UNIT II
BUILDING COMPONENTS AND STRUCTURES

Foundations: Types, Bearing capacity – Requirement of good foundations.
Superstructure: Brick masonry – stone masonry – beams – columns – lintels – roofing – flooring –plastering – Mechanics – Internal and external forces – stress – strain – elasticity – Types of Bridges and Dams – Basics of Interior Design and Landscaping.

2.1 Introduction

Every family needs a building to reside. Apart from residential purposes buildings are required for educational, institutional, business, assembly and for industrial purposes. Buildings are required for the storage of materials also.

In this chapter basic requirements of buildings are presented and then planning of the building with respect to orientation, utility of space, energy efficiency and other requirements are explained.

2.1.1 Elements of a building

The following are the basic elements of a building:

1. Foundation
2. Plinth
3. Walls and columns
4. Sills, lintels and chejjas
5. Doors and windows
6. Floors
7. Roofs
8. Steps, stairs and lifts
9. Finishing work
10. Building services.

The functions of these elements and the main requirement of them is presented in this article.

1. Foundation: Foundation is the most important part of the building. Building activity starts with digging the ground for foundation and then building it. It is the lower most part of the building. It transfers the load of the building to the ground. Its main functions and requirements are:

(*a*) Distribute the load from the structure to soil evenly and safely.

(*b*) To anchor the building to the ground so that under lateral loads building will not move.

(*c*) It gives level surface for the construction of super structure.

2. Plinth: The portion of the wall between the ground level and the ground floor level is called plinth. It is usually of stone masonry. If the foundation is on piles, a plinth beam is cast to support wall above floor level.

At the top of plinth a damp proof course is provided. It is usually 75 mm thick plain concrete course.

The function of the plinth is to keep the ground floor above ground level, free of dampness. Its height is not less than 450 mm. It is required that plinth level is at least 150 mm above the road level, so that connections to underground drainage system can be made.

3. Walls and Columns: The function of walls and columns is to transfer the load of the structure vertically downwards to transfer it to foundation. Apart from this wall performs the following functions also:

(*a*) It encloses building area into different compartments and provides privacy.

(*b*) It provides safety from burglary and insects.

(*c*) It keeps the building warm in winter and cool in summer.

4. Sills, Lintels and Chejjas: A window frame should not be directly placed over masonry. It is placed over 50 mm to 75 mm thick plain concrete course provided over the masonry. This course is called as sill. Lintels are the R.C.C. or stone beams provided over the door and window openings to transfer the load transversely so as to see that door or window frame is not stressed unduly. The width of lintels is equal to the width of wall while thickness to be provided depends upon the opening size. Chejja is the projection given outside the wall to protect doors and windows from the rain. They are usually made with R.C.C. In low cost houses stone slabs are provided as chejjas. The projection of chejja varies from 600 mm to 800 mm. Sometimes drops are also provided to chejjas to improve acsethetic look and also to get additional protection from sun and rain.

5. Doors and Windows: The function of a door is to give access to different rooms in the building and to deny the access whenever necessary. Number of doors should be minimum possible. The size of the door should be of such dimension as will facilitate the movement of the largest object likely to use the door.

Windows are provided to get light and ventilation in the building. They are located at a height of 0.75 m to 0.9 m from the floor level. In hot and humid regions, the window area should be 15 to 20 per cent of the floor area. Another thumb rule used to determine the size and the number of windows is for every 30 m^3 of inside volume there should be 1 m^2 window opening.

6. Floors: Floors are the important component of a building. They give working/useful area for the occupants. The ground floor is prepared by filling brick bats, waste stones, gravel and well compacted with not less than 100 mm sand layer on its top. A lean concrete of 1 : 4 : 8, 100 mm thick is laid. On this a damp proof course may be provided. Then floor finishing is done as per the requirement of the owner. Cheapest floor finish for a moderate house is with 20 to 25 mm rich mortar course finished with red oxide. The costliest floor finish is mossaic or marble finishing.

7. Roof: Roof is the top most portion of the building which provide top cover to the building. It should be leak proof. Sloping roof like tiled and A.C. sheet give leak proof cover easily. But they do not give provision for the construction of additional floor. Tiled roof give good thermal protection.

Flat roofs give provision for additional floors. Terrace adds to the comfort of occupants. Water tanks can be easily placed over the flat roofs.

8. Step, Stairs and Lifts: Steps give convenient access from ground level to ground floor level. They are required at doors in the outer wall. 250 to 300 mm wide and 150 mm rise is ideal size for steps. In no case the size of two consecutive steps be different. Number of steps required depends upon the difference in the levels of the ground and the floor. Stairs give access from floor to floor. They should consists of steps of uniform sizes.

In all public buildings lifts are to be provided for the conveniences of old and disabled persons. In hostels G + 3 floors can be built without lifts, but in residential flats maximum floors permitted without lifts is only G + 2. Lift is to be located near the entrance. Size of the lift is decided by the number of users in peak hours. Lifts are available with capacity 4 to 20 persons.

9. Finishing: Bottom portion of slab (ceiling), walls and top of floor need smooth finishing with plaster. Then they are provided with white wash, distemper or paints or tiles. The function of finishing work is:

(*a*) Give protective cover

(*b*) Improve aesthetic view

(*c*) Rectify defective workmanship

(*d*) Finishing work for plinth consists in pointing while for floor it consists in polishing.

10. Building Services: Water supply, sanitation and drainage works, electric supply work and construction of cupboards and show cases constitute major building services.

For storing water from municipal supply or from tanker a sump is built in the house property near street. From the sump water is pumped to over head tanks placed on or above roof level so as to get water all the 24 hours. Plumbing work is made so as to get water in kitchen, bathrooms, water closets, sinks and garden taps.

For draining rain water from roofs, down take pipes of at least 100 mm diameters should be used. Proper slopes should be given to roof towards down take pipe. These pipes should be fixed at 10 to 15 mm below the roof surface so that rain water is directed to the down take pipe easily.

The sanitary fittings are to be connected to stone ware pipes with suitable tr

aps and chambers. Stone ware pipes are then connected to underground drainage of municipal lines or to the septic tank.

Many carpentry works are required for building service. They are in the form of showcases, cupboards, racks etc.

Electric supply is essential part of building services. The building should be provided with sufficient points for supply of lights, fans and other electric gadgets.

2.1.1.2 Basic requirements of a building

The planning and construction of a building should be aimed at fulfilling the following requirements:

1. Strength and stability
2. Dimensional stability
3. Resistance to dampness
4. Resistance to fire
5. Heat insulation
6. Sound insulation
7. Protection against termite attack
8. Durability
9. Security against burglary
10. Lighting and ventilation
11. Comforts and convenience
12. Economy.

1. Strength and Stability: Building should be capable of transferring the expected loads in its life period safely to the ground. Design of various structural components like slabs, beams, walls, columns and footing should ensure safety. None of the structural components should buckle, overturn and collapse.

2. Dimensional Stability: Excessive deformation of structural components give a sense of instability and result into crack in walls, flooring etc. All structural components, should be so designed that deflections do not exceed the permissible values specified in the codes.

3. Resistance to Dampness: Dampness in a building is a great nuisance and it may reduce the life of the building. Great care should be taken in planning and in the construction of the building to avoid dampness.

4. Resistance to Fire: Regarding achieving resistance to fire, the basic requirements laid down in the codes are:

(*a*) the structure should not ignite easily.

(*b*) building orientation should be such that spread of fire is slow.

(*c*) In case of fire, there should be means of easy access to vacate building quickly.

5. Heat Insulation: A building should be so oriented and designed that it insulates interior from heat.

6. Sound Insulation: Buildings should be planned against outdoor and indoor noises.

7. Protection from Termite: Buildings should be protected from termites.

8. Durability: Each and every component of the building should be durable.

9. Security against Burglary: This is the basic need the owner of the building expects

10. Lighting and Ventilation: For healthy and happy living natural light and ventilations are required. Diffused light and good cross ventilation should be available inside the building.

11. Comforts and Conveniences: Various units in the building should be properly grouped and integrated keeping in mind the comfort and convenience of the user.

12. Economy: Economy without sacrificing comfort, convenience and durability is another basic requirement of the building.

2.1.1.3 PLANNING

All buildings should be properly planned, keeping in view the various requirements of a good building. Except strength requirement, all other requirements of a good buildings are taken care at the stage of planning. Strength requirement is taken care during structural design of building components. However in planning the building by-laws of the statutory authorities should not be violated. Planning of the building is an art combined with science.

Principles of planning of buildings may be grouped into:

1. Orientation
2. Energy efficiency
3. Utility
4. Other requirements of the building.

2.1.1.4 Planning suitable orientation

Orientation means setting out the plan of the building with respect to north-south and east-west directions to provide an opportunity to user to enjoy sun-shine and breeze when required and to avoid the same whenever not required. This is also known as planning the aspect of a building. Aspect means arrangement of doors, windows in the external wall to make good use of nature. This term has nothing to do with the architectural aspect of outlook of building. Kitchen should have eastern aspect to enjoy morning sunshine, means, kitchen should be located on the eastern side of the building to make use of morning sun rays. The following are the required aspects for various parts of the building in the northern hemisphere of earth:

(*a*) Kitchen–eastern aspect.

(*b*) Dining room–southern aspect to enjoy winter sun.

(*c*) Drawing and living room–southern or south-eastern aspect to enjoy winter sun. (*d*) Bed rooms–western or south-western aspect to enjoy breez in summer.

(*e*) Reading room, class room, stairs, northern aspect to enjoy diffused light.

2.1.1.5 Planning for energy efficiency

A building should be planned in such a manner that it gives maximum day lighting, ventilation and heat insulation. If these requirements are fulfilled, requirement of electric energy comes down.

(*a*) Light: Natural light provides hygenic atmosphere. Light should not be glaring but it should be uniformly distributed. Providing windows and ventilators of appropriate size at suitable positions contributes a lot for natural lighting. For residential buildings window area to floor area should not be less than 1/10th while for school buildings it should not be less than 1/5th of floor area. For factory buildings north light trusses should be provided to get maximum diffused light.

(*b*) Ventilation: Ventilation is the circulation of the air in the building. Natural ventilation can be achieved by selecting and positioning of doors, windows and ventilators at suitable places. Always cross ventilations should be planned suitably. Provision of ventilators at roof level helps in driving out hot airs. In case it is not possible to achieve natural ventilation for any part of the building provide ordinary or exhaust fans.

(*c*) Heat Insulation: Thicker exterior walls provide insulation against heat. Proper ventilation also helps in achieving heat insulation. Sun shades provided to doors, windows and ventilators help in achieving heat insulation. In factories and assembly halls height should be more to reduce temperature inside the building. The position of furnaces in the factories should be located away from the other parts of the factory. The openings should be provided at higher level in the wall to remove hot air.

2.1.1.6 Planning for suitable utility

Principles of planning for suitable utility are:

1. Roominess
2. Furniture Requirements
3. Groupings
4. Circulation.

2.1.1.7 Planning for meeting other requirements

Principle of planning involves planning for meeting the following requirements also:

1. Sanitary convenience
2. Prospects
3. Elegance
4. Flexibility
5. Privacy
6. Resistance to fire
7. Sound insulation
8. Protection from termite
9. Security against burglary
10. Econoy
11. Provisions for future alterations.

2.2 Conventional spread footings

This type of foundations is commonly used for walls and masonry columns. These foundations are built after opening the trenches to required depth. Such footings are economical up to a maximum depth of 3 m. As these foundations are suitable depth, they are grouped under *shallow foundations.*

Figure 2.2.1 shows a conventional spread footing for a wall and Fig. 2.2.2 shows it for a masonry column.

