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SFI GEC PALAKKAD

Chapter 12

FOUNDATIONS

12.0 Introduction

The different parts of the building are classified into two main categories. They are *i) sub structure* and *ii) super structure.* Foundation belongs to the substructure. As the most important part of the building, it is to be properly designed to suit the soil characteristics of soil available at the site. The basic functions and classifications of foundations are discussed in this chapter. Foundations are the structural components of the building which are in direct contact with the ground and which transmit the loads of superstructure to the ground.

12.1 Purposes of foundations

1. Even distribution of load: Foundation distributes load coming from superstructure over a large area so that the load intensity at its base does not exceed the bearing capacity of soil.

2. Reduction of differential settlement: All the non-uniform loads from the superstructure are distributed properly on the subsoil by the foundation and hence the differential settlement is minimized. Differential settlement means unequal settlement at different parts of the building.

3. Safety against sliding and overturning: Foundation provides sufficient safety against sliding and overturning effects due to lateral loads. Dead weight of foundation provides stability for the structure.

4. Safety against undermining: The building is protected by the foundation against scouring or undermining due to floodwater or burrowing animals.

5. Firm and level surface: Foundations provide a level and firm surface for the construction of superstructure.

12.2 Bearing capacity of the soil

The selection of a suitable foundation is an important task for any structure. The type, depth, shape and size of the foundation are to be determined so that it can safely transmit the load to the soil. The loads from a structure are finally transmitted to the soil and hence, it is important to study strength and behavior of the soil. The supporting power of soil without any failure is called bearing capacity. Knowledge of bearing capacity of the soil is very important in design of foundations. Bearing capacity depends on various factors like

a) Properties of soil like cohesion, angle of internal friction, density.
b) Allowable and differential settlement.
c) Position of water table
d) Physical features of foundation like type, size, shape and rigidity.

Ultimate bearing capacity (q_f): It is defined as the minimum gross pressure intensity at the base of foundation that soil fails in shear. Normally the term bearing capacity means ultimate bearing capacity.

Net ultimate bearing capacity (q_{nf}): It is defined as the minimum net pressure intensity at which soil fails in shear.

$$q_f = q_{nf} + \gamma_D$$

Where γ_D - overburden pressure.

γ - Unit weight of soil. D = Depth of foundation.

Net safe bearing capacity (q_{ns}): It is obtained by dividing the net ultimate bearing capacity of the soil by a factor of safety.

$$\text{Net Safe bearing capacity} = \frac{\text{Net Ultimate Bearing Capacity}}{\text{Factor of safety}}$$

Usual factor of safety of adopted is 2 to 5. The following table gives the range of safe bearing capacity of different soils.

Type of soil	Safe bearing capacity
Soft rock	450 KN/m^2
Gravel	250 to 450 KN/m^2
Sand	150 to 250 KN/m^2
Clay	100 to 150 KN/m^2

The commonly adopted field tests are

1) Plate load test
2) Standard penetration test

12.3.1 Types of foundations

Foundations may be divided into following categories.

1. Shallow Foundations
2. Deep Foundations

When the depth of the foundation is less than or equal to the width then they are called shallow foundations. Deep foundations have depth more than width. A shallow foundation is also known as *open foundation* because it is normally constructed by way of open excavations.

Shallow or spread foundations

The shallow foundations are placed immediately below the lower part of the super structure supported by it. *Footing* is another term. which often used along with foundation. A *footing* is a foundation unit constructed in masonry or concrete under the base of the column or wall. A foundation may have one or more footings. The various types of shallow foundations are:

1. Isolated or column footing.
2. Wall or strip footing.
3. Combined footing
4. Continuous footing
5. Cantilever footing
6. Inverted arch footing
7. Grillage foundation
8. Raft or mat foundation

12.6.1 Isolated or column footing

Isolated footing is the foundation provided for column to transfer the load safely to the soil beneath. When the load on the column is less, a spread is given under the column. This is called isolated footing. The footings can be of various types as shown in figure. A simple footing may be adopted for light load. A stepped or sloped footing may be adopted for medium and heavy column loads. In sloped footing, the total width of the footing is gradually attained. These footings are constructed in stone masonry, brickwork, and concrete or in combination of these.

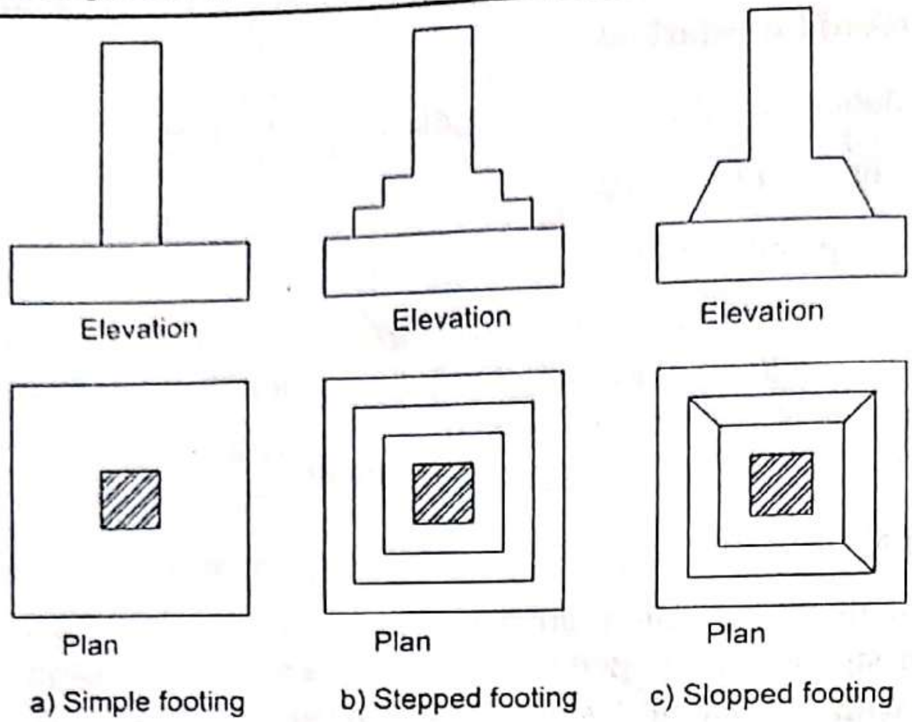


Fig. 12.1 Isolated footings

12.4.2 Wall or strip footing

The footing, which is provided for throughout the length of a continuous structure is called strip footing. Strip footings are normally adopted for load bearing walls. These may be simple or stepped. A simple strip footing is shown in figure.

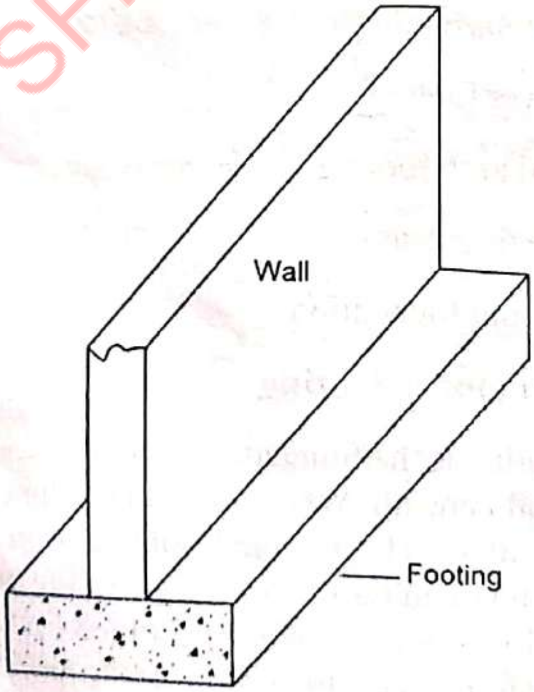


Fig. 12.2 Strip footing

12.4.3 Combined footing

When a footing is constructed for two or more columns then it is called as combined footing. The shape of the footing is rectangular or trapezoidal as shown in Fig.10.5. The shape of the combined footing is proportioned such that the centroid of the footing area coincides with the centre of gravity of the loads on footing.

