art of brick laying can be understood very easily, and even unskilled masons can do the brick masonry. Stone masonry construction requires highly skilled masons.

5. Bricks are easily available at all sites, unlike stones which are available only at quarry sites. Due to this, they do not require transportation from long distances.

6. Ornamental work can be easily done with bricks.

7. Light partition walls and filler walls can be easily constructed in brick masonry.

## 6.2. TYPES OF BRICKS

Bricks used in masonry can be of two types :

(*i*) Traditional bricks (*ii*) Modular bricks.

*Traditional bricks* are those which have not been standardized in size. The dimensions of traditional bricks vary from place to place. Their length varies from 20 to 25 cm, width varies from 10 to 13 cm and thickness varies from 5 cm to 7.5 cm. The commonly adopted nominal size of traditional brick is 23 cm × 11.4 cm × 7.6 cm ($9'' \times 4\frac{1}{2}'' \times 3''$) approximately.

*Modular bricks* conform to the size laid down by Bureau of Indian Standard Institution, India. Any brick which is of the same uniform size as laid down by BIS is known as the *modular brick*. The *nominal size* of the modular brick is 20 cm × 10 cm× 10 cm while the *actual size* of the brick is 19 cm × 9 cm × 9 cm. *Nominal size* includes the mortar thickness. Masonry modular bricks are economical to manufacture, require less area for drying, and staking, and requires less *brick work* for the same surface area of the wall, in comparison to conventional bricks. The masonry with modular bricks thus workout to be cheaper.

### Classes of bricks

Quality wise, masonry bricks are classified into three classes: (*i*) First class bricks (*ii*) Second class bricks and (*iii*) Third class bricks.

(*i*) ***First class bricks.*** First class bricks are those which strictly conform to the standard size of modular bricks, *i.e.*, 19 cm × 9 cm × 9 cm actual size, such that ten layers of brick laid in mortar will form masonry of 1 metre height. Good bricks are manufactured from good quality plastic earth which is free from saline deposits. They are of good uniform colour. They are well burnt; hard ringing sound is emitted when two bricks are struck together. They have straight edges and even surfaces. They are free from cracks, chips, flaws and nodules of lime. When immersed in

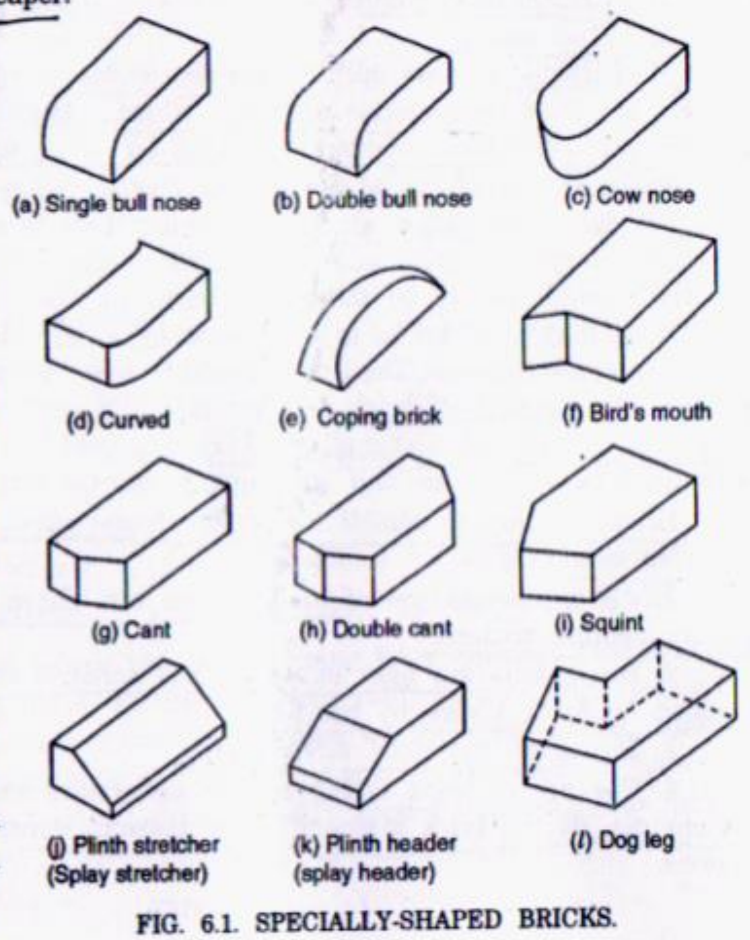



FIG. 6.1. SPECIALLY-SHAPED BRICKS.

water for one hour, they do not absorb water more than one-sixth of their weight, on drying, they do not show any sign of afflorescence.

***(ii) Second class bricks.*** Second class bricks also conform to the standard size, but they are slightly, irregular in shape and colour. They are also fully burnt, and ringing sound is emitted when two bricks are struck together. When immersed in water for one hour, they do not absorb water more than one-fourth of their weight.

***(iii) Third class bricks.*** These are the one which are quite irregular in their size, shape and finish. They are not burnt fully, due to which they are of reddish-yellow colour. These bricks have low crushing strength. They are not used for quality brick-masonry.

**Moulded bricks.** Moulded bricks are those which are manufactured in special shapes and sizes to be used for giving architectural shapes. Such bricks are used for copings, cornices, string courses, sloping walls etc. Fig. 6.1 shows some commonly used specially-shaped bricks.

## 6.3. SOME DEFINITIONS

**1. Stretcher.** A stretcher is the longer face of the brick (*i.e.* 19 cm × 9 cm) as seen in the elevation of the wall. A course of bricks in which all the bricks are laid as stretchers on facing is known *as a stretcher course* or *stretching course.*

**2. Header.** A header is the shorter face of the brick (*i.e.* 9 cm × 9 cm) as seen in the elevation of the wall. A' course of bricks in which all the bricks are laid as headers on the facing is known as *header course* or *heading course.*

**3. Lap.** Lap is the horizontal distance between the vertical joints of successive brick courses.

**4. Perpend.** A perpend is an imaginary vertical line which includes the vertical joint separating two adjoining bricks.

**5. Bed.** Bed is the lower surface (19 cm × 9 cm) of the brick when laid flat.

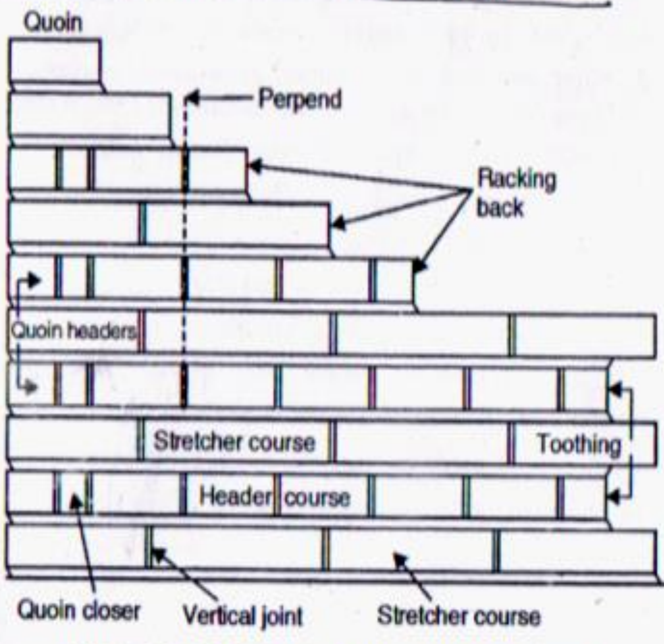



FIG. 6.2. ELEVATION OF A BRICK WALL.

**6. Closer.** It is a portion of a brick with the cut made *longitudinally,* and is used to close up bond at the end of the course. A closer helps in preventing the joints of successive sources (higher or lower) to come in a vertical line. Closers may be of various types, defined below.

**7. Queen-closer.** It is a portion of a brick obtained by cutting a brick lengthwise into two portions (Fig. 6.3 *b*). Thus, a queen- closer is a brick which is half as wide as the full brick. This is also known as *queen-closer-half.* When a queen-closer is broken into two pieces, it is known as *queen-closer-quarter.* Such a closer is thus a brick piece which is one-quarter of the brick size (Fig. 6.3 *c*).

**8. King closer.** It is the portion of a brick which is so cut that the width of one its end is half that of a full brick, while the width at the other end is equal to the full width (Fig. 6.3 *d*). It is thus obtained by cutting the triangular piece between the centre of one end and the centre of the other (lay) side. It has half-header and half-stretcher face.

**9. Bevelled closer.** It is a special form of a king closer in which the whole length of the brick (*i.e.*. stretcher face) is bevelled in such a way that half width is maintained at one end and full width is maintained at the other end (Fig. 6.3 *e*).

**10. Mitred closer.** It is a portion of a brick whose one end is cut splayed or mitred for full width. The angle of splay may vary from 45° to 60°. Thus, one longer face of the mitred closer is of full length of the brick while the other longer face is smaller in length (Fig. 6.3 *f*).

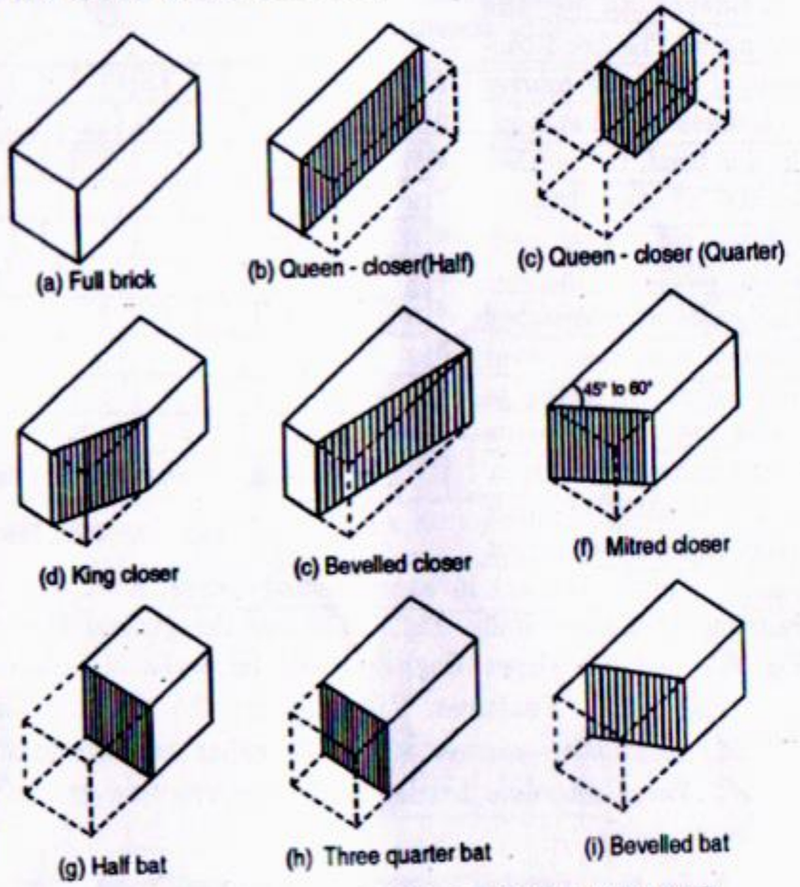



FIG. 6.3. VARIOUS FORMS OF BRICK PORTIONS.

**11. Bat.** It is the portion of the brick cut across the width. Thus, a bat is smaller in length than the full brick. If the length of the bat is equal to half the length of the original brick, it is known as *half bat* (Fig. 6.3 *g*). A *three-quarter-bat* (Fig. 6.3 *h*) is the one having its length equal to three-quarters of the length of a full brick. If a bat has its width bevelled, it is known is bevelled bat (Fig. 6.3 *i*).

**12. Arris.** It is the edge of a brick.

**13. Bull nose.** It is a special moulded brick with one edge rounded (*single bull nose*, Fig. 6.1 *a*) or with two edges rounded (double bull nose, Fig. 6.1 *b*). These are used in copings or in such positions where rounded corners are preferred to sharp arises.

**14. Splays.** These are special moulded bricks which are often used to form plinth. *Splay stretcher* (plinth stretcher) and *splay header* (plinth header) are shown in Fig. 6.1 (*j*) and (*k*) respectively.

**15. Dogleg or angle.** It is also special form of moulded bricks (Fig. 6.1 *l*) which are used to ensure a satisfactory bond at quoins which are at an angle other than right angle. The angle and lengths of the faces forming the dogleg vary according to requirements. These are preferred to mitred closer.

**16. Quoin.** It is a corner or the external angle on the face side of a wall. Generally,

quoins are at right angles. But in some cases, they may be at angles greater than 90° also.

**17. Frog or kick.** A frog is an indentation in the face of a brick to form a key for holding the mortar. When frog is only on one face, that brick is laid with that face on the top. Sometimes, frogs are provided on both the faces. However, no frogs are provided in wire-cut bricks. A pressed brick has two frogs (as a rule) and a hand-made brick has only one frog.

**18. Racking back.** It is the termination of a wall in a stepped fashion, as shown in Fig. 6.2.

**19. Toothing.** It is the termination of the wall in such a fashion that each alternate course at the end projects, in order to provide adequate bond if the wall is continued horizontally at a later stage (Fig. 6.2).

## 6.4. BONDS IN BRICK WORK

*Bond* is the interlacement of bricks, formed when they lay (or project beyond) those immediately below or above them. It is the method of arranging the bricks in courses so that individual units are tied together and the vertical joints of the successive courses do not lie in same vertical line. Bond of various types are distinguished by their elevation or face appearance. Bricks used in masonry are all of uniform size. If they are not arranged (or bonded ) properly, continuous vertical joints will result. *An unbonded wall*, with its continuous vertical joints has little strength and stability. Bonds help in distributing the concentrated loads over a larger area. Since bricks are small units, having uniform dimensions, the process of bonding is easily performed. **Rules for bonding** For getting good bond, the following rules should be observed:

1. The bricks should be of uniform size. The length of the brick should be twice its width plus one joint, so that *uniform lap* is obtained. Good bond is not possible if lap is non-uniform.

2. The amount of lap should be minimum $\frac{1}{4}$ brick along the length of the wall and $\frac{1}{2}$ brick across the thickness of the wall.

3. Use of brick bats should be discouraged, except in special locations.

4. In alternate courses, the centre line of header should coincide with the centre line of the stretcher, in the course below or above it.

5. The vertical joints in the alternate courses should be along the same perpend.

6. The stretchers should be used only in the facing; they should not be used in the hearting. Hearting should be done in headers only.

7. It is preferable to provide every sixth course as a header course on both the sides of the wall.

**Types of bonds.** Following are the types of bonds provided in brick work :

1. Stretcher bond.
2. Header bond.
3. English bond.
4. Flemish bond.
5. Facing bond.
6. English cross bond.
7. Brick on edge bond.
8. Dutch bond.
9. Raking bond.
10. Zigzag bond.
11. Garden wall bond.

### 6.5. STRETCHER BOND

*Stretcher bond or stretching bond* is the one in which all the bricks are laid as stretchers on the faces of walls. The length of the bricks are thus along the direction of the wall. This pattern is used only for those walls which have thickness of half brick (*i.e.* 9 cm), such as those used as partition walls, sleeper walls, division walls or chimney stacks. The bond is not possible if the thickness of the wall is more.

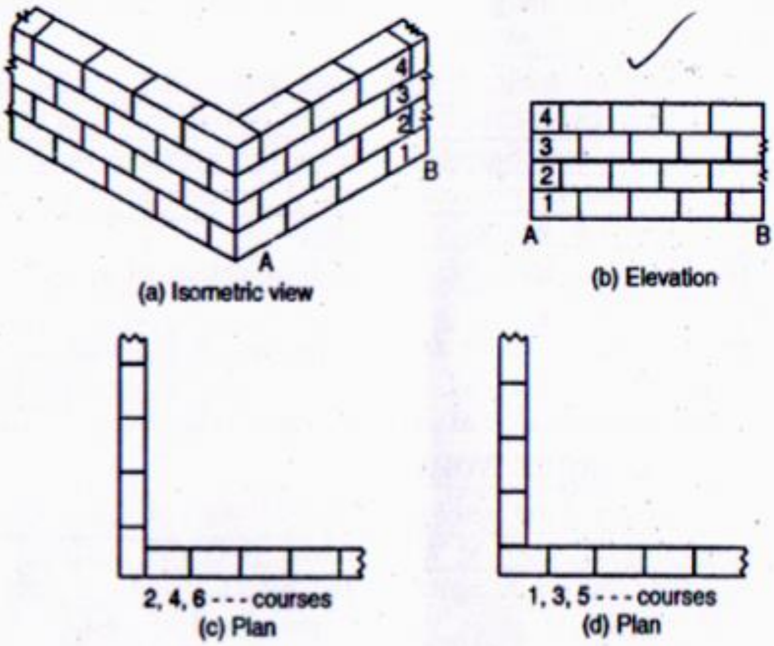



FIG. 6.4. STRETCHER BOND.

### 6.6. HEADER BOND

*Header bond or heading bond* is the one in which all the bricks are laid as headers on the faces of walls. The width of the brick are thus along the direction of the wall. The pattern is used only when the thickness of the wall is equal to one brick (*i.e.*, 18 cm). The overlap is usually kept equal to half the width of brick (*i.e.* $4\frac{1}{2}$ cm). This is achieved by using three-quarter brick bats in each alternate courses as quoins. This bond does not have strength to transmit pressure in the direction of the length of the wall. As such, it is unsuitable for load bearing walls. However, the bond is specially useful for curved brick work where the stretchers, if used, would project beyond the face of

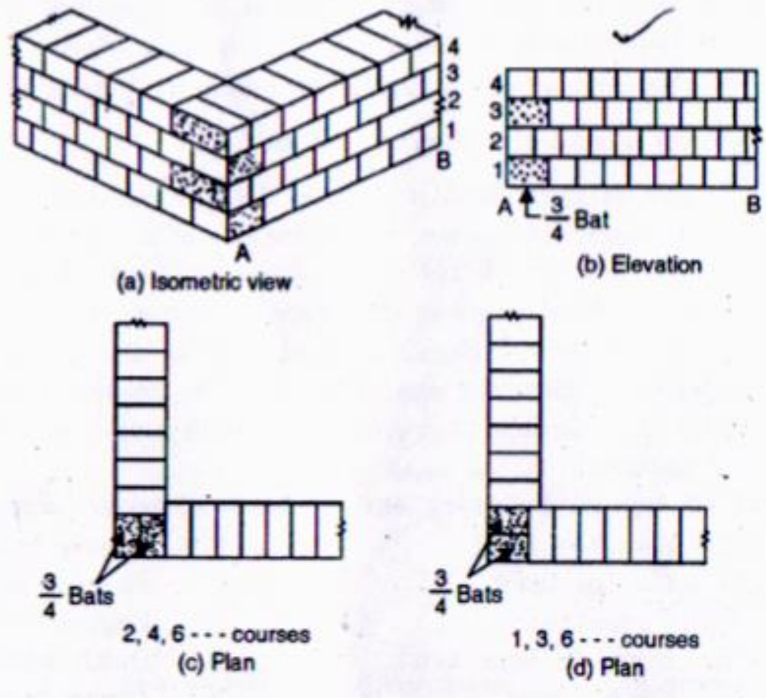
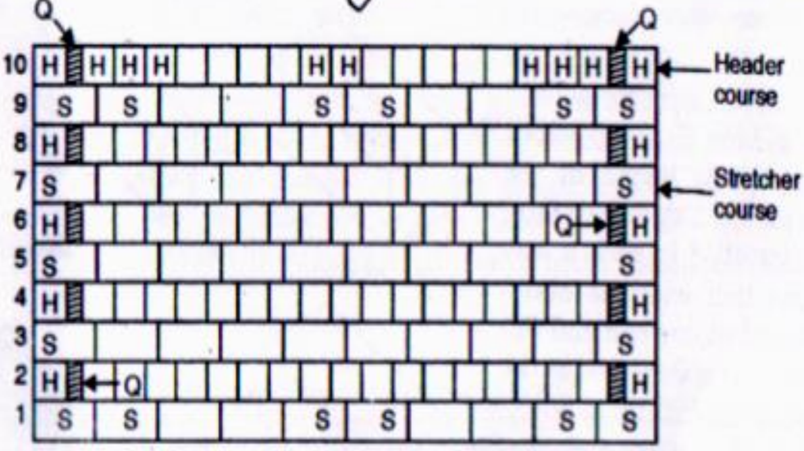



FIG. 6.5. HEADER BOND

the wall and would necessitate inconvenient cutting. This is also used in construction of footings.

## 6.7. ENGLISH BOND

This is the most commonly used bond, for all wall thicknesses. This bond is considered to be the strongest. The bond consists of *alternate* courses of headers and stretchers. In this bond, the vertical joints of the header courses come over each other; similarly, the vertical joints of the stretcher courses also come over each other. In order to break the vertical joints in the successive courses, it is essential to place queen closer after the first header (quoin header) in each heading course. Also, only headers are used for the hearting of thicker walls. Fig. 6.6 shows the general elevation of the English bond. Fig. 6.7 and 6.8 shows English bonds for walls of various thicknesses.




S = Stretcher ; H = Header ; Q = Queen closer

FIG. 6.6. ENGLISH BOND.

**Essential Features.** Following are the essential features of English bond.

1. Alternative courses will show either headers or stretchers in elevation.

2. Every alternate header comes centrally over the joint between two stretchers in course below.

3. In the stretcher course, the stretchers have a min. lap of $\frac{1}{4}$th their length over headers.

4. There is no continuous vertical joint.

5. Walls of even multiple of half bricks (*i.e.* 1 brick thick wall, 2-bricks thick wall, 3-bricks thick wall) present the same appearance on both faces. Thus a course showing stretchers on the front face will also show stretchers on the back face.

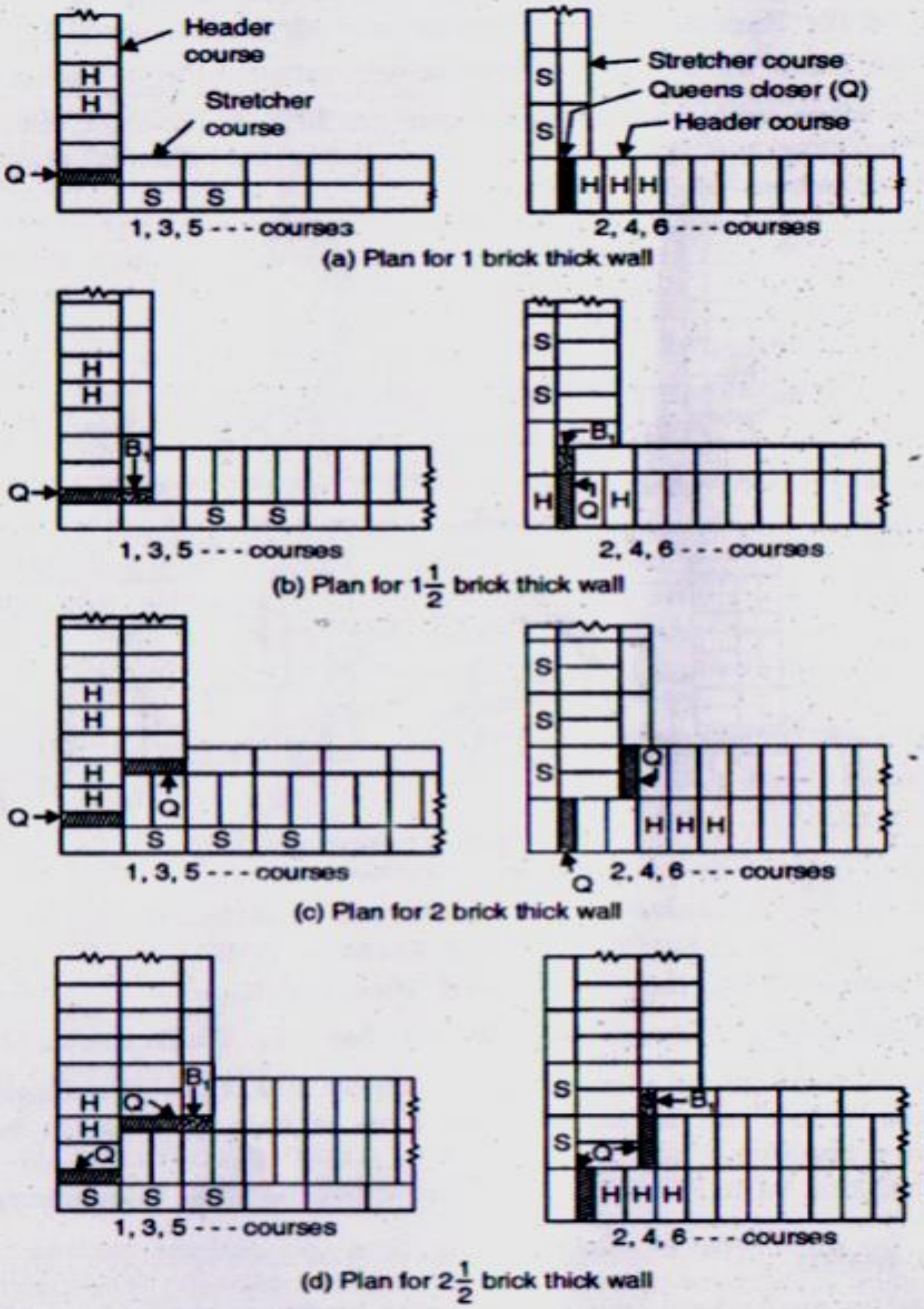
6. Wall of odd multiple of half bricks (*i.e.* $1\frac{1}{2}$ brick thick wall, $2\frac{1}{2}$ brick thick wall etc.) will show stretchers on one face and headers on the other face.

7. The hearting (middle portion) of each of the thicker walls consists entirely of headers.

8. At least every alternate transverse joint is continuous from face to face.

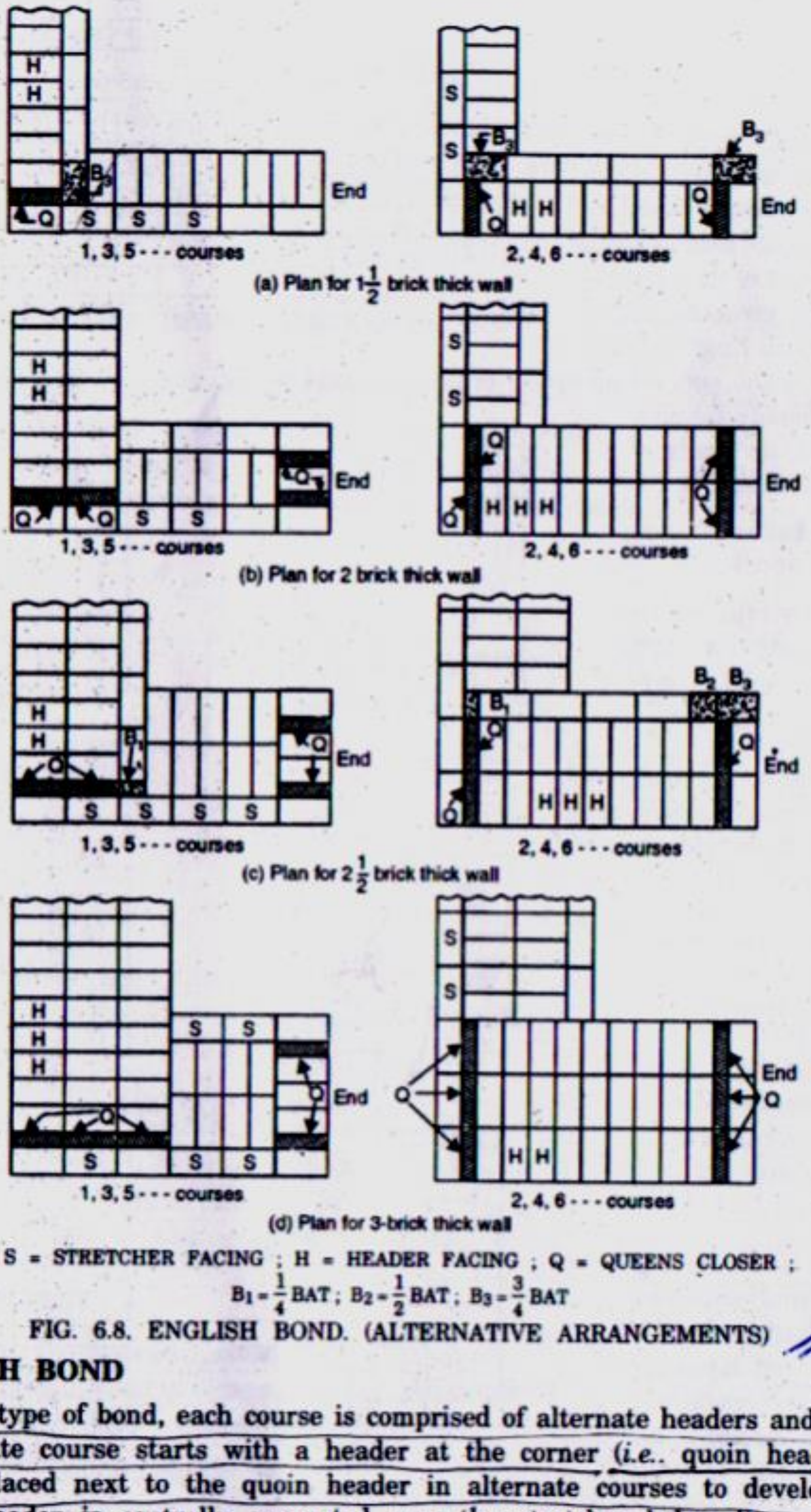
9. A header course should never start with queen's closer, as it will get displaced. The queen's closer should be placed just next to the quoin header. Queen's closers are not required in stretcher courses.

10. Since the number of vertical joints in the header course are twice the number of vertical joints in the stretcher course, the joint in the header course are made thinner than the joints in the stretcher course.




S = STRETCHER FACING ; H = HEADER FACING ; Q = QUEENS CLOSER ;
$B_1$ = QUARTER BAT ( QUARTER QUEEN'S CLOSER )

FIG. 6.7. ENGLISH BOND




S = STRETCHER FACING ; H = HEADER FACING ; Q = QUEENS CLOSER ;

$B_1 = \frac{1}{4}$ BAT ; $B_2 = \frac{1}{2}$ BAT ; $B_3 = \frac{3}{4}$ BAT

FIG. 6.8. ENGLISH BOND. (ALTERNATIVE ARRANGEMENTS)

## 6.8. FLEMISH BOND

In this type of bond, each course is comprised of alternate headers and stretchers. Every alternate course starts with a header at the corner (*i.e.*. quoin header). Quoin closers are placed next to the quoin header in alternate courses to develop the face lap. Every header is centrally supported over the stretcher below it.

Flemish bonds are of two types :

(*i*) Double flemish bond (*ii*) Single flemish bond.

**1. Double flemish bond**

In the double flemish bond, each course presents the *same appearance* both in the front face as well as in the back face. Alternate headers and stretcher are laid in each course. Because of this, double flemish bond presents better appearance than English bond.

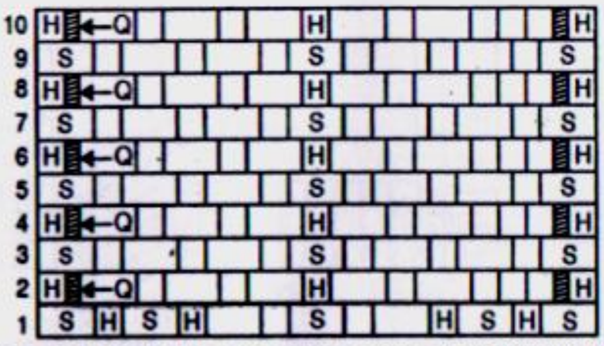


FIG. 6.9. DOUBLE FLEMISH BOND (ELEVATION).

Fig. 6.9 shows the general elevation of flemish bond, for all the wall thicknesses. Fig.6.10 shows the double flemish bond in plan, for walls of various thicknesses.

**Special features of double flemish bond**

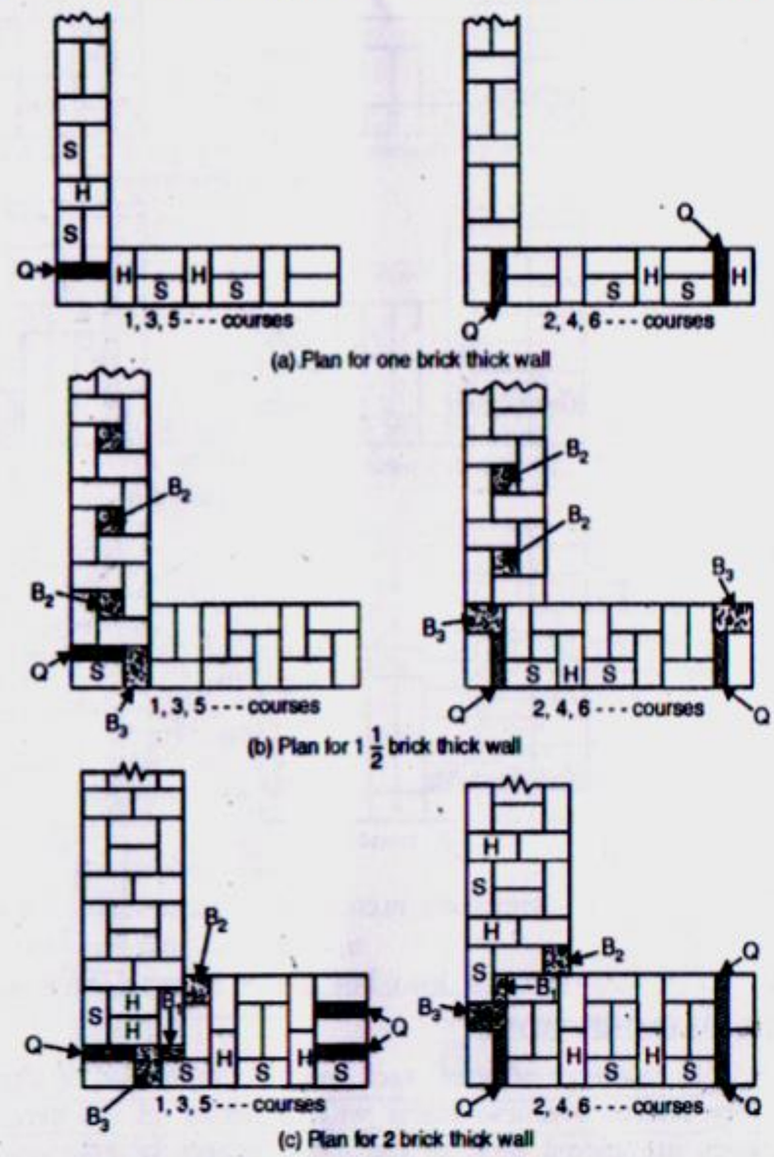
1. Every course consists of headers and stretchers placed alternately.