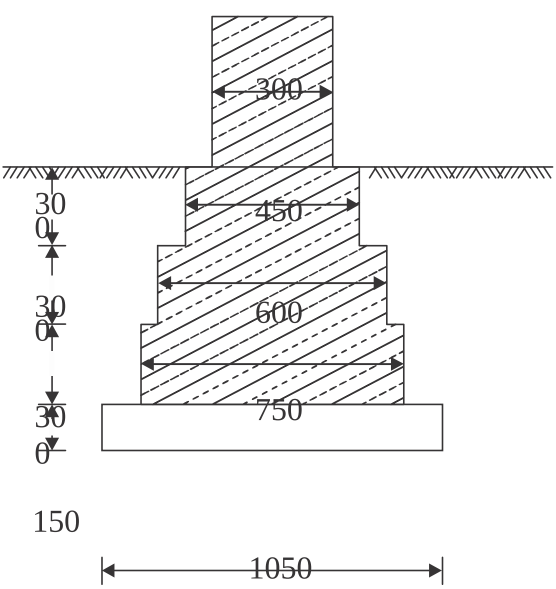


Fig. 2.2.1. Wall footing

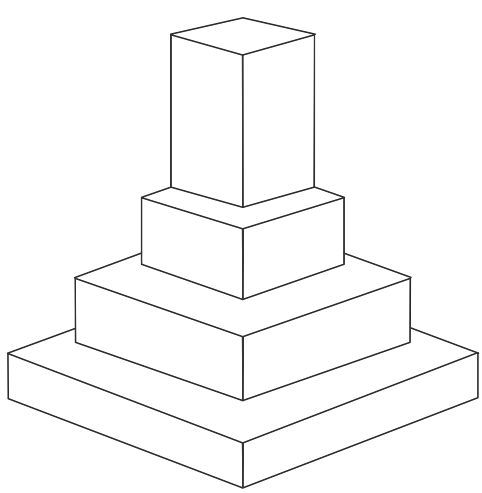


Fig. 2.2.2 Foundation for masonry pier

Before building these footing trenches are opened to required depth and the soil is rammed well. Then a plain concrete of mix 1 : 4 : 8 is provided. Its thickness varies from 150 to 200 mm. Over this bed, stone masonry footing is built. It is built in courses each course projecting 50 to 75 mm from the top course and height of each course being 150 to 200 mm. In case of wall footing the projections are only one direction while in case of columns, they are in both directions. The projection of bed concrete from the lowest course of foundation masonry is usually 150 mm.

2.2.2 R.C.C. footings

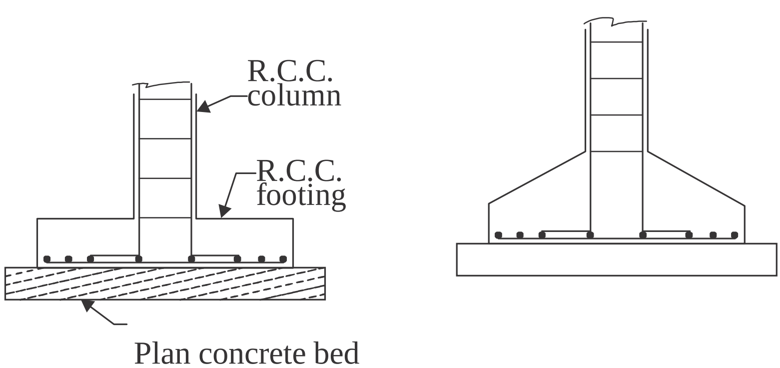
There are mainly two types of R.C.C. footings:

1. One way reinforced footings.
2. Two way reinforced footings.

1. One Way Reinforced Footing: These footings are for the walls. In these footings main reinforcements are in the transverse direction of wall. In longitudinal directions there will be only nominal reinforcement.

2. Two Way Reinforced Footings: For columns two way reinforced footings are provided. The following types of the footings are common:

(*i*) Isolated Column Footings: If separate footings are provided for each column, it is called isolated column footing. Figure 2.2.2.1 shows a typical isolated column footing. The size of footing is based on the area required to distribute the load of the columns safely over the soil .These footings are provided over a 100 to 150 mm bed concrete. Required reinforcements and thickness of footing are found by the design engineers. Thickness may be uniform or varying.



(a) Footing with uniform thickness (b) Sloping footing

Fig. 2.2.2.1 Isolated R.C.C. footing

(*ii*) Combined Footings: Common footings may be provided for two columns. This type of footing is necessary when a column is very close to the boundary of the property and hence there is no scope to project footing much beyond the column face. Figure 2.2.2.2 shows a typical combined footing. The footing is to be designed for transferring loads from both columns safely to the soil. The two columns may or may not be connected by a strap beam.

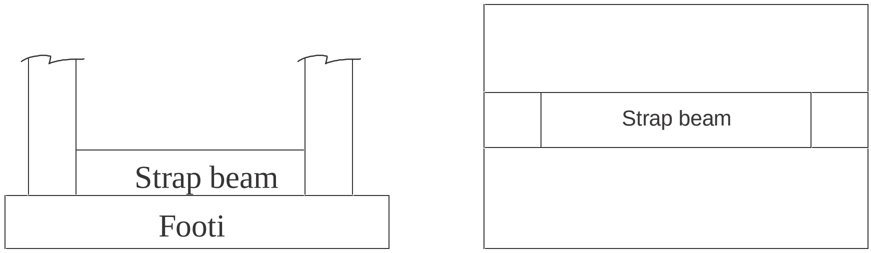


Fig. 2.2.2.2. Combined footing [Strap beam may or may not be provided]

(*iii*) Continuous Footings: If a footing is common to more than two columns in a row, it is called continuous footing. This type of footing is necessary, if the columns in a row are closer or if SBC of soilis low. Figure 2.2.2.3shows this type of footing.

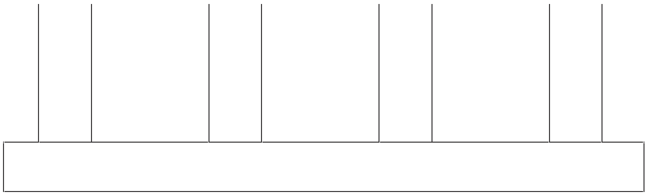


Fig.2.2.2.3 Continuous footing

(*iv*) Mat Footing/Raft Footing: If the load on the column is quite high (Multistorey columns) or when the SBC of soil is low, the sizes of isolated columns may work out to be to such an extent that they overlap each other. In such situation a common footing may be provided to several columns as shown in Fig. 2.2.2.4 Such footings are known as raft footings.

If the beams are provided in both directions over the footing slab for connecting columns, the raft foundations may be called as grid foundation also.

The added advantage of such footing is, settlement is uniform and hence unnecessary stresses are not produced.

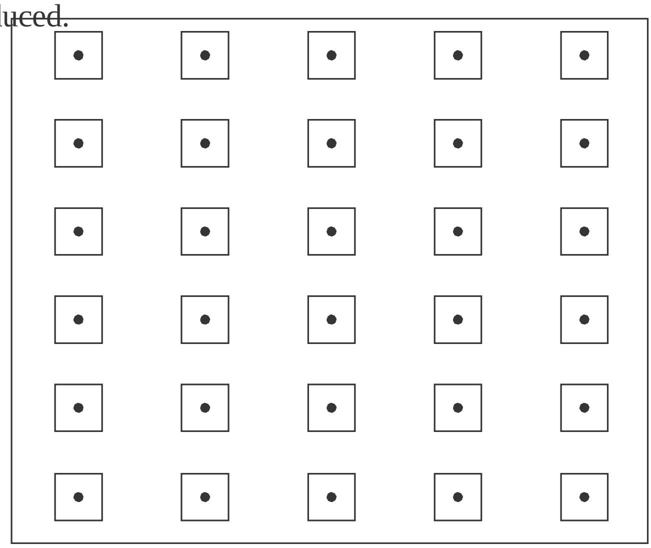
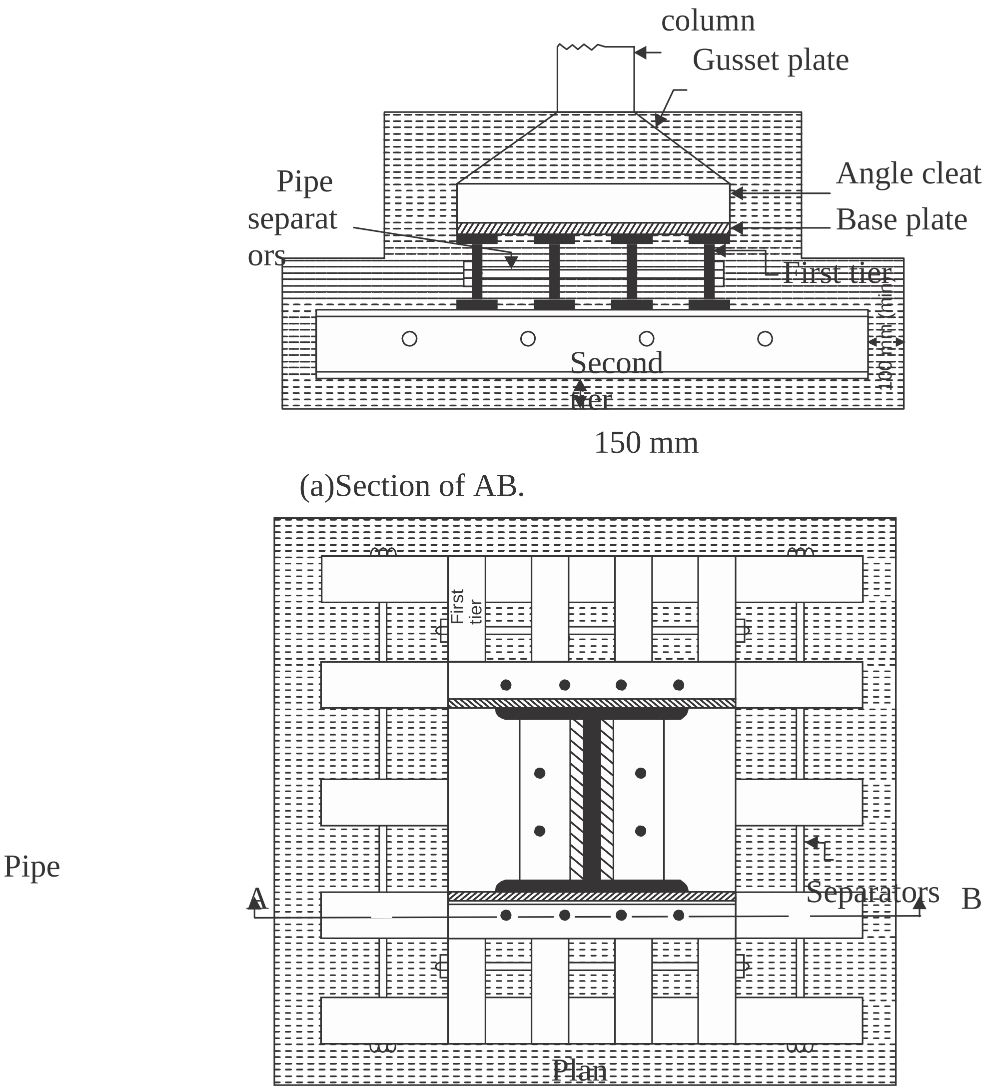


Fig.2.2.2.4 Raft foundation

2.2.2.1 Grillage footing

High rise buildings are built with steel columns encased in concrete. Such columns carry very heavy load and hence they need special foundations to spread the load to a larger area of soil. Grillage foundation is one such special foundation. It consists of one tier or more tiers of I-sections steel beams. Fig 2.2.2.5 shows a typical two tier grillage foundation. Top tier consists of less number but large size steel section while lower tier consists of larger number but smaller size steel sections. Column load is transferred to the top tier through a base plate. The grillage beams are unpainted and are encased in concrete with minimum cover of 100 mm beyond the edges of steel sections. A minimum clear space of 75 mm should be maintained between the flanges of adjacent grillage beams so that concreting can be made properly.To maintain spacing, pipe separators are used.

Fig. 2.2.2.5 Grillage foundation



2.2.3 Arch foundation

Inverted arch foundations are provided in the places where the SBC of the soil is very poor and the load of the structure is through walls. In such cases inverted arches are constructed between the walls. End walls should be sufficiently thick and strong to withstand the outward horizontal thrust due to arch action. The outer walls may be provided with buttress walls to strengthen them. Figure 2.2.3.1 shows a typical inverted arch footing.