Usually combined footings are adopted for liftwell columns, water tank supporting columns, bus shelters supporting columns etc.

These are adopted under the following circumstances.

a) Two individual footings overlap.

b) When bearing capacity of the soil is less, requiring more area for individual footings.

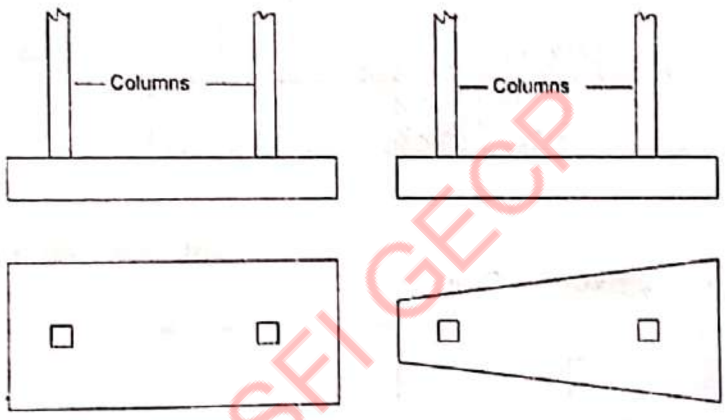


Fig. 12.3 Combined footings

12.4.4 Continuous footing

A single continuous reinforced concrete slab is provided as foundation for three or more columns in a row. Continuous footing is more suitable to prevent the differential settlement in the structure and for the safety against earthquake.

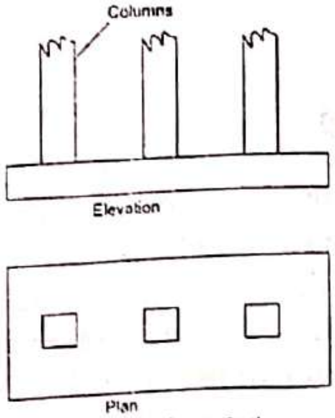


Fig. 12.4 Continuous footing

12.4.5 Cantilever footing

Cantilever Footing consists of an eccentric footing for the exterior column and a concentric footing for the interior column. A strap or a cantilever beam connects them. These footings are used when it is impossible to place a footing directly below a column because of limitations of boundary of site or eccentric loading conditions. The load of the interior column counteracts the load from the exterior column. A number of arrangements are available for strap footing. A typical one is shown in the figure.

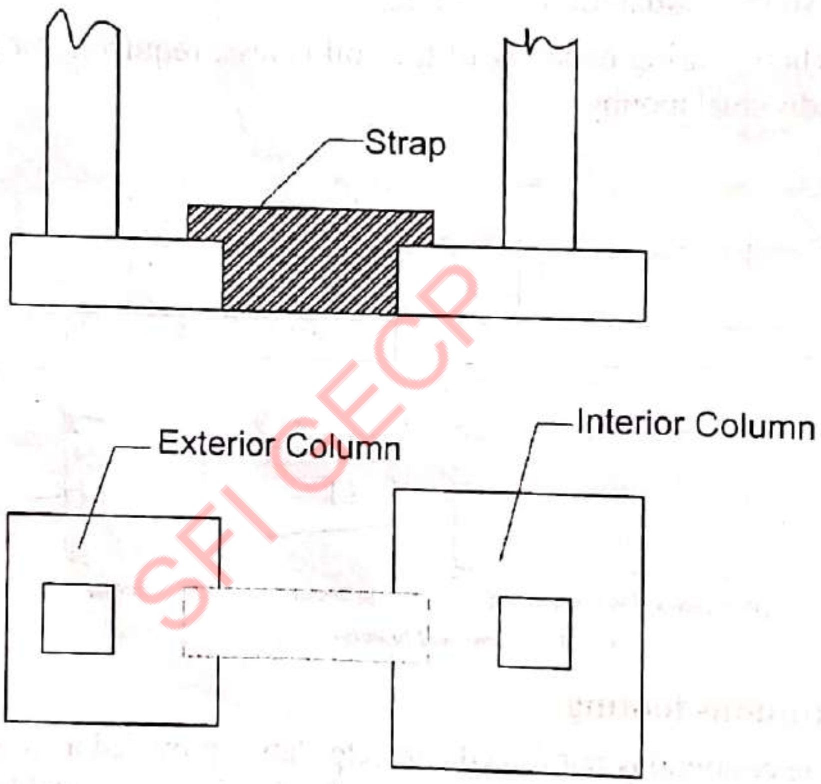


Fig. 12.5 Contilever footing

12.4.6 Inverted arch footing

Inverted arch footing is used to transmit loads above an opening to the supporting walls. These are constructed between the two walls at the base. In this, the end columns are to be designed to resist the outward pressure caused by arch action. This type of the foundation is commonly used for bridge piers, reservoirs, tanks and support for drainage works. Refer the fig. 10.8a for details.

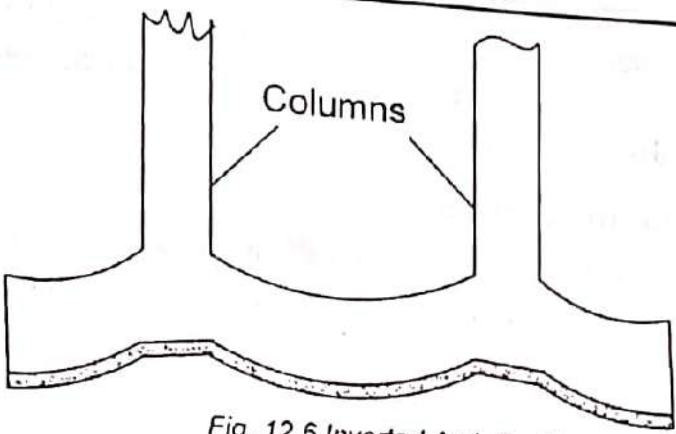


Fig. 12.6 Inverted Arch Footing

12.4.7 Grillage foundation

Grillage foundations are constructed by rolled steel joists (R.S.J), which are placed in single or double tier. In double tier grillage foundation, the top tier is placed at right angles to the bottom tier. The distance between the flanges of R.S.J are kept equal to 1.5 to 2.0 times the width of flange or 30 cm whichever is small. Pipe separators and nuts are used to keep the steel joists of the grillage in the position. The entire arrangements of the rolled steel joists are completely embedded in concrete. The concrete filling is provided not to take any load but it keeps the steel joists in position and acts as a cover against corrosion. A minimum depth of 15 cm is adopted for concrete bed. A grillage foundation may be constructed for a single column or for more than one column.