2. The facing and backing of the wall, in each course, have the same appearance.

3. Quoin closers are used next to quoin headers in every alternate course.

4. In walls having thickness equal to odd multiple of half bricks, half bats and three-quarter bats are amply used.

5. For walls having thickness equal to even multiple of half bricks, no bats are required. A header or stretcher will come out as header or stretcher on the same course in front as well as back faces.




S = STRETCHER ; H = HEADER ; Q = QUEENS CLOSER ;
$B_2$ = HALF BAT ; $B_3 = \frac{3}{4}$ BRICK ; $B_1$ = QUARTER BAT

FIG. 6.10. DOUBLE FLEMISH BOND.

### 1. Double flemish bond

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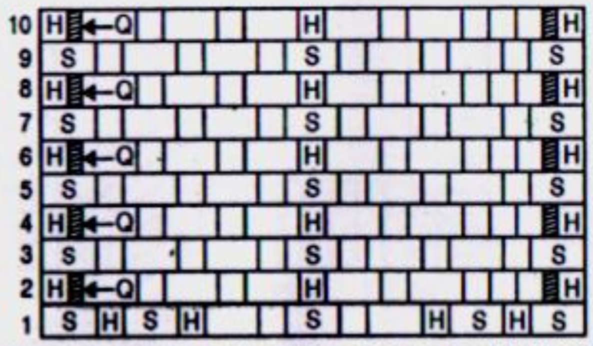


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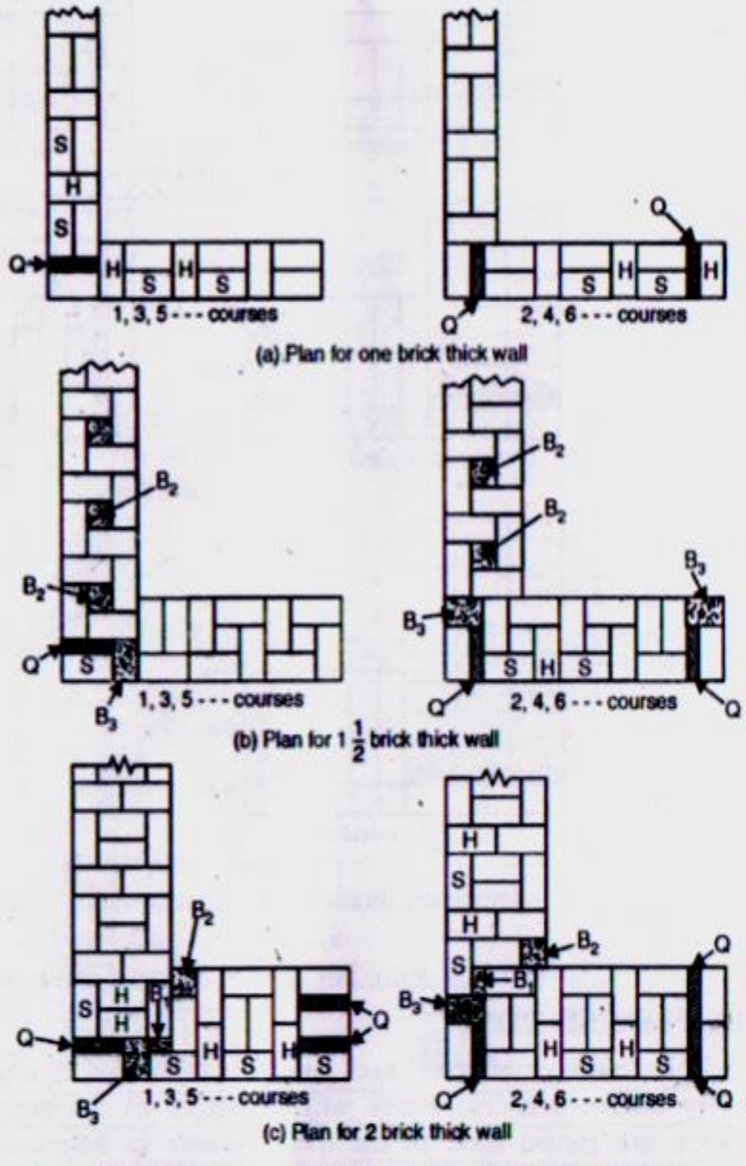
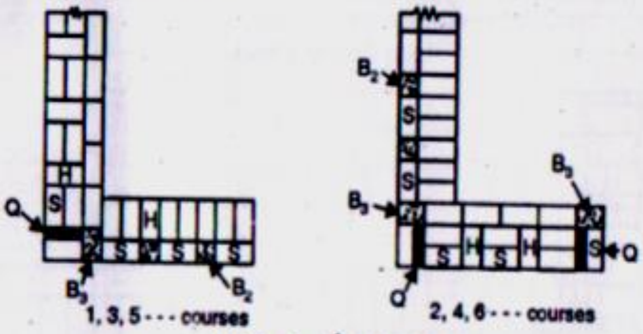



S = STRETCHER ; H = HEADER ; Q = QUEENS CLOSER ;

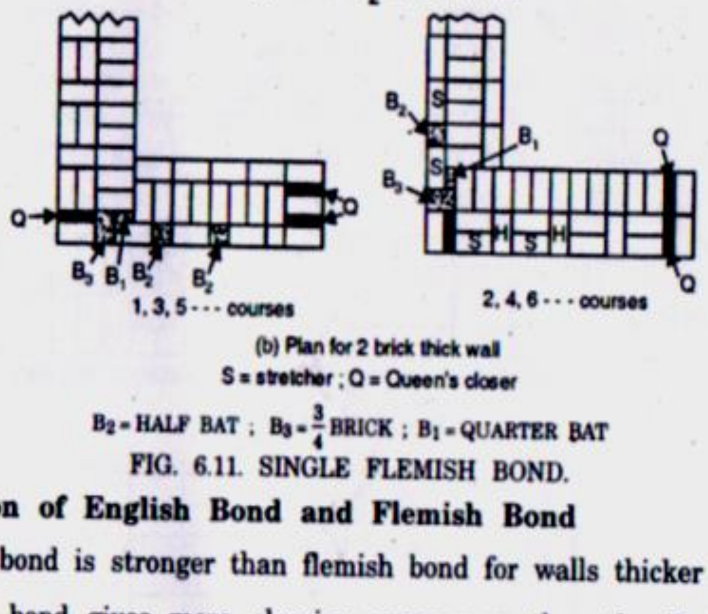
$B_2$ = HALF BAT ; $B_3 = \frac{3}{4}$ BRICK ; $B_1$ = QUARTER BAT

FIG. 6.10. DOUBLE FLEMISH BOND.

**2. Single flemish bond** : Single flemish bond is comprised of double flemish bond facing and English bond backing and hearting in each course. This bond thus uses the strength of the English bond and appearance of flemish bond. However, this bond can be used for those walls having thickness at least equal to $1\frac{1}{2}$ brick. Double flemish bond facing is done with good quality expensive bricks. However, cheaper bricks can be used for backing and hearting. Fig. 6.11 shows the plan of single flemish bond for various thicknesses of the wall.




(a) Plan for $1\frac{1}{2}$ brick thick wall




(b) Plan for 2 brick thick wall

S = stretcher ; Q = Queen's closer

$B_2$ = HALF BAT ; $B_3 = \frac{3}{4}$ BRICK ; $B_1$ = QUARTER BAT

FIG. 6.11. SINGLE FLEMISH BOND.

**Comparison of English Bond and Flemish Bond**

1. English bond is stronger than flemish bond for walls thicker than $1\frac{1}{2}$ brick.

2. Flemish bond gives more pleasing appearance than the English bond.

3. Broken bricks can be used in the form of bats in Flemish bond. However, more mortar is required.

4. Construction with Flemish bond requires greater skill in comparison to English bond.

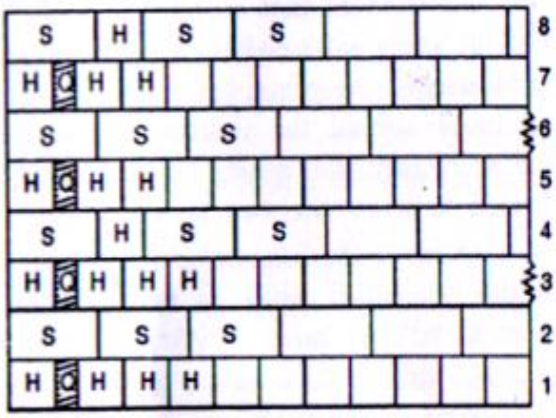
## 6.9. FACING BOND

This bond is used where bricks of different thickness are to be used in the facing and backing of the wall. In this bond, a header course is provided after several stretcher courses. Since the thickness of bricks are different in the facing and backing, the vertical distance between the *successive* header courses is kept equal to the *least common multiple* of the thickness of backing and facing bricks. Thus, if the nominal thickness of facing bricks is 10 cm and that of backing bricks is 9 cm, the header course is provided at a vertical interval of 90 cm. This type of bond is not structurally good and load distribution is not uniform.

## 6.10. ENGLISH CROSS BOND

This is a modification of English bond, used to improve the appearance of the wall. This bond combines the requirements of beauty and strength. Special features of the bond (Fig. 6.12) are as follows:

1. Alternate courses of headers and stretchers are provided as in English bond.
2. Queen closers are placed next to quoin headers.
3. A header is introduced next to the quoin stretcher in every *alternate* stretcher course.




H = Header ; S = Stretcher ; Q = Queen's closer

FIG. 6.12. ENGLISH CROSS BOND

## 6.11. BRICK ON EDGE BOND (SILVERLOCK'S BOND OR SOLDIER'S COURSE)

This type of bond uses stretcher bricks on edges instead of bed. This bond is weak in strength, but is economical. Hence it is used for garden walls, compound walls etc. Bricks are kept standing vertically on end. The bricks are arranged as headers and stretchers in such a manner that *headers are placed on bed* and *stretchers are placed on edge* thus forming a continuous cavity. Due to this, the bond consumes less number of bricks.

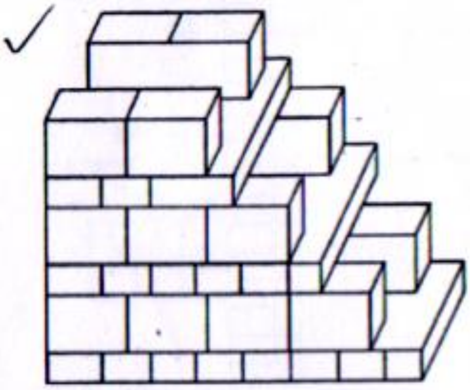
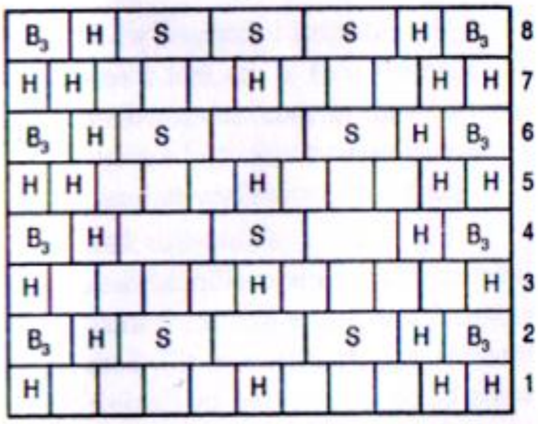


FIG. 6.13. SILVERLOCK'S BOND




H = Header ; S = Stretcher ; $B_3$ = 3/4 brick bat

FIG. 6.14. DUTCH BOND.

## 6.12. DUTCH BOND

This is another modified form of English bond. In this bond the corners of the wall are strengthened. Special features of this type of bond is as follows (Fig. 6.14);

1. Alternate courses of headers and stretchers are provided as in English bond.
2. Every stretcher course starts at the quoin with a three-quarter bat.
3. In every *alternate* stretcher course, a header is placed next to the three-quarter brick bat provided at the quoin.

## 6.13. RAKING BOND

This bond is used in thick walls. In this type of bond, the bonding bricks are kept at an inclination to the direction of the wall. Due to this, the longitudinal stability of thick wall built in English bond is very much increased. This bond is introduced at certain intervals along the height of the wall. Following are special features of raking bond:

1. The bricks are arranged in inclined direction, in the space between the external stretchers of the wall.

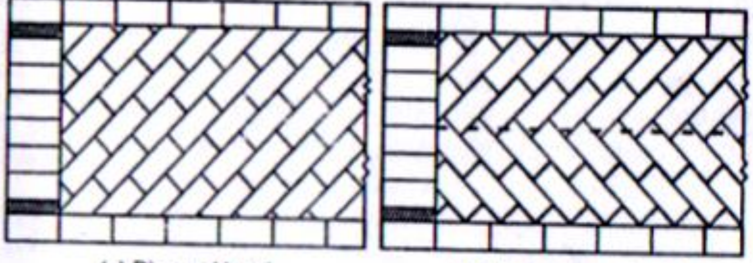
2. The raking or inclination should be in opposite direction in alternate courses of raking bond.

3. Raking bond is *not* provided in successive courses. It is provided at a regular interval of four to eight courses in the height of a wall.

4. The raking course is generally provided between the two stretcher courses of the wall having thickness equal to even multiple of half-bricks, to make the bond more effective.

Raking bonds are of *two types* :

**1. Diagonal bond** [Fig. 6.15 (*a*)]. In this type of bond, bricks are arranged at 45° in such a way that extreme corners of the series remain in contact with the external line of stretchers. Bricks cut to triangular shapes and of suitable sizes are packed in the small triangular spaces at the ends. This bond is best suited for walls which are 2 to 4 bricks thick. The bond is introduced at regular vertical interval, generally at every fifth or seventh course. *In every alternate course of the bond, the direction of bricks is reversed.*



(a) Diagonal bond (b) Herring - bone bond

FIG. 6.15. RAKING BONDS.

**2. Herring-bone bond** [Fig. 6.15 (*b*)]. This bond is more suitable for walls which are thicker than four bricks thick. Bricks are arranged at 45° in two opposite directions from the centre of the wall thickness, as shown in [Fig. 6.15 (*b*)]. The bond is introduced in the wall at regular vertical interval. *In every alternate course, the directions of bricks are changed.* The bond is also used for ornamental finish to the face work, and also for brick flooring.

## 6.14. ZIG ZAG BOND

This bond is similar to herring-bone bond, except that the bricks are laid in zig-zag fashion, as shown in Fig. 6.16. This bond is commonly used for making ornamental panels in the brick flooring.

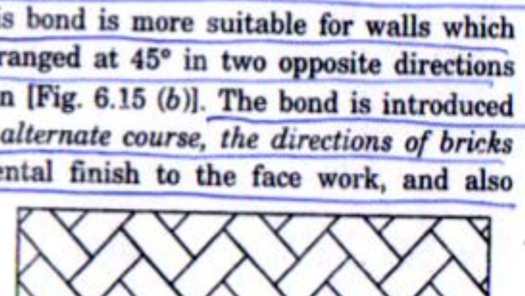


FIG. 6.16. ZIG-ZAG BOND.

## 6.15. GARDEN WALL BONDS

As the name suggests, this type of bond

is used for the construction of garden walls, boundary walls, compound walls, where the thickness of the wall is one brick thick and the height does not exceed two metres. This type of bond is not so strong as English bond, but is more attractive. Due to this reason, it is sometimes used in the construction of outer leaves of cavity walls. Garden wall bonds are of three types:

(i) Garden wall English bond

(ii) Garden wall Flemish bond

(iii) Garden wall Monk bond.

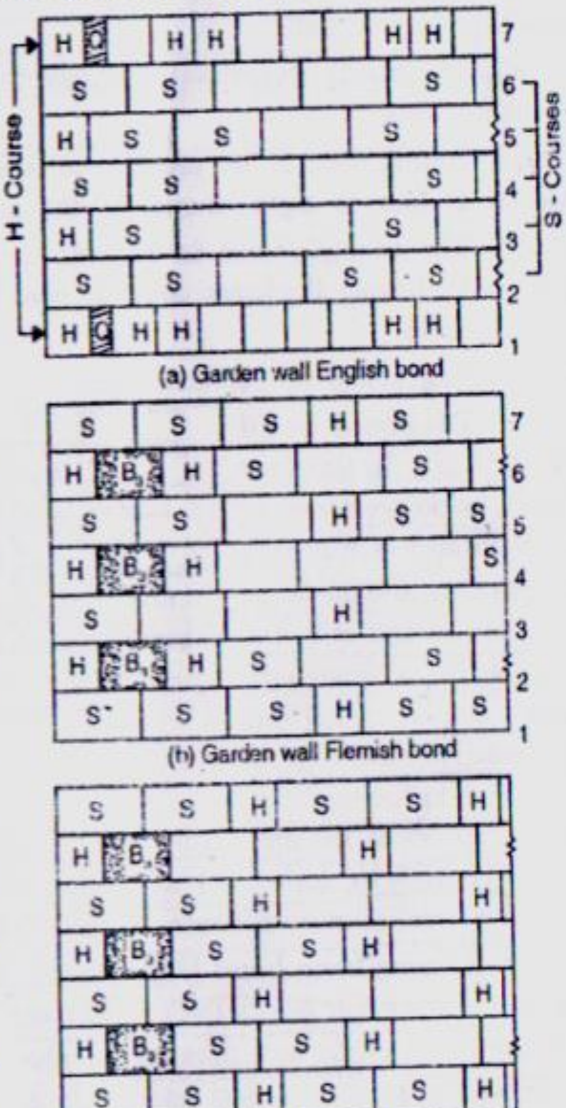
**1. Garden wall English bond** [Fig. 6.17(*a*)] : In this bond, the header course is provided only after three to five stretchers courses. In each header course, a queen closer is placed next to quoin header, to provide necessary lap. In stretcher courses, quoin headers are placed in alternate courses.

**2. Garden wall Flemish bond** [Fig. 6.17(*b*)] : In this bond, each course contains one header after three to five stretchers continuously placed, throughout the length of the course. Each alternate course containes a three-fourth brick bat placed next to the quoin header, develop necessary lap, and a header laid over the middle of each central stretcher.

This bond is also known as *scotch bond or sussex bond.*

**3. Garden wall Monk bond** [Fig. 6.17(*c*)]

This is special type of garden-wall Flemish bond in which each course contains one header after two successive stretchers. Every alternate course contains a quoin header followed by a $\frac{3}{4}$ brick bat. Due to this, the header rests over the joint between two successive stretchers.




S = Stretcher ; H = Header ; $B_3$ = 3/4 Brick bats

FIG. 6.17. GARDEN WALL BONDS.

## 6.16. BOND AT CONNECTIONS

*Connection* is the place where two walls coming from different directions meet. The walls should be properly *united* at the connecting point through some proper *bond.* The following three requirements should be satisfied by the bond at the connection. (*i*) There should be no continuity in the vertical joints, (*ii*) use of brick bats should be as minimum as possible, and (*iii*) the connection should be structurally strong to resist differential settlement, if any. *Connections* are of the following two types :

(*a*) Junctions (*b*) Quoins.

*Junction* is that connection which is formed at the meeting of one (subsidiary) wall at same intermediate position of another wall. When both these walls meet at right angles, we get a *tee-junction*. If the subsidiary wall crosses the main wall and continues beyond the junction, we have a *cross-junction* or *intersection*. However, if the subsidiary wall meets the main wall at some intermediate point, and if the angle formed between the two is other than a right angle, a *squint junction* is formed.

*Quoin* is the connection formed when two external walls meet. Alternatively, quoin is the connection which is formed when a wall takes a turn. When the two walls meet at 90°, we have a *right angled* or *square quoin*. If the angle at the connection is other than 90°, a *squint quoin* is formed.

### (A) JUNCTIONS

Junctions are of the following types :

(*a*) ***Right-angled junction***

(*i*) Tee-junction

(*ii*) Intersection or cross-junction.

(*b*) *Squint-junction.*

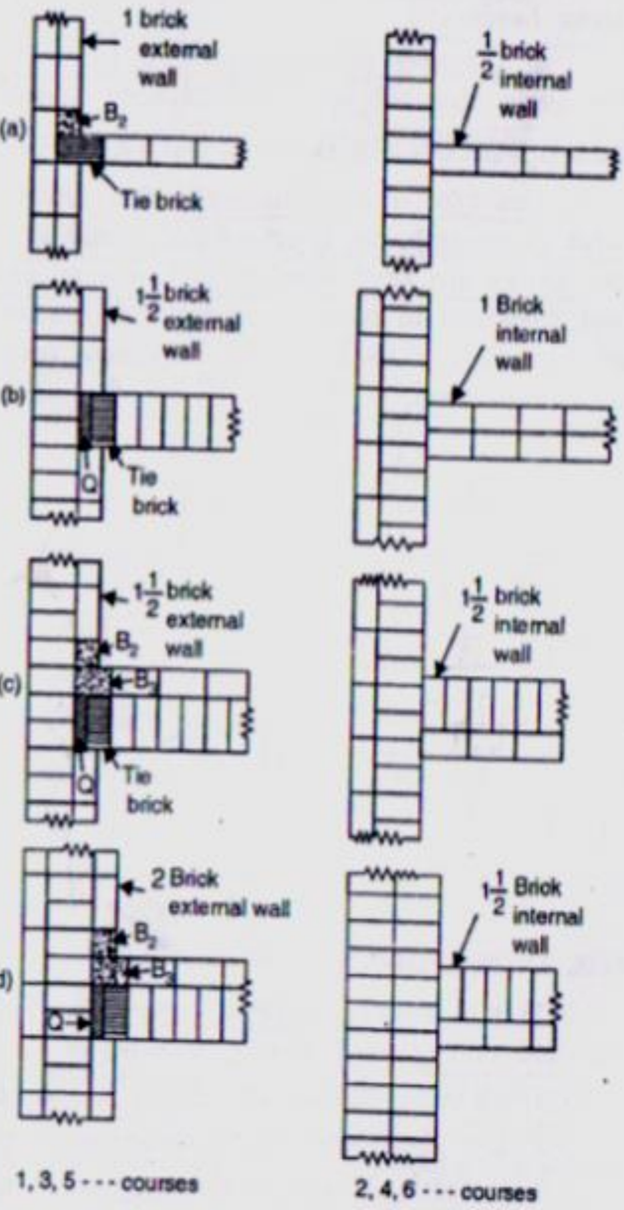
### 1. (*i*) Tee-junction

#### (*a*) *External and Internal walls in English bond*

Tee-junction is formed when the internal wall at its end meets external wall at some intermediate position. Tee-junctions can be either in English bond or in Flemish bond.

Fig. 6.18 (*a*) shows the Tee-junction between a one-brick thick external wall and a half-brick thick internal wall (partition wall), both walls being constructed in English bond. Bond is obtained by making alternate courses of internal wall entering into the stretcher course of the main wall. Due to this, lap of half brick is obtained through the brick (shown shaded). Alternate courses of both the walls remain unbonded.

Fig. 6.18 (*b*) shows the Tee-junction between $1\frac{1}{2}$ brick thick external wall and one-brick thick in-




$B_2$ = Half brick ; $B_3 = \frac{3}{4}$ Brick

FIG. 6.18. T-JUNCTIONS IN ENGLISH BOND

# Masonry-1 : Stone Masonry

## 5.1. MASONRY

*Masonry* may be defined as the construction of building units bonded together with mortar. The building units (commonly known as *masonry units*) may be stones, bricks or precast blocks of concrete. When stones are used as the building units or building blocks, we have *stone masonry*. Similarly, in *brick masonry*, bricks are used as the building units. A composite masonry is a construction in more than one type of building units. *Masonry work* is one of the major building crafts and one of the oldest. It has built itself great reputation as one of the premier traditional materials of building. Even though new principles of construction and new materials become prominent in building construction practices, masonry has got the highest importance in building industry.

Masonry is normally used for the construction of foundations, walls, columns and other similar structural components of buildings. The basic advantage of masonry construction lies in the fact that in load-bearing structures, it performs a variety of functions such as (*i*) supporting loads, (*ii*) subdividing space, (*iii*) providing thermal and acoustic insulation, (*iv*) affording fire and weather protection etc., which in a framed structure has to be provided separately. Earlier, the use of masonry construction had its limitations in multistoreyed buildings. The 16 storey 'Monadnock Building' in Chicago designed by John Rort (1891) has 180 cm thick brick walls at the base. However, extensive research, including large scale testing, has been carried out in regard to the behaviour of masonry which has enabled engineers to design tall masonry structures on sound engineering principles with greater exactitude, economy and confidence. There are recent examples of masonry construction in advanced countries in which 12 to 20 storey *load-bearing masonry buildings* have only 25 to 40 cm thick walls. Depending upon the type of building units used, masonry may be of the following types :

1. Stone masonry
2. Brick masonry
3. Hollow concrete blocks masonry
4. Reinforced brick masonry
5. Composite masonry.

In this chapter, stone masonry has been discussed. Other types of masonry have been discussed in subsequent chapters.

## 5.2. DEFINITION OF TERMS USED IN MASONRY

Following are some of the technical terms used in masonry work. Since these terms are frequently used in the description and procedures, it is essential to understand the meaning of these terms. The terms which apply exclusively to the brick masonry have been defined separately in the next chapter.

**1. Course.** A course is a horizontal layer of masonry unit. Thus, in stone masonry, the thickness of a course will be equal to the height of the stones plus thickness of one mortar joint. Similarly, in brick masonry, the thickness of a course will be equal to the thickness of modular brick plus thickness of one mortar joint.

**2. Header**. A header is a full stone unit or brick which is so laid that its length is perpendicular to the face of the wall. Thus, the longest length of a header lies at right angles to the face of the work. In the case of stone masonry header is sometimes known as *through stone*. In the case of modular bricks, a brick header will show its face measuring 10 cm × 20 cm on the face of the wall.

**3. Stretcher.** A stretcher is a full stone unit or brick which is so laid that its length is along or parallel to the face of the wall. Thus, the longest length of stretcher lies parallel to the face of the work. Thus, in the case of modular bricks, a brick stretcher will show its face measuring 10 cm × 20 cm.

**4. Header Course.** A course of brick work showing only headers on the exposed face of the wall is known as header course or heading course. Thus a header course of bricks will show all the brick units measuring 10 cm × 10 cm of the face of the wall.

**5. Stretcher Course.** A course of brick work showing only the stretchers on the exposed face of the wall is known as the strecher course or stretching course.

**6. Bed.** This is the lower surface of a brick or stone in each course. This is the surface of stone or brick perpendicular to the line of pressure.

**7. Natural bed.** Building stones are obtained from rocks which have distinct planes of divisions along which the stones can be easily split. This plane is known as natural bed. In stone masonry, the direction of natural bed should be perpendicular to the line of pressure.

**8. Bond**. Bond is a term in masonry, applied to the overlapping of bricks or stones in alternate courses, so that no continuous vertical joints are formed and the individual units are tied together.

**9. Quoins.** The exterior angle or corner of a wall is known as quoin. The stones or bricks forming the quoins are known as stone quoins or quoin bricks. If the quoin is laid in such a manner that its width is parallel to the face of the wall, it is known as quoin header. If, however, the length of the quoin is laid parallel to the face of the wall, it is known as quoin stretcher. Quoin stones are selected sound and large and their beds are properly dressed.

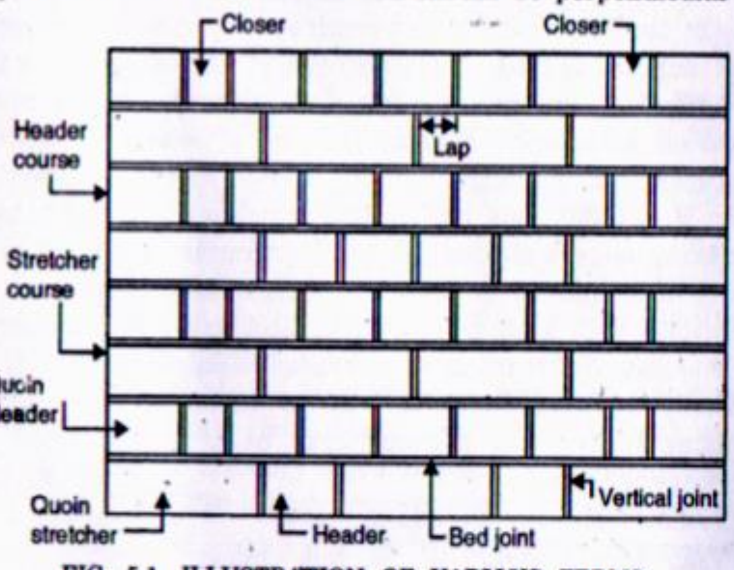



FIG. 5.1. ILLUSTRATION OF VARIOUS TERMS.

**10. Face.** It is the surface of the wall exposed to the weather.

**11. Back.** The inner surface of the wall which is not exposed to weather is termed as *back*.

**12. Facing.** The material used in the face of the wall is known as facing.

**13. Hearting.** The inner portion of the wall between the facing and backing is known as the hearting.

**14. Side.** It is the surface forming the boundary of bricks or stones in a direction transverse to the face and bed.

**15. Joint.** The junction of adjacent units of bricks or stones is known as a joint. Joints parallel to the bed of bricks or stones is known as *bed joint.* Bed joints are thus horizontal mortar joints upon which masonry courses are laid. Joints perpendicular to the face of the wall is known as *cross-joint or vertical joints*. All joints are formed in cement mortar, lime mortar or mud mortar. A joint which is parallel to the face of the wall is known as wall joint.

**16. Closer.** It is the portion of brick cut in such a manner that its one long face remains uncut. Thus, a closer is a header of small width.

**17. Queen closer.** It is the portion of a brick obtained by cutting a brick length-wise into two portions. Thus, a queen closer is a brick which is half as wide as the full brick.

**18. King closer.** It is the portion of a brick which is so cut that width of one of its end is half that of a full brick, while the width at the other end is equal to the full width. It is thus obtained by cutting off the triangular piece between the centre of one end and the centre of the other (long) side.

**19. Bevelled closer.** It is the special form of king closer in which the whole length of the brick is bevelled in such a way that half width is maintained at one end and full width is obtained at the other end.

**20. Mitred closer.** It is a brick whose one end is cut splayed or mitred for full width. The angle of splay may vary from 45° to 60°. Thus, one longer face of the mitred closer is of full length of the brick while the other longer face is smaller in length.

**21. Bat.** It is the portion of the brick cut across the width. Thus a bat is smaller in length than the full brick. If the length of the bat is equal to half the length of the original brick, it is known as *half bat. A three quarter bat* is the one having its length equal to three quarters of the length of a full brick. If a bat has its width bevelled, it is known as *bevelled bat.*

**22. Perpend.** It is that vertical joint on the face of the wall, which lies directly above the vertical joints in alternate courses.

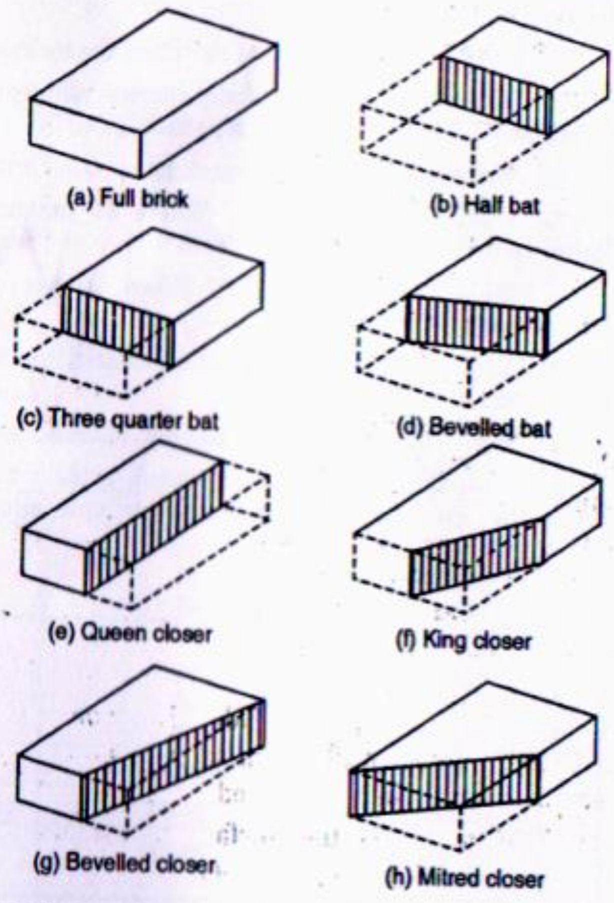



FIG. 5.2. VARIOUS FORMS OF BRICK PORTIONS.

**23. Frog.** It is an indentation or depression on the top face of a brick made with the object of forming a key for the mortar. This prevents the displacement of the brick above.

**24. Through Stone.** A through stone is a stone header. Through stones are placed across the wall at regular interval. If the thickness of the wall is small, through stone may be of length equal to the full width of the wall. If, however the wall is considerably thick, two through stones with an overlap are provided, as shown in Fig. 5.3 (*b*). Through stones should be strong, and non-porous, and should be of sufficient thickness.

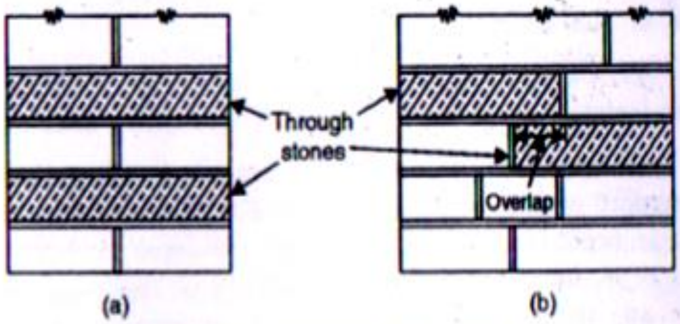



FIG. 5.3. THROUGH STONES.

**25. Sill.** The bottom surface of a door or a window opening is known as a sill. Sill is thus the horizontal member of brick, stone, concrete or wood provided to give support for the vertical members of the opening, and also to shed off rain water from the face of the wall immediately below the opening. Sill stones, when provided, are so dressed that they prevent the entry of water to the interior of the building.

**26. Lintel.** It is a horizontal member of stone, brick, wood, steel, or reinforced concrete, used to support the masonry and the super-imposed load above an opening.