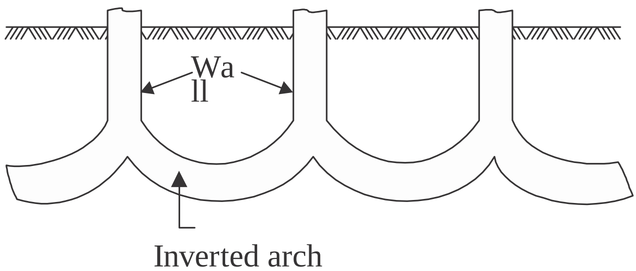
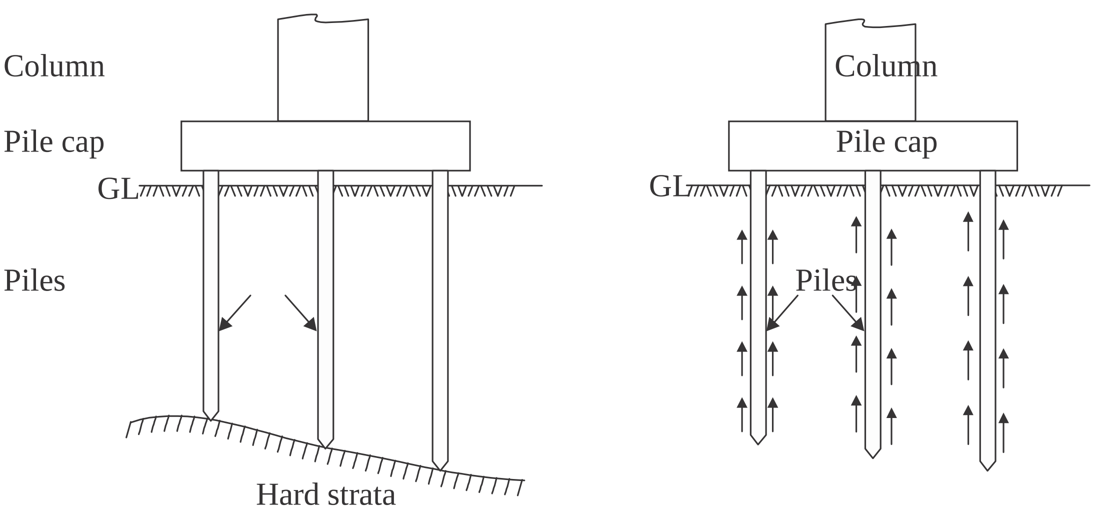


Fig. 2.2.3.1 Inverted arch footing

2.2.4 Pile foundations

These foundations are known as deep foundations. A pile is a slender column made of wood, concrete or steel. A pile is either driven into the soil or formed in situ by excavating a hole and then filling it with concrete. A group of piles are driven to the required depth and are capped with R.C.C. slab, over which super structure is built. The pile transfer the load to soil by friction or by direct bearing, in the latter case, piles being taken up to hard strata. This type of foundations is used when top soil is not capable of taking the load of the structure even at 3–4 m depth.



(a) Bearing pile (b) Friction pile

Fig. 2.2.4.1 Pile foundations

Pile foundations are classified according to the materials used and also on the nature of load transfer.

Classification According to Materials Used:

Piles may be classified as:

(*a*) Timber piles

(*b*) Concrete piles

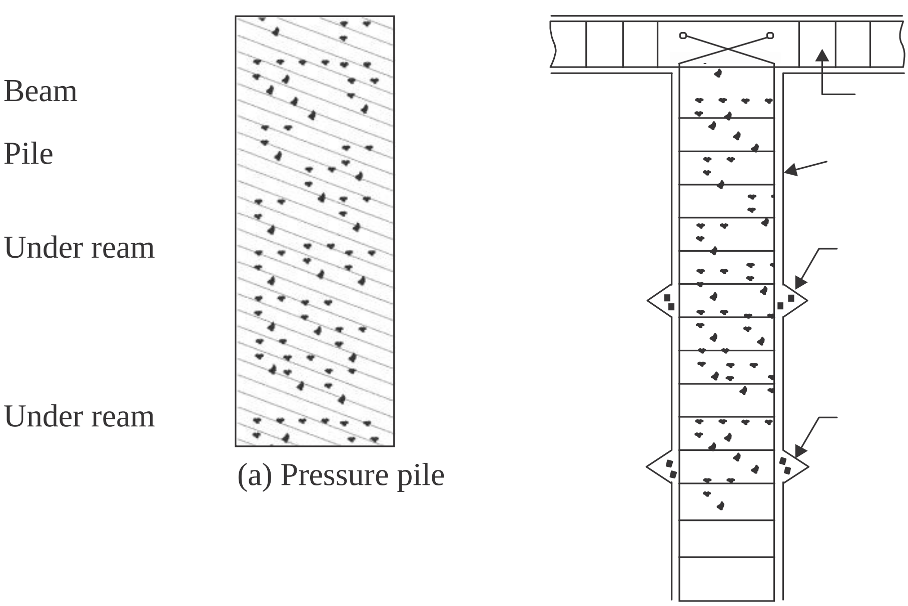
(*c*) Steel piles and

(*d*) Composite piles.

(*a*) Timber piles: Circular seasoned wood can be used as piles. Their diameter may vary from 200 mm to 400 mm. Similarly square piles of sizes 200 mm to 400 mm are also used. The length of timber pile should not be more than 20 times its lateral dimension. The bottom of the pile is sharpened and is provided with iron shoe, so that it can be driven in the ground easily by hammering. These piles should be always kept below water table; otherwise alternating wet and dry condition cause the decay. These piles are cheap and can be easily driven rapidly. The main disadvantage is their load carrying capacity is low and are likely to be damaged during driving in the soil.

(*b*) Concrete piles: These piles may be further classified as precast piles and cast in situ piles. *Precast piles* are reinforced with steel and are manufactured in factories. The cross-section diameter/dimension varies from 200 mm to 500 mm. Square, circular and octagonal sections are commonly used. The length of piles may be up to 20 m. They are provided with steel shoe at the lowest end. These piles can carry fairly large loads. These piles are highly resistant to biological and chemical actions of the soil. The disadvantage of these piles is they need more time to manufacture and are heavy to handle.

Figure 2.2.4.2(*a*) and (*b*) show concrete piles.



(a) Pressure pile

(b) Under-reamed pile

Fig. 2.2.4.2. Cast in situ concrete pile

Cast in situ concrete piles are formed first by boring the holes in the soil and then concreting them. Concreting is usually made using casing tubes. If the hole is filled with only plain concrete it is pressure pile. The load carrying capacity of the piles may be increased by providing enlarged base.

The reinforcement caging may be inserted in the bored holes and to increase load carrying capacity one or two under reams may be formed. After that concreting may be carried out. Such piles are known as under reamed piles. These piles are provided at regular interval of 2 to 4 m and capping beam is provided over them.

(*c*) Steel Piles: A steel pile may be a rolled steel I sections, tubes or fabricated in the form of box. These piles are mostly used as bearing piles since surface available for friction is less and also the coefficient of friction is less. If tubes are used the soil inside the tube is driven out by compressed air and concrete is filled. These piles are very useful for driving close to existing structures since they disturb the soil least.

(*d*) Composite Piles: Composite piles may be of concrete and timber or of concrete and steel. Wooden piles should not be subjected to alternating wet and dry conditions. Hence they are preferred for the portion below water table. The portion above water table are built with cast in situ concrete piles.

If the required length of steel piles is less than the depth of pile, many times upper portions are built with concrete. Thus steel and concrete composite piles are sometimes used.

Classification of Piles According to Load Transfer:

According to the load transfer to the soil piles may be classified as

(*a*) Bearing piles and

(*b*) Friction piles.

Bearing piles rest on hard strata and transfer the load by bearing. Such piles are preferred. These piles are used if the hard strata are available at reasonable depth.

Friction piles transfer the load to the soil by the friction between soil and the pile. Such piles are used if hard strata are not available to a considerable depth. The friction developed is to be properly assessed before deciding the length of the pile. The surface of such piles is made rough to increase the skin friction so that required length of pile is reduced.

2.2.2.5 Stone masonry

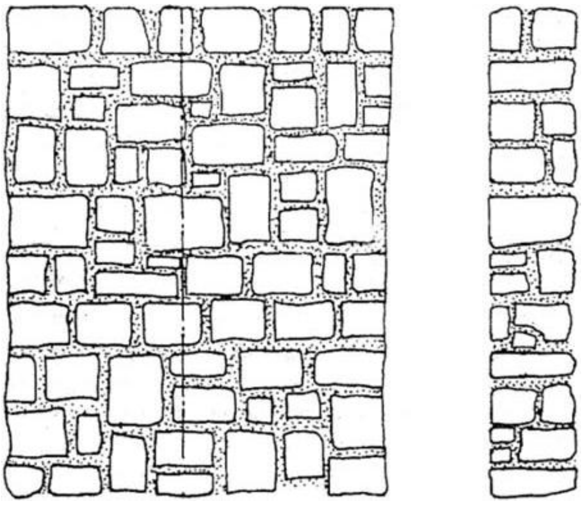
Masonry means construction of buildings using building blocks like stone, bricks, concrete blocks etc. Masonry is used for the construction of foundation, plinth, walls and columns. Mortar is the binding material for the building blocks. In this article different types of stone masonry used are explained and points to be observed while supervising stone masonry works are listed.

TypesofStone Masonry

Mainly there are two types of stone masonry:

1. Rubble Masonry
2. Ashlar Masonry.

1. Rubble Masonry: In this type of constructions stones of irregular sizes and shapes are used. To remove sharp shapes they may be hammered. The rubble masonry may be *coursed* or *uncoursed* [Fig. 2.2.2.5.1 and 2.2.2.5.2]. In *uncoursed rubble masonry* the wall is brought to level at every 300 mm to 500 mm. The mortar consumed in these construction is more. Course rubble masonry is used for the construction of public and residential buildings. Uncoursed rubble masonry is used for the construction of foundations, compound walls, garages, labour quarters etc. A skilled mason may arrange the facing stones in *polygonal shapes* to improve the aesthetic of the wall.



(a) Elevation (b) Section x – x

Fig.2.2.2.5.1 Uncoursed rubble masonry

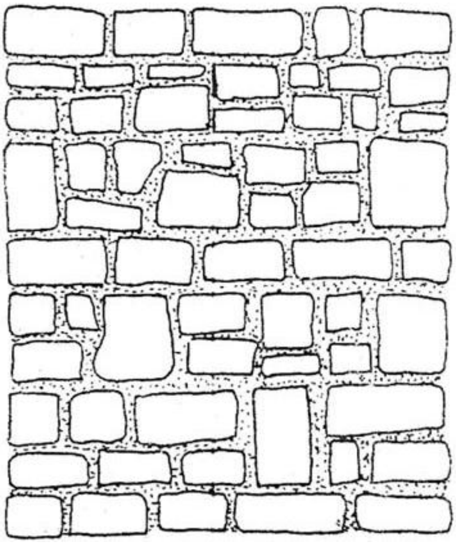
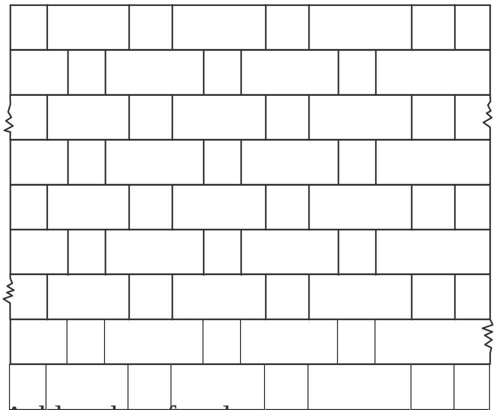


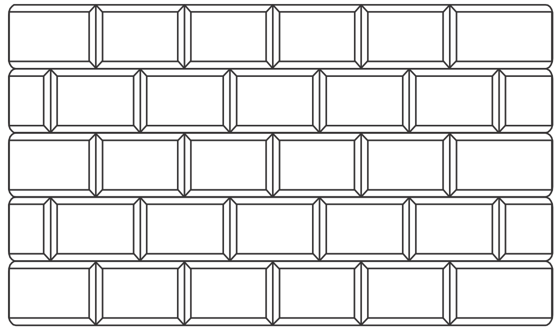
Fig. 2.2.2.5.2 Coursed rubble masonry

2. Ashlar Masonry: In this type of masonry stones are dressed to get suitable shapes and sizes. The height of the stones varies from 250 mm to 300 mm. The length should not exceed three times the height. The dressing of the stone need not be very accurate on all sides. Usually good dressing is made on facing side. In such construction mortar consumption is less compared to rubble masonry.