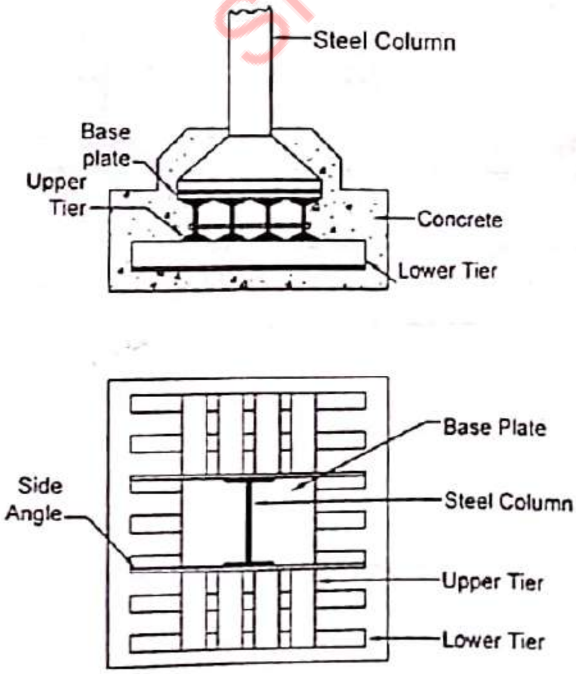


Fig. 12.7 Grillage Foundation

Grillage foundations are suitable for heavy structural loads from steel columns to a soil having low bearing capacity. These are adopted in supporting columns of railway platforms etc.

12.4.8 Raft or mat foundation

Raft foundation is combined footing which covers entire area beneath the structure. It may consists of a single continuous reinforced concrete slab or an inverted beam and slab construction. The load is transmitted to soil by a continuous slab covering entire area. Refer figure.

Raft foundations are adopted when

1. The load is heavy but bearing capacity is less.
2. When isolated footings of each column require large area, i.e. when total footing area is more than half of total area.
3. Soil is sufficiently erratic such that differential settlement is suspected.
4. In highly compressible soils.
5. When localized weak spots and loose pockets in soil mass are suspected or detected.
6. To counteract the effect of hydrostatic uplift.

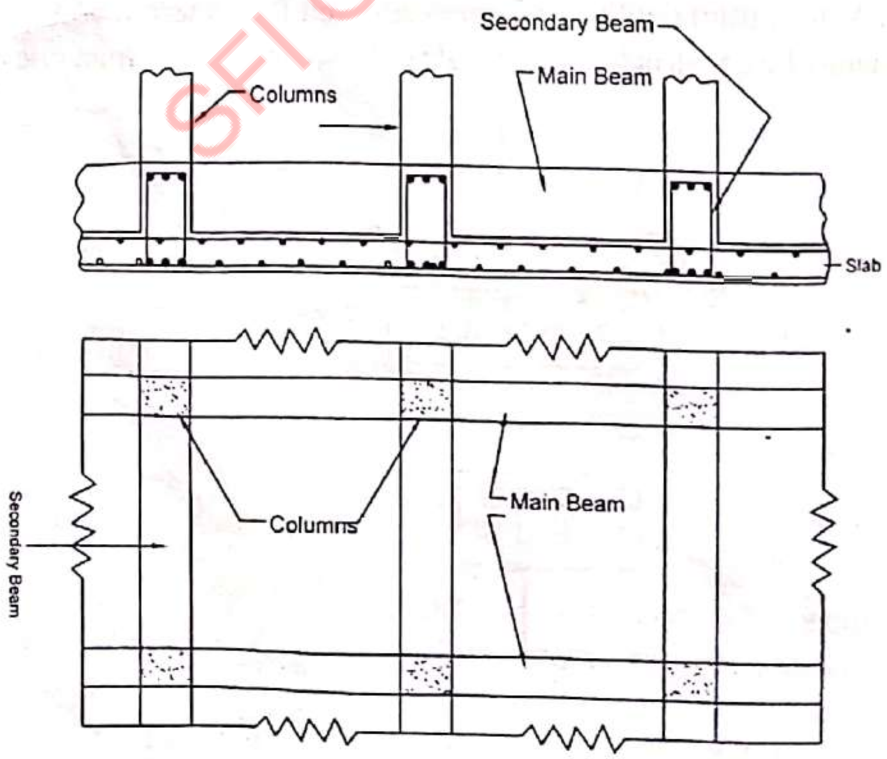


Fig. 12.8 Raft foundation

Raft foundations are normally constructed in such a way that the resultant of column loads passes through the centre of gravity of the raft. This is to ensure that the pressure developed under the foundation is uniform thereby avoids differential settlement.

Based on the design and construction, raft foundations are divided into three groups.

1) Solid slab system
2) Beam slab system
3) Cellular system

When column spacing and loads are small, a single solid slab is adopted as raft. But for heavy loads, with large spacing, beams are to be provided. In this both main and secondary beams are to be provided. Refer figure. When loads are extremely heavy, two-way grid structure made deep beams as of cellular construction is used.

12.5 Deep foundations

The foundations having very large depth compared to width are called deep foundations. The various types of deep foundations are

1. Pile foundations
2. Well foundations.

12.5.1 Pile foundation

When the load is to be transferred to under ground strata of due to poor bearing capacity of the surface soil, pile foundations are adopted. Pile is a slender structural member made up of concrete, steel, timber or composite materials to transfer the load. Pile foundations may be advocated under following circumstances.

1. Loose foundation soil but hard strata is available at a depth of 10-15 meters.
2. Heavy dead and live loads.
3. Position of water table is likely to fluctuate appreciably.
4. Adoption of other foundations like grillage or raft is not economical.
5. Near seashore or riverbed where scouring action of water occurs.
6. The subsoil water level is high such that pumping of water from the open trenches for the other types of foundations is difficult and uneconomical.

7. The top layer soil has very low bearing capacity.
8. When there are canals or deep drainage lines near by.
9. The top layer is of expansive soil.
10. Suitable where deep strip foundation is not possible due to the difficulty of maintaince sides of the trench from falling down.

Classification of piles

The piles may be classified based on following aspects.

12.5.2 Classification of piles based on function or use

Based on the function or use of the piles, these can be classified into two main categories.

i) End Bearing Piles

ii) Friction Piles

iii) Under reamed piles

The piles, which transfer the load from the super structure to the soil, are called load-bearing piles. End bearing piles and Friction piles are of this category.

i) End bearing piles

These piles rest on hard strata available under surface soil and transmit load to it. These act as columns or piers. It is adopted where hard strata is available at 10-15 meters.

ii) Friction piles

Friction Piles generate sufficient load bearing capacity by friction. These piles are driven up to a depth where the total frictional resistance developed on sides is equal to the load coming on pile. This frictional force is called skin friction.

iii) Compaction piles

When the foundation soil available is very loose, compaction piles are used to compact the soil and to increase the load bearing capacity. These piles are not load carrying piles. Sand piles are used as compaction piles.

12.5.3 Classification of piles based on materials

The classification of piles based on materials is as follows.

1. Concrete piles
   a) Cast in situ piles
      i. Cased cast in situ piles
      ii. Un cased cast in situ piles
   b) Pre cast piles
2. Steel piles
3. Cast iron piles
4. Timber piles
5. Composite piles
6. Sand piles

i) Concrete piles

Concrete piles are further classified as cast-in situ concrete piles and pre- cast concrete piles.

a) Cast-in situ piles: In this type, the piles are cast in the site. A hole is made by excavating with auger or by driving a casing. The hole is filled up with cement concrete. The casing may be withdrawn after the hole is made or it may be left in its position.

Under reamed piles

In black cotton soil and other type of soils, buildings often crack due to relative ground movements. This can be prevented by using under-reamed piles. These piles have one or more enlargements called bulbs. They are also suitable for tower footings, retaining walls and abutments. In sandy soils with higher water table, it is very difficult to build conventional footings, but it is possible to provide these piles under such circumstances.