**27. Plinth.** Plinth is the horizontal projecting course of stone or brick, provided at the base of the wall above the ground level. Plinth raises the level of ground floor above the natural ground level, thus protecting the building from rain, water, froast and other weather effects.

**28. Plinth course.** It is the uppermost course of the plinth masonry.

**29. String course.** It is the continuous horizontal course of masonry, projecting from the face of the wall for shedding rain water off the face. It is generally provided at every floor and sill level. A string course breaks the monotony of a plane surface, and thus imparts aesthetic appearance to the structure. The string course is suitably *weathered and throated* so as to throw off water clear of the wall surface.

**30. Jambs.** Jambs are the vertical sides of a finished opening for the door, window or fire place etc. Jambs may be plain or splayed or may be provided with the recess to receive the frames of doors and windows.

**31. Reveals.** These are the exposed vertical surfaces left

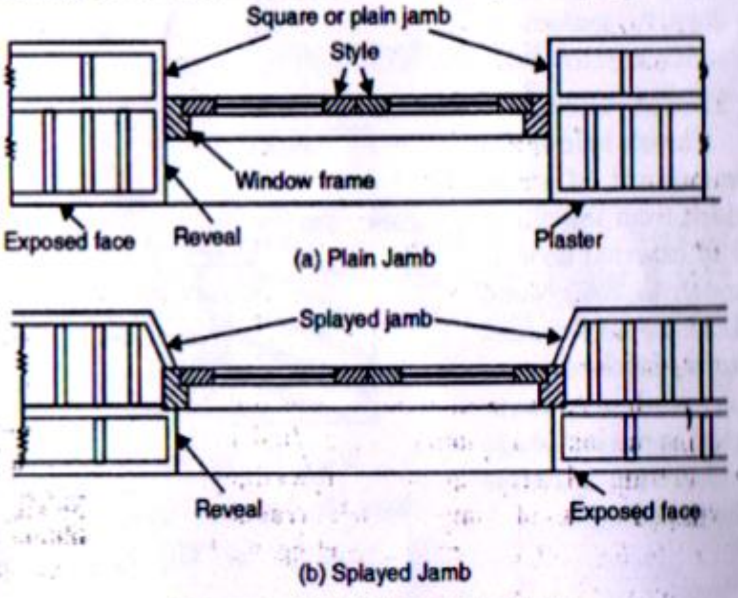



FIG. 5.4. JAMBS AND REVEALS.

on the sides of an opening after the door or window frame has been fitted in position.

**32. Corbel.** A corbel is a projecting stone which is usually provided to serve as support for joist, truss, weather shed etc. Corbels are generally moulded and given ornamental treatment. Corbels should extend atleast two-thirds of their length into the wall, so that they do not overturn or come out of the wall.

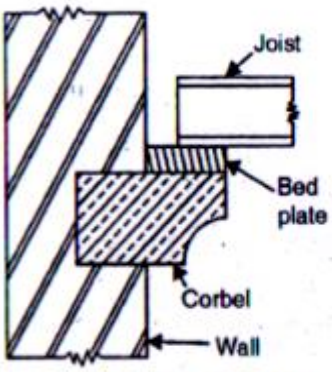



FIG. 5.5. CORBEL

**33. Cornice.** It is a projecting ornamental course near the top of a wall or at the junction of wall and the ceiling. It penetrates the full width of the wall. It is weathered and throated to dispose off rain water. In order to prevent overturning of cornice, extra weight in the form of parapet wall should be provided (see Fig 5.6).

**34. Coping.** It is a covering of stone, concrete, brick of terracota, placed on the exposed top of a wall, to prevent seepage of water. It may also be provided on the top of compound wall. A coping is suitably weathered and throated (Fig. 5.7).

**35. Weathering.** It is the term used to denote the provision of the slope on the upper surface as sills, cornices, string courses, copings etc.

**36. Throating.** It is a groove provided on the underside of projecting elements such as sills cornices, copings etc., so that rain water can be discharged clear of the wall surface.

**37. Parapet.** It is the portion of low height wall constructed along the edge of the roof to protect the users. Parapet acts as a protective solid balustrade for the users. In the case of pitched roofs, parapet is constructed to conceal the gutter at the eaves level.

**38. Arch.** Arch is a structural construction of masonry constructed by mechanical arrangement of wedge-shaped blocks of stone or brick arranged in the form of a curve supporting wall or load above the opening.

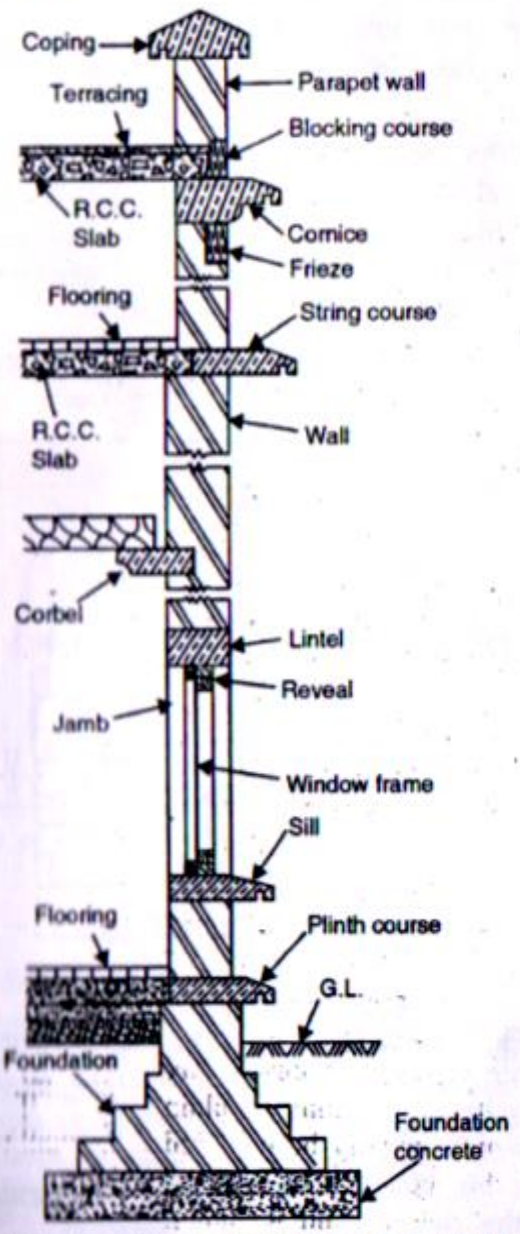



FIG. 5.6. SECTION THROUGH A WALL.

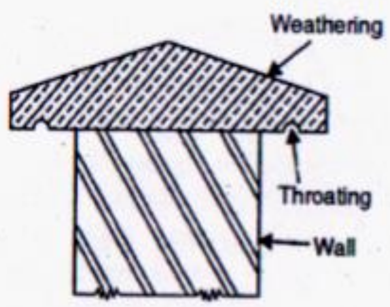



FIG. 5.7. COPING.

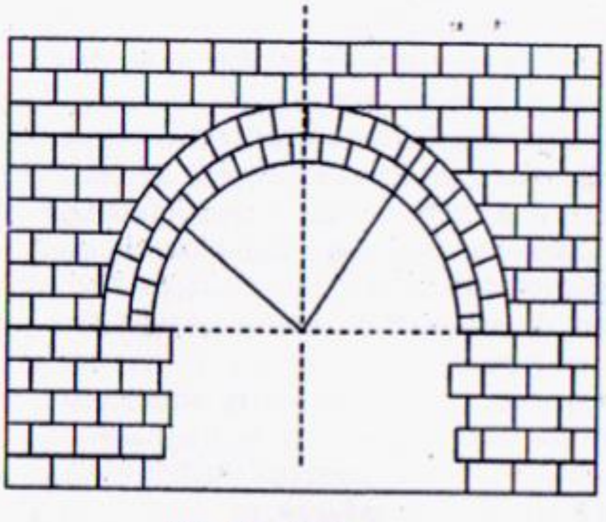


FIG. 5.8. ARCH.

**39. Gable.** It is a triangular shaped masonry work, provided at the ends of a sloped roof.

**40. Freeze.** It is a course of stone placed immediately below the cornice, along the external face of the wall, intended to improve the appearance of the wall.

**41. Blocking course.** It is another course of stone placed immediately above the cornice. Apart from improving the appearance of the wall, it adds to the stability of the cornice against overturning.

**42. Toothing.** These are the bricks left projecting in alternate courses for the purposes of bonding future masonry work.

FIG. 5.9. STONE GABLE

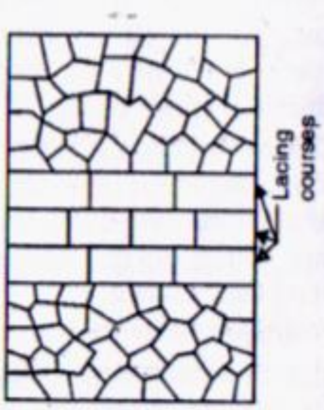



FIG. 5.10.

**43. Lacing course.** It is the horizontal course of stone blocks provided to strengthen a wall made of irregular courses of small stones, as shown in Fig. 5.10. The Lacing course may be either in ashlar masonry or coursed rubble masonry or brick masonry.

**44. Spalls.** Spalls are the chips or small pieces of stones obtained as a result of reducing big blocks of stones into the regular stone blocks. These spalls are used in filling the interstices of stone masonry.

**45. Stoolings.** These are the horizontal stones provided to receive jambs and mullions. These are formed at the ends of sills, transomes and heads.

**46. Template or bed block.** It is defined as the block of stone or concrete provided under a beam or girder to distribute the concentrated load over a greater area of the bearing surface.

**47. Column.** It is a vertical load bearing member of masonry, which is constructed in an isolation from the wall, and whose width does not exceed four times its thickness.

**48. Pier or Pilaster.** Pier is an isolated vertical mass of stone or brick masonry to support beams, lintels, arch etc, the width of which exceeds four times its thickness. If it is made monolithic with the wall and projecting a little beyond to support the ends of a beam or truss etc, then it is called a pilaster.

**49. Buttress.** It is a sloping or stepped masonry projection from a tall wall intended to strengthen the wall against the thrust of a roof or arch.

**50 Offsets.** These are the narrow horizontal surfaces which are formed by reducing the thickness of the wall. Walls of tall buildings are formed with offsets. Similarly, offsets are also provided in masonry footings.

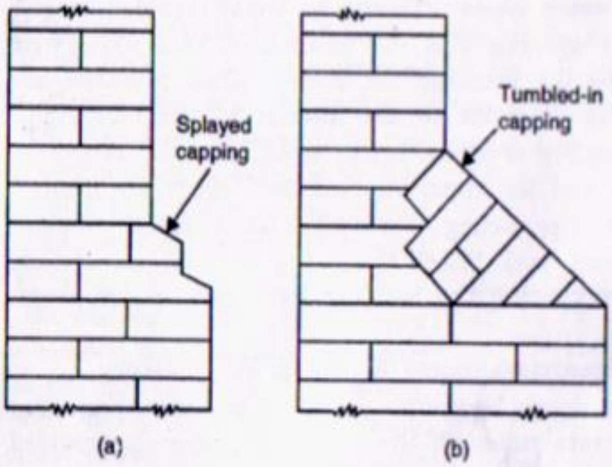



FIG. 5.11. BUTTRESSES.

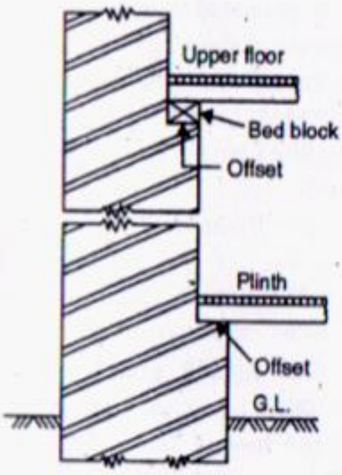



FIG. 5.12. OFFSETS.

**51. Thresh holds.**

Thresh hold is the arrangement of steps provided from the plinth level of external door or verandah to the ground level. These may consist of stone, brick or concrete, and are constructed at the last stage of construction activities of the building.

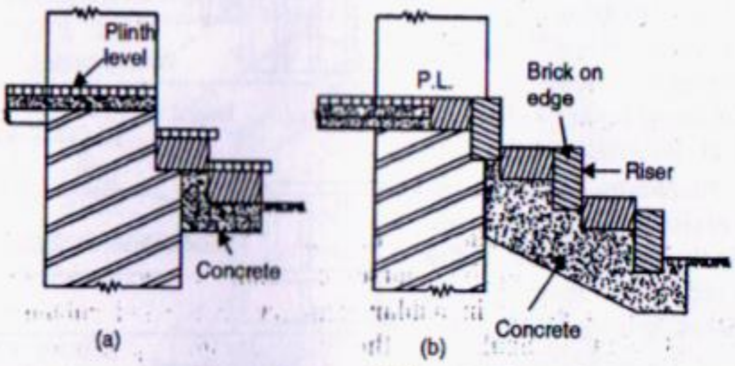



FIG. 5.13. THRESH HOLDS.

## .3. MATERIALS FOR STONE MASONRY

The following two materials are used for stone masonry:

1. Mortar
2. Stones.

### (A) MORTAR

#### 1. Definition and types

Mortar is a homogenious mixture, produced by uniform mixing of a *binder with inert material* (such as sand) and water to make a paste of required consistency and is used to bind a masonry unit. The following ingradienets are used for mortar making:

(*a*) Materials which cause adhesion when dried from wet plastic state such as clay, mud, etc., and

(*b*) Cementitious ingradients such as cement, lime or combination of these two, Portland pozzolana cement and lime-pozzolana mixture where sand is used as a fillter along with these binders to reduce the shrinkage characteristics of the mortar.

Choice of mortar and its grade for binding masonry units is governed by several considerations such as type of masonry, situations of use, load intensity, degree of exposure to weather, bond and durability reqirements, and other special considerations like fire resistance, insulation, rate of setting and hardening etc.

Cement used for preparing masonry mortars may be (*i*) ordinary portland cement, (*ii*) rapid hardening cement, (*iii*) blast furnace slag cement (*iv*) portland pozzolana cement, (*v*) masonry or trief cement.

If lime mortar is used, lime may be of hydraulic or semi-hydraulic category. However, where fat lime is used, it is essential to add pozzolana such as burnt clay pozzolana or fly ash.

If mud mortar is used, the mud should be prepared from carefully selected soil of tenacious nature of sand content not less than 35 percent and plasticity index 8-10 for clayey soil and 6-10 for silty soils. In case suiable soil is not available, the blending of sand with clayey soil or *vice verse* may be done in suitable proportions so as to achieve the above physical characteristics of the soils. The sulphate content of such a selected soil shall not exceed 0.1 percent. Mud mortars are not preferred in stone masonry. It is sometimes used in brick masonry where low strength bricks are available and where the superimposed loads are not heavy.

#### 2. Consistency of mortars

The quantity of water to be added to the mortar should be such that working consistency is obtained. Excess water should be avoided. In the case of cement lime mortars, the following formula may be used to get approximate quantity of water:

$$V_w = 0.65\,(W_c + W_l) \qquad ...(5.1)$$

where $V_w$ = volume of water (in litres), per $m^3$ of sand

$W_c$ = added mass of cement (in kg) per $m^3$ of sand.

$W_l$ = added mass of lime (in kg) per $m^3$ of sand.

In general, the quantity of water depends upon the following factors :

(*i*) Nature and condition of fine aggregate,

(*ii*) Temperature and humidity at the time of working, and

(*iii*) Richness of the mix, i.e., whether richer or leaner than 1 : 3.

The working consistency of the mortar is usually judged by the mason during application. The water should be just enough to maintain the required fluidity of mortar during application. The consistency of the mortar to maintain required fluidity depends upon the joints of masonry. For example, thinner joints will require greater fluidity while joints subjected to heavy pressure intensity require stiffer mortar with less fluidity.

**3. Lime mortar**

Lime mortars are prepared from hydraulic and semi-hydraulic limes corresponding to class A and class B of IS : 712-1973. If fat limes corresponding to Class C is used, addition of pozzolana is essential. Prepared lime mortars shall be kept damp and shall never be allowed to go dry. This may be ensured. Partly set or dried mortar shall never be retempered for use.

Strength of lime mortar depend upon mix proportions. Table 5.1 gives the compressive strength for various mix proportions.

TABLE 5.1. COMPERESSIVE STRENGTH OF MASONRY LIME MORTAR

| *S.No.* | *Proportion of mix (by volume)* | | | *Compressive strength at 28 days* | |
|---|---|---|---|---|---|
| | *Lime* | *Pozzolana* | *Sand* | $kg/cm^2$ | $N/mm^2$ |
| 1. | 1 (B) | — | 3 | 5—7 | 0.5—0.7 |
| 2. | 1 (A) | — | 3 | 20—30 | 2—3 |
| 3. | 1 (C) | — | 1 | 30—50 | 3—5 |
| 4. | 1 (C) | 1 | 2 | 7—15 | 0.7—1.5 |
| 5. | 1 (C) | 2 | — | 30—50 | 3—5 |
| 6. | 1 (C) | 3 | — | 20—30 | 2—3 |

**Note.** (A), (B) and (C) denote the class of lime to be used, as specified in Indian Standard (IS : 712-1973).

**4. Cement mortar**

The mortars with cement as an ingredient should be used as early as possible, preferably within half an hour from the time, water is added to the cement during mixing operation or at the latest within one hour of its mixing. Cement mortars are generally more suitable for making high strength mortars. In addition to sand, pozzolana may also be added. Table 5.2 gives the compressive strength of cement mortars of various mix proportions :

TABLE 5.2. COMPRESSIVE STRENGTH OF CEMENT MORTARS

| S.No. | *Mix proportion (by volume)* | | | *Compressive strength at 28 days* | |
|---|---|---|---|---|---|
| | *Cement* | *Pozzalana* | *Sand* | *kg/cm²* | *N/mm²* |
| 1. | 1 | 0 | 8 | 7—15 | 0.7—1.5 |
| 2. | 1 | 0.4 | 8 | 7—15 | 0.7—1.5 |
| 3. | 1 | 0 | 7 | 15—20 | 1.5—2.0 |
| 4. | 1 | 0.4 | 7 | 15—20 | 1.5—2.0 |
| 5. | 1 | 0 | 6 | 30—50 | 3.0—5.0 |
| 6. | 1 | 0.4 | 6 | 30—50 | 3.0—5.0 |
| 7. | 1 | 0 | 5 | 50 and above | 5 and above |
| 8. | 1 | 0.4 | 5 | —Do— | —Do— |
| 9. | 1 | 0 | 4 | —Do— | —Do— |
| 10. | 1 | 0.4 | 4 | —Do— | —Do— |
| 11. | 1 | 0 | 3 | —Do— | —Do— |
| 12. | 1 | 0.4 | 3 | —Do— | —Do— |

### 5. Lime cement mortars (Gauged mortars)

The mortar in which cement is included as an ingredient in addition to lime is known as *gauged mortar or composite mortar.* The rate of stiffening of lime mortar is improved by gauging the lime with cement. Table 5.3 gives the compressive strength of gauged mortars of various mix proportions.

TABLE 5.3. COMPRESSIVE STRENGTH OF GAUGED MORTARS

| S.No. | *Mix proportion by volume* | | | | *Compressive strength at 28 days* | |
|---|---|---|---|---|---|---|
| | *Cement* | *Lime* | *Pozzolana* | *Sand* | *kg/cm²* | *N/mm²* |
| 1. | 1 | 3(B) or 4(C) | 0 | 12 | 7—15 | 0.7—1.5 |
| 2. | 1 | 2(B) | 0 | 9 | 20—30 | 2—3 |
| 3. | 1 | 1(C) or 1(B) | 0 | 6 | 30—50 | 3—5 |
| 4. | 1 | 3(C) | 3 | 9 | 40—50 | 4—5 |
| 5. | 1 | 0 to $\frac{1}{4}$(B) or (C) | 0 | 4 | 50 and above | 5 and above |
| 6. | 1 | 1(C) | 2 | 4 | —Do— | —Do— |
| 7. | 1 | $\frac{1}{2}$ or $\frac{1}{4}$(C) | 0 | 4.5 | —Do— | —Do— |

## (B) STONES

The stones used for masonry should be hard, durable, tough and sound, and free from weathering, decay or defects like cavities, cracks, sand holes, injurious veins, patches of loose or soft materials etc. The stones should be obtained only from the approved quarry. The stone units should be obtained by quarrying large massive rock, and not by breaking small size boulders having rounded faces.

Rocks from which building stones are obtained, are divided into three groups: (1) Igneous (2) Sedimentary and (3) Metamorphic.

**1. Igneous rock.** These have been formed by agency of heat, the molten material subsequently become solidified. The chief building stone in this class is *granite*. Granite is hard and durable, and is used in steps, sills, facing work, walls etc. However, it is unsuitable for carving work. It is more suitable for heavy engineering works such as docks, break waters, light houses, masonry bridges and piers.

**2. Sedimentary rocks.** These are those which have been formed chiefly through the agency of water. Most of these have been derived from breaking up of igneous rocks whose particles are conveyed and deposited by streams and accumulated to form thick strata that have been subsequently hardened by pressure. The principal building stones in this group are *lime stones* and *sand stones.*

***Lime stones.*** They consist of particles of carbonate of lime cemented together by a similar material. These are used in floors, steps and walls.

***Sand stones.*** These are composed of consolidated sand and consist chiefly of grains of quartz (silica) united by cementing material. Sand stone is the most widely used building stone for steps, facing work, columns, walls etc.

**3. Metamorphic rocks.** These rocks form a group which embraces either igneous or sedimentary rocks which have been changed from their original form (or metamorphosed) by either pressure, or heat, or both. The common building stones that fall under this category are *slates and marbles. Slates* easily spilt along natural bedding planes. They are not very suitable for masonry work. They are used for roofing work, sills, damp-proof course etc. *Marbles* can take fine polish. Since they are costly, they are not used for masonry work. These are used for flooring, facing work, steps, ornamental work etc. Marbles can be easily sawn and carved. Table 5.4 gives the recommendations for use of different types of stones for different purposes.

**TABLE 5.4. RECOMMENDATIONS FOR TYPE OF STONES TO BE USED**

| *Purpose* | *Type of stone to be used* |
|---|---|
| 1. Heavy engineering works such as docks, break waters, bridges, piers, etc., carry high intensity of pressure. | Fine grained granite and gneisses. |
| 2. Masonry work in industrial area, exposed to smoke and chemical fumes. | Granite, compact sand stone, and quartzite |
| 3. General building work. | Lime stone and sand stone. |
| 4. Face work of buildings. | Marble, granite and closed grained sand stone |
| 5. Carvings and ornamental work. | Marble, laterite and soft sand stone. |
| 6. Pavings, door sills, steps. | Slate, sand stone, marble. |
| 7. Fire resistant masonry. | Compact sand stone. |

## 5.4. CLASSIFICATION OF STONE MASONRY

Depending upon the arrangement of stones in the construction, degree of refinement used in shaping the stone and finishing adopted, stone masonry can be classified as follows:

(*a*) *Rubble Masonry* (*b*) *Ashlar Masonry.*

### (A) RUBBLE MASONRY

In the rubble masonry, the blocks of stone that are used are either undressed or comparatively roughly dressed. The masonry has wide joints, since stones of irregular sizes are used. Rubble masonry may be out of the following types :

| | | |
|---|---|---|
| (*a*) *Random Rubble* | (*i*) Uncoursed. | |
| | (*ii*) Built to courses. | |
| (*b*) *Square Rubble* | (*i*) Uncoursed | |
| | (*ii*) Built to courses. | |
| | (*iii*) Regular coursed | |
| (*c*) *Miscellaneous types* | (*i*) Polygonal walling. | |
| | (*ii*) Flint walling. | |

(*d*) *Dry rubble masonry*.

**1. Random Rubble : Uncoursed**

This is the roughest and cheapest form of stone walling. In this type of masonry, the stones used are of widely different sizes.

Since the stones are not of uniform size and shapes, greater care and ingenuity have to be exercised in arranging them in such a way that they adequately distribute the pressure over the maximum area and at the same time long continuous vertical joints are avoided. Sound bond should be available both transversely as well as longitudinally. Transverse bond is obtained by the liberal use of *headers*. Larger stones are selected for quoins and jambs to give increased strength and better appearance. This type of masonry is also known as *uncoursed rubble masonry*.

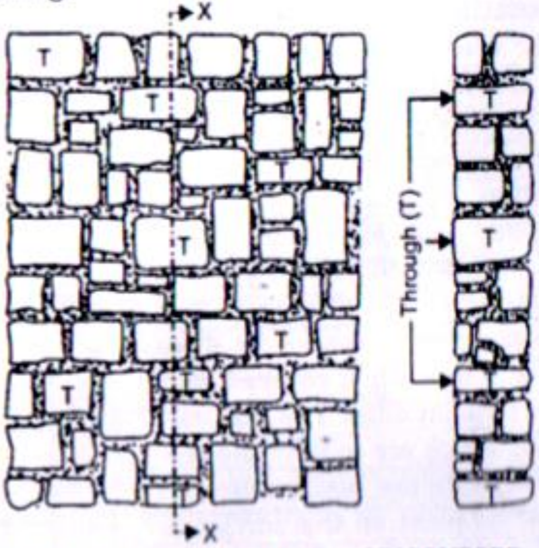



FIG. 5.14. RANDOM RUBBLE : UNCOURSED.

**2. Random Rubble : Built to Courses**

The method of construction is the same as above except that the work is roughly levelled up to form courses varying from 30 to 45 cm thick. All the courses are not of the same height. For the construction of this type of masonry, quoins are built first and line (string) is stretched between the tops of quoins. The intervening walling is then brought up to this level by using different size of stones. Fig. 5.15 shows the procedure, in which the stone have been numbered in the order in which they are placed. This form of masonry is better than uncoursed random rubble masonry.

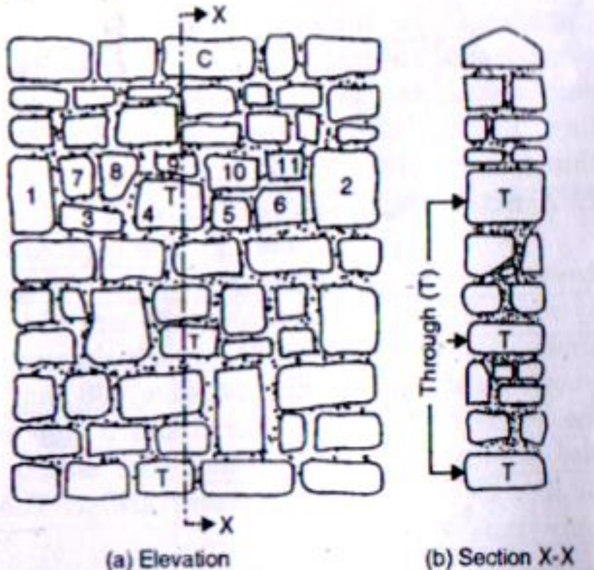



FIG. 5.15. RANDOM RUBBLE : BUILT TO COURSES.

### 3. Square Rubble : Uncoursed (Square-snecked rubble)

Square rubble masonry uses stones having straight bed and sides. The stones are usually squared and brought to hammer dressed or straight cut finish.

In the uncoursed square rubble, also sometimes-known as *square-snecked rubble,* the stones with straight edges and sides are available in different sizes (heights). They are arranged on face in several irregular pattern.

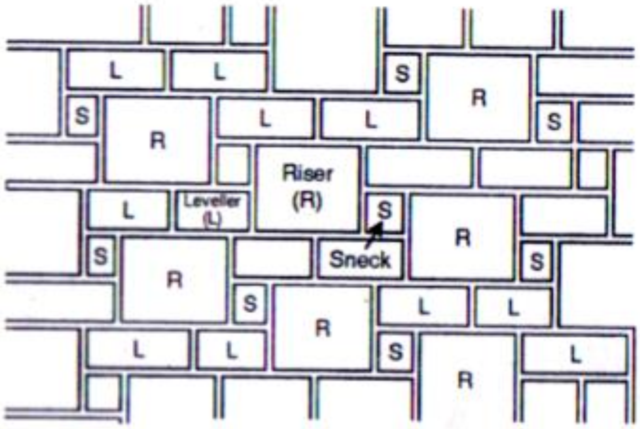



FIG. 5.16. UNCOURSED SQUARE RUBBLE.

Good appearance can be achieved by using *risers* (a large stone, generally a through stone), *leveller* (thinner stones) and *sneck or check* (small stone) in a pattern, having their depths in the ratio of 3 : 2 : 1 respectively. Snecks are the characteristics of this type of construction, and hence the name. This prevents the occurrence of long continuous joints.

### 4. Square Rubble : Built to courses

This type of masonry also uses the same stones as used for uncoursed square rubble. But the work is levelled up to courses of varying depth. The courses are of different heights. Each course may consist of quoins, jamb stones, bonders and throughs of the same height, with smaller stones built in between them upto the height of the larger stones, to complete the course.

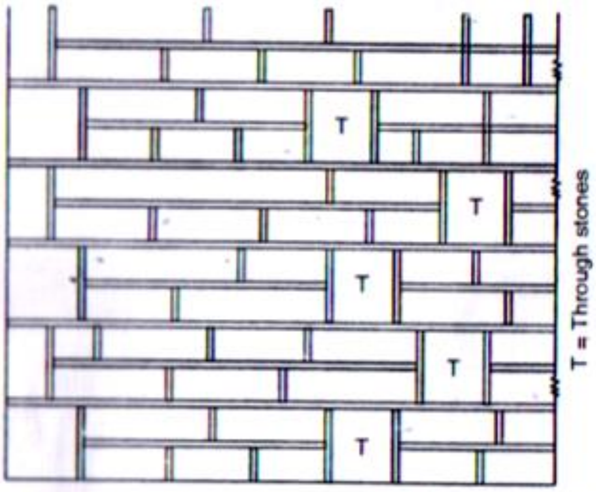



FIG 5.17. SQUARE RUBBLE : BUILT TO COURSES.

### 5. Square rubble : Regular coursed– Coursed rubble masonry

**5. Square rubble : Regular coursed– Coursed rubble masonry** : In this type of masonry, the wall consists of various courses of varying heights, but the height of stones in one particular course is the same. When the height of the courses is *equal*, it is usually called *coursed rubble masonry* (CR masonry).

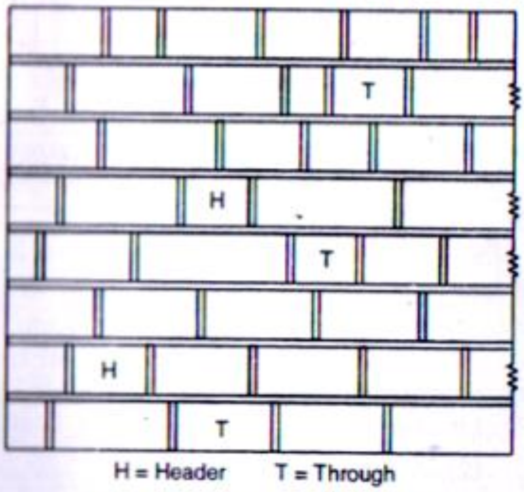
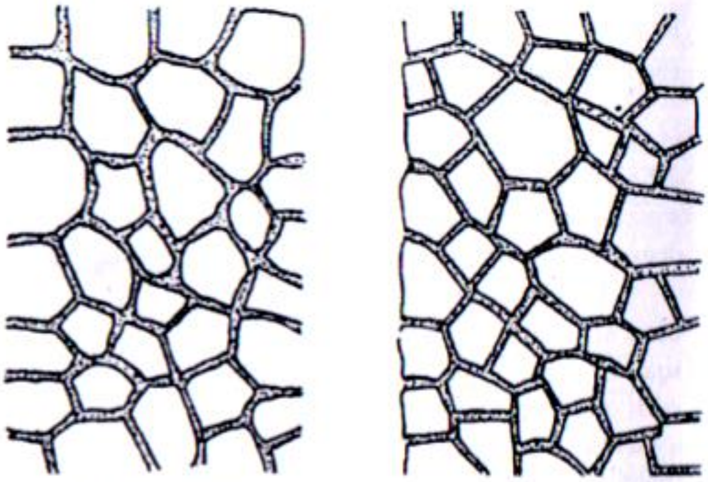



FIG. 5.18. SQUARE RUBBLE : REGULAR COURSED.

**6. Polygonal Walling (Polygonal rubble masonry)**

In this type the stones are hammer finished on face to an irregular polygonal shape. These stones are bedded in position to show face joints running irregularly in all directions. Two types of polygonal walling may be there : in the first type the stones are only roughly shaped, resulting in only rough fitting. Such a work is known as *rough picked work*. In the second type, the faces of stones are more carefully formed so that they fit more closely. Such a work is known as *close-picked work*.



(a) Rough picked (b) Close picked

FIG. 5.19. POLYGONAL RUBBLE MASONRY.

**7. Flint Walling (Flint rubble masonry)**

The stones used in this masonry are flints or cobbles, which vary in width and thickness from 7.5 to 15 cm and in length from 15 to 30 cm. These are irregularly shaped nodules of silica. The stones are extremely hard. But they are brittle and therefore may break easily. The face arrangement of the cobbles may be either coursed or uncoursed or built to courses. Strength of flint wall may be increased by introducing lacing courses of either thin long stones or bricks at vertical interval of 1 to 2 metres.

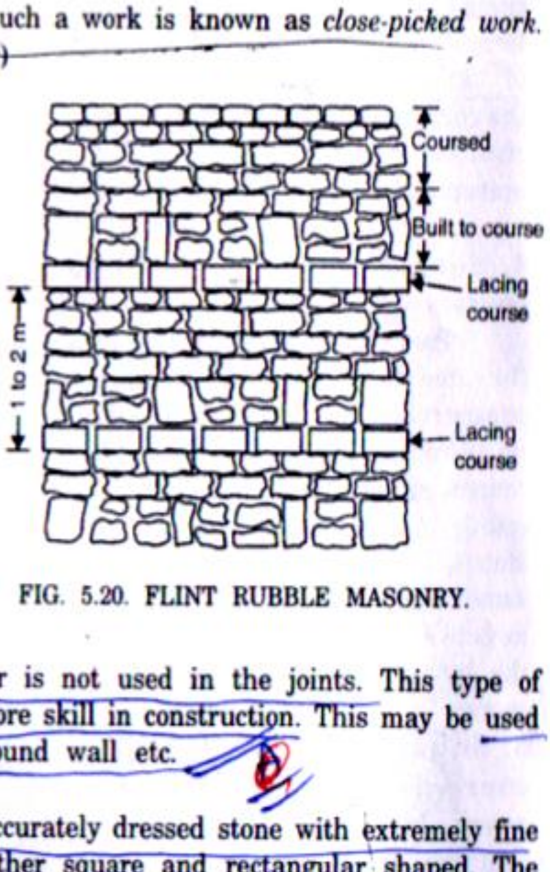



FIG. 5.20. FLINT RUBBLE MASONRY.