There are different types of ashlar masonry depending upon the type of dressing such as Ashlar fine dressed, Ashlar rough dressed, Ashlar rock or quarry faced, Ashlar facing, Ashlar chamfered etc. Figure 8.3 show some of such masonry



(b) Ashlar chamfered



(a)Fig.2.2.2.5.3 Fine finished ashlar

Fig.2.2.2.5.4Ashlar masonry

Supervision of Stone Masonry Construction

The following points should be kept in mind in supervising stone masonry work:

1. Hard and durable stones, free from defects like flaws, cavities veins etc. should be used.
2. Dressing of the stones should be as per the requirement.
3. Stones should be properly wetted before they are used so as to avoid sucking of water from mortar.
4. Stones should be laid on their natural bed.
5. Facing and backing faces should be laid neatly and levelled and checked with wooden template.
6. The heart of masonry should be filled with stone chips and mortars. To thick mortar joints should be avoided.
7. Verticality of the wall should be frequently checked with plumb-bob.
8. Mortars with correct proportion of sand and cement should be used.
9. Continuous vertical joints should be avoided.
10. Through stones should be used within 1.5 m distances.
11. The height of masonry should be raised uniformly.
12. Under the beams, trusses, sills etc large flat stones should be used.
13. Before continuing work, the masonry built on previous day should be well cleaned and freed from loose particles.
14. Curing should be done properly for 2 to 3 weeks.

2.6 Brick masonry

Brick masonry is built with bricks bonded together with mortar. For temporary sheds mud mortar may be used but for all permanent buildings lime or cement mortars are used.

The various types of bonds generally used in brick masonry are

1. Stretcher bond
2. Header bond
3. English bond and
4. Flemish bond.

1. Stretcher Bond: A stretcher is the longer face of the brick as seen in the elevation. In the brick of size 190 mm × 90 mm × 90 mm, 190 mm × 90 mm face is the stretcher. In stretcher bond masonry all the bricks are arranged in stretcher courses as shown in Fig. 2.6.1 However care should be taken to break vertical joints. This type of construction is useful for the construction half brick thick partition wall.

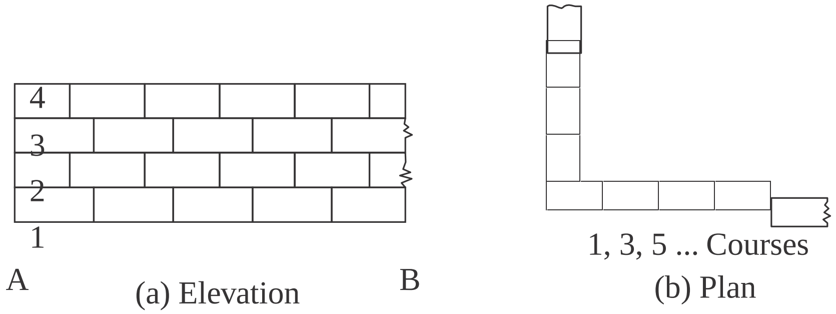


Fig. 2.6.1 Stretcher bond

2. Header Bond: A header is the shorter face of the brick as seen in the elevation. In a standard brick it is 90 mm × 90 mm face. In header bond brick masonry all the bricks are arranged in the header courses as shown in Fig. 2.6.2. This type of bond is useful for the construction of one brick thick wall

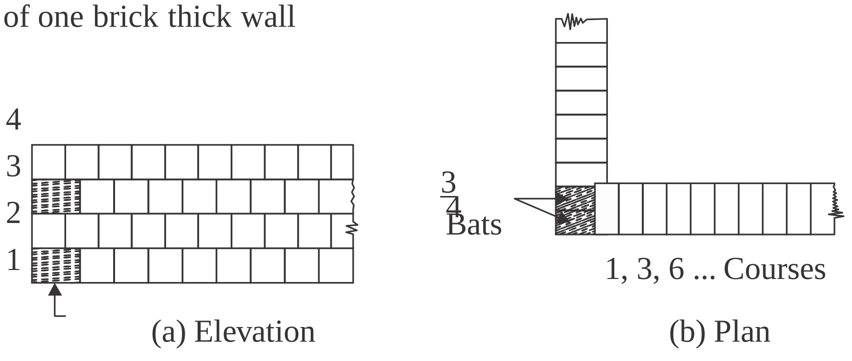


Fig. 2.6.2 Header bond

3. English Bond: In this alternate courses consist of headers and stretchers. This is considered to be the strongest bond. Hence it is commonly used bond for the walls of all thicknesses. To break continuity of vertical joints a brick is cut lengthwise into two halves and used in the beginning and end of a wall after first header. This is called queen closer. Figure 2.6.3 shows typical one brick and one and half brick thick wall with English bond.

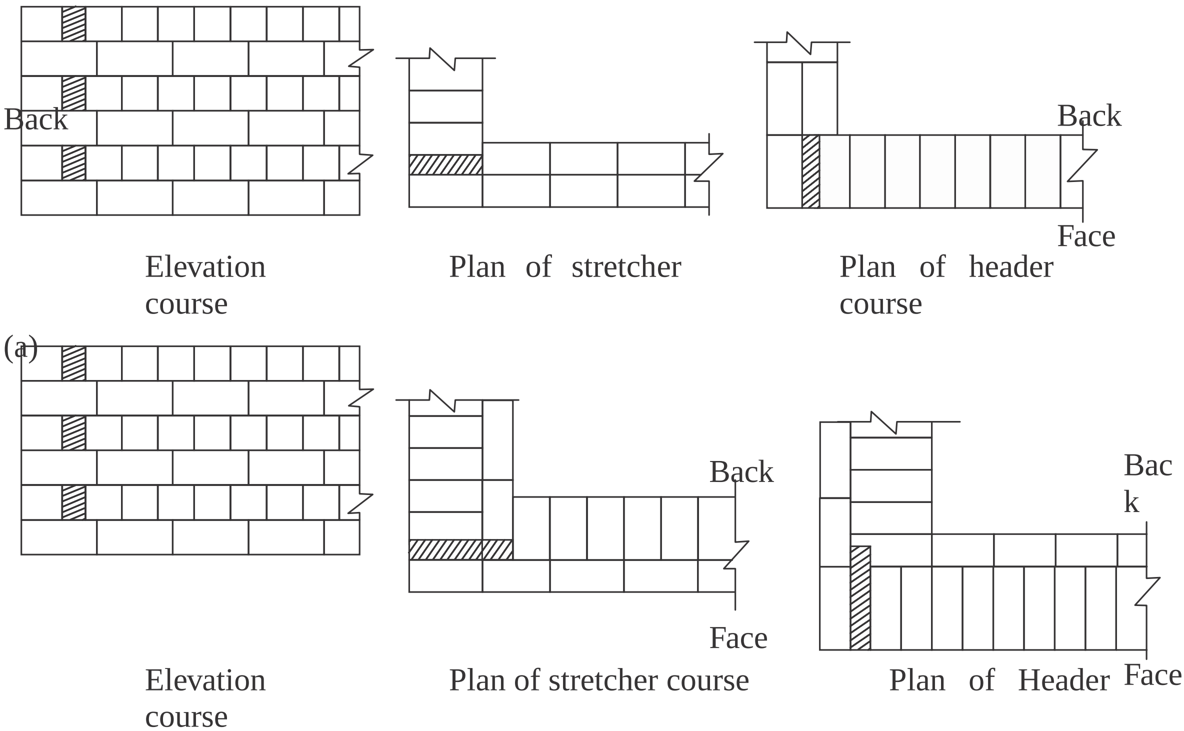


Fig. 2.6.3 English bond

4. Flemish Bond: In this type of bond each course comprises of alternate header and stretcher fig 2.6.4 Alternate courses start with stretcher and header. To break the vertical joints queen closers are required, if a course starts with header. Every header is centrally supported on the stretcher below it.

Flemish bonds may be further classified as

(*a*) Double Flemish Bond

(*b*) Single Flemish Bond.

In case of *double flemish bond*, both faces of the wall have flemish look, *i.e.* each course consist of alternate header and stretcher, whereas *single flemish bond* outer faces of walls have flemish look whereas inner faces have look of English bond

Construction of flemish bond needs greater skill. It gives more pleasing appearance. But it is not as strong as English bond. If only pointing is to be used for finished wall, flemish bond may be used to get good aesthetic view. If plastering is going to be used, it is better to use English bond.

The following points should be observed in the construction of brick masonry:

1. Use bricks of good quality with uniform colour, well burnt, with exact shape and size.
2. Before using the bricks in masonry, they should be soaked in water for 2 hours so that bricks do not absorb water from the mortar.
3. Bricks should be laid with the frog pointing upward.
4. Construction of brick wall should start from the end or corner.
5. Brick courses should be perfectly horizontal.
6. Verticality of the wall should be ensured by frequently checking with plumb-bob.
7. Mortar used should be as per specification.
8. Whenever work is stopped brick masonry should be left with toothed end.
9. Use of brick bats should be avoided.
10. Walls should be raised uniformly. In no case difference between adjoining walls be more than 1 m. In a day no wall should be raised by more than 1.5 m.
11. To get proper key for plastering or pointing, the face joints should be raised to a depth of 12 to 20 mm, when the mortar is green. If plastering or pointing is not to be provided, face joints should be stuck flush and finished neatly.
12. Holdfasts for doors and windows should be embedded in brick masonry with cement mortar or concrete, at the time of constructing the wall itself.
13. Brick masonry should be regularly cured for 2 weeks.
14. For carrying out brick work at higher levels, only single scaffolding should be used.

Advantages and Disadvantages of Brick Masonry Over Stone Masonry

Advantages:

1. Since shape and size of bricks are uniform, it do not need skilled labour for the construction.
2. Bricks are light in weight and hence handling them is easy.
3. Bricks are easily available around cities and their transportation cost is less because their weight is less. Stones are to be brought from quarries which are located only at few places.
4. It is possible to use all types of mortar in brick masonry. For unimportant buildings even mud mortar can be used.
5. Thinner walls can be constructed with bricks but it is not so with stones.
6. It is easy to form openings for doors and windows.
7. Dead load of brick masonry is less.
8. In brick masonry mortar joints are thin and hence construction cost is reduced considerably.
9. Brick masonry has better fire and weather resistance compared to stone masonry.

Disadvantages:

1. Strength of brick masonry is less than that of stone masonry.
2. Durability of brick masonry is less.
3. Brick masonry needs plastering and plastered surface needs colour washing. Stone masonry don't need them and hence maintenance cost is more in brick masonry.
4. Brick masonry absorbs water and there are possibility of dampness. There is no such problem in stone masonry.
5. More architectural effects can be given in stone masonry compared to that in brick masonry.
6. Stone masonry gives massive appearance and hence monumental buildings are built in stone masonry.

2.7 Beams

Beams are defined as horizontal load carrying member in a structure. Reinforced cement concrete, concrete, prestressed concrete and steel I sections are used as beams to support the slabs.

Classified:

- ✓ Simply supported beam
- ✓ Rigidly fixed beam
- ✓ Cantilever beam
- ✓ Over hanging beam
- ✓ Continuous beam

Simply supported beam:

If the ends of a beam are supported freely by columns it is called simply supported beam

Rigidly fixed beam:

It the two ends of a beam is rigidly fixed in walls then it is called fixed beams. In such cases, the moment is induced at supports because it will not allow rotation.