Advantages of cast in situ piles

1. Wastage of material is less as only the required length is cast.
2. No case of stresses due to handling and driving and hence no extra reinforcement for these.
3. Transportation is avoided.
4. Time for curing is saved.
5. No fear of breaking of piles and those are not blown by hammers.
6. They can be designed for heavy loads by providing bulbs or pedestals.

b) Pre-cast piles: Pre-cast piles are manufactured in a factory or at a place away from the construction site. Then they are driven into the ground at the place required. The cross section of precast pile may be circular, square or hexagonal. These are designed to resist the handling stresses occur during lifting and transportation. Advantages of pre-cast concrete piles are:

1. Driving of these piles is easy in soft soils.
2. These piles can be driven in water also.
3. Strict quality control is possible as manufactured in the factory.
4. Concrete attains maximum strength due to proper curing.
5. Steel reinforcement is maintained in the correct alignment.
6. Piles may be prepared to have high chemical and biological resistance.

ii) Steel piles

thick concrete slab. The bottom edge of the well foundation consists of a cutting edge.

12.7 Failures of foundation

Foundation of the building may fail due to the following reasons.

1. Inadequate bearing area resulting in soil pressure more than the safe bearing capacity of the soil
2. Unequal settlement of supporting soil
3. Seasonal expansion and shrinkage of foundation soil. This applies to only compressible clay and black cotton soils.
4. Movement of soil adjoining the structure.
5. Escape of soil below the foundation.
6. Removal of soil due to scouring action of rain and wind.
7. Lateral wind or earth pressure that tends to overturn the structure.
8. Excessive loading of masonry before the mortar sets causes unequal settlement of masonry.

12.8 Load bearing structure

In a load bearing structure, the walls of the building carries the loads from the floors and roof. Then these loads are transmitted by walls to foundation. These load-bearing walls are usually built in masonry, but may be of reinforced concrete too. In ordinary residential buildings up to two floors usually adopt this method.

Load bearing structure has limitations to resist earthquake. (If it is not done correctly.) Walls are thicker and carpet area available may be less. Room dimensions cannot be changed as walls have to be above walls only

In Load bearing structure the walls carry loads apart from providing privacy and security. In load bearing structural system external & internal walls serve as a structural element as well as serve the purpose of enclosure for protection from weather i.e. rain, sound, heat, fire etc.

In case of a load bearing structure, large span areas are not possible. Limitation of span i.e. room sizes. Limitations are there for providing openings in walls, which will affect the light and ventilation in room.

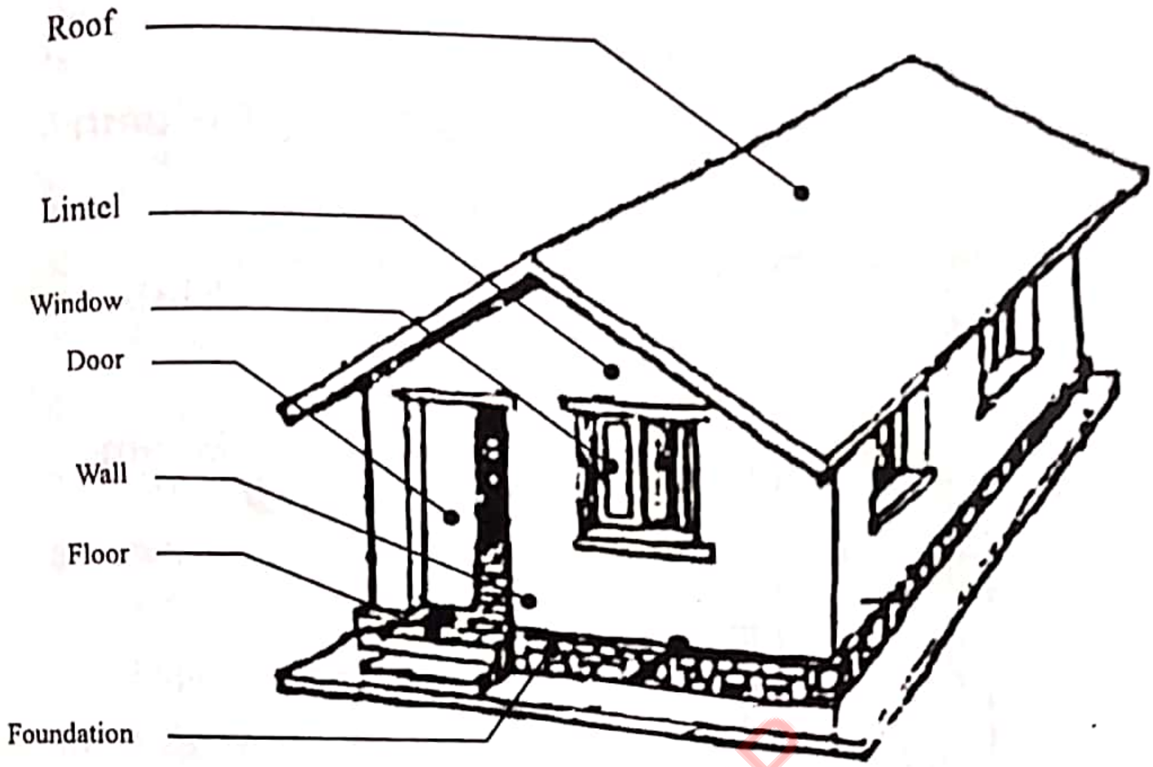


Fig. 12.9 Load bearing structure

Walls have to be built first as they support the slab / roof and hence all walls have to be built simultaneously which is time consuming.

It is not flexible in design as you cannot remove/shift walls, hence effectiveness becomes less. In load bearing structure, it is necessary to construct wall over wall, as walls are load bearing components. Therefore, you cannot change the location of wall resulting in less flexibility in use.

12.8.1 Framed structure

In a framed structure, a framework or 'skeleton' of beams and columns is used to carry the structural loads down the building to the foundations. The framework is usually of steel or reinforced concrete, but in very small structures may be of timber or aluminium.

Framed structure is more resistant to Earthquake.

Walls are thinner and carpet area available may be more. Room dimension can be altered.