**8. Dry rubble masonry.**

Dry rubble masonry is that rubble masonry, made to courses, in which mortar is not used in the joints. This type of construction is the cheapest, and requires more skill in construction. This may be used for non load bearing walls, such as compound wall etc.

**(B) ASHLAR MASONRY**

Ashlar masonry consists of blocks of accurately dressed stone with extremely fine bed and end joints. The blocks may be either square and rectangular shaped. The height of stone varies from 25 to 30 cm. The height of blocks in each course is kept equal but it is not necessary to keep all the courses of the same height. Ashlar masonry may be subdivided into the following categories :

(1) Ashlar fine tooled

(2) Ashlar rough tooled

(3) Ashlar rock, rustic or quarry faced

(4) Ashlar chamfered

(5) Ashlar block in course

(6) Ashlar facing

**1. Ashlar fine tooled**

This is the finest type of stone masonry work. Each stone is cut to regular and required size and shape so as to have all sides rectangular, so that the stone gives perfectly horizontal and vertical joints with adjoining stone. The beds, Joints and faces are chisel dressed, such that all waviness and uneveness is completely removed and a fairly smooth surface is obtained. The face which remains exposed in the final work is so dressed that no point on the dressed face is more than 1 mm from a 600 mm long straight edge placed on the surface in any direction. The top and bed is also so dressed that no point on it varies by more than 3 mm when checked with the straight edge. The side surfaces which are to form the vertical joints are also so dressed that no point on the surface is more than 6 mm from the straight edge. The surfaces forming internal joints which are not visible are also so dressed that no point on the surface is more than 10 mm from the straight edge. All angles and edges that remain exposed in the final position are kept as true square and free from chipplings. The thickness of courses is generally not less than 15 cm. The width of stone is not kept less than its height. Headers and stretchers are laid alternately in each course or course of headers and course of stretchers may be laid alternately or they may be laid as otherwise directed. The thickness of mortar joint is kept uniform throughout and it should not be more than 5 mm. The exposed joints are finely pointed.

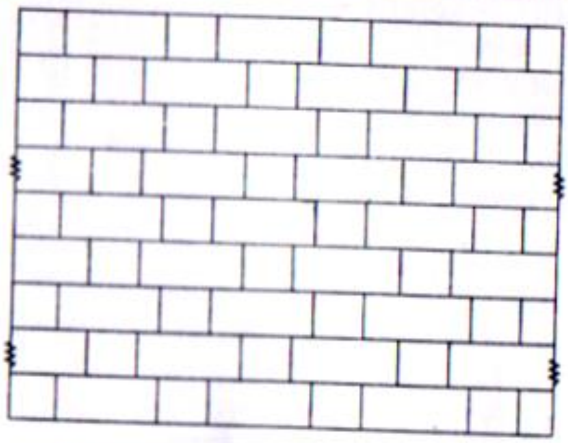


FIG. 5.21. FINE TOOLED ASHLAR MASONRY

**2. Ashlar rough tooled (Bastard ashlar)**

In this type of masonry, the beds and sides of each stone block are finely chisel dressed just in the same manner as for ashlar fine, but the exposed face is dressed by rough tooling. A strip, about 25 mm wide and made by means of a chisel is provided around the perimeter of the rough dressed face of each stone. The rough tooled face when tested with a straight edge 600 mm in length, should not show any point on the surface to vary by more than 3 mm in any direction. This type of masonry is also known as *bastard ashlar*. The size, angle, edges etc. are maintained in order, similar to that for fine dressed ashlar. The thickness of mortar joint should not be more than 6 mm.

**3. Ashlar rock faced (rustic or quarry faced)**

In this type of masonry, the exposed face of the stone is not dressed but is kept as such so as to give rock facing. However, a strip of about 25 mm wide, made by means of a chisel, is provided around the perimeter of the exposed face of every stone. The projections on the exposed face (known as *bushings*) exceeding 80 mm in height are removed by light hammering. Each stone block, however is maintained true to its size, with perfectly straight side faces and beds, and truely rectangular in shape. This type of construction gives massive appearance. The height of each block may vary from 15 cm to 30 cm. The thickness of mortar joint may be upto 10 mm.

**4. Ashlar chamfered**

This is special form of rock-faced ashlar masonry in which the strip provided around the perimeter of the exposed face is chamfered or bevelled at an angle of 45° by means of a chisel to a depth of 25 mm. Due to this, a groove is formed in between adjacent blocks of stone. Around this bevelled strip, another strip of 15 cm is dressed with the help of chisel. The space inside this strip is kept rock faced except that large bushings in excess of 80 mm projections are removed by a hammer.

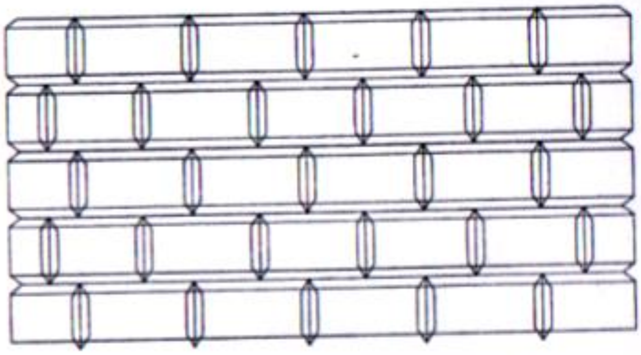


FIG. 5.22. ASHLAR CHAMFERED.

**5. Ashlar block in course**

This type of masonry is intermediate between rubble masonry and ashlar masonry. The faces of each stone are hammer dressed, and the height of blocks is kept the same in any course, though it is not necessary to keep uniform height for all the courses. The vertical joints are not as straight and as fine as in ashlar masonry. The depth of courses may vary from 15 to 30 cm. This type of masonry is adopted in heavy works such as retaining walls, bridges etc.

**6. Ashlar facing**

Ashlar facing masonry is provided along with brick or concrete block masonry, to give better appearance. The sides and beds of each block are properly dressed so as to make them true to shape. The exposed faces of the stone are rough tooled and chamfered. The backing of the wall may be made in brick masonry.

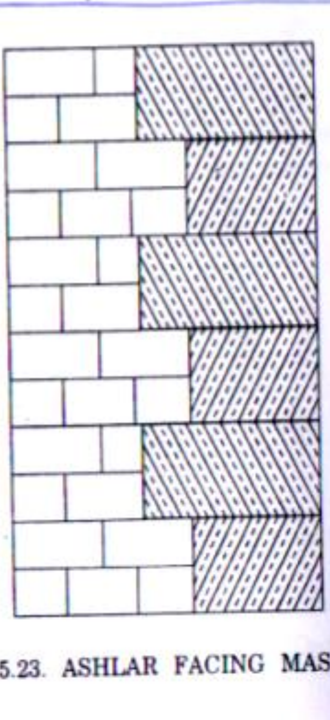


FIG. 5.23. ASHLAR FACING MASONRY.

## 5.5. DRESSING OF STONES

The surfaces of stones obtained from quarry are rough. The blocks are irregular in shape and non-uniform in size. Hence their dressing is essential. The dressing of stones is sometimes done at the quarry itself because freshly quarried stones are soft due to the moisture (called *quarry sap*) contained by them. The local workers are more experienced in the art of dressing of that particular type of stone. Also, if the stones are dressed at the quarry site itself, the trasportation costs are reduced because of reduction in the weight due to dressing.

**Tools and implements for stone dressing**

The following tools are used for dressed stones (Figs. 5.24 and 5.25).

1. *Spall hammer* : Used for rough dressing of stones.
2. *Scrabbling hammer* : Used for removing irregular bushings.
3. *Mash hammer* : Used for rough dressing.
4. *Wallers hammer* : Used for removing spalls.
5. *Club hammers* : Used to strike narrow-headed chisels.
6. *Mallet* : Used to strike mallet headed chisels.
7. *Dummy* : Used for striking chisels for carving work.
8. *Gad* : Used to split stones
9. *Drag* : Used to give drag finish.
10. *Hand saw* : Used to cut soft stones.
11. *Cross-cut saw* : Used to cut hard stones.
12. *Frame saw* : Used to cut large blocks of stones.
13. *Pitching tool* : Used to make stones of required size.
14. *Square* : Used to set edges at right angles.
15. *Boaster* : Used to cut soft stones.
16. *Punch* : Used for rough dressing.
17. *Point* : Used for rough dressing of hard stones.
18. *Gouge* : Used to dress stones for cornices, string courses etc.
19. *Broad tool* (nicker) : Used to form chisel lines on stone surface.
20. *Wood handled chisel* : Used to dress soft stones.
21. *Claw chisel* : Used to dress hard stones.
22. *Tooth chisel* : Used to dress hard stones.
23. *Drafting chisel* : Used for fine dressing.

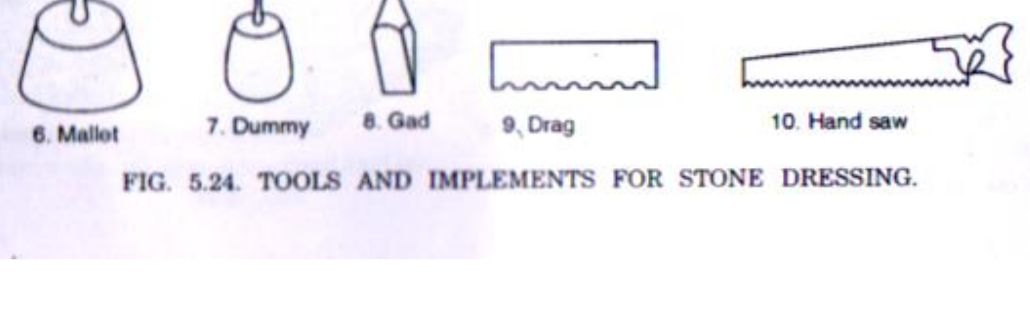



FIG. 5.24. TOOLS AND IMPLEMENTS FOR STONE DRESSING.

# Masonry-3 : Composite Masonry

## 7.1. INTRODUCTION

*Composite masonry* is the one which is constructed out of two or more types of building units or of different types of building materials. The composite masonry may be adopted due to two reasons :

(*i*) Improvement in the appearance of walls, etc.,

(*ii*) Use of available materials, to obtain optimum economy.

Composite masonry may be of the following types :

1. Stone-composite masonry.
2. Brick stone composite masonry.
3. Cement concrete masonry.
4. Hollow clay tile masonry.
5. Reinforced brick masonry.
6. Glass block masonry.

## 7.2. STONE COMPOSITE MASONRY

Composite stone masonry generally, consists of a combination of ashlar masonry and rubble masonry. Rubble masonry is generally very cheap, while ashlar masonry gives pleasing appearance. Hence rubble masonry is used in backing of the wall while the ashlar masonry is used in the facing, as shown in Fig. 7.1.

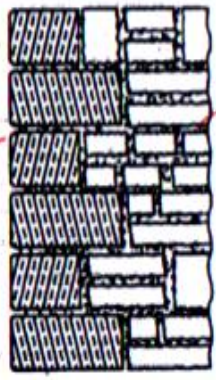


FIG. 7.1.

In order that both the facing and backing of the wall act monolithically, it is essential to observe utmost care during construction. The following points should be specifically attended to :

(1) Through stones should be used at regular interval, and in sufficient number.

(2) The backing and facing portions should be constructed in rich cement mortar.

(3) Construction of both the backing and facing should be carried out simultaneously so that proper bond is obtained.

(4) If necessary, metal cramps, dowels, lead plugs etc. should be provided between facing and backing.

## 7.3. BRICK-STONE COMPOSITE MASONRY

Bricks and stones can be simultaneously used in three forms of composite masonry:

(*i*) Brick-backed ashlar masonry

(*ii*) Brick-backed stone slab facing

(*iii*) Rubble-backed brick masonry.

Fig. 7.2 (*a*) shows *brick-backed ashlar masonry*. The ashlar may be rough tooled. It is preferable to use the height of ashlar as a multiple of brick thickness plus masonry joints, so that coursed masonry is obtained. Cement mortar should be used for construction. Bricks should be laid in proper bond. Alternate courses of ashlar may be headers. Under each projecting course of ashlar, header bricks should be used.

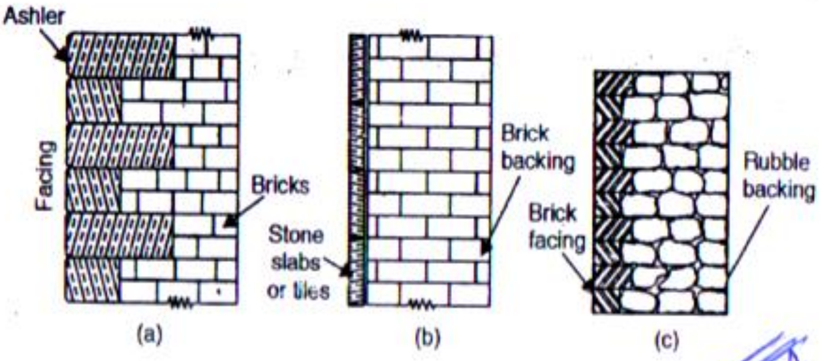


FIG. 7.2. BRICK-STONE COMPOSITE MASONRY.

Fig. 7.2 (*b*) shows the facing of stone slabs or stone tiles. The backing consists of bricks laid in courses with proper bond. This type of construction is quite common, since stone tiles may be of marble stone. If stone slabs are used, they are fine dressed, and are used in big panels. It is preferable to use metal cramps to connect the facing and backing masonry of the wall.

Fig. 7.2. (*c*) shows a rubble-backed brick masonry. It is commonly used at locations where rubble stone is available in large quantities, but ashlar is not available. In that case, the facing of the wall may be done in bricks laid in courses. Each alternate brick course consists of quoin header.

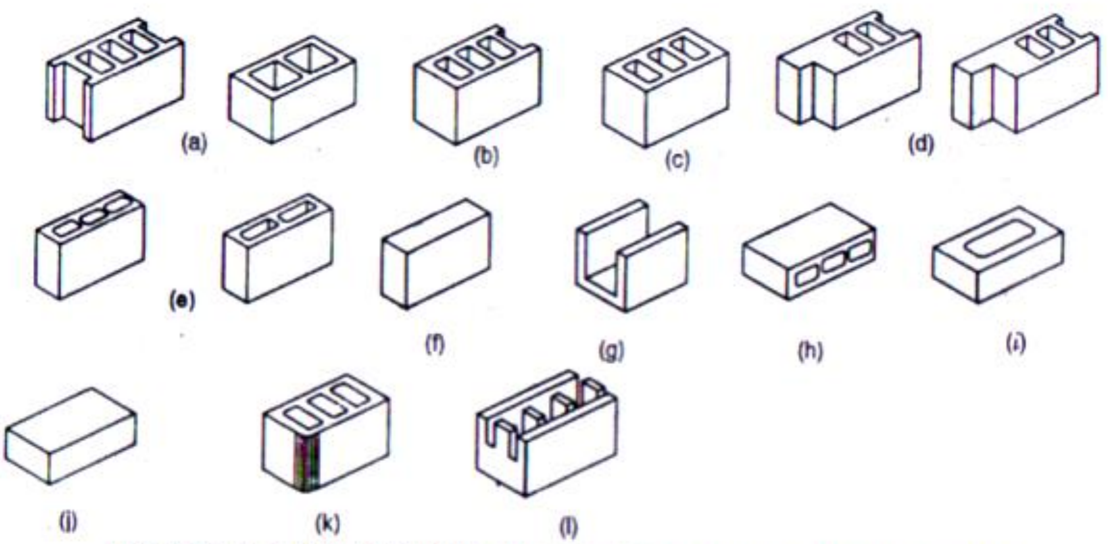
## 7.4. CONCRETE MASONRY

*Concrete masonry or cement-concrete masonry* uses cement concrete blocks, either hollow or solid, for wall construction, with or without stone facing. A *hollow unit*, is defined as that unit which has core-void area greater than 25% of the gross area. Various types of *concrete masonry units*, depending upon shape and size, are manufactured, and these can be grouped in two heads :

(*i*) Regular concrete blocks (*ii*) Hollow concrete units.

*Regular concrete blocks* are manufactured from dense aggregate, and they are used in load bearing walls. *Hollow concrete units* are manufactured from light weight aggregates. They may be used both for load bearing as well as non-load bearing walls. They are light in weight. Fig. 7.3 shows various forms of concrete masonry units.

*Concrete Association of India* recommends that the face thickness of the hollow blocks should atleast be 5 cm, and the net area should atleast be 55 to 60% of the gross area. The cores in the blocks should atleast be two in number and should preferably be oval shaped. The recommended size of common blocks are 39 cm × 19 cm × 30 cm; 39 cm × 19 cm × 20 cm and 39 cm × 19 cm × 10 cm. The aggregate used in the




(a) STRETCHER BLOCKS (b) CORNER BLOCK (c) DOUBLE CORNER OR PILLAR BLOCK (d) JAMB BLOCKS (e) PARTITION BLOCKS (f) SOLID BLOCK (g) BEAM OR LINTEL BLOCK (h) FLOOR BLOCK (i) FROGGED BRICK BLOCK (j) SOLID BRICK BLOCK (k) BULL NOSE BLOCK (l) LINTEL BLOCK

FIG. 7.3. CONCRETE MASONRY BLOCKS.

block manufacture consists of 60% fine (*i.e.* sand) and 40% course aggregate of 6 to 12 mm size, with a combined fineness modulus of 2.9 to 3.6. The cement-aggregate mix is in 1 : 6 proportion. The strength of the blocks should be atleast 3 $N/mm^2$.

Concrete masonry blocks are manufactured in the following *surface finishes:*

(*i*) Common finished surface.
(*ii*) Glazed finish.
(*iii*) Slumped finish.
(*iv*) Specially faced finish.
(*v*) Coloured finish.

*Common finish surface* has fine to course texture which can be obtained by varying the mix proportions and by using appropriate aggregates. If the exposure of the aggregates is required, it can be obtained either by treating the surface by dilute acid solution or by scrubbing it while the concrete has not fully set. *Glazed finish* is used for decorative work. It can be obtained in a manner similar to glazing of tiles. Glazed finish concrete blocks are water resistant. *Slumped finish* is the *rough finish* which is obtained by using the concrete of desired slump. When the forms are open, the blocks settle slightly, causing rough surface. In *specially faced finish*, finishing material such as marble etc. is incorporated on the facing side of the block. *Coloured finish* can be obtained by mixing various pigments to the concrete mix.

**Manufacture of concrete masonry blocks**

The following points should be kept in mind while manufacturing the concrete masonry bricks :

1. The cement-aggregate ratio should not be leaner than 1 : 6.

2. The aggregate should have a mixture of fine aggregate 60% and coarse aggregate (6 to 12 mm size) 40%. The fineness modulus as the mixed aggregate should be between 2.9 to 3.6.

3. Blocks should be taken out from the moulds only when concrete has sufficiently set.

4. Concrete should not have very lean consistency. If hand moulding is done,

the hollows should be vertical. Proper compaction should be obtained.

5. Machine casting is preferable to hand casting, to obtain better finish.

6. After taking the blocks out of mould, they should be kept under shade for atleast 24 hours, and then immersed in water tank for curing for atleast one week. After that, the blocks may be stacked with cells horizontal.

7. Blocks should be used only *after* about 3 to 4 weeks of their taking out of the curing tank.

8. The compressive strength of blocks should not be less than $3\ N/mm^2$ after 28 days curing.

**Construction of walls** : The method of constructing the wall with concrete blocks is the same as that used for brick masonry. First, the corners or ends of the wall are constructed with few courses of blocks. Mortar is applied to the bottom of the concrete block at the horizontal face members only. For vertical joints, the mortar is applied to the projections at the sides of the block. For building the portion in between the corners, the string is spread between the two horizontal end blocks of a course, and the blocks are laid in between. The final closing block is fitted carefully.

The following points should be kept in mind while supervising the construction work :

1. Before use, it should be ensured that the blocks are *dry*. They should not be drenched in water before use.

2. Blocks of successive courses should be so laid that vertical joints are staggered.

3. The joints should be 5 to 10 mm thick, and should be uniform.

4. The mortar used for construction should not be stronger than the concrete mix used for manufacture of blocks. Generally cement-lime-sand mortar of mix proportion 1 : 1 : 10 is used.

5. The blocks used for external walls should have absorption less than 10%. For internal walls, the absorption should be less than 15%.

6. Concrete blocks have high thermal expansion, due to which walls crack at corners. Long walls may have cracks even at its mid-length. Hence at the junction of walls, solid concrete blocks or hollow blocks filled with concrete should be used.

**Wall thickness** : Table 7.1. gives the thickness of walls made of hollow concrete blocks.

**TABLE 7.1. WALL THICKNESS (cm)**

| *No. of floors* | *Foundation or basement* | *Ground floor* | *1st floor* | *2nd floor* | *3rd floor* |
|---|---|---|---|---|---|
| — | 20 to 30 | 20 | — | — | — |
| 1 | 30 | 20 | 20 | — | — |
| 2 | 30 | 30 | 30 | 20 | — |
| 3 | 40 | 40 | 30 | 30 | 20 |

**Advantages of hollow concrete block masonry**

1. Concrete blocks are regular in size, requiring no dressing work. Hence construction is very rapid.

2. Blocks are light and therefore easy to handle.

3. Because of their lightness, the loads transferred to foundations is much less

than the stone masonry. This is important consideration in locations where soil has low hearing capacity.

4. There is great saving in the material.

5. Hollow blocks are structurally stronger than bricks.

6. Thinner walls can be easily constructed, resulting in increase in the floor area.

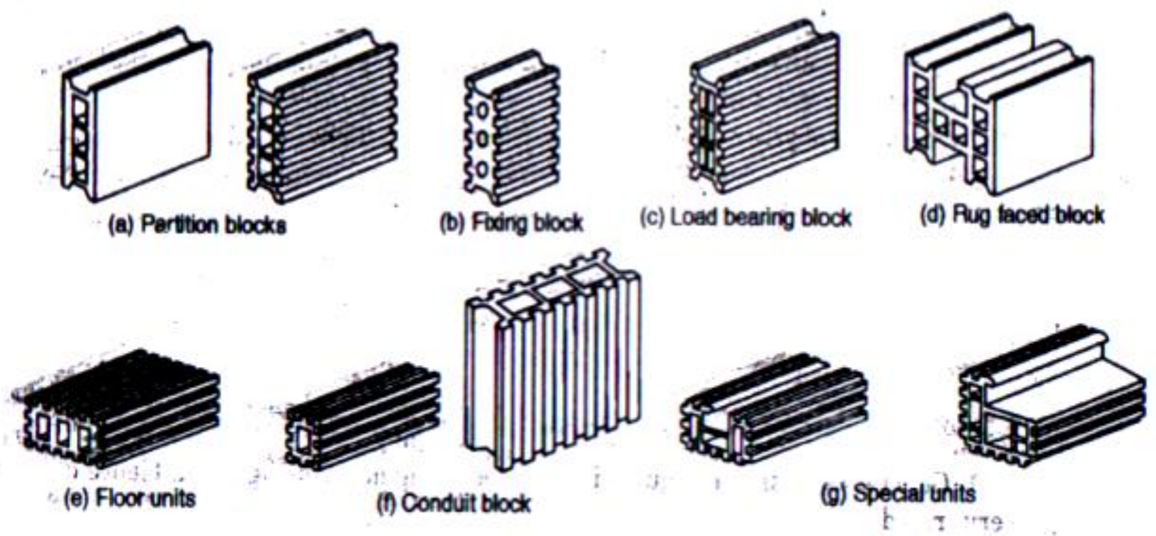
7. Because of large size of the blocks, the number of joints in the masonry is less. This results in saving in mortar.

8. Because of hollow space, the resulting wall has better insulating properties against sound, heat and dampness.

9. Blocks can withstand the atmospheric actions, and do not require plaster or any other covering or facia work.

## 7.5. HOLLOW CLAY BLOCKS MASONRY

Hollow clay blocks (or tiles) are made of selected clay or diatomaceous earth, which is dried and burned. The clay blocks are used to build foundations, walls, partitions, floors and other structural members. Even though the walls of the blocks are relatively thin, they are quite strong and light. These tiles are fire proof, resistant to termite and free from decay caused by the contact of moisture or chemicals. Because of large amount of air within the cells of blocks, the thermal insulation is very good. Hollow clay blocks are manufactured in various shapes and sizes. They are also made of various grades, such as load bearing (L.B.) and extra load bearing (L.B.X.). Fig. 7.4 shows various shapes and sizes of structural clay units. The shell of a clay block constitutes the four sides surrounding the hollow interior, while the webs serve as partitions between the cells. The overall average thickness of the shells should not be less than 2 cm and of the web not less than 1 cm for end construction blocks. Tiles may have *grooves* on one or more faces. The area covered by grooves should not exceed 50 % of the area of cored faces. Grooved tiles are used only where plastering is to be done : otherwise smooth tiles should be used.



The load bearing main walls and partition walls should be constructed in 1 : 1 : 6 ( cement, lime, sand ), and non-load bearing main walls and partition walls are generally constructed in 1 : 2 : 9 mix.

All the blocks should be dipped in water before use. The corner blocks are first laid at the ends of the wall. Special closer units may be required at the ends. The conduit and/or closer blocks are laid with cavities vertical. Load bearing blocks are laid with cavities horizontal. Jambs are constructed for special blocks.

## 7.6. REINFORCED BRICK MASONRY

*Reinforced brick work* is the one in which the brick masonry is strengthened by the provision of mild steel flats, hoop iron, expanded mesh or bars. It is adopted or used in the following circumstances :

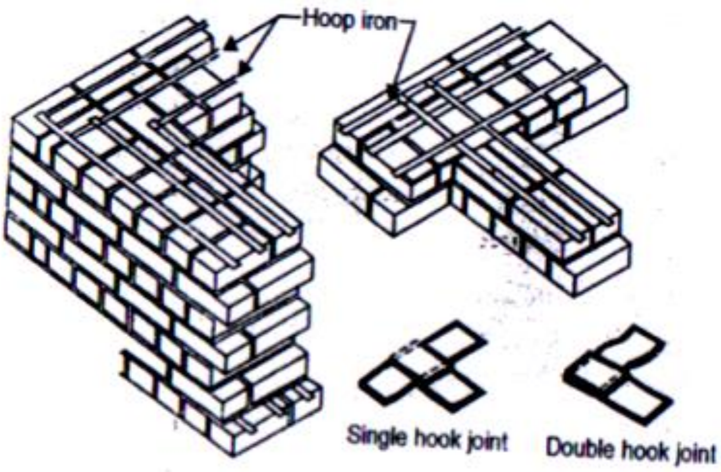
1. When the brick work has to bear tensile and shear stresses.
2. When it is required to increase the longitudinal bond.
3. When the brick work is supported on soil which is susceptible to large settlement.
4. When the brick work is supposed to act as a beam or lintel over openings.
5. When the brick work is to resist lateral loads, such as in retaining walls etc.
6. When the brick wall is to carry heavy compressive loads.
7. When the brick work is to be used in seismic areas, since it can also resist lateral loads.

Reinforced brick work uses first class bricks with high compressive strength. Dense cement mortar is used to embed the reinforcement. The reinforcing material may be (*i*) hoop iron, (*ii*) mild steel bars, (*iii*) mild steel flats and (*iv*) expanded mesh. The reinforcement is laid either horizontally or vertically.

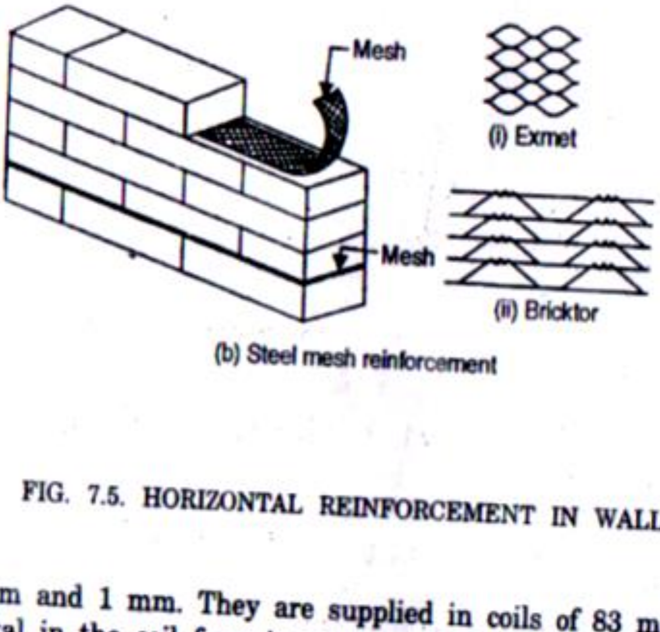
### (*a*) Horizontal reinforcement

Horizontal reinforcement *for wall* consists of either (*i*) wrought iron flat bars, known as *hoop iron,* or (*ii*) steel mesh. Fig. 7.5 (*a*) shows the hoop iron reinforcement for a brick wall. Generally, two strips of hoop iron are used per header brick and one hoop iron per stretcher brick *i.e..,* one strand of hoop iron for each half brick thickness of wall. Mild steel flats may also be used in place of hoop iron. It is usual to reinforce *every sixth course.* Mild steel flat bars may have width between 22 to 32 mm and thickness equal to 0.25 to 1.6 mm. Protection against rust is provided by dipping the bars in hot tar, these are then at once sanded to increase the adhesion of the mortar. At the ends (quoins), the bars are beaten flat and then double hooked to bars coming from transverse direction. At the junctions, the bars crossing each other are interlaced and single hooked. Hoop iron is now rarely used because of its higher cost and because of its thickness, unless thicker joints are used.

Another form of horizontal reinforcement, which is more commonly used, is the provision of steel meshed strips called *Exmet,* made from their rolled steel plates which are cut and stretched (or expanded) by a machine to diamond network. Such a strip is known as *expanded metal* (*Exmet*) and is provided at *every third course.* These strips are available in widths of 65 mm, 178 mm and 230 to 305 mm, with thicknesses




(a) Hoop iron reinforcement

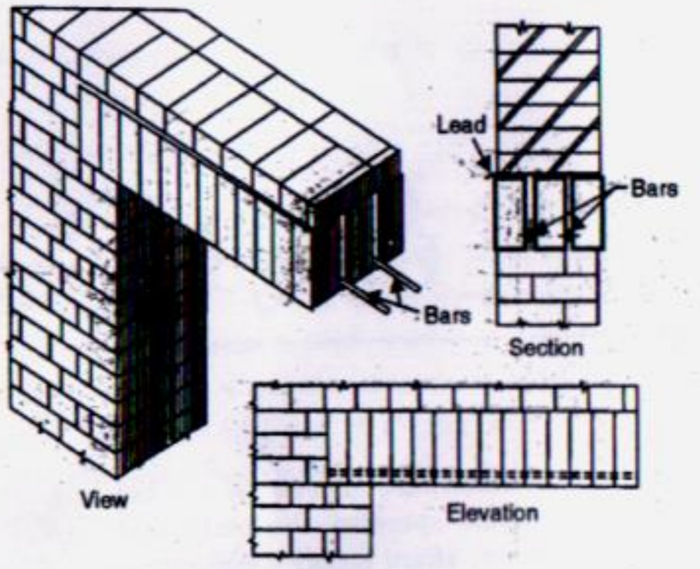



(b) Steel mesh reinforcement

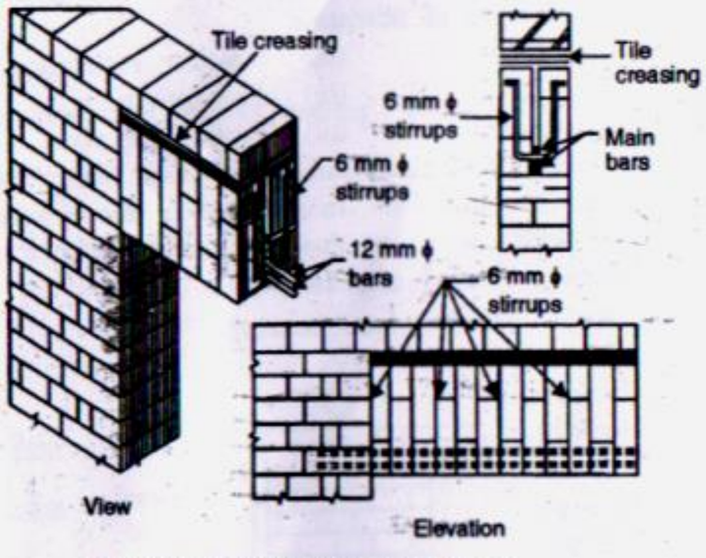
FIG. 7.5. HORIZONTAL REINFORCEMENT IN WALLS.

of 0.6 mm, 0.8 mm and 1 mm. They are supplied in coils of 83 m length. To prevent corrosion, the metal in the coil form is coated with oil and then dipped in asphaltum paint. Cement mortar is first trowelled on the bed and the Exmet is uncoiled and pressed down in the mortar. Another form of meshed reinforcement, called *Bricktor,* is made of a number of straight *tension wires* (1.4 mm) interlaced with *binding wires* (1.1 mm). One such strip is provided for every half-brick thickness of wall.

Horizontal reinforcement is also used for brick lintels, as shown in Fig. 7.6. Generally, mild steel bars (6 mm to 12 mm dia.) are provided through the vertical joint, all along the span of lintel. If the lintel carries heavy loads, resulting in heavy shear force, 6 mm dia. steel wire stirrups are provided at every 3rd vertical joint, as shown in Fig. 7.6 (*b*). The longitudinal steel bars (main reinforcement) should extend 150 mm beyond the jambs.




(a) Longitudinal reinforcement




(b) Longitudinal reinforcement with stirrups

FIG. 7.6. REINFORCED BRICK WORK LINTELS.

### (b) Vertical reinforcement

Vertical reinforcement, in the form of mild steel bars, is provided in brick columns, brick walls and brick retaining walls. In such a circumstance, special bricks, with one or two holes extending upto the face, are used. Vertical mild-steel bars are then placed in the holes. These bars are anchored by steel plate or wire-tie at some suitable interval. Fig. 7.7 shows the details of reinforced brick work piers.