Cantilever beam:

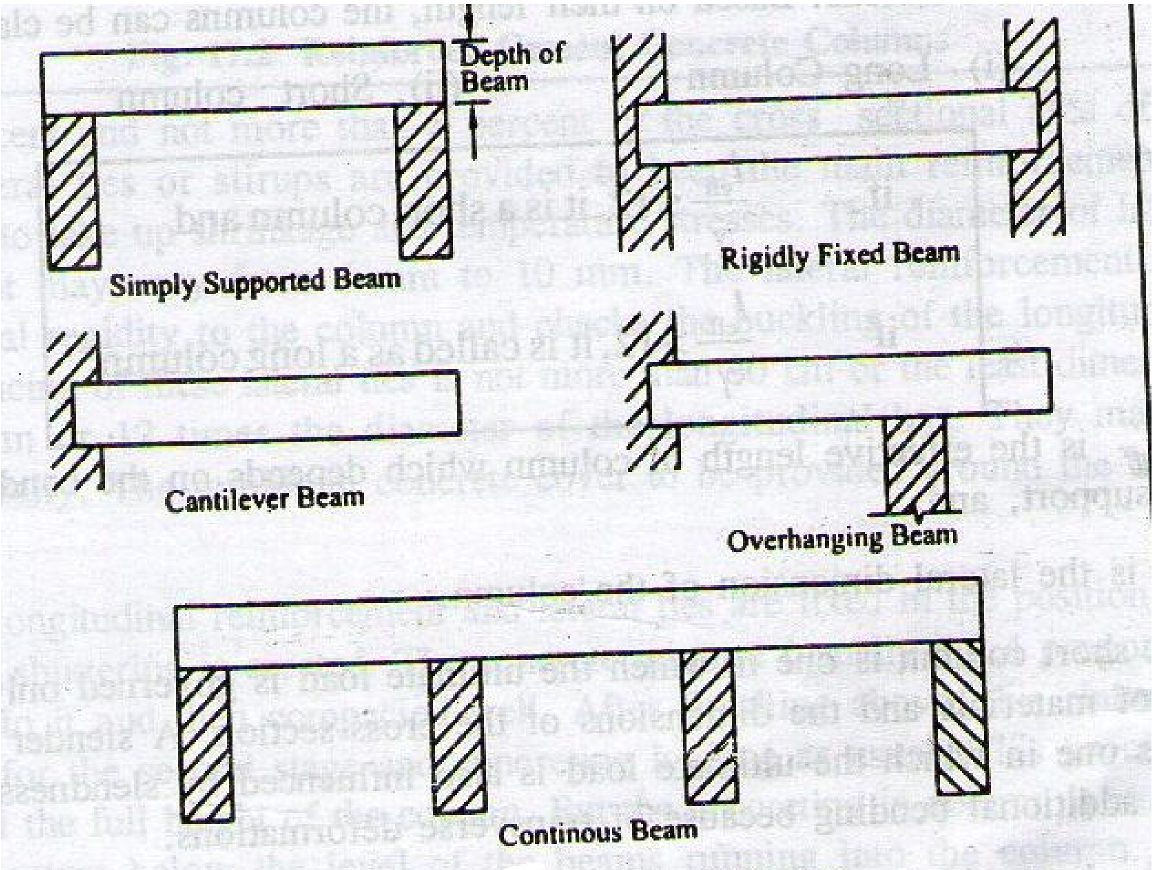
If a beam is fixed in one end and the other end is free then it is called cantilever beam.

Overhanging beam:

If a beam having its end portion extended beyond the support, it is called overhanging beam.

Continuous beam:

If a beam is supported on more than two supports, then it is known as continuous beam.



Types of Beams

2.8 Columns

The vertical load carrying member of a structure is called column. They are constructed of timber, stone, reinforced cement concrete of steel section.

Classified:

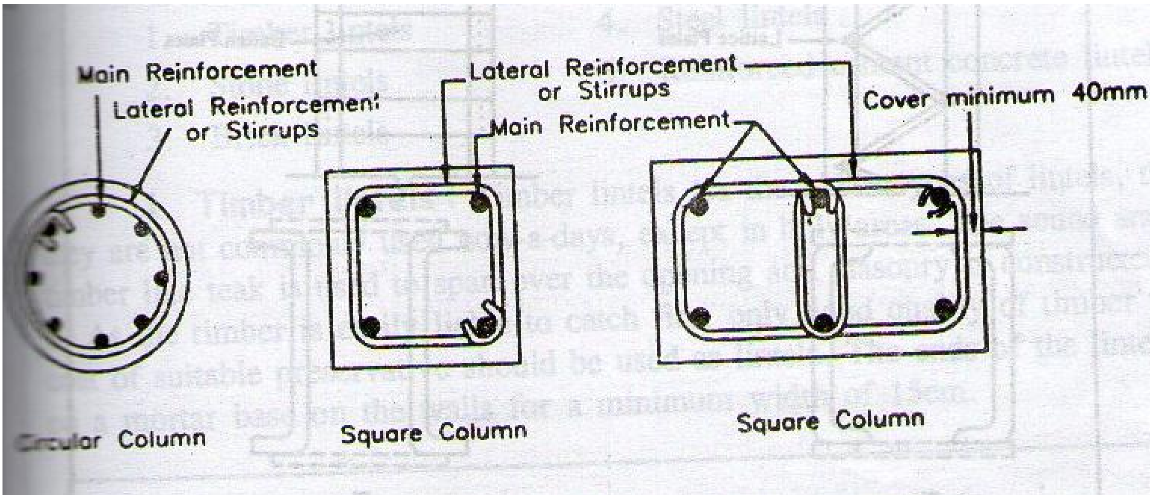
- ✓ Long column
- ✓ Short column

Long column

The ratio of effective length to least later dimension is less than 12 called as long column

Short column

The ratio of effective length to least later dimension is more than 12 called as long column



Reinforced Cement Concrete Columns

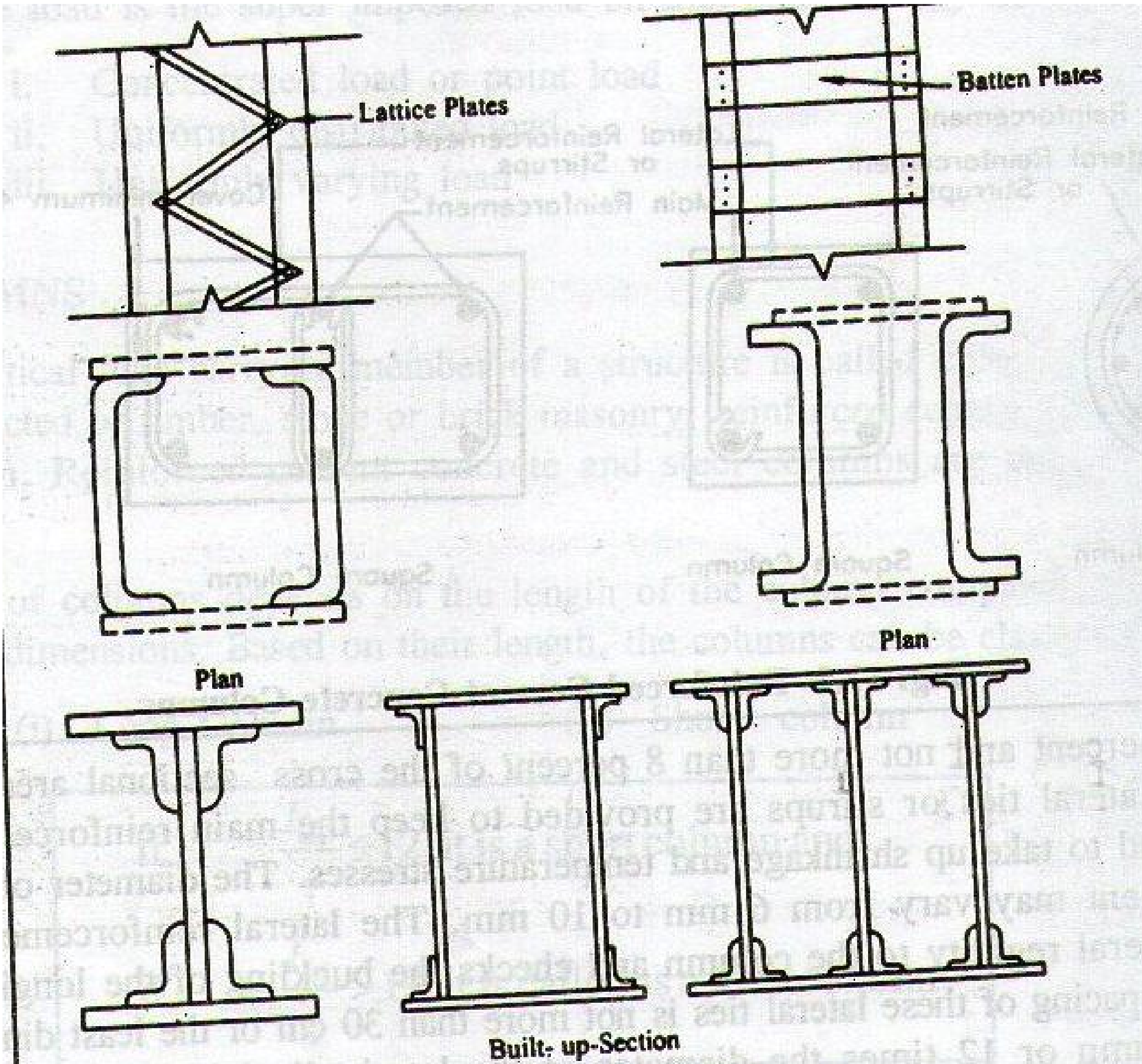
Reinforced cement concrete column

Usually the reinforced cement concrete column are cast in-situ type. They may be constructed in square, rectangular, circular shapes. Vertical reinforcements or main reinforcements are provided to take up major load coming over the column. Generally the diameter of vertical reinforcement may vary from 10mm to 40mm.Longitudinal reinforcement bars should not be less than 0.8% and not more than 6% of the cross sectional area of the column. The diameter of lateral reinforcement may vary from 6mm to 10mm.

In the multi storyed buildings, the section of the column in upper stories may be reduced as they have to carry lesser loads. But the centre lines of various columns of different stories must coincide in a same vertical line.

Steel columns

The various cross sections of steel columns are shown in fig. Struts of one or two angles are used as compression member in roof trusses. Latticed columns made up of channels or angles connected by lattice bars are often used where light loads are to be supported on long columns. battened columns made up of channels or angles connected only batten plate are also used as column. Rolled H-columns which are available in depths ranging from 150 mm to 500 mm and are now commonly used in steel Skelton construction



Steel Columns

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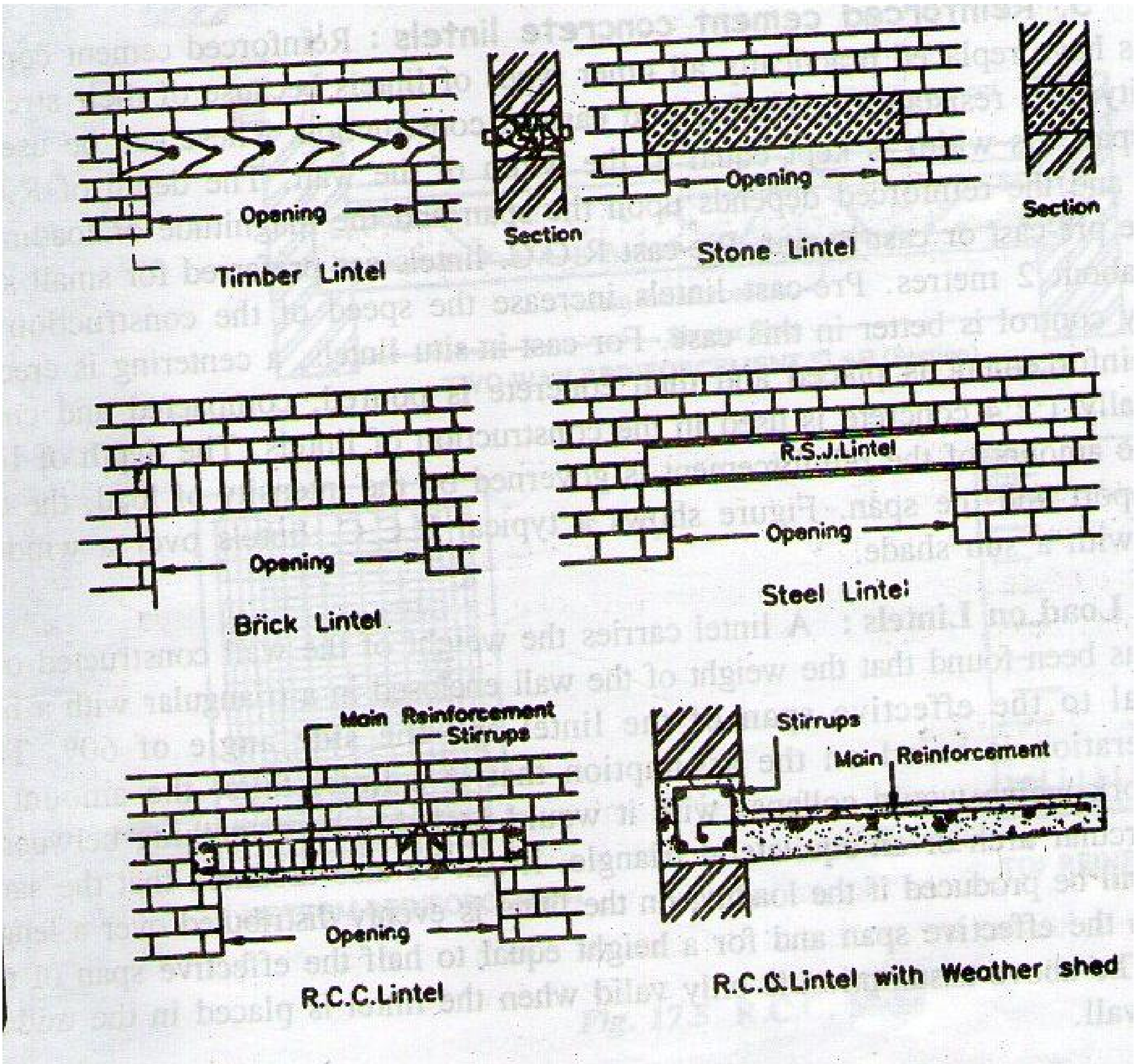
2.9 Lintels

A lintel is a horizontal member which is placed across the openings. Openings are invariably left in the wall for the provision of doors, windows etc. A lintel is thus a sort of beam, the width of which is equal to the width of which is equal to the width of the wall, and the ends of which are built into the wall.