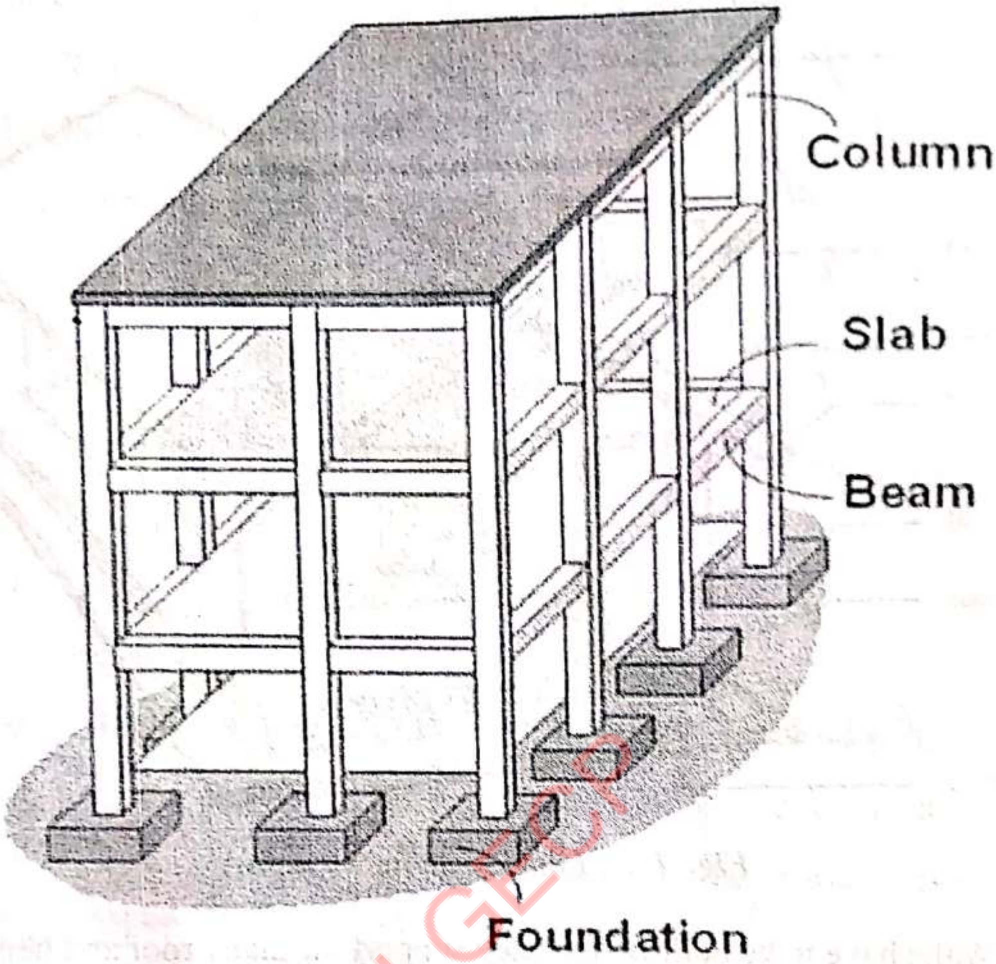


Fig. 12.10 Framed structure

12.8.2

Here the walls are for privacy and security. No limitation exists in form of taking walls over walls and rooms over rooms. In framed structural system, external & internal walls serve only the purpose of enclosures for creation of rooms and protection from weather.

In framed structure, large span areas are possible. No Limitation of span i.e. room sizes. Large openings in walls are possible.

Generally, RCC framed structure is constructed first and the external as well as partition walls are constructed later.

It is flexible in design as you can shift location of walls. More functional architectural design and flexible utilization of space are possible. Any wall can be taken anywhere. Hence, there is flexibility in use.

Chapter 14

ROOFING

14.0 Introduction

Roof is the uppermost part of the building provided as a structural covering, to protect the building from weathering agencies like sun, rain, wind etc. The roof, as a structural element supports the roof covering. Structural element may be truss, beam, slab, shell or dome. The roof covering may be of corrugated sheets, tiles, slates or slab.

14.1 Requirements of an ideal roof

1. It should protect the building from weathering agencies like sun, rain, wind etc.
2. It should be durable.
3. Roof should be waterproof with good drainage arrangements.
4. It should be fire resistant.
5. Should have adequate strength and stability.
6. It should have thermal and sound insulation properties.

14.2 Types of roofs

Generally roofs can be classified into the following categories based on its geometry.

1. Pitched or sloping roofs
2. Flat roofs
3. Curved roofs

Pitched roofs are sloped roofs. The slope is given towards different sides. Since the top surface is sloped, the drainage is excellent in these roofs. Buildings with irregular shapes cannot have pitched roofs effectively. *Flat roofs* are suitable for places where rainfall is moderate, where there is no snowfall. *Curved roofs* have the top surface curved. This is done with shells and domes. These are adopted when large column free areas are required

14.3 Terms

1. **Span:** It is the clear distance between the supports of roof.
2. **Rise:** It is the vertical distance between the top of the ridge and wall plate.

3. **Pitch:** It is the slope of the roof. It is obtained as the ratio of rise to span.
4. **Ridge:** It is the apex line of the sloping roof.
5. **Eaves:** The lower edge of the inclined roof surface is called eaves.
6. **Hip:** It is the ridge formed by joining of two sloping surfaces, external 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. **Principal rafter:** This is the inclined member running from the ridge to the eaves.
9. **Purlins:** These are horizontal wooden or steel members, used to support roofing material of a roof. Purlins are supported on trusses or walls.
10. **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 principal rafters.
11. **Battens:** These are thin strips of wood, called scantlings, which are nailed to the rafters for lying roof materials above.
12. **Cleats.** These are short sections of wood or steel, which are fixed on the principal rafters of trusses to support the purlins.
13. **Truss:** A roof truss is a framework, usually of well-formed triangles, designed to support the roof covering or ceiling over rooms.

14.4 Steel roof trusses

Steel trusses are suitable for large column free buildings like factories, auditoriums, cinema halls, stadia etc. The situations where steel trusses are adopted:

1. When large column free area required.
2. When the span of the roof is more than 10 m.
3. When the height of the roof is more compared to the ordinary buildings.
4. Where other roofs proved to be uneconomical.
5. For speedy construction.

Steel trusses are fabricated from structural steel sections. Normally angle, channel, plate, T and tube sections are used for fabrication of trusses. Various configurations are adopted for the trusses based on its span.

The various configurations of truss are shown below. The suitable configuration is selected according to the span of the truss.

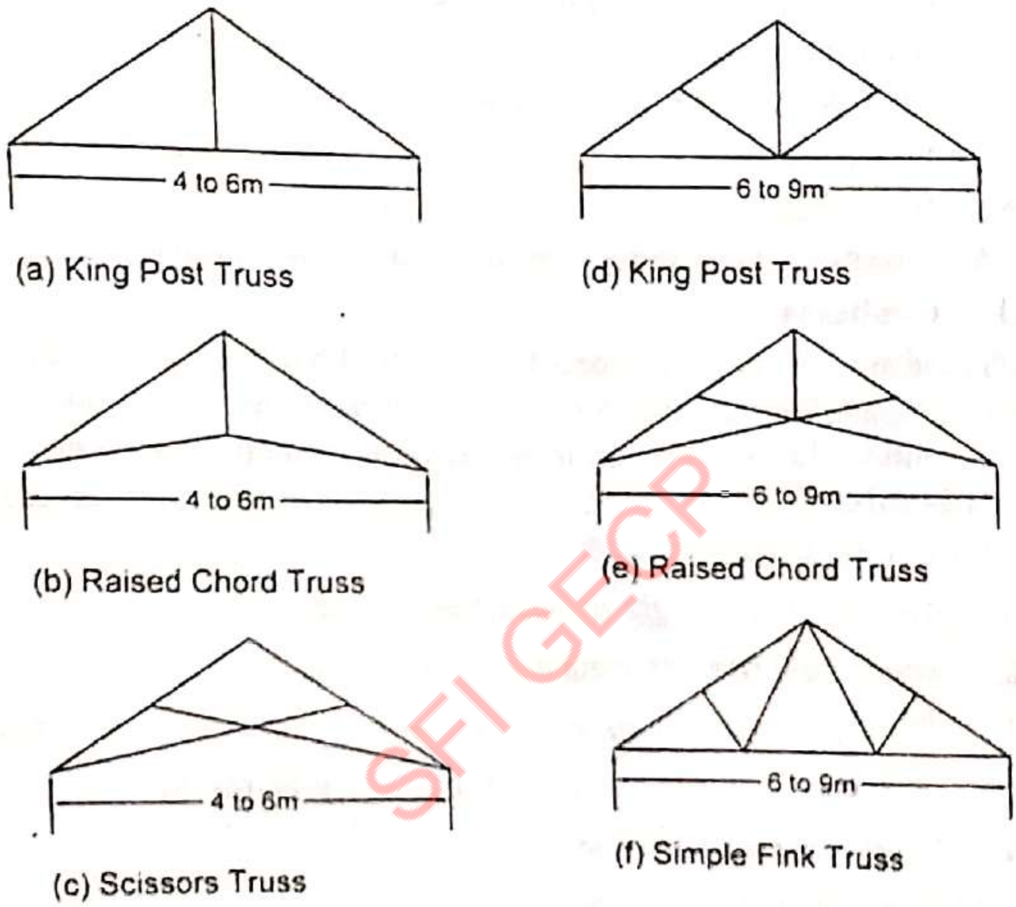


Fig. 14.1 Steel roof trusses

14.4.2 Advantages of steel trusses

1. They are economical compared to R.C.C. roofs
2. Easy to construct and erect.
3. Fire proof and resists termite attack.
4. These are rigid and light.
5. Maintenance is easy.