Brick retaining walls are often reinforced since such a work is cheaper than the reinforced cement concrete, when the height of the wall is upto 3 m. Vertical reinforcing bars are placed vertically near each face, in addition to steel meshed strips at every fourth course. The bricks opposite each bar are purpose made, having a groove. The size of the groove is kept slightly more than the diameter of the bar so that

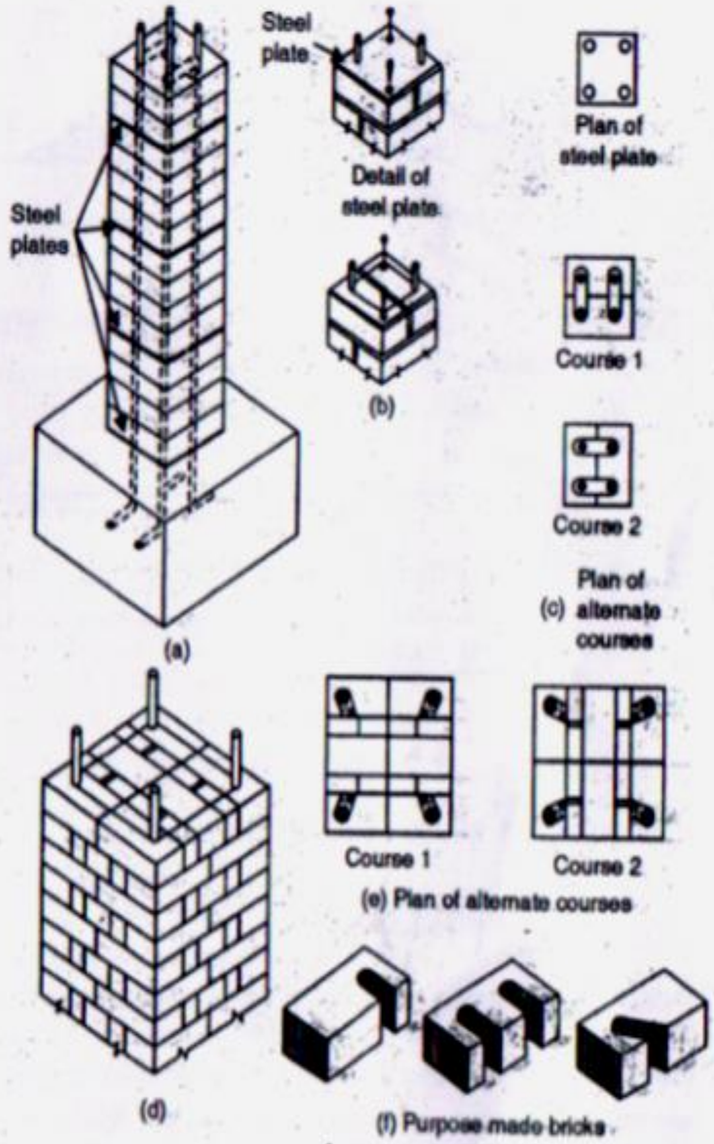



FIG. 7.7. REINFORCED BRICK WORK PIERS.

it may be grouted in with cement mortar, to prevent corrosion. Steel wire ties may be provided at every fourth course.

In all types of reinforced brick work, it is essential to embed the steel reinforcement in rich cement mortar (usually 1 : 3), with proper cover so that reinforcement is not corroded. Corrosion will result in expansion of the joint and consequent cracking. The bricks should also be of high quality, possessing high compressive strength so that optimum use is made of all the materials (*i.e.* bricks, mortar and reinforcement).

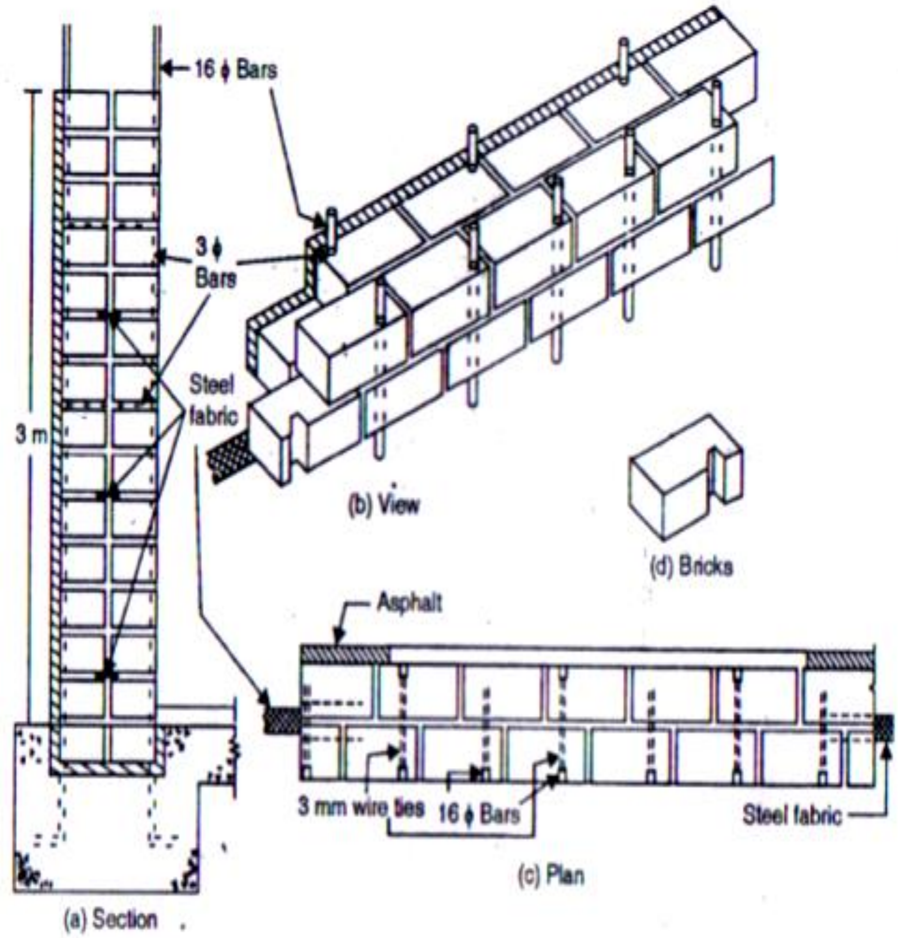



FIG. 7.8. REINFORCED BRICK WORK RETAINING WALLS.

## PROBLEMS

1. What do you understand by 'composite masonry' ? Enumerate various types of composite masonry, and state the circumstances under which each type is used.

2. Describe, with the help of sketches, various forms of stone brick composite masonry.

3. What do you understand by concrete masonry ? State the advantages of hollow block concrete masonry. State various types of surface finishes in such a masonry.

4. Write a note on hollow clay block masonry.

5. What do you understand by 'reinforced brick masonry ? When do you use it ? Give examples.

6. Explain, with the help of sketches the provision of various types of horizontal reinforcement in reinforced brick masonry.

7. Explain, with the help of sketches, provision of vertical reinforcement in (*a*) reinforced brick column (*b*) reinforced brick retaining wall.

# CONCRETE

Cement concrete is a mixture of cement, sand, pebbles or crushed rock and water. When placed in the skeleton of forms and allowed to cure, becomes hard like a stone. Cement concrete is important building material because of the following reasons.

1. It can be moulded into any size and shape of durable structural member.
2. It is possible to control the properties of cement concrete.
3. It is possible to mechanise completely its preparation and placing processes.
4. It possesses adequate plasticity for mechanical working.

The cement concrete has the following properties

1. It has high compressive strength
2. It is free from corrosion
3. It hardens with age and continues for a long time after concrete has attained sufficient strength
4. It is proved to be economical than steel
5. It binds rapidly with steel and it is weak in tension, steel reinforcement is placed in cement concrete at suitable places to take up tensile concrete or simply R.C.C.
6. It forms a hard surface, capable of resisting abrasion stresses. This is called reinforced cement.

7. It has tendency to be porous to avoid this proper grading & consolidation of the aggregates, minimum water-cement ratio should be adopted.

**Constituents - Requirements.**

The main constituents of concrete are

a) **Cement / Lime:** Before introduction of ordinary Portland cement, lime was used as cementing material. At present most of the cement concrete works in the building construction is done with ordinary Portland cement. But other special varieties of cement such as rapid hardening cement, high alumina cement are used under certain circumstances. The cement should comply with all standard specifications

b) **Fine Aggregates:** The material, which is passed through 4.7625mm B.S.test sieve, is termed as fine aggregates. Usually natural river sand is used as fine aggregates. But places where natural sand is not available economically, finely crushed stone may be used as fine aggregates.

c) **Coarse Aggregates**: The material retained on 4.7625mm size B.S.test sieve is termed as coarse aggregates. Broken stone is generally used as coarse aggregates. For thin slabs, and walls, the maximum size of coarse aggregates should be limited to one third the thickness of the concrete section

d) **Water**: Water to be used in the concrete work should have the following properties.

1) It should be free from oils

2) It should be free from acids or alkalies

3) It should be free from Iron, Vegetables matter or other substance, which is likely to have adverse effect on concrete.

4) It should be fit for drinking purpose

**Function of Water**

1. It acts as lubricant for fine and coarse aggregates.

2. It acts chemically with cement to form binding paste with coarse aggregates and reinforcement.

3. It is necessary to flux the cementing material over the surface of the aggregates.

4. It is employed to damp the concrete in order to prevent them absorbing water vitally necessary for chemical action

5. It enables the concrete mix to blow into moulds.

**6.2. Uses and types Uses of Concrete:**

1:2:2 - For heavy loaded R.C.C columns and R.C.C arches of long spans

1:2:2 - For small pre cast members of concrete like fencing poles, telegraph poles etc. watertight construction.

1:2:3 - For water tanks, bridges, sewers etc. 1:2½:3½ - For foot path, concrete roads

1:2:4 - For general work of RCC such as stairs, beams, columns, slabs, etc

1:4:8 /

1:5:10 For mass concrete for heavy walls, foundation footings etc.

**Preparation of concrete mix:**

There are two types of concrete mixing

(i) Hand mixing

(ii) Machine mixing

1. **Hand Mixing:** This method of mixing concrete is resorted to when the quantity if concrete to be used in a work is insufficient to warrant the necessity of machine. This is used with advantage in places where machinery cannot be used on account of their non-availability or in works near a hospital where the noise of machine is not desirable. Hand mixing is done on a clean, hard and impermeable surface. Cement and sand are first mixed dry with the help of shovels until the mixture attains a uniform colour. Aggregative are then added to this mixture and the whole mixture is then turned by shovels until the stone pieces uniformly spread throughout. After this, desired are quantity of water is poured into the heap from a can fitted with a rose. The mass is then turned until a workable mixture is obtained. It is advised to add 10% extra cement to guard against the possibility of inadequate mixing by this method.

**2. Machine Mixing:** - The machine used for mixing concrete is termed as concrete mixer. Two types of concrete mixers are in common are

1. Continuous mixers

2. Batch mixers

Continuous mixers are employed in massive construction where large and continuous flow of concrete is desired. The process of feeding the mixing is more or less automatic. The machine requires careful supervision so as to obtain the concrete mix of desired consistency.

In batch type of concrete mixer. The desired proportion of materials are fed into the hopper of a drum in which the materials get mixed by the series of blades or baffles inside the mixer. Batch mixers are further two types 1. Tilting drum type 2. closed drump type. In the first type, components are fed in the revolving drum in a tilted position and after sometime the concrete mix is discharged by tilting the drums in the opposite direction. In the latter type the drum remains rotating in one direction and emptied by means of hopper which tilts to receive the discharge.

While using the mixer, coarse aggregates should be fed first, sand and cement should be put afterwards. In this revolving state, the components get mixed while water is poured with the help of can. The concrete should be for atleast 2 minutes, the time being measured after all the ingredients including water have been fed into the drum. The batch type concrete mixer is as shown in the fig 6.1.

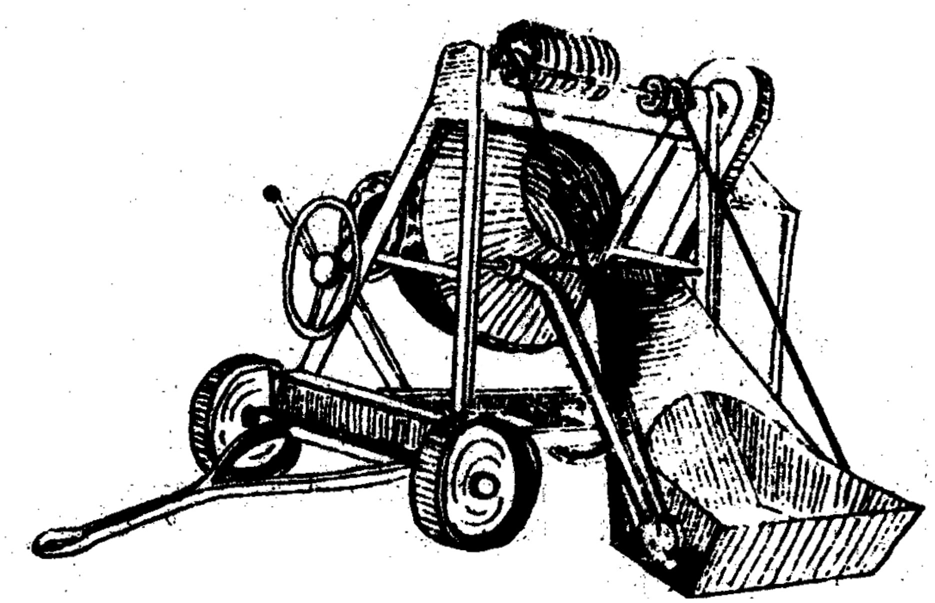


**Fig 6.1 Batch type Concrete Mixer**

**Compaction - Methods:**

Concrete should be placed and compacted immediately after mixing. The concrete should be placed within 30 to 40 minutes to prevent the danger of concrete getting its initial set, before laying the concrete, the shuttering should be cleaned of all of dust or debris. Crude oil or grease etc is usually applied to the shuttering before concreting to prevent the shuttering absorbing the water from the concrete or getting struck to it. In placing the concrete, care should be taken to see that it should not be thrown from heights. Concrete should be laid in layers 15 to 30 cm (6” to 12”) in thickness and each layer should be properly compacted before laying the next one.

Compaction of concrete should be proceed immediately
after placing. The function of compaction of concrete is to expel

the air bubbles in the mass and make it impermeable in addition to its securing the desired strength. The concrete mass should be consolidated or compacted till the cream of the cement starts appearing on the surface. Over compaction may lead to segregation of concrete while-under-compaction may leave air voids in concrete and results in honey combing. Compaction may be done by hand or mechanical device.

(i) **Hand compaction**: The hand compaction may be done by rodding, tamping or hammering. Tamping is usually adopted for compacting concrete for slabs or other such surfaces. Rodding is done for thin vertical members. Hammering is done for massive plain concrete works and for compacting an almost dry concrete the surface is beaten with heavy flat bottom rammers till the thin film of mortar start appearing on the surface.

(ii) Mechanical compaction: Mechanical compaction is done by the use of vibrators. Vibrators are of three types 1. Internal 2. External 3. Surface. Internal vibrators are commonly used in large works for flat surface compaction. In this the vibrator is immersed in the full depth of concrete layer. The vibrator should be kept in one position for about 3 minutes and then removed and placed another position. External vibrators are placed against the form work and are only adopted for thin section of members or in places where internal vibrators cannot be used with ease. Surface vibrators are generally employed in concrete road construction. Compaction of concrete by use of vibrators permits the use of stiff concrete mix of high strength and ensure better compaction than that obtained by the method of hand compaction

**Curing of concrete:**

Curing of concrete is one of the essential requirement of process of concreting. Curing is process of keep the set concrete damp for some days in order to enable the concrete gain more strength

**Purposes:**

(i) Curing protects concrete surfaces from sun and wind

(ii) Presence of water is essential to cause the chemical action which a companies the setting of concrete

**SYNOPYSIS**

1. Concrete is a mixture of cement, sand, pebbles or crushed rock and water
2. Concrete is uses for

i) Heavy loaded RCC columns, arches etc

ii) Pre-cast members

iii) Water tanks, bridges, sewers etc

iv) Foot path, concrete roads etc

v) Foundation footings

3. The preparation of concrete may be

i) By hand mixing

ii) Machine mixing

4. Machine mixing may be carried out commonly by

i) Continuous mixers

ii) Batch mixers

5. The function of consolidation or compaction is to expel the air bubbles in the mass and make it impermeable in addition to its securing desired depth
6. Compaction may be done by

i) rodding – vertical members like columns

ii) tamping – slabs

iii) hammering – massive plain concret works

7. Mechanical compaction may be done by

i) Internal vibrators

ii) External vibrations

iii) Surface vibrations

8. Curing of concrete is the process of keep the set concrete damp for some days in order to enable the concrete gain more strength
9. By curing the concrete should get

i) Strength

ii) Durability and impermeability

iii) Resistance to abrasion

**SHORT ANSWER QUESTIONS**

1. What are the ingradients of concrete?
2. What are requirements of materials in concrete

a) Cement b) Sand c) C.A. d) Water

3. Write any four important uses of concrete
4. What are the types of concrete?
5. What is meant by compaction?
6. What is the importance of compaction?
7. What is meant by curing?
8. What is use of curing of concrete?

**ESSAY TYPE QUESTIONS**

1. Explain the requirements of constituents of concrete
2. Write the uses of concrete
3. Explain the preparation of concrete by

1. Hand mixing 2. Machine mixing

4. What is meant by curing of concrete? Explain importance of curing.
5. What is compaction of concrete? Explain the importance of compaction.

# Plastering and Pointing

## 19.1. PLASTERING

*Plastering* is the process of covering rough surfaces of walls, columns, ceilings and other building components with thin coat of *plastic mortars* to form a smooth durable surface. The coating of plastic material (*i.e.* mortar) is termed as *plaster*. Plastering on external exposed surfaces is known as *rendering*.

**Objects of plastering.** Plastering is done to achieve the following objects :

(1) To protect the external surfaces against penetration of rain water and other atmospheric agencies.

(2) To give smooth surface in which dust and dirt cannot lodge.

(3) To give decorative effect.

(4) To protect surfaces against vermit.

(5) To conceal inferior materials or defective workmanship.

**Requirements of good plaster.** The plaster material should fulfill the following requirements :

(1) It should adhere to the background, and should remain adhered during all variations in seasons and other atmospheric conditions.

(2) It should be hard and durable.

(3) It should possess good workability.

(4) It should be possible to apply it during all weather conditions.

(5) It should be cheap.

(6) It should effectively check penetration of moisture.

## 19.2. TYPES OF MORTARS FOR PLASTERING

The selection of type of plaster depends upon the following factors :

1. Availability of binding materials.
2. Durability requirements.
3. Finishing requirements.
4. Atmospheric conditions and variations in weather.
5. Location of surface (*i.e.* exposed surface or interior surfaces.)

Following types of *mortars* are commonly used for plastering

(*i*) Lime mortar. (*ii*) Cement mortar. (*iii*) Lime cement mortar.

## 1. Lime mortar

Lime used for plastering may be either fat lime or hydraulic lime. However, fat lime is preferred since it yields good putty after slaking. Hydraulic lime contains particles which slake very slowly as it comes in contact with atmospheric moisture; such slaking may even continue for 6 to 8 months. If unslaked particles remain in such a plaster, blisters are formed during the process of slow slaking. Thus the plastered surface gets damaged. Hydraulic lime yields harder and stronger surface. If hydraulic lime is used for plastering, it should be ground dry with sand. It is then left for 2 to 3 weeks and then reground before use. Fat lime on the other hand, is slaked wet. The mix proportion (*i.e.* lime : sand) varies from 1 : 3 to 1 : 4 for fat lime and 1 : 2 for hydraulic or kankar lime. The binding properties of lime mortar can be improved by adding *gugal* at the rate of about 1.6 kg per cubic metre of mortar. The adhesive and tensile properties of lime mortar can further be improved by mixing *chopped hemp* at the rate of about 1 kg per cubic metre of mortar. Such a treatment prevents the formation of tensile cracks on the plastered surface.

## 2. Cement mortar

Cement mortar is the best mortar for external plastering work since it is practically non-absorbant. It is also preferred to lime plaster in both rooms etc., and in damp climates. Cement mortar is much stronger than lime mortar. The mix proportion (*i.e.* cement:sand) may vary from 1 : 4 to 1 : 6. Sand used for plastering should be clean, coarse and angular. Before mixing water, dry mixing is thoroughly done. When water is mixed, the mortar should be used within 30 minutes of mixing, well before initial setting takes place.

## 3. Lime-cement mortar

Lime-cement mortar contains properties of both the lime mortar as well as cement mortar. Cement mortar as such does not possess sufficient plasticity. Addition of lime to it imparts plasticity, resulting in smooth plastered surface. Mix proportions generally used are 1 : 1 : 6 (cement : lime : sand), 1 : 1 : 8 or 1 : 2 : 8. Generally, fat lime is used. Table 19.1 gives the recommendations for various types of mortar to be used in various situations.

TABLE 19.1 RECOMMENDED MORTAR MIXES

| | *Situation* | *Composition of mortar* | *I.S. grading of lime* |
|---|---|---|---|
| 1. | External Plaster in localities where rainfall is less than 500 mm per year and where subsoil water is not within 2.5 m below the ground surface : | | |
| | (*a*) Below D.P.C. | 1 cement 6 sand | — |
| | | 1 cement 2 lime 9 sand | B or C |
| | | 1 lime 2 sand | A |
| | | 1 lime 1 sand 1 surkhi | B or C |
| | | 1 lime 2 surkhi | B or C |
| | (*b*) Above D.P.C. | 1 cement 2 lime 9 sand | B or C |
| | | 1 lime 2 sand | A |
| | | 1 lime 1 surkhi 1 sand | B or C |
| | | 1 lime 2 surkhi | B or C |

| | Situation | Composition of mortar | I.S. grading of lime |
|---|---|---|---|
| 2. | External plaster in localities where rain fall is more than 1300 mm per year and where subsoil water is not within 2.5 m below ground surface : | | |
| | (a) Below D.P.C. | 1 cement 4 sand | — |
| | | 1 cement 1 lime 6 sand | B or C |
| | | 1 lime 2 surkhi | B or C |
| | (b) Above D.P.C. | 1 cement 2 lime 9 sand | B or C |
| | | 1 lime 2 sand | A |
| | | 1 lime 1 sand 1 surkhi | B or C |
| | | 1 lime 2 surkhi | B or C |
| 3. | External plaster in localities where the subsoil water is within 2.5 m of the ground : | | |
| | Below D.P.C. | 1 cement 3 sand | — |
| 4. | Internal plaster in all localities | 1 lime 2 sand | A |
| | | 1 lime 1 surkhi 1 sand | B or C |
| | | 1 lime 2 surkhi | B or C |
| | | 1 cement 2 lime 9 sand | B or C |

**Note.** The ratio of lime varies with % purity of lime and these ratios may be suitably adjusted depending upon local practice.

## 19.3. TERMINOLOGY USED IN PLASTERING WORK

**1. Back ground.** It is the surface to which the first coat of plaster is applied.

**2. Blistering.** This is the development of local swellings on the finished plastered surface, due to residual unslaked lime nodules.

**3. Cracking.** This is the development of one or more fissures in the plaster due to movements in the back ground or surrounding structure.

**4. Crazing.** This is the development of hair cracks, usually in an irregular pattern, over the finished surface.

**5. Dado.** This is lower part of plastered wall, where special treatment is given to make it better resistance.

**6. Dots.** These are small projections of plaster, laid on background for fixing of screeds etc. The size of dots may be 15 cm × 15 cm.

**7. Dubbing coat.** This is the process of filling up hollow spaces in the solid background, before applying the main body of the plaster.

**8. Finishing coat.** It is the final coat of plaster. Such a coat is also known as *setting coat* or *skimming coat.*

**9. Flaking.** It is the process of scaling away patches of plaster of previous coat, due to lack of adhesion with the under-coat.

**10. Gauging.** It is the process of mixing various constituents of plaster.

**11. Grinning.** It is the reflection or appearance on the surface of plaster, of the pattern of joints or similar patterns in the background.

**12. Grounds.** These are the wooden strips fixed to the back-ground to which primary finishing may be secured.

**13. Hacking.** This is the process of roughening the back-ground to provide suitable bond or key for plastering.

**14. Keys.** These are openings or indentations or corrugations on the background or surface of under-coat, to which plaster will form mechanical bond.

**15. Laitance.** When freshly laid concrete or mortar is subjected to excessive trowelling a screen consisting of thin layer of fine cement particles is formed. This layer is known as laitance.

**16. Peeling.** This is the term applied to the dislodgment of plaster work from the background.

**17. Under-coats.** These are the coats of plaster applied under the finishing coat.

## 19.4. TOOLS FOR PLASTERING

The following tools are commonly used for plastering work:

**1. Gauging trowel** (Fig. 19.1 *a*). A gauging trowel is used for gauging small quantities of materials and for applying mortar to mouldings, corners etc. The end of the trowel blade may be either pointed or bull-nosed.

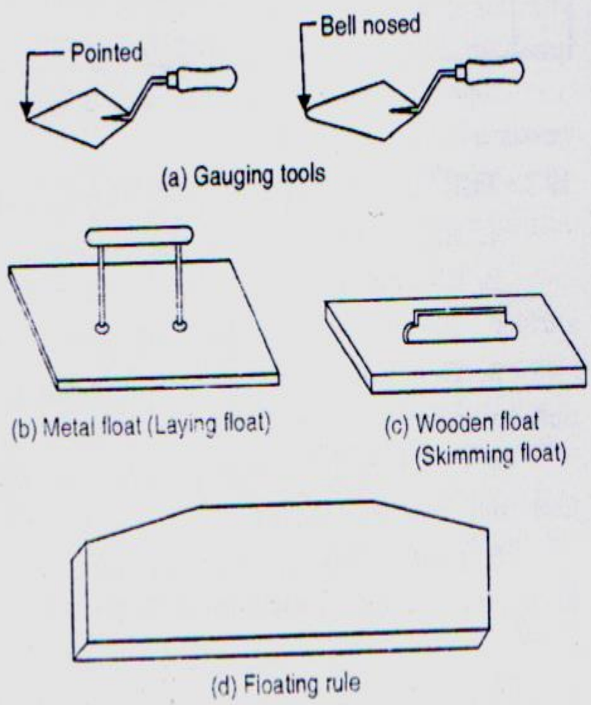



FIG. 19.1. TOOLS USED FOR PLASTERING.

**2. Float.** A float is used for applying and spreading mortar on the surface. It is made of either metal or wood. *Metal float*, made of thin tempered steel, is known as *laying trowel* (Fig. 19.1 *b*). The laying trowel is used for laying the plaster material and for trowelling so as to get desired finish. The blade size is generally 10 cm × 30 cm. For good work, two types of laying trowels are used. The first type having stiff plate is used for applying and trowelling the plaster, while the second type having thin plate possessing slight springing action, is used for finishing coat. The *wooden float*, commonly known as *skimming float* (Fig. 19.1 *c*) is used for the finishing coat of plaster. The size of the float varies from 10 cm × 30 cm to 11 cm × 33 cm with thickness of 10 to 12 mm. Sometimes, a *devil float*, having nail projection of about 3 mm from the surface, is used for making zig-zag lines on the plastered surface so as to form key for the subsequent coat.

**3. Floating rule** (Fig. 19.1 *d*). It is used for checking the level of the plastered surface between successive screeds.

**4. Miscellaneous Tools.** These include plumb bob, spirit level, set square, straight edges brushes, scratchers etc.

## 19.5. NUMBER OF COATS OF PLASTER

The background over which plastering is to be done depend upon the type of wall construction, such as random rubble (R.R.) masonry, coarsed rubble masonry, brick masonry and cement block work etc. Different thickness of plaster is required for different types of back-grounds. Plastering is therefore, applied in one, two or three coats. Plaster in one coat is applied only for inferior work, since it causes heavy shrinkage and consequent cracking. Generally, lime plaster is applied in three coats while cement plaster is applied in two coats. Table 19.2 gives Indian Standard recommendation for the number of coats to be applied for different type of back grounds:

**TABLE 19.2. NO. OF COATS**

| *Background* | *No. of Coats* |
|---|---|
| 1. Stone work | 3 or 2 |
| 2. Brick work or hollow clay tiles | 3, 2 or 1 |
| 3. Concrete cast in situ | 2 or 1 |
| 4. Building blocks | 3, 2 or 1 |
| 5. Wood or metal lath | 3 |
| 6. Fibre building board | 2 or 1 |
| 7. Wood wool slabs | 3 or 2 |
| 8. Cork slabs | 2 or 1 |

The *first coat* (under-coat or *rendering coat*) provide means of straightening or levelling an uneven surface. It seals the surface of wall and to some extent prevent rain penetration. The *second coat* is known as *floating coat*. The *third or final coat* provide smooth surface; it is also known as *setting or finishing coat*. The average thickness of rendering coat and floating coats may be 10 to 15 mm and 6 to 9 mm respectively. The final coat may be of 2 to 3 mm thickness. If plastering is done in single coat only, its thickness should not exceed 12 mm nor should it be less than 6 mm.

## 19.6 METHODS OF PLASTERING

**Preparation of background.** For plastering new surfaces, all masonry joints should be raked to a depth of 10 mm in brick masonry and 15 mm in stone masonry for providing key to the plaster. All mortar droppings and dust, and laitance (in case of freshly laid concrete) should be removed with the help of stiff wire brush. Any unevenness is levelled before rendering is applied. For finishes applied in three coats, local projections should not be more than 10 mm proud of general surface and local depressions should not exceed 20 mm. For two coat plaster, these limitations are 5 mm and 10 mm respectively. The surface should be washed with clean water and kept damp uniformly to produce optimum suction. In no case the surface should be kept soaked with water so as to cause sliding of mortar before it sets or kept less wet to cause strong suction which withdraws moisture from mortar and makes it weak, porous and friable. If plaster is to be applied on old surface, all dirt, scool, oil, paint etc. should be cleaned off. Loose and crumbling plaster layer should be removed to its full thickness and the surface of the background should be exposed and joints properly raked. The surface should be washed and kept damp to obtain optimum suction.

## 1. LIME PLASTER

Lime plaster is applied either in three coats or in two coats. Before the application of plaster, the background is prepared as described above.

### (*a*) Three-coat plaster

In the 3-coat plaster, the first coat is known as *rendering coat* second coat is known as *floating coat* and the third coat is known as setting coat or finishing coat.

### 1. *Application of rendering coat*

The mortar is forcibly applied with mason's trowel and pressed well into joints and over the surface. The thickness of coat should be such as to cover all inequalities of the surface ; normal thickness is 12 mm. This is allowed to slightly harden, and then scratched criss-cross with the edge of trowel (or with devil float); the spacing of scratches may be 10 cm. The surface is left to set atleast for 7 days. During this period, the surface is cured by keeping it damp and then allowed to dry completely.

### 2. *Application of floating coat*

The rendering coat is cleaned off all dirt, dust and other loose mortar droppings. It is lightly wetted. Patches 15 cm × 15 cm or strips 10 cm wide are applied at suitable spacings to act as gauges. The mortar is then thrown with mason's trowel, spread and rubbed to the required plain surface with wooden float. The surface so obtained should be true in all directions. In case of lime-sand plaster, the finishing coat is applied immediately. In the case of lime-surkhi plaster, the floating coat is allowed to slightly set and then lightly beaten criss-cross with floats edge at close spacings of 4 cm. It is then cured to set completely for atleast 10 days and then allowed to dry out completely. In either case, the thickness of coat varies from 6 to 9 mm.

### 3. *Application of finishing*

In the case of lime-sand mortar the finishing coat is applied immediately after the floating coat. The finishing coat consists of cream of lime (called *neeru* or *plaster's putty*, having lime cream and sand in the ratio of 4 : 1) applied with steel trowel and rubbed and finished smooth. The rubbing is continued till it is quite dry. It is left for 1 day, and then curing is done for atleast 7 days. In the case of lime-surkhi mortar, the finishing coat is applied 7 days after the floating coat, after cleaning the surface of all dirt, dust and mortar droppings and after fully wetting the surface of previous coat. The finishing coat is rubbed hard and finished smooth.

### (*b*) Two-coat plaster

In the case of two-coat plaster, the *rendering coat* is a combination of the rendering floating coats of 'three-coat plaster' and is done under one continuous operation except that the scratching of rendering coat, as specified in the three-coat plaster, is not done. The total thickness may be about 12 mm. The finishing is then applied in a manner similar to the three-coat plaster.

## 2. CEMENT PLASTER AND CEMENT-LIME PLASTER

Cement plaster is applied either in two coats or in three coats, the former being more common. For inferior work, single coat plaster is sometimes provided.

(*a*) **Two-coat plaster.** The following procedure is adopted :

1. The background is prepared by racking the joint to a depth of 20 mm, cleaning the surface and well-watering it.

2. If the surface to be plastered is very uneven, a preliminary coat is applied to fill up the hollows, before the first coat.

3. The *first coat* or *rendering coat* of plaster is applied, the thickness being equal to the specified thickness of plaster less 2 to 3 mm. In order to maintain uniform thickness of plaster, *screeds* are formed of plaster on wall surface by fixing dots of 15 cm × 15 cm size. Two dots are so formed in vertical line, at a distance of about 2 m, and are plumbed by means of a plumb bob. A vertical strip of mortar, known as screed, is then formed. A number of such vertical screeds are formed at suitable spacing. Cement mortar is then applied on the surface between the successive screeds and the surface is properly finished.

4. Before rendering hardens, it is suitably worked to provide mechanical key for the final or finishing coat. The rendering coat is trovelled hard forcing mortar into joints and over the surface. The rendering coat is kept wet for at least 2 days, and then allowed to dry completely.

5. The thickness of final or *finishing coat* may vary between 2 and 3 mm. Before applying the final coat, the rendering coat is damped evenly. The final coat is applied with wooden floats to a true even surface and finished with steel trowels. As far as possible, the finishing coat should be applied starting from top towards bottom and completed in one operation to eliminate joining marks.

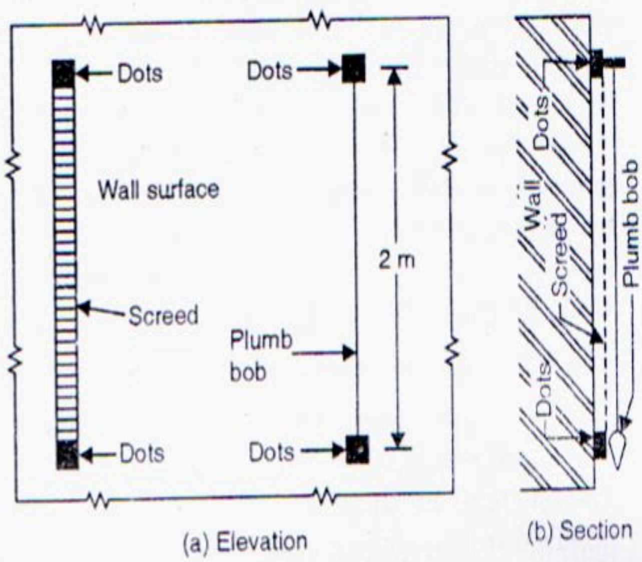



FIG. 19.2. DOTS AND SCREEDS.