Classification

- ✓ Timber lintels
- ✓ Stone lintels
- ✓ Brick lintels
- ✓ Steel lintels
- ✓ Reinforced cement concrete lintels



Types of Lintels

Timber lintels are the oldest types of lintels, though they are not commonly used now-a-days, except in hilly areas. The sound and hard it. As the timber is easily liable to catch fire, only good quality is constructed over coat of suitable preservative should be used as lintels.

Stone lintels

Stone lintels are used in stone masonry structures. This consists of a simple stone slab of greater thickness. Stone lintels can also be provided over openings in brick walls.

Brick lintels

Brick lintels are not structurally strong and they are used for small openings, generally not exceeding not exceeding 1 meter span, and light loads. They are built up with hand well burnt, copper colored, free from cracks and with sharp and straight edged bricks.

Steel lintels

Steel lintels are provided where the opening is large and the super imposed loads are also heavy. It consists of rolled steel joists or channel sections.

Reinforced cement concrete lintels

Reinforced cement concrete lintels have replaced practically all other types of lintels because of their strength, rigidity, fire resistance economy and case in construction. Its width is kept equal to the width of the wall. The depth of R.C.C lintel and the reinforced depends upon the span and magnitude of loading. It can be pre-cast ot cast-in-situ, pre-cast R.C.C lintels are preferred for small spans upto about 2 meters. The depth of lintel and the reinforcement is governed by the intensity of load, the type of support and the span.

3.0 Flooring

Purpose of flooring is to get a good hard, level and beautiful surface for living. The floors directly resting on the ground are known as ground floors while the floors of each storey are known as upper floors.

GroundFloor

Apart from giving good finished surface, these floors should have good damp resistance. The ground surface is rammed well and a layer of red earth or sand is placed which is compacted. A layer of broken bricks, stones etc. is provided up to 150 mm below floor finish level and rammed. While ramming the surface is kept moist to get good compaction. Then 1 : 4 : 8 concrete of 100 to 150 mm thickness is provided as base course. Over this bed floor finish is laid.

The types of flooring used are:

1. Mud and moorum
2. Brick
3. Flag stone
4. Cement concrete
5. Terrazo
6. Mosaic
7. Marble
8. Tiles
9. Timber
10. Rubber
11. P.V.C.

1. Mud and Moorum Flooring: These floorings are used in low cost housing, specially in villages. Over the hard layer of earth filling mud or moorum layer is provided. The floor needs a thin wash of cow dung at least once a weak.

2. Brick Flooring: This is also a cheap floor construction. It is commonly used in godowns and factories. Bricks are laid flat or on edges. Bricks of good quality should be used for the construction. Brick layer is provided on sand bed or on lean concrete (1 : 8 : 16) bed. In both cases joints are rendered flush and finished with cement mortar.

3. Flag Stone Flooring: Laminated sand stones or slates of 20 mm to 40 mm thick in the form of slabs of 300 mm × 300 mm or 450 mm × 450 mm or in the form of rectangles of size 450 mm × 600 mm are used as floor finishes. The stone slabs are laid on 20 to 25 mm thick mortar spread over concrete bed. The joints are to be finished with rich mortar.

4. Cement Concrete Floors: It is modestly cheap and durable floor and hence commonly used in residential, commercial and industrial buildings. It consists of two courses-base course and wearing coat. Base course is laid over well compacted soil. Its thickness is usually 75 mm to 100 mm. It consists of lean cement concrete mix (1 : 4 : 8) or lime concrete containing40% of 1 : 2 lime mortar and 60% of coarse aggregate of 40 mm size. After base coarse ishardened wearing coat of 40 mm is laid. It consists of panels of 1 m × 1 m, 2 m × 2 m or 1 m× 2 m. Alternate panels are laid with 1 : 2 : 4 concrete using wooden, glass or asbestos strip separators of 1.5 mm to 2.0 mm thickness.

To get good bond between base coarse and wearing coat cement slurry wash is given before laying wearing coat panels. After 3–4 days of laying of one set of panel, another alternate panels are laid. Top of these panels are finished by tamping the surface with wooden floats and tapping with trowels, till cement slurry appears on top. It needs curing for 7 to 14 days. To get good appearance many times red-oxide finishing coat is provided.

5. Terrazo Flooring: Terrazo finishing coat is applied over concrete flooring to get pleasing appearance. Terrazo finish consists of 75 to 80% of surface marble chips embedded in cement mortar.

Marble chips are mixed in cement in the proportion 1 : 1.25 to 1 : 2 and about 6 mm terrazo topping is laid. The top is tamped and rolled. Additional marble chips are spread during tamping to get proper distribution of marble chips on the surface. After drying it for 12 to 20 hours, it is cured for 2–3 days.

Then grinding is made in the following three steps:

Ist grinding—Using coarse grade (No. 60) carborundum stones.

IInd grinding—Using medium grade (No. 120) carborundum stones.

IIIrd grinding—Using fine grade (No. 320) carborundum stones.

Plenty of water is used during grinding. After each grinding cement grout of cream-like consistency is applied and cured for 6–7 days. After final grinding and curing the floor is washed with plenty of water and then with dilute oxalic acid solution. Then floor is finished with polishing using machines and wax polish.

6. Mosaic Flooring: It consists of a finishing coat of small pieces of broken tiles of China glazed or of marble arranged in different patterns set in lime-surkhi or cement mortar. The base coarse is concrete flooring and on it 30 to 40 mm mortar layer is provided. On this mortar layer broken pieces of China glazed or marble are set to get different attractive patterns. After 20 to 24 hours of drying the top is rubbed with carborundum stone to get smooth and polished surface.

7**. Marble Flooring:** Marble slabs are cut to get marble tiles of 20 to 25 mm thickness. They are laid on floors similar to other tiles. With power driven machine surface is polished to get even and shining surface. This type of flooring is widely used in hospitals and temples.

8. Tiled Flooring: This is an alternative to terrazo flooring, used commonly used in residential, office and commercial buildings. Tiles of clay, cement or terrazo of standard sizes are manufactured in factories under controlled conditions. On the concrete base, 25 mm to30 mm thick mortar is laid and these tiles are placed and pressed with trowel or woodenmallet. Before placing tiles care is taken to see that, neat cement slurry is applied to bottom side and sides of tiles to get good bond. Next day joints are cleaned of loose mortar and raked up to 5 mm depth. Then that is filled with coloured cement slurry to get uniform colour on the top surface. After curing for 7 days grinding and polishing is made as in the case of terrazo flooring.

9. Timber Flooring: Timber flooring are used in dancing halls and in auditoriums. Timber plates may be directly placed on concrete bed or may be provided over timber frame work. In latter case it is necessary to provide proper ventilation below the floor. This flooring is costly.

10. Rubber Flooring: Tiles or sheets of rubber with fillers such as cotton fibres, asbestos fibre or granulated cork are manufactured in variety of patterns and colours. These sheets or tiles may be fixed to concrete or timber floors. These floors are attractive and noise proof. However they are costly.

11. P.V.C. Flooring: Poly-Vinyl-Chloride (PVC) is a plastic which is available in different colour and shade. Nowadays tiles of this material are used widely. Adhesives are applied on concrete base as well as on bottom of PVC tiles. Then the tile is pressed gently with 5 kg wooden roller till the oozing of adhesive is seen. The oozed out adhesive is wiped and the floor is washed with warm soap water. The floor finish is smooth, attractive and can be easily cleaned. However it is slippery and costly.

3.1UpperFloor

In olden days upper floors were made of *timber floors* or *steel joist and stone slabs*. For larger spans jack arch floorings were used. *Jack arch floor* consisted of I-section steel beams supported on walls and gap between I-sections beams filled with concrete arch. Figure 3.1.1 shows a typical jack arch flooring.

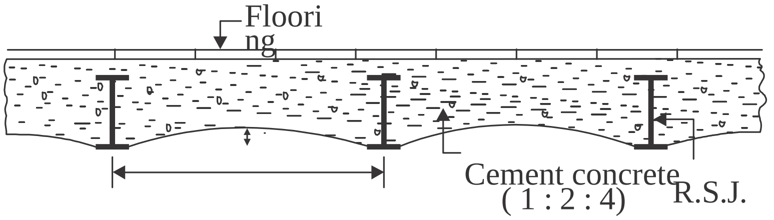
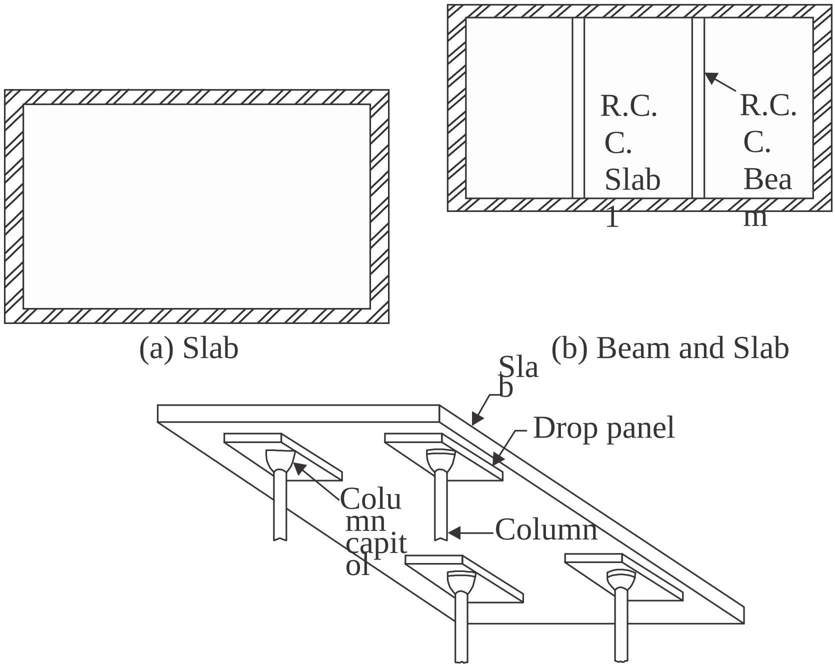


Fig. 3.1.1 Jack arch flooring

Nowadays *R.C.C. floors* are commonly used. It may consist of *only slab*, if span is less or it may be *beam and slab flooring*. In halls of hotels and assembly, many provide *flat slabs i.e.* slabs directly supported over columns.

The columns are provided with widened portion called column head. They give elegant look to halls, particularly when the head room is high. R.C.C. floors need proper thickness and reinforcements. They are arrived at by structural design engineers. Figure 3.1.2 shows typical R.C.C. slabs.



(a) Slab (b) Beam and Slab

(c) Flat slab

Fig. 3.1.2 R.C.C. floors

In R.C.C. concrete is used to resist compression and steel to resist tension. Hence the concrete in tension zone do not contribute in resisting the load. It just keeps the steel at required position. In *reinforced brick slab* an attempt is made to replace concrete in tension zone by bricks. It is better thermal efficient than solid concrete floors. Figure 3.1.3 shows a typical reinforced brick slab.