14.5 Roof coverings

Different materials are used for covering the steel trusses. Corrugated sheets made up of various materials are suitable for steel trusses. The types of sheets are:

1. Asbestos cement sheets (A.C. sheets)
2. Galvanized iron corrugated sheets (G.I.) sheets
3. Aluminum sheets
4. FRP sheets (Fibre glass sheets)
5. Powder coated sheets
6. Roof tiles

A.C. sheets and G.I. sheets covering materials used for industrial buildings.

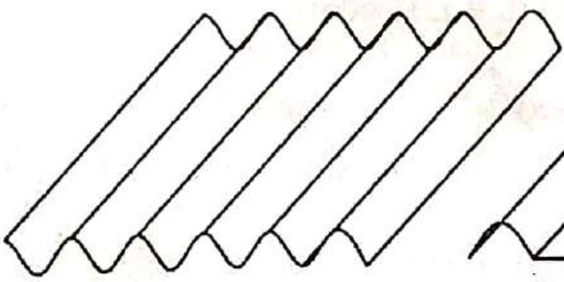
14.5.1 A.C. sheets

These are widely used sheets for industrial buildings, factories, sheds, cinema halls, auditoriums etc. A.C. sheets are manufactured from asbestos, which is a silky fibrous material, found in veins of metamorphized volcanic rocks. It is mixed with Portland cement and these sheets are made. The advantages of asbestos sheets are:

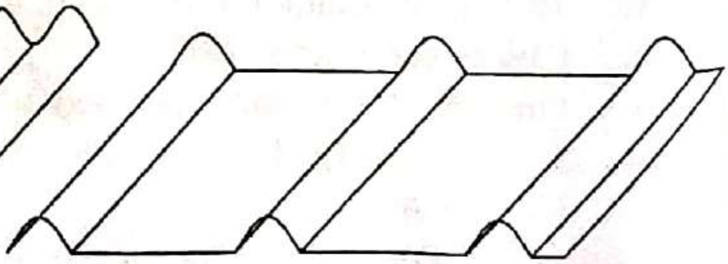
1. They are cheap, light in weight and durable.
2. Water tight, fire resisting and termite resistant.
3. These are available in larger size, which makes the laying fast.
4. A.C. sheets do not require any protective paints etc.
5. Maintenance is also less.

These sheets are available in three forms

1. Corrugated sheets
2. Semi corrugated sheets
3. Plain sheets



Corrugated sheets



Semi corrugated sheets

14.5.2 G.I. sheets

Galvanized Iron sheets are also used for steel trusses. They are stronger than A.C. sheets. But these sheets are costly. These are iron sheets galvanized with zinc to prevent rusting. These sheets are not suitable for flatter slopes. These are mainly used in warehousing sheds, shelters, security cabins, garages, site cabins, bus stations, ticket counters, parcel offices, shade-shelters. These sheets are water proof with better impact strength and fire resistance. These are light in weight yet strong and free from problems of cracking, warping and buckling.

14.5.3 Aluminium sheets

Another variety of roof sheets is aluminium sheets. These are long lasting, economical than PVC, steel & cement sheets and make inside atmosphere cool. The most important advantage is that it is corrosion free. This has almost zero maintenance and eco healthy. No side effects on human body. It has very good scrap value. It is light in weight and with better appearance. These are used for sheds, industrial buildings, and temporary constructions.

14.5.4 FRP sheets

Fibre Reinforced Polymer (FRP) sheets are made with glass or any suitable fiber with a suitable resin. It is popularly known as *Fibre Glass Sheets*. It is available in different colours and shapes. The advantages possessed by these sheets are:

a) UV Protected

b) Does not warp or wilt

c) Non combustible material of construction

d) Can be easily cut, tooled, and handled at site with conventional tools.

e) Resists the corrosive action of chemicals and acidic vapours

f) Rustproof.

g) Lightweight

h) High durability

i) Does not absorb dust, grim, moss, or mildew.

j) Virtually maintenance free

k) High flexibility

l) Can be bent perpendicular or parallel to the corrugation

m) High thermal insulation

These sheets are used for all types of buildings and structures now a days because of its advantages over other type of roofing materials.

14.5.5 Poweder Coated Sheets

Conventional GI or Aluminium sheets are enhanced by applying powder coating on the surface. This increases the life and improved the appearance. They are boradly two types.

1. Powder coated GI sheets

The GI Sheets are coated with different coloured epoxy resins. These have excellent chemical resistance and good mechanical properties. It minimizes the rusting of the GI sheets. It also gives good appearance. It is also available in all patterns like corrugated, plain, traffored etc.

2. Powder coated aluminium sheets

When aluminium sheets are coated with nepoxy resins, they are called powder coated aluminium sheets. It improves the appearance and life. Different patters are available viz. plain, corrugated, trafford and etc. *Unitiled* powder coated aluminium sheets are another pattern which are very commonly used now. This gives the appearance of a tiled roof building.

The different types of bolts used for connecting the roofing sheets to the purlins are given below.

14.6 Roof Tiles

Roof tiles are thin members used for covering roofs made out of clay or concrete. They are of different shapes and sizes. Different varieties of roofing tiles are discussed below.

14.6.1 Clay Roofing tiles

Roof tiles are thin members used for covering roofs made out of clay or concrete. They are of different shapes and sizes. Different varieties of roofing tiles are given below.

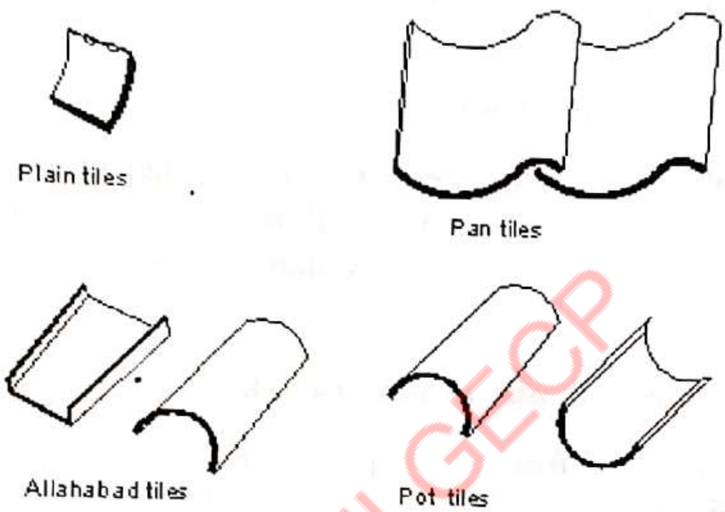
1. Plain tiles
2. Pan tiles (Flemish tiles)
3. Pot tiles

4. Mangalore tiles

5. Allahabad tiles

6. Guna tiles

1. Plain tiles: These are rectangular in shape and with a thickness 10 to 17 mm. Size of tiles 25 x 15 cm to 28 x 18cm. This tile has two projecting lug (nib) or a continuous projection at one end to enable the tile to hang on the battens of the roof.



2. Pan tiles (Flemish tiles): These are curved shape (S shape) as shown in figure. Size is 33cm to 38 cm in length and 23 cm in width.

3. Pot tiles: Pot tiles are semicircular in section and tapering along the length. The diameter at larger end is about 23 cm and smaller end is about 20cm. These are laid in such a way that alternate rows of tiles are concave and convex sides up to prevent the entry of rain water through the roof. These are also called *Half Round* or *Country tiles*.