(*b*) **Three-coat plaster.** The procedure for applying three-coat plaster is similar to the two-coat plaster except that an intermediate coat, known as *floating coat* is applied. The purpose of this coat of plaster is to bring the plaster to an even surface. The thickness of rendering coat, floating coat and finishing coat are kept 9 to 10 mm, 6 to 9 mm and 2 to 3 mm respectively. The rendering coat is made rough. The floating coat is applied about 4 to 7 days after applying the first coat. The finishing coat may be applied about 6 hours after the application of floating coat.

(*c*) **Single-coat plaster**. This is used only in inferior quality work. It is applied similarly as two coat plaster except that the rendering coat, as applied for two-coat plaster, is finished off immediately after it has sufficiently hardened.

## 19.7. PLASTER ON LATH

Laths are adopted to provide foundation for plaster work. Laths are also provided for plastering thin partition walls and for plastering ceilings. Laths may be of two types : (*i*) wooden laths and (*ii*) metal laths.

*Wooden laths* used for plastering over wooden partition walls and ceilings, are in the form of well-seasoned wooden strips 25 mm wide and 1 to 1.2 m long. These strips are fixed in parallel lines with clear spacing of 10 mm, and secured to the surface with galvanised iron nails.

*Metal laths* are available under various patent names. The plain expanded metal lath (Exmat) is commonly used. Metal laths are fixed to the surface by G.I. staples. In case of concrete or masonry surface, wooden plugs have to be embedded for fixing the lath.

After fixing the lath, the surface is plastered, usually in three coats. Cement mortar is used.

## 19.8. TYPES OF PLASTER FINISHES

Plastered surface may be finished in the following varieties:

**1. Smooth cast finish.** In this finish, smooth, levelled surface is obtained. The mortar for the finish may be made of cement and fine sand in the ratio of 1 : 3. Mortar is applied with the help of wooden float. Steel floats are not recommended for external renderings since they give a very smooth finish which is liable to cracking and crazing under exposure to atmospheric conditions.

**2. Sand faced finish.** This is obtained by plastering in two coats. The first coat is applied in 1 : 4 cement sand mortar for 12 mm thickness. It is provided with zig-zag lines. After curing it for 7 days, the second coat is applied in the thickness of 8 mm. The mortar for the second coat is prepared from cement sand mix ratio 1 : 1. The sand for this is perfectly screened so that uniform size is obtained. Sponge is used in the second coat when it is still wet. The surface of final coat is finished by rubbing clean and washed sand of uniform size by means of wooden float. This results in the surface having sand grains of equal and uniform density.

**3. Rough cast finish or spatter dash finish.** In this, the mortar for the final coat contains fine sand as well as coarse aggregate in the ratio of $1 : 1\frac{1}{2} : 3$ (cement : sand : aggregate). The coarse aggregate may vary from 3 mm to 12 mm in size. The mortar is dashed against the prepared plastered surface by means of large trowel. The surface is then roughly finished using a wooden float. Such a finish is water proof, durable and resistant to racking and crazing, and may be used for external renderings.

**4. Pebble dash or dry dash finish.** In this the final coat, having cement : sand mix proportion of 1 : 3 is applied in 12 mm thickness. Clean pebbles of size varying from 10 to 20 mm size are then dashed against the surface, so that they are held in position. The pebbles may be lightly pressed into the mortar, with the help of wooden float.

**5. Depeter finish.** This is similar to pebble dash finish in which the 12 mm coat is applied and while it is still wet, the pieces of gravel or flint are pressed with hand on the surface. Flints of different colours may be used to obtain beautiful patterns.

**6. Scrapped finish.** In this, the final coat of 6 to 12 mm thick is applied and after it has stiffened for few hours, the surface is scrapped in patterns for a depth of 3 mm. For scrapping, steel straight edge, old saw blade or such other tool may be used. Such scrapped surface is less liable to cracks.

**7. Textured finish.** This is used with *stucco plastering*. Ornamental patterns or textured surfaces are made on the final coat of stucco plastering, by working with suitable tools.

## 19.9. SPECIAL MATERIALS USED IN PLASTERING

Special materials are used in plastering or over the plastered surface to meet some specific requirements of the finished surface, such as increased durability, better or attractive appearance, fire proofing, heat insulation, sound insulation etc. Following are the usual special materials used for plastered surfaces.

**1. Acoustic plaster.** This contains gypsum mixtures applied as final coat in finishing the plastered surface. Such a coat undergoes chemical reaction resulting in production of gas bubbles and consequent formation of tiny openings in the coat. These honey-combed minute openings absorb sound. Such plaster is useful in the interior walls of halls, auditoriums etc. The plaster is applied in two coats each of 6 mm thickness, using wooden float.

**2. Asbestos marble plaster.** This plaster is made of cement, asbestos and finely crushed marble, imparting marble like finish.

**3. Barium plaster.** It is made from cement, sand and barium sulphate, and is provided in X-ray rooms, to protect the persons working in it.

**4. Granite silicon plaster.** This plaster is used for superior type of construction, since it is quick setting and possess highly elastic properties which eliminate cracks.

**5. Gypsum plaster (plaster of Paris)** Plaster of Paris is obtained from heating finely ground gypsum heated at 160° to 170°*C*. It hardens within 3 to 4 minutes of adding water. To extend the setting time, suitable retarders are used. Plaster of Paris is generally used in combination with lime, for ornamental work, and for repairing holes and cracks. Gypsum plaster has the following properties :

(*i*) It is fire-resisting, and hence can be effectively used on timber and metal components of buildings.

(*ii*) It is light weight.

(*iii*) It has sound insulating properties.

(*iv*) It is highly useful for ornamental work.

(*v*) It has good adhesion to fibrous materials.

(*vi*) It sets with little change in volume. Thus there is no shrinkage on drying.

However, gypsum plaster is soluble in water, hence it can be used only for interior work.

**6. Kenee's cement plaster.** Kenee's cement is obtained by the calcinating plaster of Paris with alum. This is very hard and sets in few days, taking white, glass-like polish. It is used for situations such as angles, skirtings etc. Because of its polishing characteristics, it is also useful for ornamental work and decorative plastering.

**7. Martin's cement plaster.** Martin's cement is obtained when pearl ash is calcined with Plaster of Paris. It has quick setting properties, and forms a white hard surface on drying. It is used for internal finishing work.

**8. Parian cement plaster.** Parian cement is obtained when borax is calcined with Plaster of Paris. Like Kenee's cement, it is also used for interior work. However it is cheaper than Kenee's cement.

**9. Scagliola plaster.** Scagliola is obtained by dissolving Kenee's cement and colouring pigments in glue. It is used for plastering pilasters, panels, columns etc. It appears like marble.

**10. Sirapite plaster.** Sirapite is obtained when plaster of Paris is slaked in petroleum. It is quick setting and fire resisting. It produces white hard surface on drying.

**11. Snowcrete and colourcrete cements.** These are the trade names given to white and coloured cement respectively. These are used on external walls to create good appearance.

**12. Thistle hardwall.** It is a product of high grade gypsum. It sets rapidly and produces excellent finish. It is used for interior work.

## 19.10 DEFECTS IN PLASTERING

The following defects may arise in plaster work :

**1. Blistering of plastered surface.** This is the formation of small patches of plaster swelling out beyond the plastered surface, arising out of late slaking of lime particles in the plaster.

**2. Cracking.** Cracking consists of formation of cracks or fissures in the plaster work resulting from the following reasons :

(*i*) Imperfect preparation of background.
(*ii*) Structural defects in building.
(*iii*) Discontinuity of surface.
(*iv*) Movements in the background due to its thermal expansion or rapid drying.
(*v*) Movements in the plaster surface itself, either due to expansion (in case of gypsum plaster) or shrinkage (in case of lime-sand plaster).
(*vi*) Excessive shrinkage due to application of thick coat.
(*vii*) Faulty workmanship.

**3. Crazing.** It is the formation of a series of hair cracks on plastered surface, due to same reasons which cause cracking.

**4. Efforescene.** It is the whitish crystalline substance which appears on the surface due to presence of salts in plaster-making materials as well as building materials like bricks, sand, cement etc. and even water. This gives a very bad appearance. It affects the adhesion of paint with wall surface. Efforescene can be removed to some extent by dry brushing and washing the surface repeatedly.

**5. Flaking.**. It is the formation of very loose mass of plastered surface,, due to poor bond between successive coats.

**6. Peeling.** It is the complete dislocation of some portion of plastered surface, resulting in the formation of a patch. This also results from imperfect bond.

**7. Popping.** It is the formation of conical hole in the plastered surface due to presence of some particles which expand on setting.

**8. Rust stains.** These are sometimes formed when plaster is applied on metal laths.

**9. Uneven surface.** This is obtained purely due to poor workmanship.

## 19.11. POINTING

The term pointing is applied to the finishing of mortar joints in masonry. In exposed masonry, joints are considered to be the weakest and most vulnerable spots from which rain water or dampness can enter. Pointing consists of raking the joints to a depth of 10 to 20 mm and filling it with better quality mortar in desired shape.

**Mortar**. pointing is done with the following mortar mixes :

(*i*) Lime mortar 1 : 2 mix (1 lime : 2 sand or surkhi)
(*ii*) Cement mortar 1 : 3 mix (1 cement : 3 sand)

The mortar for lime pointing is made with fat lime, by grinding it with sand or surkhi in a mortar mill.

**Preparation of surface**

(*i*) ***New work***. All the joints are raked down to a depth of 20 mm while the mortar is still soft. The surface and joints are then cleaned and thoroughly wetted.

(*ii*) ***Old work***. All loose pointing and superfluous mortar on the surface and in the joints are removed. The joints and surface are cleaned, and then thoroughly wetted.

**Method of pointing**

After preparing the surface and cleaning and wetting the joints as desired above, mortar is carefully placed in desired shape in these joints. A small trowel is used for placing the mortar in the joint: the mortar is pressed to bring perfect contact between the old interior mortar of the joint and new mortar. Care should be taken to see that in case of ashlar and brick-work with Ist class bricks, the mortar does not cover face edges. The pointed surface is kept wet for atleast a week or till it sets after application.

**Types of pointings :** Pointing is carried out in the following common shapes :

**1. *Flush pointing* (Fig. 19.3 *a*)**

This type of pointing is formed by pressing mortar in the raked joint and by finishing off flush with the edge of masonry units. The edges are neatly trimmed with trowel and straight edge. It does not give good appearance. However, the pointing is more durable since it does not provide any space for the accumulation of dust, water, etc. Due to this reason, flush pointing is extensively used.

**2. *Recessed pointing* (Fig. 19.3 *b*)**

The pointing is done by pressing the mortar back from the edges by 5 mm or more. The face of the pointing is kept vertical, by a suitable tool. The pointing gives very good appearance.

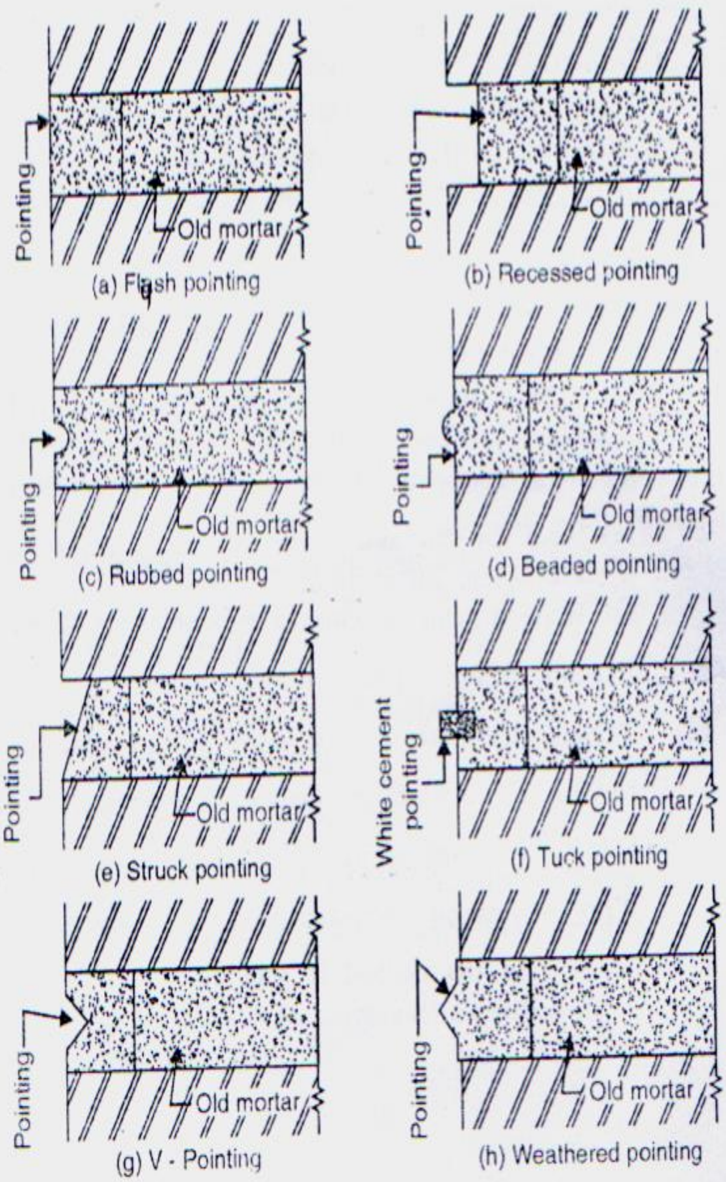



FIG. 19.3. TYPE OF POINTINGS.

**3. *Rubbed, keyed or grooved pointing* (Fig. 19.3 *c*)**

This pointing is a modification of flush pointing by forming a groove at its mid height, by a pointing tool. It gives better appearance.

**4. *Beaded pointing* (Fig. 19.3 *d*)**

This is the special type of pointing formed by a steel or ironed with a concave edge. It gives good appearance, but is liable to damage easily.

**5. *Struck pointing* (Fig. 19.3 *e*)**

This is a modification of flush pointing in which the face of the pointing is kept inclined, with its upper edge pressed inside the face by 10 mm. This pointing drains water easily.

**6. *Tuck pointing* (Fig. 19.3 *f*)**

. The pointing is formed by first pressing the mortar in the racked joint and finishing flush with the face. While the pressed mortar is green, groove or narrow channel, having 5 mm width and 3 mm depth is cut in the centre of the groove. This groove is then filled in or *tucked in* with white cement putty, kept projecting beyond the face of the joint by 3 mm. If projection is done in mortar, it is called *Bastard pointing* or *half tuck pointing*.

**7. *V-pointing* (Fig. 19.3 *g*)**

This pointing is formed by forming V-groove in the flush-finishing face.

**8. *Weathered pointing* (Fig. 19.3 *h*)**

This pointing is made by making a projection in the form of V-shape.

## PROBLEMS

1. (*a*) Explain in brief the objects of plastering and pointing.
   (*b*) What are the requirements of good plaster ?
   (*c*) Write a note on 'mortars' required for plastering and pointing.
2. (*a*) What do you understand by preparation of back ground for :
   (*i*) Plastering, (*ii*) Pointing ?
   (*b*) Write a note on number of coats used in plastering.
3. Explain various types of plaster finishes.
4. Explain the method of three-coat lime plaster.
5. Explain the method of two-coat lime plaster.
6. Write a note on various types of special materials used in plastering.
7. Write a note on various defects in plastering.
8. (*a*) Explain the method of pointing.
   (*b*) Describe various types of pointings.

# Painting, Distempering and White-Washing

## 20.1. PAINTS AND PAINTING

Paints are liquid compositions of pigments and binders which when applied to the surface in thin coats dry to form a solid film to impart the surface a decorative finish, apart from giving protection to the base material (*i.e.*, concrete, masonry and plaster surfaces) from weathering, corrosion and other chemical and biological attacks. Paints preserve timber structures against warping and decay. Most of the metals corrode if not painted at suitable interval. Painting on surfaces impart decoration, sanitation and improved illumination.

Calcareous surfaces, like lime and cement plastered surfaces, are highly alkaline in the initial stages, they retain large quantities of water during construction and it takes long time for the greater part of the water to evaporate even when the atmospheric conditions are favourable. Therefore, in applying a paint system on these surfaces, it is essential to take cognisance of the stored up moisture and also the alkalinity of the surfaces. These surfaces are porous and present problems, such as variable suction, surface imperfections, growth of moulds, mosses, lichens and algae. As each of these have adverse effect on most of the surface coating materials, finishing of these surfaces need special care.

## 20.2. CHARACTERISTICS OF AN IDEAL PAINT

An ideal paint should possess the following characteristics :

(1) Paint should form hard and durable surface.

(2) It should give attractive appearance.

(3) It should be cheap and readily available.

(4) It should be such that it can be applied easily to the surfaces.

(5) It should have good spreading quality, so as to cover maximum area in minimum quantity.

(6) It should dry in reasonable time.

(7) It should not show hair cracks on drying.

(8) It should form film of uniform colour, on drying.

(9) It should be stable for a longer period.

(10) It should not be affected by atmospheric agencies.

For efficient planning and execution of painting work on plaster surfaces, the following informations should be collected :

(*a*) Type of concrete, masonry or plaster surfaces to be painted, the type and nature of previous treatment, if any.

(*b*) Situations of use, namely, external finish or an internal finish; and the extent to which the surface will be exposed to weather and rain ; and

(*c*) In the case of new plastered surfaces, the nature of backing, the type of plaster undercoat and finish, the approximate date of completion of the plaster work in individual rooms ; and any addition of lime to the plaster finishing coat should be noted.

## 20.3. CONSTITUENTS OF A PAINT

A paint generally is made up of the following constituents :

(*i*) A base.

(*ii*) A vehicle or carrier.

(*iii*) A drier.

(*iv*) A colouring pigment.

(*v*) A solvent or thinner.

### 1. Base

A base is a solid substance in a form of fine powder, forming the bulk of a paint. It is generally a metallic oxide. The type of base determines the character of the paint and imparts durability to the surface painted. Various bases commonly used are : (*i*) White lead, (*ii*) Red lead, (*iii*) Oxide of Zinc (Zinc white), (iv) Oxide of iron, (*v*) Titanium white, (vi) Antimony white, (*vii*) Aluminium powder, and (*viii*) Lithophone. For a detailed description and characteristics of these, reference may be made to Author's book 'Building Materials'. A base in a paint provides of opaque coating to hide the surface to be painted.

### 2. Vehicle or carrier or binder

These are liquid substances which hold the different ingradients of a paint in liquid suspension. The carrier or vehicle makes it possible to spread the paint evenly on the surface. The vehicles generally in use are : (*i*) various forms of linseed oils (such as raw linseed oil, boiled linseed oil, pale boiled linseed oils, double boiled linseed oil and stand oil, (*ii*) tug oil, and (*iii*) poppy oil, and (*iv*) nut oil. Raw linseed oil is thin, but it takes a long time to dry. Boiled linseed oil is thicker. For delicate work, however, only raw linseed oil is used along with driers and poppy and nut oil. It is used for interior work. Double boiled linseed oil dries very quickly and is suitable for external work. It requires thinning agent like turpentine. *Tug oil* is used for preparing paints of superior quality. Colours in poppy oil last longer.

### 3. Drier

Driers are used to accelerate the process of drying and hardening, by extracting oxygen from the atmosphere and transferring it to the vehicle. However, driers reduces the elasticity of the paint; they should not be used in the final coat. Driers may be in the form of soluble driers or paste driers. Liquid driers are finely ground compounds of metals such as cobalt, lead, manganese dissolved in a volatile liquid. Paste driers consist of compounds of the above metals mixed with large percentages of inert fillers such as barytes, whiting etc., and then ground in linseed oil. The inert fillers serve the following purposes : (*i*) reduce the cost of paint, (*ii*) improve durability, (*iii*) modify the weight, and (*iv*) prevent shrinkage and cracking. However, these are termed as adultrants, and their weight should not exceed one-fourth the weight of the base. Litharge (PbO), red lead ($Pb_3O_4$) and sulphates of zinc and manganese are also used as driers. Litharge is most common in use but in general lead drier should not be used with zinc paints.

**4. Colouring pigment**

Colouring pigments are added to the base to have different desired colours. Pigments can be divided into the following divisions

(*i*) *Natural colours* : Ochres, umbers, iron oxides.

(*ii*) *Calcined colours* : Lamp black, Indian red, carbon black, red lead.

(*iii*) *Precipitates* : Prussian blue, chrome green, chrome yellow.

(*iv*) *Lakes* : Prepared by discolouring barytes or china clay with the help of suitable dyes.

(*v*) *Metal powders* : Powders of aluminium, bronze, copper, zinc, etc.

The desired shade or tint of the paint may be obtained by using single or combination of the following colouring pigments.:

| *Tint* | *Pigment* |
|---|---|
| 1. Black | : Lamp black ; carbon black ; bone black ; graphite, vegetable black ; ivory black. |
| 2. Blue | : Indigo ; Prussian blue ; cobalt blue ; ultramarine. |
| 3. Brown | : Burnt umber, raw umber, burnt seinna, vandyke brown. |
| 4. Green | : Paris green : chrome green; green earth; virdigris copper sulphate. |
| 5. Red | : Indian red; venitean red; vermillion red; carmine; red lead. |
| 6. Yellow | : Chrome yellow; raw seinna; yellow occhre; zinc chrome. |

The concentration of pigment in a paint is denoted by *pigment volume concentration number* ( P.V.C.N.) defined by the equation.

$$\text{P.V.C.N.} = \frac{V_1}{V_1 + V_2}$$

where $V_1$ = volume of pigment in the paint.

$V_2$ = Volume of non-volatile vehicle or carrier in the paint.

The durability and gloss of a paint is inversely proportional to the value of P.V.C.N. The following table gives P.V.C.N. for paints used for various purposes :

| *P.V.C.N. range* | *Type of paint* |
|---|---|
| 25 to 40 | Paint for prime coat on metals. |
| 35 to 40 | Paint for prime coat on timber. |
| 28 to 40 | Paint for exterior surfaces of buildings. |
| 35 to 45 | Semi-gloss paint. |
| 50 to 75 | Faint paint. |

**5. Solvents or thinners**

Solvents are added to the paint to make it thin so that it can be easily applied on surfaces. It also helps the paint in penetrating through the porous surface of the background. The thinning agent commonly used is the spirit of terpentine. Other solvents contain some part of spirit of terpentine, and therefore inferior. Thinner reduces the gloss of the paint. Terpentine oil is affected by weather; hence minimum quantity of thinner should be used for painting external surfaces. Following is the list of thinners for various types of paints :

| *Type of paint* | *Thinner* |
|---|---|
| 1. Oil paints | (*i*) Spirit of terpentine. (*ii*) Naphtha, (*iii*) Benzine |
| 2. Spirit liquors | Alcohol. |
| 3. Cellulose paints | Ethyl amyl acetate. |
| 4. Distempers | Water. |

## 20.4. CLASSIFICATION AND TYPES OF PAINTS

Standardising the classification of paints is difficult in view of the large number of variations in each of the constituents, but a simple classification based on the media or binder, and on the basis of its ultimate use and performance is given here.

(*a*) **Classification based on binders**

(*i*) Oil paints
(*ii*) Paints based on non-oil resins.
(*iii*) Cellulose paints.
(*iv*) Water based paints.
(*v*) Miscellaneous paints.

(*b*) **Classification based on ultimate use**

(*i*) General purpose paints, including primers, under-coat paint and finishing coat paints
(*ii*) Acid and alkali resistant paints
(*iii*) Fire resistant paints
(*iv*) Fungicidal paints
(*v*) Miscellaneous paints, such as fire resistant paints, anti-condensation paint etc.

(*c*) **Mixed classification : types of paints**

(*i*) Aluminium paint.
(*ii*) Anti-corrosive paints
(*iii*) Asbestos paints
(*iv*) Bituminous paints
(*v*) Bronze paints
(*vi*) Casein paints
(*vii*) Cellulose paints
(*viii*) Cement-based paints
(*ix*) Colloidal paints
(*x*) Emulsion paints
(*xi*) Enamel paints
(*xii*) Graphite paints
(*xiii*) Inodorous paints
(*xiv*) Oil paints
(*xv*) Plastic paints
(*xvi*) Silicate paints
(*xvii*) Synthetic rubber paints.

1. **Aluminium paints.** It consists of finely ground aluminium suspended in either quick-drying spirit varnish or slow-drying oil varnish, as per actual requirements. A thin metallic film of aluminium is formed when the spirit or oil evaporates. It is used for painting wood work or metal surfaces. This paint has following advantages: (*i*) Weather resistant, (*ii*) Water proof, (*iii*) Highly heat reflective, (*iv*) Corrosion resistant, (*v*) High electrical resistance, (*vi*) High covering capacity, (*vii*) Visibility in darkness, (*viii*) Better appearance.

2. **Anti-corrosive paints.** It is used to protect metal structures against adverse effects of moisture, fumes, acids, corrosive chemical ravages of rough weather. It consists

of oil and a strong drier and a colouring mixed with very fine sand. Due to this, it is cheaper than white / lead paints. It lasts longer. However, it gives black appearance. Linseed oil is generally used as vehicle.

**3. Asbestos paints.** This is a special-purpose paint used for painting surfaces which are exposed to acidic gases and steam, and also for patch work or stopping leakage in metal roofs. It is also used for painting gutters, pouts, flashings etc., to protect them from rusting. The paint consists of fibrous asbestos as the main ingradient.

**4. Bituminous paints**. These paints are prepared by dissolving asphalt, tar or mineral pitches in naphtha, petroleum or white spirit. These paints are alkali resistant and are mainly used for painting structural steel under water, and iron water mains. The paint gives black appearance, and deteriorates when exposed to the direct sun rays.

**5. Bronze paints**. These paints are also used for painting interior and exterior metallic surfaces. The paint consists of nitro-cellulose lacquer as vehicle and a aluminium bronze or copper bronze as pigments. Because of its high reflective property, the paint is used on radiators.

**6. Caesin paints**. Caesin, a protein substance extracted from milk curd, is mixed with a base consisting of white pigments, to form the paint which is available in powder or pasty form. The paint can be applied on walls, ceilings, wall boards etc. to enhance the appearance. It can be tinted in any desired shade of colour. For painting exterior surfaces, a little quantity of drying oil or varnish is added to make it weather well.

**7. Cellulose paints.** This paint is different from the ordinary oil paints. It is prepared from nitrogen-cotton, celluloid sheets, photographic films and amyl-acetate substitutes. The paint hardens by evaporation of thinner or solvent, while oil paints harden by oxidation. The paint gives very smooth finish which remains unaffected by hot water, smoky or acidic atmosphere etc. Due to its high cost, it is used for painting motor cars, aeroplanes etc.

**8. Cement-based paints.** This paint is a type of water paint in which white or coloured cement forms the base. No oil is used. It is available in powdered form, consisting of cement, pigment, accelerator and other additives; it is available in different trade names such as snow-cem etc. The paint is readily made by mixing water to the powder to obtain thick smooth paste and then diluting it to the required consistency. The paint is very much useful for painting external surfaces, since it is water proof. For new surfaces, it is applied in three coats while for old surfaces, it is applied in two coats.

**9. Colloidal paints**. This paint does not contain any inert material. Because of its colloidal properties, it takes more time to settle. In the process of settlement, it penetrates through the surface on which it is applied.

**10. Emulsion paints.** This paint contains binding materials (vehicles) such as polyvinyl lacetate, styrene, alkyd resin and other synthetic resins. The vehicle imparts alkali-resistance to the paint. The paint dries quickly, within $1\frac{1}{2}$ to 2 hours. It has good workability and high durability. The principle film forming constituent of this paint is emulsified in water, so that it may be thinned with water instead of solvent. The painted surface can be washed with water. It is recommended for use on stuccoplaster, bricks and masonry surfaces which contain free alkali.

11. **Enamel paints.** Enamel paint contains four basic constituents — metallic oxide (white lead or zinc white), oil, petroleum spirit and resinous matter. The paint dries slowly, but on drying, it produces a hard, impervious, glossy, elastic smooth and durable film. Different types of enamel paints are available in readymade forms, in a variety of colours. The painted surface is not affected by acids, alkalies, fumes of gas, hot and cold water, steam etc. It is commonly used on doors, windows, metal grills, porches, decks, stairs, concrete stairs etc.

12. **Graphite paints**. This paint has black colour, and is used for painting iron surfaces which come in contact with ammonia chlorine, sulphur gases. It is also used for mines and underground structures.

13. **Inodorous paints.** This paint contains white lead or zinc white mixed with methylated spirit. Shellac with some quantity of linseed oil and caster oil is dissolved in methylated spirit. No turpentine is used. The paint dries very quickly, due to evaporation of methylated spirit, leaving behind a thin film of shellac.

14. **Oil paints.** Oil paint is an ordinary paint consisting of two principal constituents : a base and a vehicle. However, driers and colouring pigments are also added. Vehicles that are generally used in oil paints are : linseed oil (raw), boiled linseed oil, linseed oil pale boiled, tug oil etc. The base pigments generally used are white lead, red lead, zinc white, lithophone and titanium oxide. Driers commonly used are litharge, red lead, and sulphates of zinc and manganese. Oil paints are generally used in three coats: prime coat, under coat and finishing coat, each having varying composition. Oil paints are cheap, easy to apply and possess good capacity and low gloss. They are used in general for all types of surfaces such as walls, ceilings, wood work, metal work, etc. However, oil paint should not be applied during humid and damp weather. Oil paints possess all the characteristics of a good paint, therefore, are commonly used.

15. **Plastic paints**. These paints contain plastic as the base which forms the main constituent of the paint. These paints have the qualities of quick drying, high covering power and decorative appearance. *Plastic emulsion paint* has become very popular these days. The emulsion, which is a liquid having fine suspended particles of a substance, is composed of a plastic compounds such as vinyl acetate and acrylate which are held in water. A litre of plastic emulsion paint, weighing about 1.4 kg, contains about 0.20 kg of binder, 0.50 kg pigments, 0.10 kg other solids and 0.60 kg water. One litre of plastic emulsion paint can cover 15 $m^2$ of wall surface per coat. It is applied in two coats, either with the help of a brush or a spray gun.

16. **Silicate paints.** A silicate paint is prepared by mixing calcined and finely ground silica with resinous substances. Silica imparts good adhesion to the paint. It forms very hard and durable surface on drying. It can withstand extreme heat. It is not affected by alkalies. The paint has no chemical action on metals.

17. **Synthetic rubber paints**. These paints consist of synthetic resins dissolved in appropriate solvents and mixer with suitable pigments. The paint has excellent acid, alkali and moisture resistance properties. it is little affected by rain, sunlight and other weather changes. It dries quickly, and uniform colour is maintained. It has moderate cost, and can be applied on cement concrete more and interior and exterior masonry surfaces.

## 20.5. PAINTING ON DIFFERENT SURFACES

### 1. PAINTING ON NEW WOOD WORK

The painting on new wood work is done on the following steps. For good work, 4 coats of paints are required, while for inferior work, only 2 to 3 coats are applied.

(*i*) **Preparation of surface.** For good results, wood work should be well-seasoned, and should not contain more than 15% moisture. The surface is dusted off thoroughly to remove dust, shavings, foreign matter etc. Heads of nails are punched to a depth 3 mm below the surface to be painted. Greasy spots, if any, should be removed by rubbing with piece of clean white muslin soaked in benzine or terpentine, allowed to dry, and glass papered if necessary.

(*ii*) **Knotting.** Knotting is the process of covering or killing all knots in the wood work with a substance through which the resin cannot come out or exude. Otherwise, the resin coming out of knots would damage the paint. Knotting can be done by three methods. In the first method, called *ordinary or size knotting*, two coats are applied. The first coat consists of grounding 15 g of red lead in 2 litres of water, adding 225 g of glue and heating the solution. This coat dries in 10 minutes, and then the second coat is applied. The second coat consists of red lead ground in boiled linseed oil and thinned with turpentine oil. The second method is known as *patent* which consists of applying a coat of hot lime, leaving it for 24 hours, scrapping off the surface and then carrying out ordinary or size knotting.

(*iii*) **Priming**. After knotting, the surface is rubbed smooth with a abrasive paper. Priming consists of applying first coat of paint to fill all the pores. Priming coat creates a layer or film which provides adhesion of the paint with the surface. Usually, the ingradients of the paint are kept the same as in subsequent coats though in varying proportion. The composition of primer for *ordinary work* may be composed of 3 kg red lead, 3 kg white lead 3 litre of linseed oil or terpentine. For superior work, the following composition is recommended :

| *For interior work* | | | *For exterior work* | | |
|---|---|---|---|---|---|
| Red lead | = 0.25 kg | (base) | Red lead | = 0.04 kg | (base) |
| White lead | = 3.5 kg | | White lead | = 4.5 kg | |
| Boil Linseed oil | = 0.5 litre | (vehicle) | Raw linseed oil | = 2.25 litre | (vehicle) |
| Raw Linseed oil | = 0.5 litre | | | | |
| Litharge | = 0.05 kg | (drier) | Litharge | = 0.09 kg | (drier) |

Generally, the priming coat is applied before fixing wood work in position.

(*iv*) **Stopping.** It is the process of rubbing down the wood surface by means of pumice stone or glass paper after prime coat is applied, and then filling up all cracks, all nail holes, dents, open joints etc., with putty. After putty dries up, the surface is rubbed again with pumice stone or glass paper. The putty is made by mixing powdered chalk in linseed oil to the consistency of a thick paste. For superior work, *hard stopping* is restored to by using one-third white lead and two-thirds ordinary putty in place of ordinary putty.

(*v*) **Under-coatings**. After stopping, second and successive coatings (known as under-coatings) are applied. The first coat is the primecoat. The under-coatings should be of the same shade as that of the finishing coat. The under-coatings may be necessary, depending upon the quality of work desired. Sufficient time should be allowed for each coat to dry before next coat is applied. For superior work, each coat is allowed to dry, rubbed down with pumice stone or glass paper then cleaned before next coat is applied.

(*vi*) **Finishing coat.** Finishing coat is applied after the under-coat is perfectly dry. This coat is applied very carefully, by a skilled painter, so that finished surface is smooth, uniform and free from patches and bush marks.