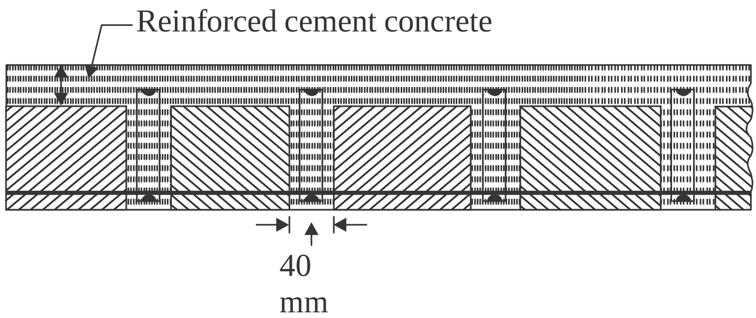


Fig. 3.1.3 Reinforced brick slab

In *ribbed or hollow tiled flooring*, the concrete in tension portion is replaced by hollow tiles. Figure 3.1.2 shows a typical floor of this type.

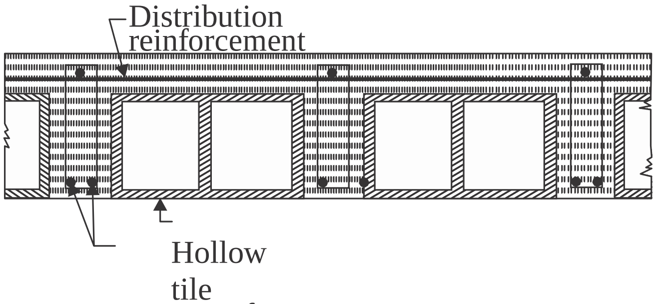


Fig. 3.1.2 Ribbed or Hollow tiled flooring

In precast concrete floor panels may be used which helps in avoiding form works, storing of sand, coarse aggregates etc. at the site and also curing. Factories manufacture these units which are to be placed over supports in the structure. Figure 3.1.4 shows the cross-section of a typical precast floor unit. These units are available in 0.25 m widths and in various spans. Interlocking grooves are provided
on the sides to get tight connection with adjoining units.

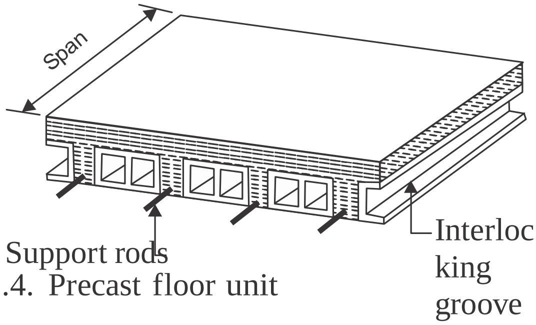


fig. 3.1.4. Precast floor unit

3.1 Roof

Roof is the upper most portion of the building which protects the building from rain, wind and sun. Various types of roofs used may be divided broadly into three types:

1. Flat roofs
2. Pitched roofs
3. Shells and folded plates.

Flat roofs are used in plains where rainfall is less and climate is moderate. Pitched roofs are preferred wherever rainfall is more. Shells and folded plate roofs are used to cover large column free areas required for auditoriums, factories etc. Brief description of these roofs is presented below:

1. Flat Roofs: These roofs are nearly flat. However slight slope (not more than 10°) is given to drain out the rain water. All types of upper storey floors can serve as flat roofs. Many times top of these roofs are treated with water proofing materials-like mixing water proofing chemicals in concrete, providing coba concrete. With advent of reliable water proofing techniques such roofs are constructed even in areas with heavy rain fall.

The *advantages* of flat roofs are:

(*a*) The roof can be used as a terrace for playing and celebrating functions.

(*b*) At any latter stage the roof can be converted as a floor by adding another storey.

(*c*) They can suit to any shape of the building.

(*d*) Over-head water tanks and other services can be located easily.

(*e*) They can be made fire proof easily compared to pitched roof.

The *disadvantages* of flat roofs are:

(*a*) They cannot cover large column free areas.

(*b*) Leakage problem may occur at latter date also due to development of cracks. Once leakage problem starts, it needs costly treatments.

(*c*) The dead weight of flat roofs is more.

(*d*) In places of snow fall flat roofs are to be avoided to reduce snow load.

(*e*) The initial cost of construction is more.

(*f*) Speed of construction of flat roofs is less.

Types of Flat Roofs:

All the types listed for upper floors can be used as flat roofs.

2. Pitched Roofs: In the areas of heavy rain falls and snow fall sloping roof are used. The slope of roof shall be more than 10°. They may have slopes as much as 45° to 60° also. The sloped roofs are known as pitched roofs. The sloping roofs are preferred in large spanned structures like workshops, factory buildings and ware houses. In all these roofs covering sheets like A.C. sheet, G.I. sheets, tiles, slates etc. are supported on suitable structures.

The pitched roofs are classified into

(*a*) Single roofs

(*b*) Double or purlin roofs

(*c*) Trussed roofs.

(*a*) **Single Roof:** If the span of roof is less than 5 m the following types of single roofs are used.

(*i*) Lean to roofs

(*ii*) Coupled roofs

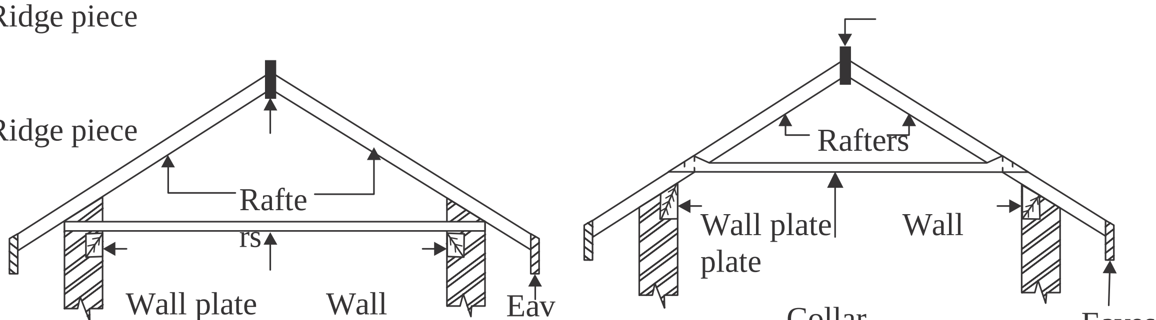
(*iii*) Coupled-close roof

(*iv*) Collar beam roof

In all these roofs rafters placed at 600 mm to 800 mm spacing are main members taking load of the roof. Battens run over the rafters to support tiles. Figure 8.13 shows various types of single roofs.

(a) Lean to roof

(b) Coupled roof



(c) Coupled close roof
beam roof

(d) Collar board

Fig.3.1.5. Single roofs

(*b*) Double or Purlin Roofs: If span exceeds, the cost of rafters increase and single roof becomes uneconomical. For spans more than 5 m double purlin roofs are preferred. The intermediate support is given to rafters by purlins supported over collar beams. Figure 3.1.6 shows a typical double or purlin roof.

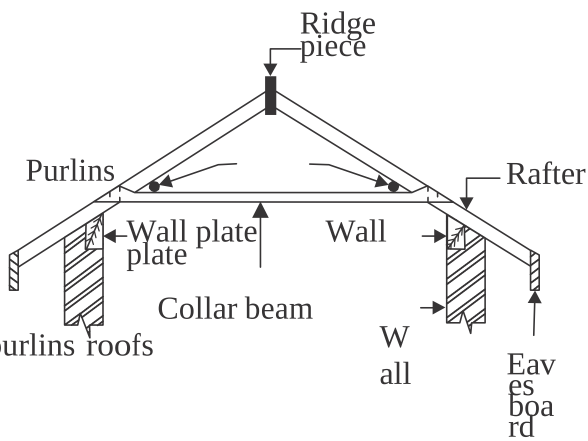
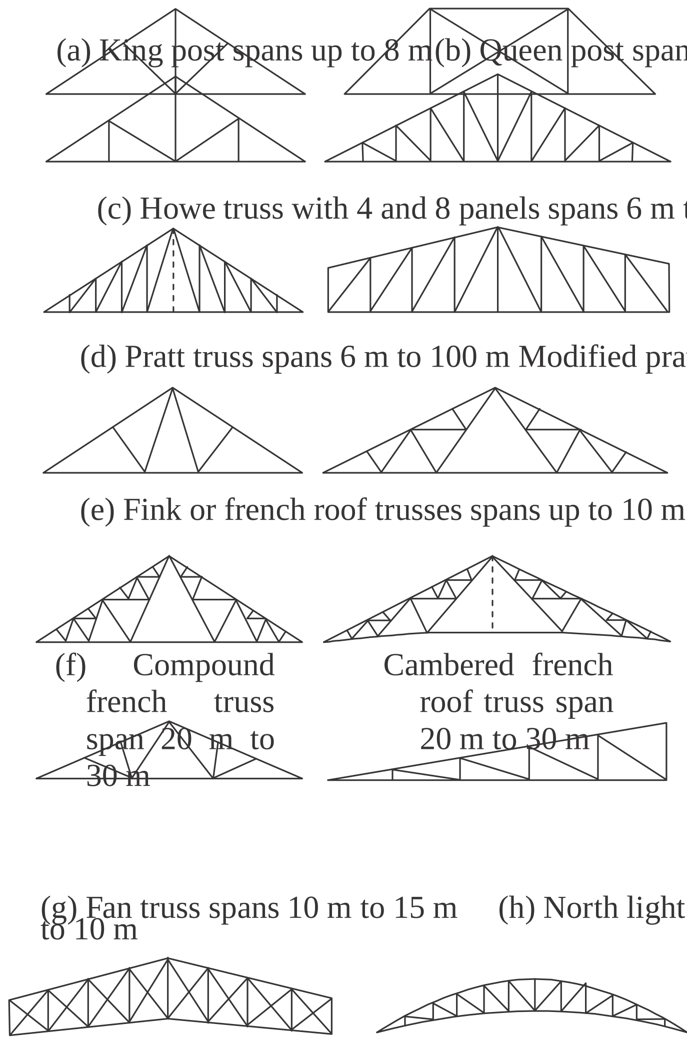


Fig. 3.1.6 Double or purlins roofs

(*c*) Trussed Roof: If span is more, a frame work of slender members are used to support sloping roofs. These frames are known as trusses. A number of trusses may be placed lengthwise to get wall free longer halls. Purlins are provided over the trusses which in turn support roof sheets. For spans up to 9 m wooden trusses may be used but for larger spans steel trusses are a must. In case of wooden trusses suitable carpentry joints are made to connect various members at a joint. Bolts and straps are also used. In case of steel trusses joints are made using gusset plates and by providing bolts or rivets or welding.

Depending upon the span, trusses of different shapes are used. End of trusses are supported on walls or on column. Figure 3.1.7 shows different shapes of trusses used.



(a) King post spans up to 8 m (b) Queen post spans up to 10 m

(c) Howe truss with 4 and 8 panels spans 6 m to 30 m

(d) Pratt truss spans 6 m to 100 m Modified pratt truss

(e) Fink or french roof trusses spans up to 10 m

(f) Compound french truss span 20 m to 30 m Cambered french roof truss span 20 m to 30 m

(g) Fan truss spans 10 m to 15 m (h) North light roof truss span 8 m to 10 m

3. Shells and Folded Plate Roofs: *Shell roof* may be defined as a curved surface, the thickness of which is small compared to the other dimensions. In these roofs lot of load is transferred by membrane compression instead of by bending as in the case of conventional slab and beam constructions. Caves are having natural shell roofs. An examination of places of worships built in India, Europe and Islamic nations show that shell structures were in usage for the last 800 to 1000 years. However the shells of middle ages were massive masonry structures but nowadays thin R.C.C. shell roofs are built to cover large column free areas. Figure 3.1.8 shows commonly used shell roofs.