4. Mangalore tiles: These are very commonly used tiles along the west coast of India, especially in Kerala and Karnataka where monsoon is more intense. These are machine moulded and burnt in kilns. This has two trough portions to carry rain water with locking arrangement on top (nibs). The sides of these tiles have grooves to lock with the adjacent tiles. The standard sizes of Mangalore tiles are 12.5 inches (317.5mm), 13.5 inches (342.9mm) and 13.75 inches (349.25 mm) with a tolerance of 0.25 inches (6.35mm).

5. Allahabad tiles: Two sets of tiles (under tile and over tile) constitute Allahabad tiles. The under tile is rectangular trough shaped and over tile is convex semicircular in shape. Refer the figure. The under tile has varying width from 27cm to 23cm and a length of 38cm. The overt tile tapers from 16.5 cm to 12cm in diameter. This tapering shape ensures the correct fitting of these tiles on the roof.

6. Guna tiles: They are hollow conical shaped tiles with burnt clay. The conical shape has a base of 100 mm diameter at the broader end and 75 mm at the narrower end. As these are conical, can be inserted one into another to form a ring of such tiles. These may be made of suitable shapes, like parabolic, elliptical, etc.

14.7 Reinforced concrete roofs

The RCC slabs are classified into one way slab and as two way slab. When length of the slab more than twice of the width of the slab, it is called one-way slab and other wise it is two way slab. The reinforcement details are different for these slabs.

14.7.1 Reinforcement details of one way slab

In one-way slab, main reinforcement is provided in the direction of the shorter span (along width direction) and distribution reinforcement is provided in the longer span (along length direction). Refer the figure. Main bars (reinforcement) are laid near the bottom of the thickness of the slab over which distribution bars are laid in the perpendicular direction. Main reinforcement is provided for bending stresses and the distribution reinforcement is provided to take up temperature and shrinkage stresses. Diameter of the bar and spacing shall be specified in the design. Alternate main bars are bent at the support as shown in the figure.

Chapter 15

FLOORING

15.0 Introduction

Floors are the horizontal elements of a building which divide building into different levels for the purpose of creating more accommodation one above other within the limited space. Floor just above the ground level is called *ground floor* and the floors above ground level are *upper floors*. These are known as first floor, second floor etc. with reference to ground floor. Floors below the natural ground are called as *basement floors*. An intermediate floor between two floors of any storey forming an integral part of floor below is called *mezzanine floor*. A floor consist of two main components:

a) **A sub-floor (or base course or sub grade)** that provides proper support to the floor covering and all loads carried on it. It imparts strength and stability to floor.

b) **A floor covering (or flooring or paving)** is a covering over sub floor which provides a smooth, clean, impervious and durable surface.

15.1 Selection of Floorings

Every flooring has its own merits and demerits that there is not even a single type which can be suitably provided under all circumstances. Floors have to serve different purposes in different types of building. The following factors govern the selection of floorings.

Initial Cost: The cost of construction is an important factor in the selection of the type of floor. Floor covering of marbles, granite, vitrified tiles, etc. is considered to be very expensive, whereas cork, slate, vinyl tile, etc. are moderately expensive. Concrete and brick floors are the cheapest type of floor construction. The cost of both floor covering and sub-floor has to be accounted while comparison.

Appearance: Flooring should achieve the desired colour effect and architectural beauty according to the use in the building. Generally flooring of terrazzo, mosaic, tiles, marble and cement concrete provides a good appearance whereas the asphalt covering and mud flooring etc. give an ugly appearance.

Durability: The flooring material should offer sufficient resistance to wear and tear, temperature, chemical action, etc. so as to provide long life.

From the durability point of view, flooring of marble, terrazzo, tiles and concrete is considered to be good. Flooring of other materials such as linoleum, rubber, cork, bricks, timber, etc. can be used where heavy floor use is not anticipated.

Cleanliness: A Floor should be non-absorbent and could be easily and effectively cleaned. All joints in flooring should be watertight. Moreover, greasy and oily substances should neither spoil the appearance nor have a destroying effect on the flooring materials. Floorings with terrazzo, marble, tiles and slates are generally found suitable for cleanliness.

Sound Insulation: According to modern building concepts, a floor should neither create noise nor transmit noise. For buildings like hospitals, libraries, studios etc. it is required that any movement on the top floors should not disturb the persons working on the other floors. Suitable flooring is provided in such situations. Cork tile and rubber floorings have excellent sound insulation properties. Timber and linoleum flooring has poor sound insulation.

Dump-resistance: All the floors, especially ground floors, should be damp- resistant to ensure a healthy environment. Normally, floors of clay tiles, terrazzo, concrete, bricks, etc. are preferred for use where the floors are subjected to dampness. Floorings with wood, rubber, linoleum, cork etc. are easily vulnerable to dampness.

Thermal Insulation: Flooring materials play an important role in maintaining the temperature inside the building even the temperature changes outside This reduces the cost of demand for heating in winter and refrigerating in summer. The floors with wood, cork etc. are best suited for this purpose.

Hardness: It is desirable to have good resistance against scratches, impressions and imprints when used for either supporting the loads or moving the loads over floors. Normally the hard surfaces rendered by concrete, marble, stone, etc. do not exhibit any impressions whereas the coverings like asphalt, cork, plastic, etc. get scratched when used.

Smoothness: The floor covering should have smooth and even surface. However, at the same time, it should not be too slippery which will cause unsafe movements over it, particularly by old people and children. Floor coverings with terrazzo, concrete, tiles are suitable in this aspect. Anti skid tiles are also available in various trade names in the market.

Fire Resistance: This is also another important factor in selection of upper floors. These floors are to act as highly resistant fire barriers on which rescue operations take place. Hence flooring materials should have sufficient fire resistance. All combustible flooring materials like wood, cork, plastic etc. should be used over fire resistant base only.

Maintenance: It is always expected that maintenance cost should be as low as possible. Generally, a covering of tiles, marble, terrazzo or concrete requires less maintenance cost as compared to the floors of wood blocks, cork, etc.

15.2 Types of Floor

Types of floor are broadly divided into two categories.

a) Ground Floor b) Upper Floor

a) Ground Floor

Ground floor or basement floor rests directly on ground. Because of this it does not require any type of sub floor. Normal construction of ground floor is by filling up the basement with any inert material up to plinth level a height about 30-45 cm from ground level. Over this uniform and even layer of floor, wearing coat or floor covering is provided. Normally the following materials used for ground floor construction.

i) Bricks ii) Stones iii) Timber iv) Concrete

Bricks, stones and concrete are laid above the ground to the desired height and over that suitable floor covering is done. Timber joists are laid above the concrete layer and the gap between the floor and concrete is filled with sand to form timber floor.

b) Upper Floor

Upper floors are classified on the basis on arrangement of beams and girders or the frame work for supporting the flooring. They are

1) Timber Floors

Timber floors are made by timber joists and wooden planks.

Single joist timber floors: In this, the joists are placed 30 cm centre to centre supporting on wall plates. Corbels (short cantilevers) are also required to support joists, if the width of the wall is less. Wooden planks of thickness 4cm thick are placed over the joists.

These are easy to construct and require less initial cost. Distribution of loads on the wall is more uniform as the joists are spaced closely. But the joists may sag and, hence, cracks will develop in the ceilings. They are not sound proof.

Double joist timber floors: They are used for longer spans of 3.6-7.5 and prevent the travel of sound waves to a great extent. Intermediate supports called binders are placed to support joists. Binders are placed at a centre-to-centre distance of about 2 m. The ends of binders are kept on or stone blocks and they are not embedded in the masonry wall.