## 2. RE-PAINTING OLD WORK

Before repainting old work, the old paint having cracks and blisters should be removed, by applying any one of the following solvents or paint removers :

(*i*) Applying solution containing 1 kg of caustic soda in 5 litres of water. The paint gets dissolved.

(*ii*) Applying mixture containing one part of soft soap, two parts of potash and one part of quicklime, while in hot state. After 24 hours of application, the surface is washed with hot water.

(*iii*) Applying mixture of equal parts of washing soda and quicklime to the required consistency. After 1 hour of application, the surface is washed with water.

After removing the old paint, the surface is properly cleaned and then rubbed with pumice stone or glass paper. The cleaned surface is given two or three coats of paint to obtain the desired finish.

## 3. PAINTING NEW IRON AND STEEL WORK

Iron and steel surfaces are painted so that rusting is prevented. Hence surface should be prepared very carefully.

(*i*) The surface is cleaned off scale and rust etc. by scrapping or brushing with steel wire brushes. Oil, grease, etc. is removed by washing the surface with petrol, benzene or lime water.

(*ii*) The cleaned surface is treated with a film of phosphoric acid. This film protects the surface from rusting and provides better adhesive surface for the paint.

(*iii*) The prime coat or first coat is then applied with a brush. The coat consists of dissolving 3 kg of red lead in 1 litre of boiled linseed oil.

(*iv*) After the prime coat has dried, two or more under-coats are applied either with a brush or with spray gun. Care should be taken to see that each successive coat is applied only after the previous coat has dried completely. The under-coat may consist of 3 kg of red oxide, dissolved in 5 litres off boiled linseed oil.

(*v*) After the under-coat has dried, the final coat of the desired type of paint is applied. The finishing coat should present smooth finish.

## 4. REPAINTING OLD IRON AND STEEL WORK

Before repainting, the old surface is thoroughly cleaned by application of soap water. The grease, if any, may be removed by washing the surface with lime and water. However, if the old paint has cracked, it has to be removed by *flame-cleaning*. A flat oxy-acetylene flame is passed over the metal, burning off the old paint and loosening rust and scale. The surface is then scrapped with wire brush and washed with solution of caustic soda and fresh slaked lime. After the surface is thus prepared, painting is carried out as for the new surface.

### 5. PAINTING GALVANISED IRON WORK

Since paint does not easily adhere to the surface of G.I. work, some special treatment is necessary before the application of prime coat. It is better to paint the work only after exposing it to weather for about a year. However, if immediate painting is required, the surface may be treated with the following :

(*i*) Solution containing 40 gm of copper acetate in one litre of water.

(*ii*) Solution containing 13 gm each of muriatic acid, copper chloride, copper nitrate and ammonium chloride in one litre of water. This solution is sufficient to cover an area of 250 to 300 $m^2$.

The solution is taken in glass vessel or earthware vessel. After application of any one of the above solutions, the surface turns black. The prime coat is then applied after 12 hours. The prime coat may consist of red lead mixed with linseed oil and turpentine in equal proportions. When the prime coat dries, suitable paint may be applied.

### 6. PAINTING OTHER METALS

Before painting, the surface should be clean, dry, and free from dirt, grease etc. Suitable prime coat should be selected for each type of metal surface to be painted. The following prime coats are suggested :

| *Metal surface* | *Prime coat* |
|---|---|
| (*i*) Aluminium surface | Zinc chromate |
| (*ii*) Zinc surface | Zinc oxide |

After applying prime coat, painting is carried out exactly in the same manner as adopted for iron and steel surfaces.

### 7. PAINTING PLASTERED SURFACES

Newly plastered surface may contain considerable moisture. Hence painting should be resorted to only after 3 to 6 months of plastering. Calcareous surfaces to lime and cement plastered surfaces are highly alkaline because lime is liberated during hydration of cement. Due to this, oil based paints and distempers are liable to alkali attack. Hence it is essential to apply *alkali resistant primer*. Absorption of liquid from a paint by a porous surface is known as *suction*. High suction may make the paint difficult to apply and leave the coating in an underbound condition. Uneven suction may cause lack of uniformity in the finished appearance. The variation in suction characteristics of the surfaces to be painted require corresponding variation of the priming coat, or, in some cases, the use of glue size, petrifying liquid or sealers according to the type of paint to be used. Surfaces which show local variations in suction, as for example, between individual bricks or on patches produced on plastered surfaces by local over-trowelling or by efflorescence, should be treated by the application of a suitable primer.

If the suction is so high or variable that normal painting procedure is likely to give a good finish, one of the following pretreatments should be applied over the whole surface as a primer, according to the type of paint to be used :

| *Type of paint* | *Pretreatment* |
|---|---|
| **(a) *Size bound distemper*** | |
| (*i*) One coat application | A coat of clearcole |
| (*ii*) Two-coat application | A coat of size alone will be sufficient. |
| **(b) *Dry distemper*** | A coat of the same distemper thinned with water or petrifying liquid Or A coat of 'sharp colour' or primer sealer with the addition of finely ground pumice. |
| **(c) *Oil paint*** | A coat of thin primer or primer-sealer, preferably in consultation with the manufactures of the paint. |
| **(d) *Emulsion paint*** | A coat of the same paint thinned with water or sealers recommended by the manufacturer. |
| **(e) *Cement paint and lime wash*** | Wet the surface before applying paint. |

In the case of *new lime plaster*, the following points are note-worthy :

1. If possible, lime plaster should be left unpainted for the first few months so as to allow the plaster to carbonate, harden and dry thoroughly. If the plaster has any tendency to craze or crack owing to shrinkage on drying, the movements should be allowed to occur before the surface is painted, so as to enable provision of suitable preparatory treatment. Heating the rooms, if accompanied by good ventilation, will assist drying, but should be cautiously adopted. Too rapid drying may damage the plaster by causing undue shrinkage and separation of the plaster coats.

2. If there is any objection to leaving the plaster base, a temporary decoration of soft distemper (non-washable distemper) may be applied. This may be removed easily at a later date and replaced by a more permanent decoration. Other types of paint suitable for early application are cement paints, silicate paints and washable distemper depending upon the final decoration in view.

3. If the background of the plaster is one likely to contain large amounts of water, for example, new brick work, concrete or building blocks, no attempt should be made to apply oil paint(specially gloss finishes) until there is every reason to believe that the walls are thoroughly dry.

4. If the background is of a dry type, for example, wood or metal lath, oil paints may be applied with the safety after a few weeks drying, and oil-bound distempers even earlier.

## 20.6. DEFECTS IN PAINTING

The following defects may occur in painting work :

1. ***Blistering.*** It is the defect caused due to the formation of bubbles under the film of paint. The bubbles are formed by water vapours trapped behind the painted surface.

2. ***Bloom.*** In this defect, dull patches are formed on finished polished surface. This may be either due to defect in paint or due to bad ventilation.

3. ***Crawling or sagging.*** This defect occurs due to the application of too thick a paint.

4. ***Fading.*** This is the gradual loss of colour of paint, due to the effect of sunlight on pigments of the paint.

5. ***Flaking.*** Flaking is the dislocation or loosening of some portion of the painted surface, resulting from poor adhesion.

**6. *Flashing*.** It is the formation of glossy patches on the painted surface, resulting from bad workmanship, cheap paint or weather action.

**7. *Grinning.*** This defect is caused when the final coat does not have sufficient opacity so that background is clearly seen.

**8. *Running*.** This defect occurs when the surface to be painted is too smooth. Due to this, the paint runs back and leaves small areas of the surface uncovered.

**9. *Sponification.*** This is the formation of soap patches on the painted surface due to chemical action of alkalies.

## 20.7. VARNISHING

Varnish is a solution of resins or resinous substances (such as common resin, amber, copal, shellac etc.) in alcohol, turpentine or oil. It is applied on wood surfaces with the following objects :

(*i*) To intensify or brighten the appearance of natural grains in wood.

(*ii*) To render brilliancy to the painted surface.

(*iii*) To protect painted surface from atmospheric action.

(*iv*) To protect unpainted wooden surfaces of doors, windows, floors, roof trusses etc. from atmospheric action.

### Characteristics of a good varnish

A good varnish should possess the following characteristics

1. It should dry quickly.

2. The protective film obtained on drying should be hard, tough, durable and resistant-to wear.

3. The finished surface should be uniform in nature and pleasing in appearance.

4. It should exhibit a glossy surface.

5. It should not shrink or show cracks on drying. It should have sufficient elasticity.

6. The colour of Varnish should not fade a way with time.

**Ingradients of varnish** : A varnish has the following essential ingradients :

(*i*) Resins or resinous substances. (*ii*) Solvents.

(*iii*) Driers.

### 1. *Resins or resinous substances*

The quality of varnish depends largely on the type of resin used. Various types of resins in use are copal, lac or shellac, resin, amber,mastic, gum dammer etc. Copal is a hard and lustrous resin obtained from ground where pine tree existed in past. Resin is obtained from pine trees. Lac or shellac is obtained by exudation of some insects which grow on some type of trees in India. Raw copal, an inferior type, is obtained from standing pine trees :

### 2. *Solvents*

Different types of solvents are available, but each is used only in conjunction with some specific resin. The following table gives the solvents for different resins:

| *Type of solvent* | *Type of resin* |
|---|---|
| 1. Boiled linseed oil | Amber, copal |
| 2. Methylated sprit of wine | Lac or shellac |
| 3. Turpentine | Mastic, gum dammer, rosin |
| 4. Wood naphtha | Raw copal and other cheap varieties of resin. |

## FORM WORK (SHUTTERING)

**Formwork** is the term given to either temporary or permanent moulds into which concrete is poured till it get sufficient strength for self supporting..

The form work involves various materials such as timber (wood), plywood, steel, aluminium, combined wood–steel etc... used as moulds in civil structures, in

which concrete is poured. The construction of form work involves considerable materials. The cost of form work may be upto 20 – 25 % of the cost of the structure in building works and even higher in bridges. In order to reduce this expenditure, it is necessary to design economical types of form work.
When the concrete reach a certain required strength, the form work is no longer needed and is removed. The operation of removing the form work is commonly known as Stripping.
Similarly, when the components of form work are removed and then reused for other parts of the civil structure for several times are known as Panel forms.

FORMWORK MATERIALS:

**Timber** is the most common material used for form work. When the form work is to be used for small works only a few times, then timber proves to be more economical than steel or aluminium.

Advantages: Formwork material of timber is

- easily available
- formwork material can be made to desired shape
- can be made to required size
- easy to carry
- economically viable and cheap
- convenient for small works

Disadvantages:

- possibility of warping, swelling and shrinkage of timber. However, those effects can be overcome by applying shuttering oil as coating. This coating prevents the material from adhering to concrete and hence the stripping (removing of formwork material) makes easier.

**Steel/Aluminium formwork**: If the formwork is desired to be re-used several times, then the use of steel or aluminium is preferred. Though the initial cost of steel is very high but for large works with many repetitions, the steel form work proves to be economical. In case of specific structures, such as round columns, curved surfaces, tunnels etc the use of steel form work should be made.

Steel form work has many advantages such as

- Can be used a number of times
- It provides ease stripping
- It ensures an even and smooth concrete surface.
- It is not liable to shrinkage/ swelling.

**Requirements for a Form work:** A good form work should satisfy the following requirements:

- The material of the formwork should be cheap and it should be suitable for re-use several times.
- It should be water proof so that it doesn't absorb water from concrete.
- Shrinkage and swelling of material should be minimum.
- It should be strong enough to withstand all loads coming on it such as dead load of concrete, live load of concrete during its pouring, compaction and curing of concrete.
- The surface of the form work material should be smooth and should afford easy stripping.
- All joints of the form work should be stiff so that lateral deformation under loads is minimized.

**Indian Standards on form work (IS 456 – 2000)**

**General:** The formwork shall confirm to the shape, dimensions etc as shown on the plans and so constructed as to remain the rigidity during the placing of the concrete and the form work shall be sufficiently tight to prevent loss of liquid from the concrete.

**Cleaning and treatment of forms:** All rubbish particularly chippings, saw dust shall be removed from the interior of the form work material before the concrete is placed.

**Procedure to be adopted for removing the form work:** All form work materials are to be removed without creating vibrations as would damage the reinforced concrete. Before the form work materials are removed, the concrete surface should be checked thoroughly.

**Tolerances:** Form work shall be so constructed that the internal dimensions are within the permissible tolerance specified by the designer.

| | |
|---|---|
|  |  |
| Formwork material (PLYWOOD) | modular steel frame work |

| | |
|---|---|
|  |  |
| **Reusable plastic form work** | Steel and plywood formwork |

| | |
|---|---|
|  |  |

| | |
|---|---|
|  |  |
| Plywood Column boxes | Column boxes |

**SCAFFOLDING**

The Scaffolding is a temporary frame work of timber or steel components having platforms at different levels, to enable the masons to work at different heights of a buildings. When the height of wall or column or other structure of a building exceeds about 1.5 mts (4’), temporary structures are used to support the platform over which the work men can sit and carry the activities. These temporary structures constructed are very close to the wall, is in the form of timber or steel frame work, commonly called scaffolding.

Scaffolding materials is needed for the repairs or even demolition of a building. In addition, surface finishing such as plastering, pointing, white washing or distempering of walls, columns etc at higher levels can also be carried out. The scaffolding should be stable and be strong enough to support work men and other construction material placed on the platform. The height of the scaffolding goes on increasing as the height of construction increases.

**Components of Scaffolding:**

**Standards:** These are the vertical members of the frame work supported on the ground or embedded into the ground.

**Ledgers:** These are horizontal members, running parallel to the wall,

**Braces:** These are diagonal members fixed on standards.

**Putlogs:** These are transverse members, placed at right angles to the wall with one end supported on ledgers and other end on the wall.

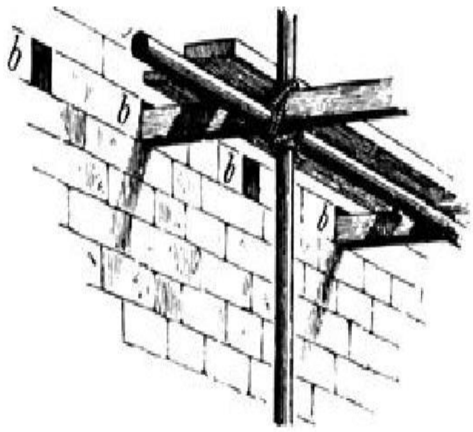
**Transoms:** These are those putlogs whose both ends are supported on ledgers.

**Boardings:** These are horizontal platform to support workmen and material and are supported on the putlogs.

Various components or members of the scaffolding are secured by means of rope lashings, nails, bolts etc…



**Standards / verticals** **Ledgers** **Braces to standards**




Putlogs ( b = putlog hole)

Transoms

Boarding


Cuplock material

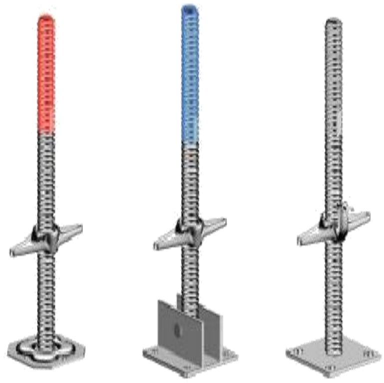

Flathead pin

Braces

Shoring frame

H – frame

Adj stirupps



**Adjustable base plates** **Props** **Cup lock system**

**TYPES OF SCAFFODING:**

- **Single / Bricklayer's / Putlog scaffolding**: It consists of a single row of standards (vertical members) which are driven into the ground. Standards are to be arranged parallel to the wall at distance of 1.20 mts. The standards are then connected to each other by ledgers (horizontal members) placed at right angles. They are secured in position by rope lashings or cuplock materials. The put logs are fastened to ledgers by rope lashings. The cross braces are used for strengthening of the structure.

- **Double scaffolding/ Mason's Scaffolding**: This type of scaffolding is stronger than the single scaffolding and is used in the constructions of stone work. The form work is similar to the single scaffolding except two rows of standards are used, one row close to the wall within 15 cm and the other at 1.2 to 1.5 m away from the face of the wall. The put logs are supported at both ends on ledgers. Sometimes, in addition to the diagonal braces, inclined supports called Racking shores are provided to prevent the slipping of scaffold away from the wall.

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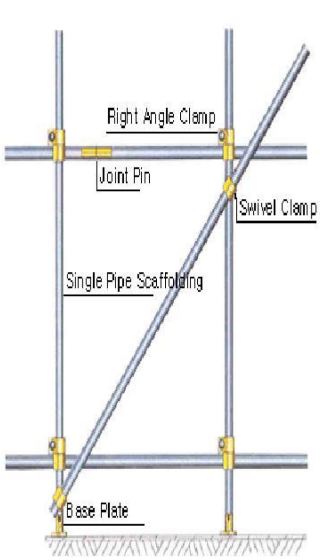
<td>
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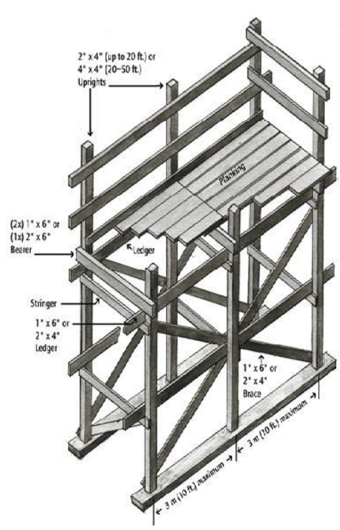
<td></td>
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<tr>
<td>Single / Bricklayer's / Putlog scaffolding</td>
<td>Double/Mason's scaffolding (wood)</td>
<td>Double/Mason's scaffolding (steel)</td>
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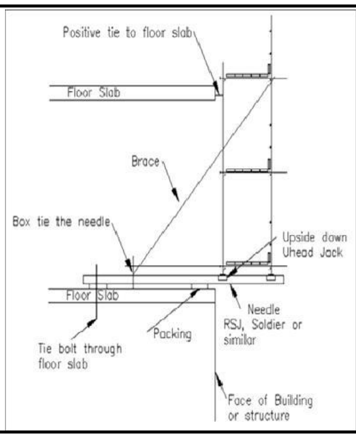
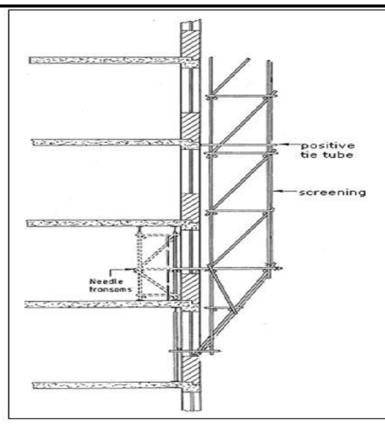
3. **Cantilever Scaffolding / Needle Scaffolding**: This type of scaffolding is needed under the following circumstances:

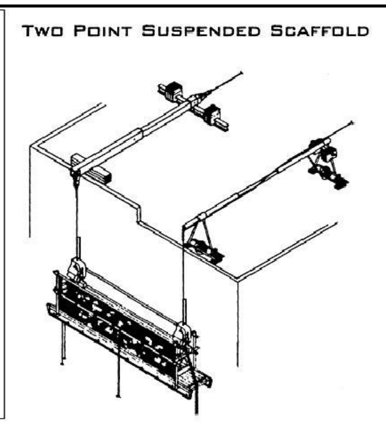
- Where it is not possible to fix the standards in to the ground
- Where the scaffolding is to be provided on the side of a busy street without obstructing the traffic on road.
- Where the scaffolding is required in case of tall buildings.

In this work, single scaffolding or double scaffolding components are supported by a series of cantilevers or needle beams (timber beams projecting from wall) passing through window openings or through holes in the wall.

4. **Suspended scaffolding**: This type of scaffolding is suitable for maintenance works such as painting, pointing, distempering etc. The working platform is suspended from the roofs by means of wire ropes or chains.. The mechanical arrangements are provided to raise or lower the platform to attain the optimum level for working.



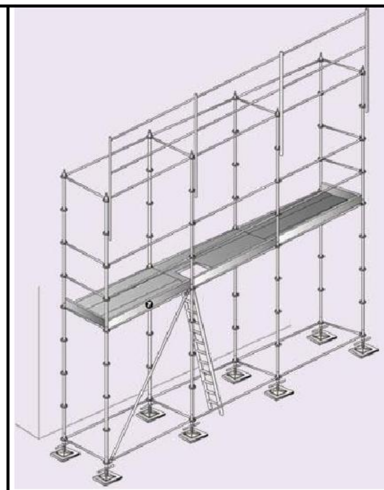




| Cantilever Scaffolding | Cantilever Scaffolding Suspended scaffolding |
|---|---|

- **Trestle scaffolding**: The working platform is supported on the top of mobile devices such as tripods, ladders etc mounted on wheels. Trestle scaffolding is suitable for minor repairs or painting work upto a maximum height of 5 mts from the supporting level.

- **Steel scaffolding/Centering**: It is practically similar to timber scaffolding except that wooden members are replaced by steel tubes and rope lashings are substituted by special couplings and set-screws at junctions. Though its initial cost is more but its salvage (The property so saved) value is higher.

- **Ladder Scaffolding / Patented scaffolding**: The working platforms are supported on brackets (with inner row of standards) which can be adjusted at any suitable height. The various components of the scaffold are fastened to each other by means of
bolts and screws.

| | | |
|---|---|---|
|  "C" Tower one level mobile scaffold |  |  |
| **Trestle scaffolding** | **Steel scaffolding** | **Patented scaffolding** |

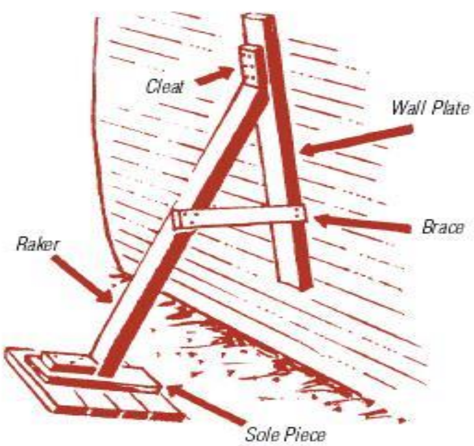
**SHORING**

The temporary support provided to an unsafe structure or to a structure under-going alterations is called a shore, and the method of its construction is called shoring. Shoring can be used in case of

- A wall cracks due to unequal settlement and need repairs.
- When an adjacent structure is to be dismantled.
- When openings are to be made or enlarged in the wall.
- When a wall shows signs of bulging due to improper workmanship which needs rectification.

**Types of shores:**

**Raking Shores:** Rakers of inclined members are used to give lateral support to the wall. Usually a raking shore consists of the following components:

| | |
|---|---|
|  | Rakers / inclined members<br>• Wall plates<br>• Needles<br>• Cleats<br>• Bracings<br>• Sole plates |
| Raking shore | |

The sole plate should be properly embedded into the ground at an inclination and the sole plate should be accommodating all the rakers and a cleat provided along the outer edge. However the rakers should be inclined to the ground by 45° to make them move effective.

**Flying or Horizontal Shores:** These are used to give horizontal support to two adjacent walls in which the shores do not reach the ground. If the walls are quite near to each other (distance upto 9 mts), single flying shore can be constructed. It consists of wall plates, needles, cleats, struts, horizontal / flying shore, folding wedges etc…. When the distance between the walls is more, a composed or double flying shore may be provided.

Flying shores have the advantage that building operations of the ground are not obstructed. Flying shores are inserted when the old building is being removed, and should be kept in position till the new unit constructed.

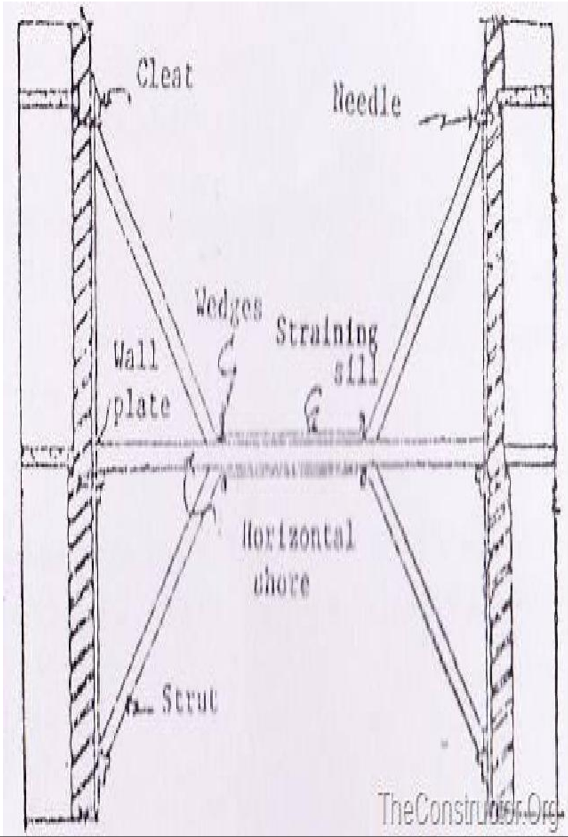
**Dead or Vertical Shores:** These consist of vertical members who support the horizontal members (needles). The horizontal members transfer the load of the wall to the vertical shores (vertical members). Such vertical shoring is provided to serve the following purposes.

- To rebuild the defective part of the lower portion of the wall;
- To deepen the existing foundations.
- To make large openings at lower levels.

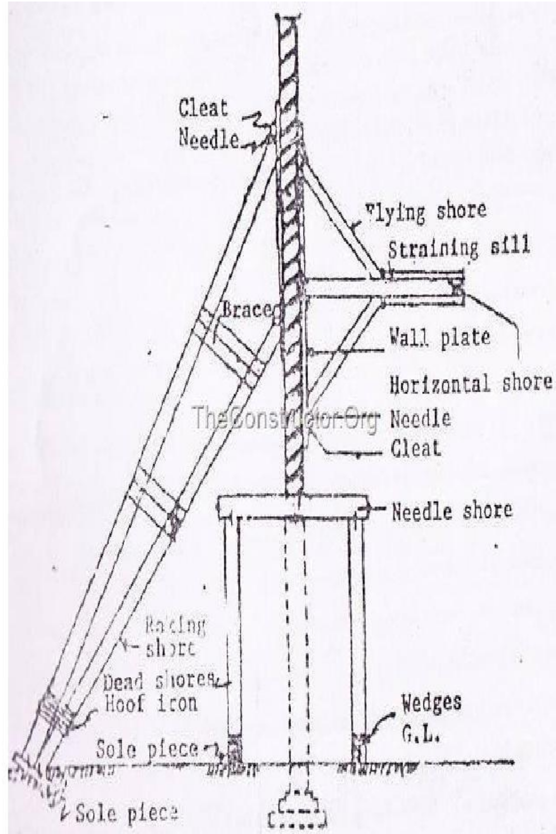
Holes are made in the wall at suitable heights and the horizontal members, which are made of thick wooded sections or of steel are inserted in the steel. Each horizontal is supported at its two ends by vertical ports / dead shores.

The horizontal members are spaced at 1 to 2 mts. A minimum of 3 horizontal shores should be used for an opening. If the external wall is weak, raking shores may be provided in addition to vertical shores.

Shores should be removed only when the mew work has gained sufficient strength, but in no case earlier than 7 days of the completion of new work. An interval of two days should be allowed between each one of these removal operations




Flying shore




Dead shoring

**UNDER PINNING:** The method of supporting a structure, while strengthening its existing foundation to take the increased load is called underpinning. Before under pinning shoring may be done according to the conditions of the structure for its stability. The use of underpinning becomes essential to meet the following requirements under different situations:

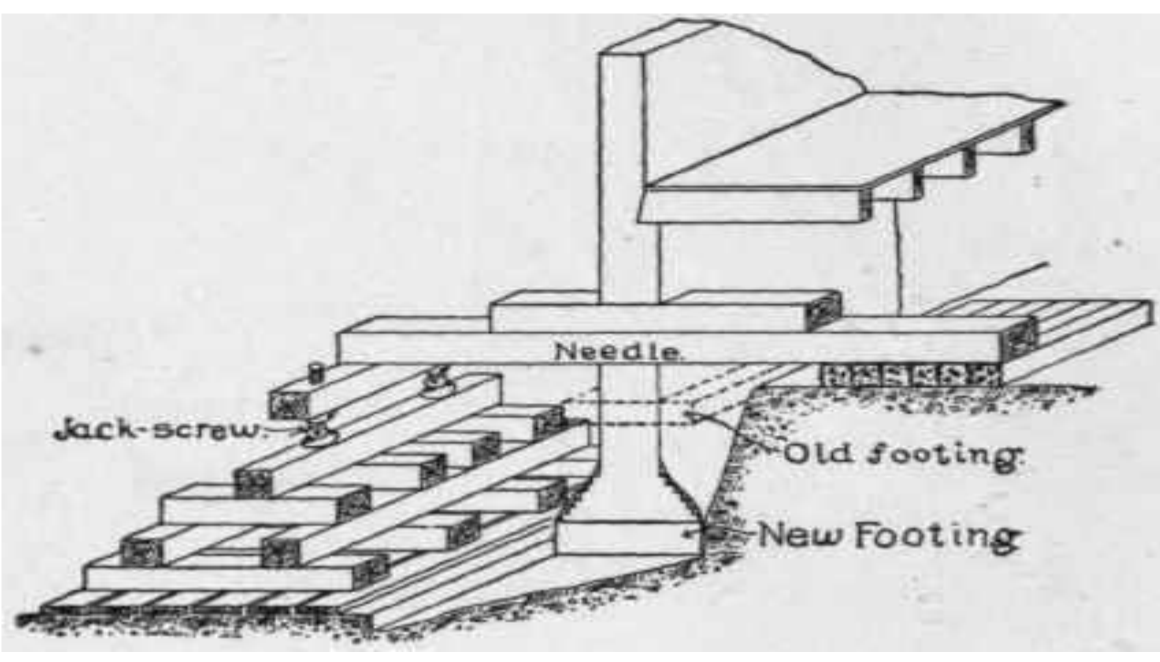
- To strengthen the shallow footing of the existing building, when a building with deep foundation is to be constructed adjoining to it.
- To deepen the existing foundation to increase its bearing capacity so as to sustain heavier loads
- To provide a basement to an existing building structure.

Underpinning can be carried out by the following methods:

1. Pit method ( pit underpinning)
2. Pile Method

**Pit method (pit underpinning):** In this method, existing wall over the foundation is divided into various sections, generally 1.2 to 1.5 mt in length. Holes are then made at adequate height in the existing wall. In these holes, steel needle beams with bearing plates are inserted and supported on either side of the wall by means of crib supports ( wooden blocks). The jacks in turn are provided below the wooden blocks.

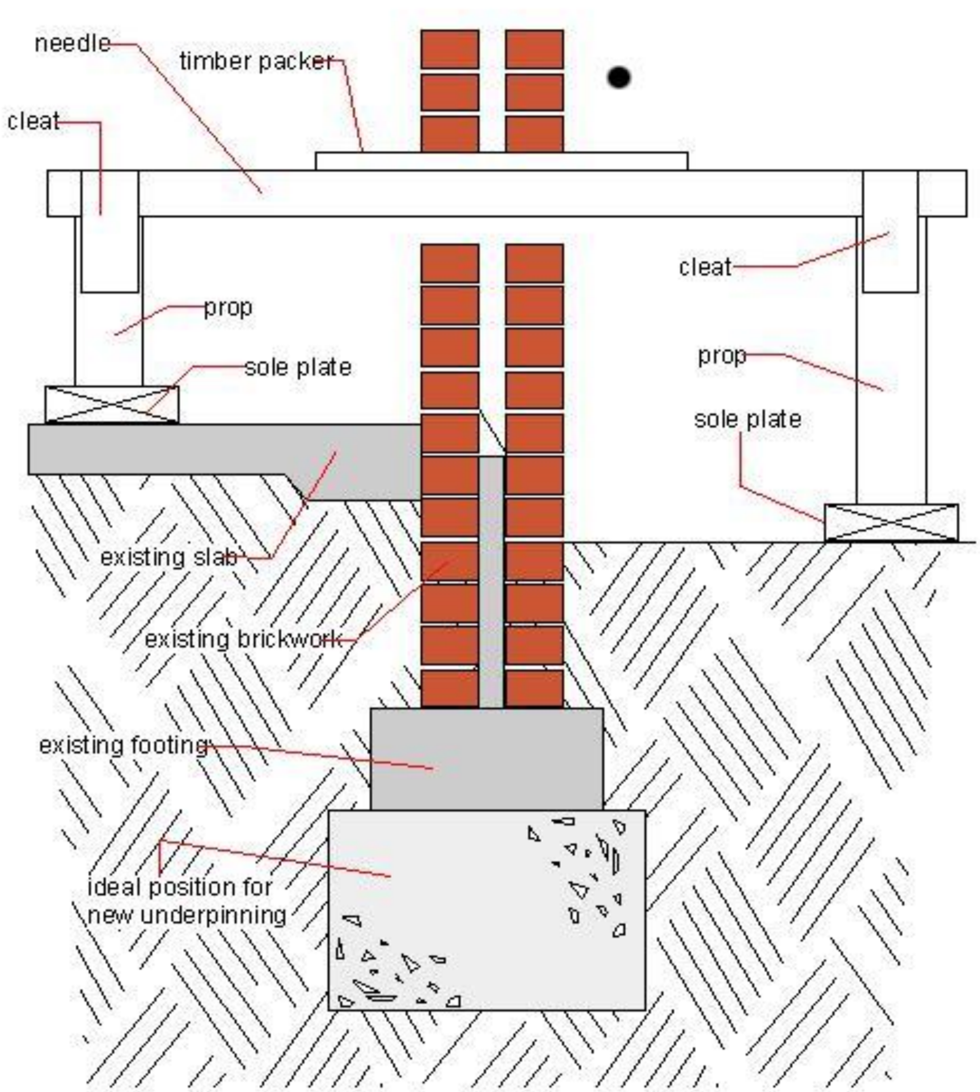
The pit is now excavated upto the desired level of the proposed new foundation . The old foundation may be extended upto level of new foundation directly or by cutting the lower part of old footing as desired.



**Pile method:** The foundation of piers and columns may be strengthened by providing underpinning by the Pile method. In this method, the piles are driven along both the sides of the existing wall and then needles in the form of pipe caps are provided through the existing wall. Thus existing wall is relieved of the loads coming on it. This method is useful in clayey soils and for water-logged areas and for walls carrying heavy loads.

In this method, under pining is carried out in two stages.