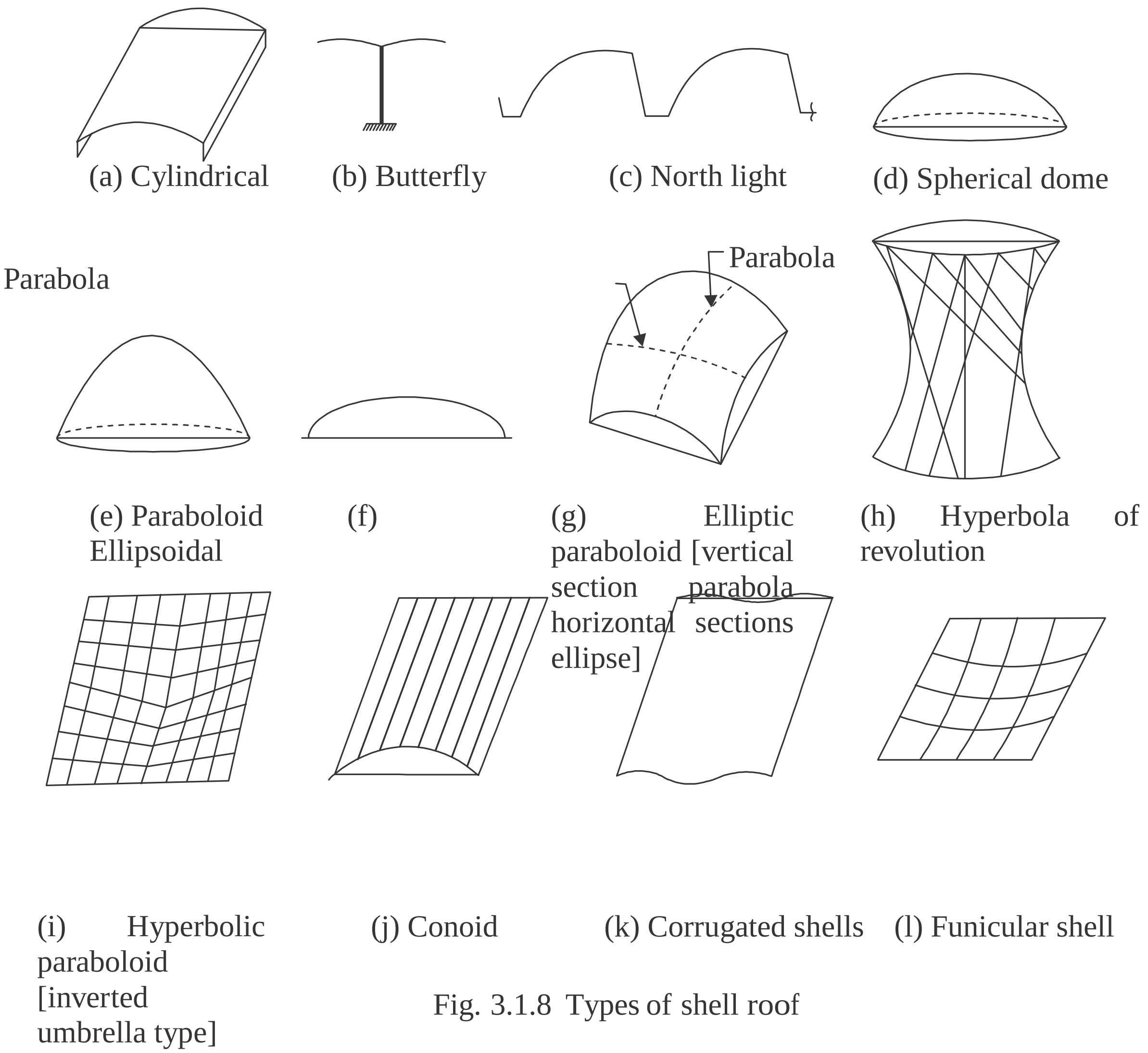


Fig. 3.1.8 Types of shell roof

Advantages and Disadvantages of Shell Roofs

Advantages of shell roofs are:

(*a*) Good from aesthetic point of view

(*b*) Material consumption is quite less

(*c*) Form work can be removed early

d) Large column free areas can be covered.

Disadvantages are:

(*a*) Top surface is curved and hence advantage of terrace is lost.

(*b*) Form work is costly.

Folded plate roofs may be looked as slab with a number of folds. These roofs are also known as hipped plates, prismatic shells and faltwerke. In these structures also bending is reduced and lot of load gets transferred as membrane compression. However folded plates are not so efficient as shells. Figure 3.1.9shows typical folded plate roofs.

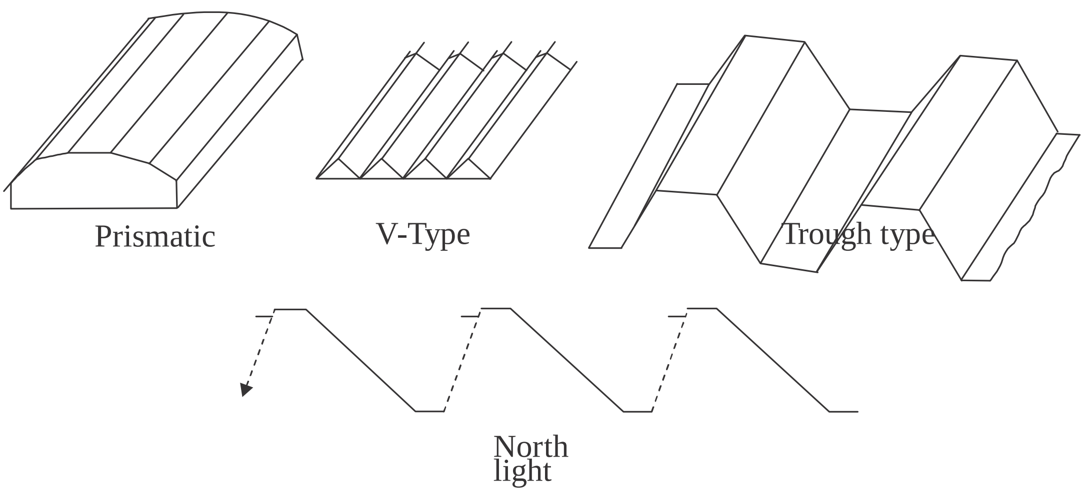


Fig. 3.1.9 Types of folded plate roofs

Advantages and Disadvantages of Folded Plate Roofs Over Shell Roofs

Advantages

(*a*) Form work required is relatively simpler.

(*b*) Movable form work can be employed.

(*c*) Design involves simpler calculations.

Disadvantages are:

(*a*) Folded plate consume more material than shells.

(*b*) Form work can be removed after 7 days while in case of shells it can be little earlier.

3.1.1 Roof Coverings for Pitched Roofs

Various types of covering materials are available for pitched roofs and their selection depends upon the climatic conditions, fabrication facility, availability of materials and affordability of the owner. Commonly used pitched roof covering materials are:

(*a*) Thatch
(*b*) Shingle
(*c*) Tiles
(*d*) Slates
(*e*) Asbestos cement (A.C.) sheets
(*f*) Galvanised iron (G.I.) sheets

(*a*) Thatch Covering: These coverings are provided for small spans, mainly for residential buildings in villages. Thatch is a roof covering of straw, reeds or similar materials. The thatch is well-soaked in water or fire resisting solution and packed bundles are laid with their butt ends pointing towards eves. Thickness varies from 150 mm to 300 mm. They are tied with ropes or twines to supporting structures. The supporting structure consists of round bamboo rafters spaced at 200 mm to 300 mm over which split bamboos laid at right angles at close spacing. It is claimed that reed thatch can last 50 to 60 years while straw thatch may last for 20–25 years.

The advantage of thatch roof is they are cheap and do not need skilled workers to build them. The disadvantages are they are very poor fire resistant and harbour rats and other insects.

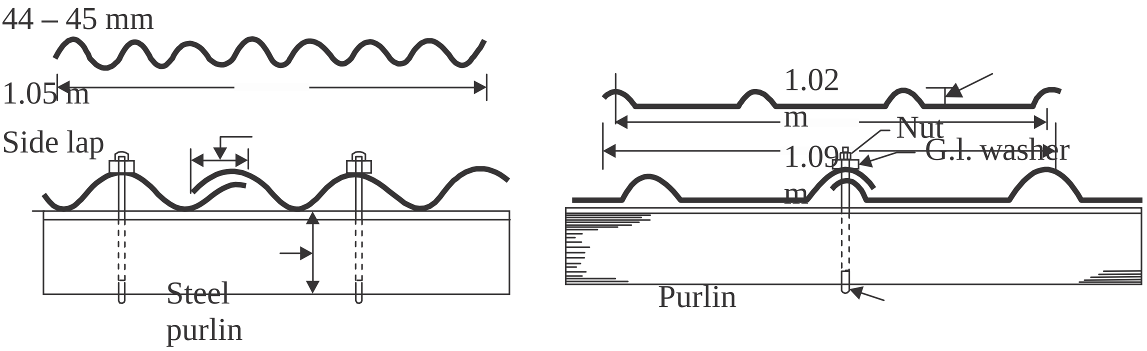
(*b*) Shingles: Wood shingles are nothing but the split or sawn thin pieces of wood. Their size varies from 300 mm to 400 mm and length from 60 mm to 250 mm. Their thickness varies from 10 mm at one end to 3 mm at the other end. They are nailed to supporting structures. They are commonly used in hilly areas for low cost housing. They have very poor fire and termite resistance.

(*c*) Tiles: Various clay tiles are manufactured in different localities. They serve as good covering materials. Tiles are supported over battens which are in turn supported by rafters/trusses etc. Allahabad tiles, Mangalore tiles are excellent inter-locking tiles. They give good appearance also.

(*d*) Slates: A slate is a sedimentary rock. Its colour is gray. It can be easily split into thin sheets.Slates of size 450 mm to 600 mm wide, 300 mm long and 4 to 8 mm thick are used as covering materials of pitched roofs in the areas where slate quarries are nearby. A good slate is hard, tough, durable. They are having rough texture and they give ringing bell like sound when struck. They do not absorb water.

(*e*) A.C. Sheets: Asbestos cement is a material which consists of 15 per cent of asbestos fibres evenly distributed and pressed with cement. They are manufactured in sufficiently large size. The width of a A.C. sheet varies from 1.0 to 1.2 m and length from 1.75 to 3.0 m. To get sufficient strength with thin sections they are manufactured with corrugation or with traffords fib 3.20

They are fixed to the steel purlins using J-bolts. The roofing is quite economical, waterproof. However not very good thermal resistant. They are commonly used as covering materials in ware houses, godowns or for larger halls. In auditorium etc., if these sheets are used, false ceilings are provided to get good thermal resistance.



3.2 Plastering

Applying mortar coats on the surfaces of walls, columns, ceiling etc. to get smooth finish is termed as plastering. Mortar used for plastering may be lime mortar, cement mortar or lime-cement mortar. Lime mortar used shall have fat lime to sand ratio of 1 : 3 or 1 : 4. If hydraulic lime is used mix proportion (lime: sand) is 1 : 2. Cement mortar of 1 : 4 or 1 : 6 mix is very commonly used for plastering, richer mix being used for outer walls. To combine the cost effectiveness of lime mortar and good quality of cement mortar many use lime-cement mortar of proportion (cement : lime : sand) of 1 : 1 : 6 or 1 : 1 : 8 or 1 : 2 : 8.

The *objective* of plastering are:

1. to conceal defective workmanship
2. to give smooth surface to avoid catching of dust.

3. to give good look.
4. to protect the wall from rain water and other atmospheric agencies.
5. to protect surfaces against vermit.

Requirement of good plaster are:
1. It should adhere to the background easily.
2. It should be hard and durable.
3. It should prevent penetration by moisture
4. It should be cheap.

Lime mortar is usually applied in 3 coats while cement mortar is applied in two or three coats for the stone and brick masonry. For concrete surfaces cement mortar may be applied in two or three coats. For concrete building blocks many times only one coat of cement mortar is applied.

The first coat provides means of getting level surface. The final coat provides smooth surface. If three coats are used second coat is known as floating coat. The average thickness of first coat is 10 to
15 mm. Middle coat thickness is 6–8 mm. The final coat is just 2 to 3 mm thick. If single coat is used its thickness is kept between 6 to 12 mm. Such coats are used on concrete surfaces not exposed to rain.

3.3 Stress and strain

When a body is subjected to a system of external forces, it undergoes a deformation. At the same time, by virtue of its strength, it offers a resistance against this deformation. This internal resistance offered by the body to counteract the applied load is called stress.

The resistance per unit cross sectional are is called stress. The deformation in unit original dimension is termed as stain.

3.3.1Types of stresses and strains

Tensile stress

When an external force produces elongation of the body in its direction, it is termed as tensile force.

P= External tensile load
R= Resistane induced in the material of the body
A=Cross sectional area

Tensile stress =Tensile load / Cross sectional are of the body

Tensile strain

Tensile strain =Increase in length/ Original length