In stage I, a precast RCC pile is installed by digging an approach pit under the existing wall foundation. A jack arrangement is set up below the foundation to assess the overload capacity. All the material surrounding the pile is removed by means of earth augers, water jets. The gap so formed is filled up with cement concrete to provide firm bearing ground. In stage II, a steel I-beam is set on and the jacks are then removed.



**Green Buildings :**

The term "**Green**" refers to environmentally, friendly practices from building design to the landscaping choices. It also optimist and Economic energy use, water use, and storm water and waste water reuse.

A **Green building** is that building which is constructed at a well planned location with proper design and sustainable materials. Fitted and painted with eco friendly materials. The building should gives to its occupants healthy and comfortable environment in all climates. It remains cool in summer, warm in winter, inside fully protected from rain, gives natural pollution free air and light through doors, windows and ventilators without any artificial means. For particular requirements it has solar, wind power and eco friendly electrical, mechanical etc. devices.

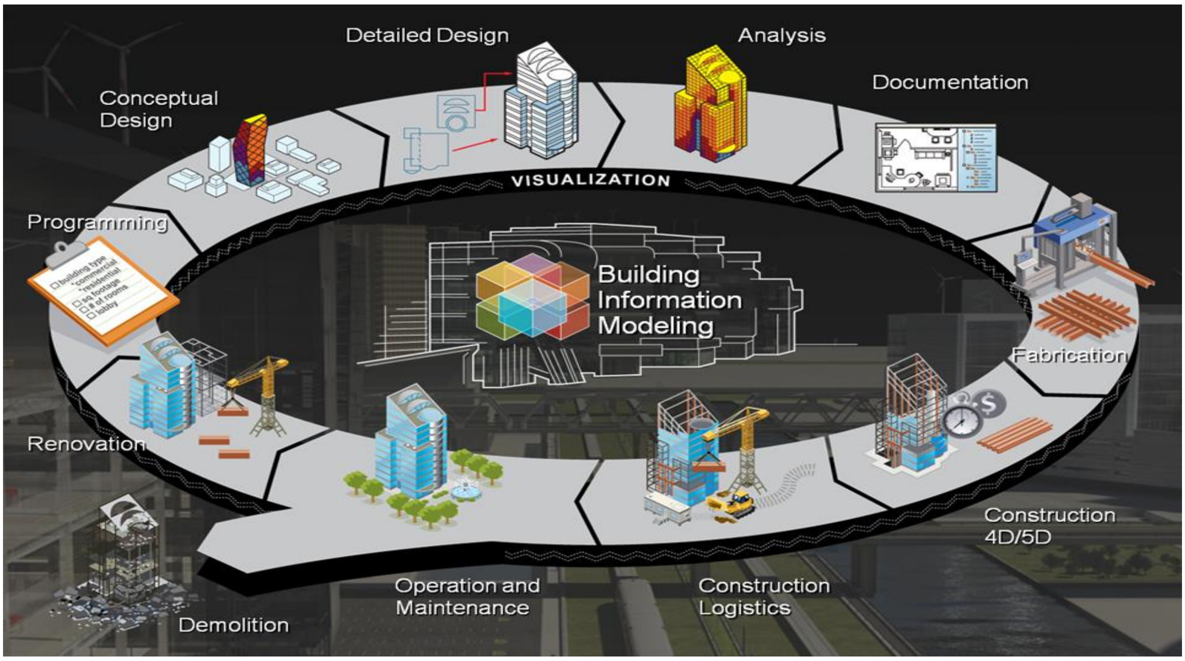
The term "**Green Building**" apply not just to products, but to construction strategies, building design and orientation, landscaping, building operations, maintenance, and more. The less impact a building has on human health and the environment, the more green it is.

A green building should have all safety devices. It should be provided with potable water, having proper drainage, sewerage and rainwater harvesting system. The building should be surrounded with trees, plants and grass to provide natural greenery.

**Building Information Modeling** (BIM) is a collaborative way of working, underpinned by the digital technologies which unlock more efficient methods of designing, creating and maintaining our assets. BIM embeds key product and asset data and a 3 dimensional computer model that can be used for effective management of information throughout a project lifecycle – from earliest concept through to operation. It has been described as a game changing ICT and cultural process for the construction sector.

**Building Information Modeling** (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition

` "With BIM (Building Information Modeling) technology, one or more accurate virtual models of a building are constructed digitally. They support design through its phases, allowing better analysis and control than manual processes. When completed, these computer-generated models contain precise geometry and data needed to support the construction, fabrication, and procurement activities through which the building is realized."




In short Green Building is a design and construction practice that promotes the economic health and well-being of your family, the community and the environment. A smart step toward personal economic rewards, Green building has positive social and environmental ramifications that assert your commitment to the future and the way we live for years to come.

**Green Retrofit :**

Renovation work undertaken on existing building that meets LEED or other Green Building standards or that includes numerous strategies across four category are as : energy, water and resource efficiency and improved indoor air quality.

**High Performance Buildings :**

A building that uses a whole building design approach to achieve energy, economic and environmental performance that is substantially better than standard practice.

**Energy Performance Simulation :**

Energy Performance Simulation program are software tools used to estimate energy performance and thermal comfort. They are typically used during the design and construction phases of a building, and they are based on basic building characteristics.

**Leadership in Energy and Environmental Design (LEED) :**

An internationally recognized green building certification system developed by the U.S. Green Building council, providing third party certification that a building or community was designed and build using strategies intended to improve performance across energy savings, water efficiency, $CO_2$ emissions reduction, improve indoor environmental quality and stewardship of resources and sensitivity to their impacts.

**Net-zero Energy Building :**

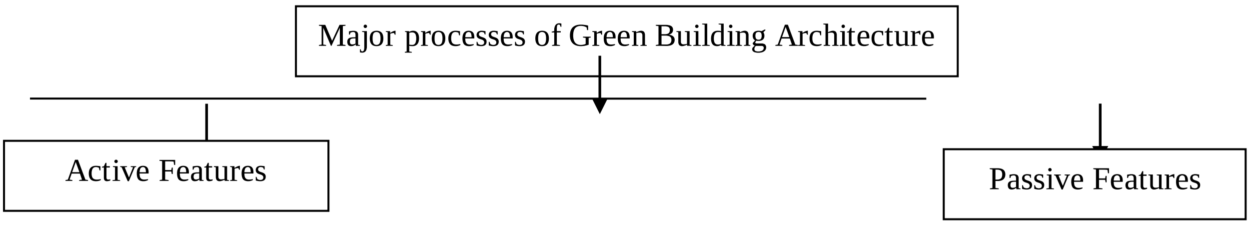
A building that uses no more energy than it generates through a combination of energy efficiency measures and on-site renewable energy generation. The U.S. Department of energy has been charged with developing marketable, net zero energy commercial buildings by 2025, as required by federal law set forth in the Energy Independence & Society Act of 2007.


Green Building with Heartland Builders, LLC.
www.heartlandbuilders.com
Exposure to the sun Consider your homes orientation to the sun to harness energy or to shield it from heat and UV light
Other Considerations – Low VOC paints, "green" flooring, energy efficient lighting. Conduct a "blower door" test on your home to determine performance.
Insulation Air sealing a home, using a blown insulation and minimizing thermal bridging lowers utility bills. Consider SIPS or ICF's
High Efficiency Low E insulated glass windows reduce energy use and protect your homes interior
Recycled Deck Materials utilize sustainable resources and reduce maintenance costs
Rain Gardens Help reduce storm water run off
Recycled Framing Materials such as finger jointed studs and an I joist floor system help reduce new lumber use
Native Landscaping Requires less maintenance and irrigation
Conserve Water with duo-flush toilets, water saving faucets and rain sensors for lawn sprinkling
Insulated Foundation Walls Improves the comfort of your home and reduces utility costs. Consider ICF's.
High Efficiency Mechanical Systems reduce your energy bills. Consider a Geothermal Heating System. Always seal your duct work.
Energy Efficient Appliances reduce utility costs
Insulated Basement Floors helps eliminate dampness and reduces utility costs
© Copyright Heartland Builders, LLC.

**Features of Green Buildings :**

- ✓ Energy efficient equipment for air conditioning and lighting systems & Use of onsite renewable energy.
- ✓ Measurement and verification plan to ensure energy & Water savings.
- ✓ Reduction of building footprints to minimize the impact on environment.
- ✓ Minimal disturbance to landscapes and site condition.
- ✓ Use of Recycled and Environmental Friendly Building Materials.
- ✓ Use of Non-Toxic and recycled/recyclable Materials.
- ✓ Efficient use of Water Recycling
- ✓ Indoor Air Quality Improvement for Human Safety and Comfort.
- ✓ Effective Controls and Building Management Systems
- ✓ Installation of high efficiency irrigation methods and selection of vegetation which have low water consumption.
- ✓ Recycling of construction debris to other sites.
- ✓ Use of building materials having a high recycled content.
- ✓ Use of rapidly renewable materials.
- ✓ Declaration of site as "Non-smoking" area or have designated area of smoking.
- ✓ Providing daylight and views for the occupied areas.

There are various design features that are to be incorporated while designing a green building. After designing the building block in a way which offers a comfortable living space along with reduction of power and usage of energy intensive materials; our next step would be towards outdoor planning which is also as important as the planning of the building itself.




Use of Solar Photovoltaic Panels
Use of Landscaping Elements
Wind Energy
Wave Energy
Use of Solar
Tall trees, Shrubs, bushes
Necessity of Parapet

Use of thick walls, Verandas
High ceilings, Balconies, Ponds
Energy Ventilators, Skylights,

**Benefits of Green Buildings :**

**Social benefits :**

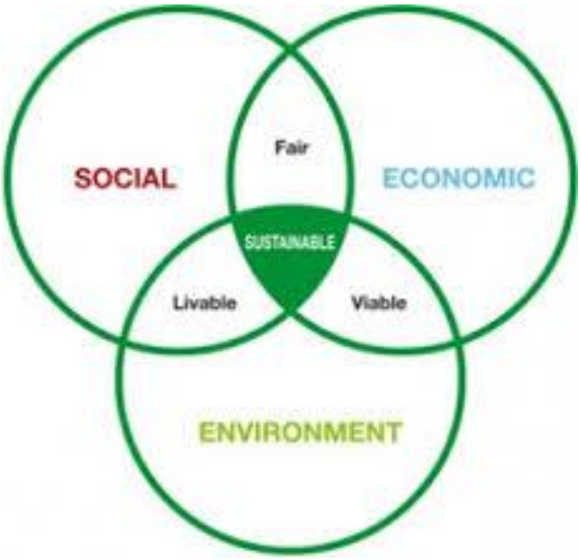
- Enhance occupant comfort and health
- Heighten aesthetic qualities
- Minimize strain on local infrastructure
- Improve overall quality of life

**Economic benefits :**

- Reduce operating costs
- Create, expand, and shape markets for green product and services
- Improve occupant productivity
- Optimize life-cycle economic performance

**Environmental benefits :**

- Enhance and protect biodiversity and ecosystems
- Improve air and water quality
- Reduce waste streams
- Conserve and restore natural resources




Apart from these, there are several benefits of Green Buildings, some of them are :

- ✓ The most tangible benefit is in reduction of operating energy and water costs right from day one during the entire life cycle of the building.
- ✓ Buildings consume at least 40-50 % less energy and 20% -30 % less water visa-versa conventional building.

- ✓ Green buildings are always fresh and healthy. The green buildings use interior materials with low volatile organic compound (VOC) emissions.
- ✓ Working in environment with access to daylight and views provides connection to the exterior environment.
- ✓ 30% to 40% reduction in operating cost.
- ✓ Health and safety of building occupants.
- ✓ Improve productivity of the occupants.
- ✓ Incorporate latest techniques and technologies.

As per the US General Services Administration research output and compared to the national average values green building uses 50% less energy, 40% less water consumption, 13% reductions in aggregate maintenance, 27% of higher occupant satisfaction, 70% solid waste reduction and 35% of less $CO_2$ emissions.


**Cost and Financial benefits of Green Buildings :**

There is general perception that buildings designed to be sustainable are likely to be more expensive than the traditional ones and have to look different with technology laden rooftops. This can be major hindrance for the mainstreaming of green building practices because of the general aversion to make additional investments in order to achieve lower energy costs. It is crucial to design buildings that are genuinely environment-friendly, accessible and do not require additional budget. For this, there has to be more emphasis on adopting the right building science and depending less on high-cost building technologies. A better scientific understanding of the way buildings work can help in avoiding high technological sophistication or the “technical fix”. In short, the challenge is to do more with less.

A report submitted to California’s sustainable Building Task Force in 2003 provided the first comprehensive analysis of the actual costs and financial benefits of green buildings (Kats 2003). Examining 33 green buildings across the USA, the report also undertook a comparison of the real constructed cost with the estimates based on similar non-green building design. The report concluded : “The benefits of building green include cost savings from reduced energy, water, and waste; lower operations and maintenance costs; and enhanced occupant productivity and health. An analysis of these areas indicates that total financial benefits of green buildings are over ten times the average initial investment required to design and construct a green building. Energy savings alone exceed the average increased cost associated with building green. Additionally, the relatively large impact of productivity and health gains reflects the fact that the direct and indirect cost of employees is far larger than the cost of construction or energy. Consequently, even small changes in productivity and health translate into large financial benefits”.

| Building | Built-up area ($ft^2$) | Increase in cost (per cent) | Energy reduction (per cent) | Payback time (years) |
|---|---|---|---|---|
| Wipro Technologies | 175,000 | 8 | 40 | 5 |
| ITC Green Centre | 170,000 | 15 | 45 | 6 |
| CII Godrej GBC | 20,000 | 18 | 63 | 7 |

## 1.10 MERITS AND DEMERITS OF GREEN BUILDINGS :

**Merits :**

- Efficient Technologies
- Easier Maintenance
- Return On Investment
- Improved Indoor Air Quality
- Energy Efficiency
- Water Efficiency
- Waste Reduction
- Temperature Moderation
- Water Conservation
- Economical Construction For Poor
- Healthier Lifestyles and Recreation
- Improved Health.

**Demerits :**

- Initial cost is high
- Availability of materials
- Need more time to construct
- Need skilled worker

**Green Building material**

**Green Building material :**Green Building material is a kind of building material which would not cause damage to human body. In other words, Green Building material is low-pollution, low-stench building material. The poison in the building material would spread through interior decoration and attach to the indoor environment. To those who stay indoors for a long time, due to long exposure to this kind of toxic environment, there is an extremely negative impact on human body. To identify the beneficial building material that protects people from poison and danger, assessment of building material is mostly based on indoor construction material and decoration material. Those building material which is qualified for the evaluating standard would be given the marker called "Green Building Material."Green Building material is divided into four types:

1.The ecological building material,
2.The healthy building material,
3.The high-performance building material,
4.The recycling building material.

1. The ecological Green Building material

   In comparison with other building material, the Green Building material is the least processed, thus the most natural, ecological material; it consumes the least energy and resource (fig1).

2. The healthy building material

   Healthy building material is of low pollution, low order, and low physiological hazard. It aims mainly at low volatile organic compounds, such as water environmental friendly paint, water-wood paint, and epoxy resin paint. (fig2)

3. The high-performance building material

   High performance building material can conquer the deficiency of traditional building material, improving quality performance. High performance soundproof Green Building material can effectively prevent noise impacts on the quality of life (fig 3).

4. The recycling building material

   Recycling building material is low processed, low energy consuming, low carbon dioxide discharge, low pollution discharge, naturally decomposed, and reusable. Mixed material recycling building material refers to wood or stone building material mixed with waste plastics, glass, etc., which produces new building material such as imitation wood and water permeable bricks (fig 4).

Fig. 1

Fig. 2

Fig. 3

Fig. 4

**Green Globes** is an online green building rating and certification tool that is used primarily in Canada and the USA. In Canada, there are Green Globes modules for:

- New Construction/Significant Renovations
- Commercial Interiors (i.e. Office Fit-ups)

These modules can be used for a wide range of commercial, institutional and multi-residential building types including offices, school, hospitals, hotels, academic and industrial facilities, warehouses, laboratories, sports facilities and multi-residential buildings.

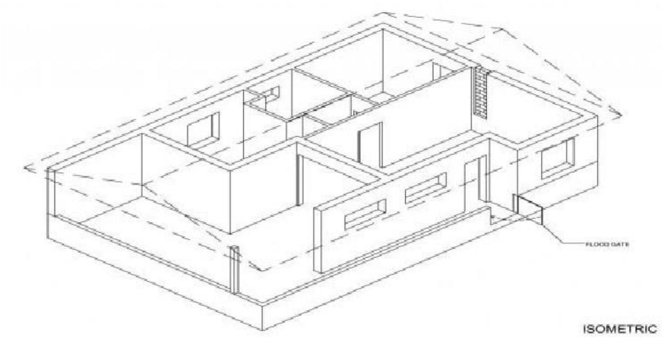
Characteristics of Green Globes

- Green Globes is structured as a self-assessment to be done in-house using a project manager and design team. The system is questionnaire-based with pop-up tips, which show the applicable technical tables that are needed to reply to the questions. An online manual is also available. Users can see how points are being awarded and how they are scoring.
- The Green Globes platform includes optional interactive guidance to help implement the integrated design process from goal setting to construction documents.
- Submittal requirements consist of documents that are normally produced as part of any well executed green construction project that uses the integrated design process. They consist of construction drawings, specifications, energy modelling, life cycle analysis, records of meetings, and any "green" plans that the team has developed - for example, storm-water management, landscaping, and commissioning.

**UNIT V: BUILDING PLANNING**

A building consists of a number of rooms including toilets / bath rooms, kitchen, Hall, bed rooms etc interconnected through corridors, passages and each room may contain a number of doors, windows, almirahs, cup boards whereas building drawing reveals the details of all building elements such as foundations, doors, windows, lintels, arches, roofs, floors, sanitary and electrical fittings. Usually these fittings represent symbolically. The graphical symbols are the shortest forms of the objects and components. Hence, drawing is the language of Engineers and Architects.

BUILDING PLANS: A plan is the graphical representation to some scale on the surface of the earth as projected and represented on the paper on which the plan is drawn. In order to represent these elements on a plan, the plan is conventionally prepare at the window sill level (The horizontal member at the base of a window opening) rather than at the plinth level ( Within the context of construction, it is the top of the foundation walls).




Window sill level


Plinth level

The art of arranging various units of a building on all floors and at ground level giving due consideration to planning, drawing; architectural, engineering, finance and management aspects is known as building planning. Hence, the building planning include drawing and is the foundation subject for civil engineering students.

A building may be completely represented by the following types of plans:

**Plan of a typical floor:** The plan of a typical floor ( ground floor plan at ground floor level , first floor plan at first floor level) is represented by a plan cut at the window sill level so that all the windows, cup boards, almirahs etc are also represented on the plan.

**Foundation plan:** Foundation is immediate beneath the lowest part of the structure, near to the ground level is known as shallow foundations. Such foundations are mostly placed on the hard strata available below the ground level.

Shallow foundations are further classified into the following types:

1.**Open trench foundations:**.

| | |
|---|---|
|  | The open-trench foundations were common whenever the terrain was sufficiently compact and the trench did not require much depth. In other situations it was necessary to reinforce the walls of the trench to prevent them from collapsing during digging |

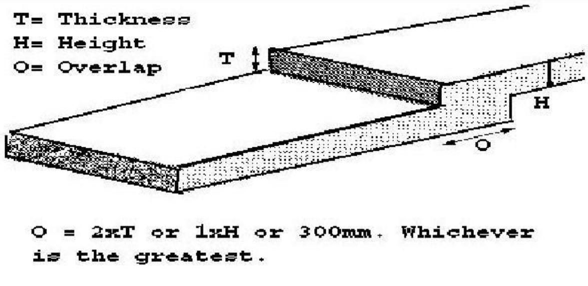
2. **Grillage foundations**: **Grillage foundation** is used when heavy structural loads from columns, piers or stanchions are required to be transferred to a soil of low bearing capacity. **Grillage foundation** is often found to be lighter and more economical. This avoids deep excavation. Depending upon the material used in construction of **grillage foundation** can be broadly divided in the following two categories.

- **Steel grillage foundation**
- **Timber grillage foundation**

**Raft foundations**:

| | |
|---|---|
|  | a foundation (usually on soft ground) consisting of an extended layer of reinforced concrete. |

4.**Stepped foundations**:




A foundation constructed in a series of steps that approximate the slope of the bearing stratum. The purpose is to avoid horizontal force vectors that might cause sliding.

5.**Inverted arch foundations/ Footing** .

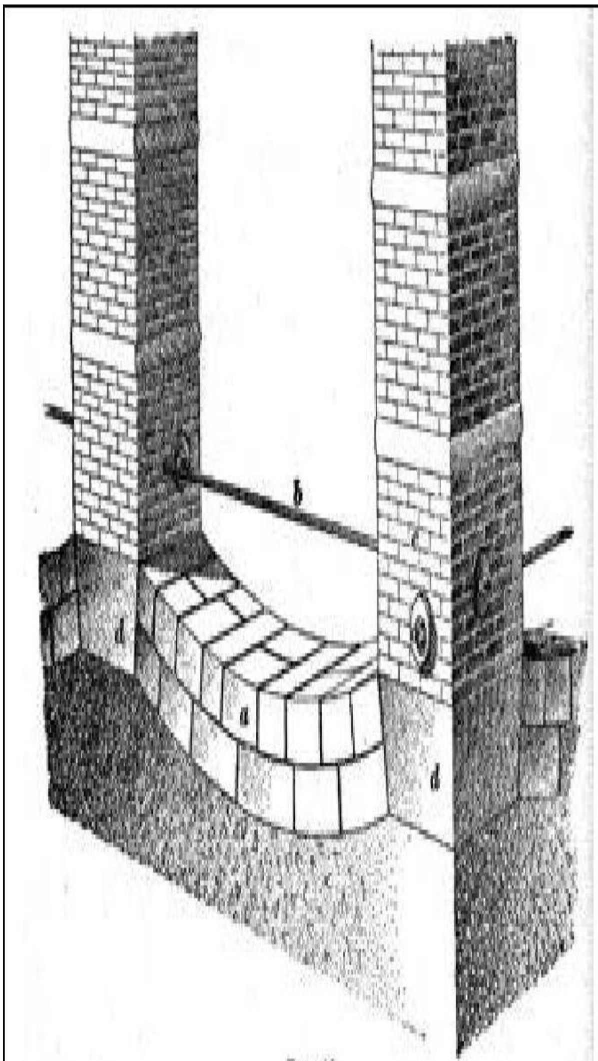


Fig. 63

It is used to be provided for multi-storeyed buildings in olden times. However, with the advent of reinforced cement concrete construction practice, **inverted arch foooting** is rarely done these days. One of the drawbacks in this type of construction is that the end piles have to be specially strengthened by buttresses to avoid the arch thrust tending to rapture the pier junction. However, the advantage of inverted arch construction is that in soft soils the depth of foundation is greatly reduced

Structural plan of a typical floor: A structural plan of a typical floor contains location, nomenclature and details of various structural elements at that floor level.

Terrace plan. The terrace plan is the plan at the roof level showing the stair cabin, lift cabin, overhead water tanks alongwith roof drainage pattern, parapet walls etc.

**Classification of buildings**: According to National Building code of India 1970, **different classification of buildings** on the basis of occupancy are:

**Group A – Residential Buildings**: All those buildings in which sleeping accommodation is provided for residing permanently or temporarily with or without cooking or dining or both facilities are termed as residential buildings, for example Apartments, Flats, Bungalows, Dormitories, Private Houses, Hotels,

Hostels, Cottages, Holiday Campus, Clubs, outhouses, Inns, etc., These buildings are further sub-divided in to 5 groups, namely; A- 1 Lodging Houses; A- 2 Family Private Dwellings; A- 3 Dormitories; A- 4 Flats; and A- 5 Hotels.

**Group B – Educational Buildings:** All those buildings which are meant for education from a nursery to the university, are included in this group, for example, schools, colleges, Universities, Training Institutes, etc. These buildings provide facilities like class – rooms, staff cabins, drawing rooms, laboratories, admin blocks, seminar halls; recreation halls, library, playfields, gymnasium etc.

**Group C – Institutional Buildings**: This group includes any building which is used for the purposes such as medical, health, physical or mental disease, care of infants or aged persons, etc. These buildings normally meant for healthcare for the occupants.

These buildings are further sub–divided into three groups viz, C–1 Hospitals; C-2 Custodian Institutions (a financial institution that has the legal responsibility for a customer's securities) and C-3 panel Institutions (a group of persons selected for some services).

**Group D – Assembly Buildings:** This group includes any building where groups of people assemble or gather for amusement / entertainment. For eg: theatres, cinema halls, assembly halls, auditoriums, exhibition halls, museums, restaurants, places of worship (temple, mosque, church, etc.), club rooms, passenger stations, public transportation services; open air theatres, sports pavilions( i.e., stadium), swimming pools, etc.

**Group E – Business Buildings** : A **commercial building** is a building that is used for commercial use. Types can include office buildings, warehouses, shopping malls, etc

**Group F – Mercantile Buildings**: This group includes any building or part of a building which is used as shops, stores, market for sale and display of products or wares either wholesale or retail.

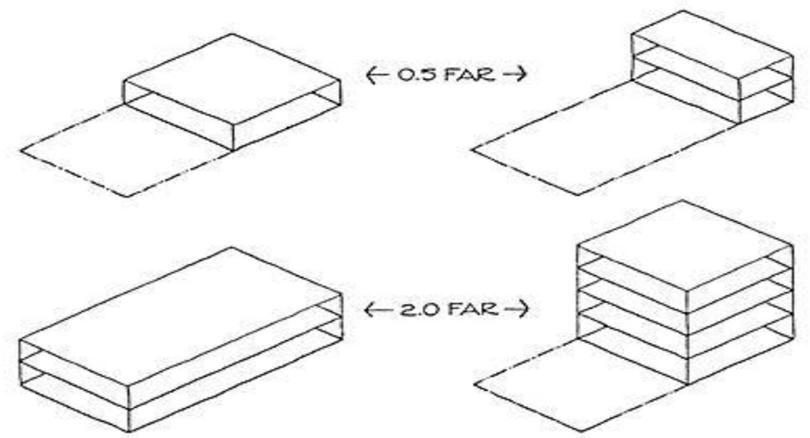
**Group G – Industrial Buildings**: This group includes any building in which products of different kinds and properties, are fabricated, assembled or processed. For example, laboratories, assembling plants, laundries, gas plants, power plants, refineries, diaries…

**Group H – Storage Buildings**: This group includes to store materials such as cement, iron/steel; home appliances etc. eg: godowns

**Group I – Hazardous Buildings**: This group includes those building structures which are used for the storage, handling, manufacture/ processing of materials which are liable to burn and prove hazardous to building contents. Hazards may be due to fire, poisonous fumes or gases , explosions, ignition, etc., from materials subjected to various operations. Buildings used for storage of explosive materials, manufacture of synthetic leather, explosives, fire works, etc.

**BASIC PRINCIPLES OF BUILDING PLANNING**: The basic principles of building planning in respect of residential buildings are:

(1) FLOOR AREA RATIO (FAR) is the ratio of the total covered area of all floors in a building on a certain plot and to the area of the plot.




FLOOR AREA RATIO

The Floor Area Ratio, describes the relationship between the size of a plot and the amount of floor space it contains. For example, a 50' x 100' lot (5,000 sft) with a single-story 50' x 50' building (2,500 sft) has a floor area ration of 0.5. If a building with the same size footprint had 4 stories, the FAR would increase to 2. Higher FARs tend to indicate more urban (dense) construction and is used by local governments in zoning codes

(2) FLOOR SPACE INDEX ( FSI): It is the ratio of built up area inclusive of walls of all the floors and to the area of the land on which the building stands.

$$\text{Floor Space Index} = \frac{\textbf{Total floor area including walls of all floors}}{\textbf{Plot Area / Building Unit}}$$

Thus, an FSI of 2.0 would indicate that the total floor area of a building is two times the gross area of the plot on which it is constructed, as would be found in a multiple-story building.

**FSI for residential buildings in the city area is 4.** The value of FSI is fixed by local authority and it is different for different areas and for different buildings of the town.

| Use | Area | FSI | Remarks |
|---|---|---|---|
| Residential | Scheme | 1 | Only Ground floor is allowed. |
| Residential | City area | 4 | Facing street of > 12 mts width |
| Residential | City areA | 3 | Facing street of < 12 mts width |

(3) ROAD SIDE MARGIN:

| **Width of Proposed Roads (mts.)** | **Minimum Road Remarks** | **Side Margin (mts)** |
|---|---|---|
| Road up to 9mts. and less. | 3.00 | (1)For the existing built up area the margins requirement may be relaxed on merits of individual case subject to other regulations. (2) Minimum side Margin shall be provided as per regulation no. 12.4.1(A)(ii). |
| More than 9 mts and upto 12 mts. | 4.50 | |
| More than 12 mts and upto 18 mts. | 6.00 | |
| More than 18 mts and upto 40 mts. | 7.50 | |

(4 ) THE AREA OF ROOMS:

| | |
|---|---|
| Bed rooms, living rooms, drawing room, dining room (min) …. | 9.4 sq mts |
| Kitchen and store rooms (min) | 5.45 sq mts |
| Bathrooms and dressing rooms … | 1.85 – 4.5 sq mts |
| Water Closet ( WC ); Urinal rooms . | 0.89 – 1.1 sq mts |

( 5 ) HEIGHT OF ROOF: Roof height on each floor is 2.7 mts ( min ) and for bath room and WC is 2.1 mts ( min)

(6) AREA OF DOORS, WINDOWS & VENTILATORS: This shall be $1/6^{th}$ to $1/10^{th}$ of the floor area of the room. In addition, every room should have ventilator .

(7) STAIR CASE: The stair case shall have area not more than 12 sq

mts. The pitch shall be in the range of 30$^o$ to 45$^o$ and flight shall have steps neither < 3 nor > 12. Minimum width of stair shall be 900 mm.

(8) LIFT: This shall be provided for buildings having more than 3 floors excluding the ground floor.

(9) SEPTIC TANK: shall be provided as per number of floors / rooms .

(10) HEIGHT OF COMPOUND WALL: The maximum height of compound wall on road side shall not be more than 1.5 mts and the gates shall open inwards. On other sides, the height of compound was shall be 1.8 mts.
(11) OPEN SPACE: The open space width shall be 1.8 mts ( min) and 3 mts ( max) for front, rear and sides .

(12) PARKING SPACE: Parking spaces for cars required for cinemas, shopping areas and offices located in central areas are to be allocated as per National Building Code.

**BUILDING BYE-LAWS**: Every locality has its own peculiarities in respect of weather conditions, availability of material and labour and thus adopts its own method of construction. In addition, every locality has certain rules and regulations which help in controlling the development of locality. The rules and regulations covering the requirements and ensure the safety of the public, minimum use of rooms , area limitations are known as "Building bye-laws". Building bye-laws are necessary to achieve the following objects:

- Gives guidelines to the architects / engineer and thus help in pre-planning the building activities.

- Allow to prevent haphazard development

• Afford safety against fire, noise pollution, structural failures etc..

While framing building bye-laws assistance of experts on various subjects such as town planning, law, health, civil engineering, traffic, general administrations etc should be sought due its weightage.

Indian Standard Institution, an organization of Govt of India has published IS 1256 "code of building laws" covering all the salient aspect of building activities.. National Building Code ( NBC) was published by the Govt of India for smooth running of building activities by realizing the importance of building bye-laws.

**EARTHQUAKE RESISTANT BUILDINGS:** A sudden movement of the Earth's surface often causing a damage is called as Earthquake. So, Earthquake causes vibrations /motions in ground in random fashion, both horizontally and vertically and also in all directions radiating from the epicenter. The intensity and duration of seismic vibrations depends upon magnitude of the earthquake , its depth of focus, distance from epicenter etc… It is therefore essential to ensure (i) stability, (ii) strength (iii) serviceability by means of design of the building.

Earthquake causes shaking of the ground so that a building resting on it will experience motion at its base and leads to collapse finally due to the resulting inertia forces.

From Newton's first law of motion even though the base of the building moves with the ground, the roof has of tendency to stay in its original position. But since the walls and columns are connected to it, they drag the roof along with them. This gives rise to **inertia forces** on the roof element.

Structural elements such as floor slabs, walls, columns and foundations and the connections between them must be designed to safely transfer

these inertia forces through them. Walls or columns are the critical elements in transferring the inertia forces. But , in traditional construction, slabs and beams receive more care and attention during design and construction than walls and columns. Failure of masonry walls have been observed because of their thin and materials used for it , in the past due to earthquake effect. Hence, importance also is to be given for walls and columns.
Twist in buildings due to earthquake induces more damage of window frames and walls. It is best to minimize this twist by ensuring that buildings have symmetry in plan. Indian Seismic Code ( IS 1893: 2002) has provisions to come certain issues.

INDIAN SEISMIC CODES for earthquake resistant building: An earthquake
resistant building has the following virtues:

(i)Good structural configuration: Its size, shape and structural system carrying loads are such that they ensure a direct and smooth flow of inertia forces to the ground.

(ii) Adequate stiffness: Load resistant system is to be followed so that the earthquake induced deformations in it do not damage under low to moderate shaking.

(iii) Lateral strength : The maximum lateral ( horizontal ) force can resist the damage induced by an earthquake.
(iv) Good ductility: Favourable design and detailing strategies resist the building from the earthquakes.

**Considerable factors in case of earthquake zones:**

Walls transfer loads to each other at their junctions and hence the masonry courses from the walls meeting at corners must have good interlocking. Large openings weaken walls from carrying the inertia forces and it is best to keep all openings as small as possible and as far away from the corners as possible. A variety of masonry units are used in the country eg clay bricks, concrete blocks, stone blocks. Since bricks are inherently porous and absorb water resulting in poor bond between brick and mortar. Hence, bricks with low porosity are to be used to inimize the amount of water drawn away from the mortar.

Various mortars are used eg mud, cement – sand, cement-sand-lime.

Excessive thickness of mortar is not desirable. Indian Standards prescribe the preferred types and grades of bricks and mortars to be used in buildings in each seismic zone.
Wall thickness should not exceed 450 mm. Round stone boulders should not be used in the construction. Since the earthquake force is a function of mass, the building shall be as light as possible.

As far as possible, the parts of the building should be tied together in such a manner that the building acts as one unit. Projecting parts shall be avoided as far as possible. If the projecting parts cannot be avoided , they shall be properly reinforced and firmly tied to the main structure and their design shall be in accordance with IS 1893: 2002.

Buildings having plans with shapes like L – T – E – Y shall preferably be separated into rectangular parts by providing separation sections at appropriate places.

Structures shall not be founded on loose soils which will subside during an earthquake.