This is a more rigid type of flooring and, hence, there is less chance of developing cracks in the plastered ceiling. It is more soundproof. Often wall plates may be avoided by the use of binders. The depth of the floor is considerably increased and, thus, the head room is reduced.

Framed timber floors: This type of timber floor is used for spans of more than 7.0 m. Girders are placed between the walls and binders are put on the girders and the bridging joists rest on the binders. The spacing between girders depends on size of binders. Girders are supported on stones or templates on the walls.

2) Jack Arch Floor

In this, brick or concrete arches are provided between the lower flanges of rolled steel joists with spacing not more than 1.5m. Steel bars are provided at end spans. The rise of the arch is normally kept one-fifth of span. These are rigidly fixed on walls; the side filling is done with lime concrete etc. Plane ceiling is not obtained when jack arch floors are used.

3) Filler Joist Floor

Rolled steel joists encased in the concrete are used in this type of floor. The joists are supported on walls or on side beams. Then the spaces between joists are filled with cement concrete.

4) Steel Joist and Flagstone Floor

In this, rolled steel joists are placed are places at suitable intervals supporting on walls or edge beams. Flag stones of 40mm are placed on the top flange and bottom flange of the joist and the empty space is filled with selected earth or concrete. Precast concrete slabs also may be used instead of flagstones.

5) RCC Floor

Reinforced Cement Concrete (RCC) floors are the most popular type of floor construction in the modern era. The slabs are directly cast over beams or wall supports. Continuous floor is cast on frame work of beams in a framed type building constructions. A suitable thickness of 10cm to 25mm is normally adopted based on the design. Beams are cast monolithically with slabs to form a combined structure in the case of framed structure. Suitable floor covering is adopted over the slabs.

6) Flat Slab Floor

In this system of floors, beams are avoided and slabs are directly supported by columns. Column heads or drops are constructed at column top. This is very advantageous because of less form work required for floor construction compared to normal beam-slab construction. False ceiling is not required in this type of floors. More head room is also available in flat slab constructions. Also it gives more aesthetic appearance.

7) RCC or Hollow Brick-ribbed Floor

These floors are used when to reduce the weight of the floor. Hollow blocks or tiles with clay or cement are placed in the gaps of steel reinforcement on slab. Then the empty spaces are filled up concrete. The floor acts as RCC floor but with light weight. This floor is economical, fire resistant, sound proof and damp roof.

8) Pre-cast Concrete Floor

With the advancement of concrete technology and construction methods, it is now possible to cast suitable elements of floors with concrete and place it over the walls or beams. Pre cast units are jointed and grouted with cement mortar at site. Suitable floor covering is adopted over the floor. No formwork is required for this type of construction; this saves both time and money.

15.3 Floor Coverings

Floor coverings or floor finishes are provided above the floors to improve the appearance, cleanliness, sound proofing and damp proofing. A variety of materials are used for floor coverings. These are selected based on the requirements and uses of the floors. Various types are briefly explained below.

15.3.1 Mud and Mooram flooring

Mud flooring is usually used in villages for their huts and other unimportant buildings. These are cheap and easy to construct and maintain. Mud floor is hard, impervious and has good thermal insulation capacity. For mud floor construction, 25-30 cm thick layer of selected moist earth is spread over a bed and it rammed well to get a thickness of 15-20cm. Chopped straw is also mixed in the earth to prevent drying cracks on the floor.

When mooram (disintegrated rocks, especially Laterite) is used for making mud flooring instead of earth, it is called mooram flooring.

15.3.2 Stone floor covering

Square or rectangular slabs of suitable stones like granite, sand stone or marble are used for this type of flooring. Normally 20-40 mm thick stones of sizes of 30 cm x 30 cm, 45 cm x45 cm, 60 cm x 60 cm, 45 cm x 60 cm etc. are used. The stones used should be hard, durable, tough and of good quality. The earthen base is levelled, compacted and watered. Over this a layer of 10-15 cm thick concrete is placed and properly rammed. Over this concrete a thin layer of mortar is laid. Before fixing the stone slabs in position, their edges and the joints are finished with cement. The stone surface may be rough or polished. A slope of 1 in 40 is provided in such type of floor covering for proper drainage.

15.3.3 Brick floor covering

Brick floors are used for cheap constructions like go-downs, barracks, stores etc. These are commonly used in alluvial places where brick earth is available in plenty and stones are scare. First of all, a well compacted and levelled ground is prepared. Then a lean mix of concrete of 1:3:6 or so is placed over for a thickness of 15cm. Then the bricks are laid in parallel and set in cement. The joints are then pointed for better appearance and durability.

This flooring is non-slippery, hard and durable. The initial cost is less compared to cement concrete. But this flooring is water absorbent.

15.3.4 Concrete floor covering

The most popular type of flooring used in these days is concrete flooring in all types of buildings. It has two parts namely

a. A base course or the sub grade and

b. A wearing course or floor finish

The concrete flooring consists of a topping of cement concrete 2.5-4 cm thick laid on a 10-15 cm base of either lime or cement concrete. A flushing coat with rich cement slurry mixed with red or black color pigment is also applied over this for better appearance. The actual construction operation consists of the following steps.

a. Ground preparation

b. formation of base course

c. Laying of topping concrete

d. Laying of wearing coat

e. Grinding and polishing and

f. Curing

Concrete flooring is non-absorbent and, hence, offers sufficient resistance to dampness. It possesses high durability and, hence, is employed for floors in kitchens, toilets, schools, hospitals, etc. It provides a smooth, hard, even and pleasing surface and can be cleaned easily. Concrete flooring is fire-resistant and can be used for fire resistant purposes in the buildings.

But defects once developed in concrete floors, whether due to poor workmanship or materials, cannot be easily rectified. The concrete flooring is difficult to repair by patchwork satisfactorily. It possesses poor insulation properties against sound and heat.

15.3.5 Mosaic floor covering

This type of floor finish is commonly used in operation theatres, temples, bathrooms, etc. For this construction, first a concrete base is constructed for laying the floor covering. Over this, while it is still wet, lime or cement mortar is placed to a depth of about 2 cm and it is levelled up. A layer of cementing material about 3 mm in thickness is spread. The cementing material consists of two parts of slaked lime, one part of powdered marble and one part of pozzolana. After 4-5 hours of laying this cementing material, a mixture of coloured cement and small pieces of broken glazed tiles (popularly known as mosaic chips) are laid. This is compacted with a light roller. This surface is left for 24 hours and then it is rubbed with pumice stone or mechanical grinders to get a smooth and polished surface. The polished surface is left for about 2 weeks before use.

15.3.6 Terrazzo floor covering

Terrazzo is a special type of concrete with cement and marble chips as aggregates. Flooring laid with this concrete is polished with carborundum stone to obtain a smooth finish at the top. Any desired color is obtained by adding marble chips of different color or using colored cements. The base for this type of floor covering is concrete and is laid in the ordinary method. Over the 3 cm concrete base, a thin layer of sand is sprinkled evenly and it is covered by tar paper. A layer of rich mortar is spread over it and then terrazzo mixture is placed over it evenly. Marble chips of 3-6 mm are mixed with white or coloured cement in the proportion 1:2 or 1:3 to get the terrazzo mixture. Dividing strips of metal, 20 gauges thick, (sometimes glass strips) are inserted into the mortar base to form the desired patterns. Terrazzo mixture is laid in the bays formed between the metal strips. The terrazzo is levelled in position by a trowel.

When the terrazzo has hardened, the surface is rubbed by coarse and fine carborundum stones, respectively to get a smooth finished surface. It is kept wet with water while rubbing. The surface is cleaned with soap solution and then wax polish is applied to the surface. This type of floor covering is costly and is used to obtain a clean, attractive and durable surface in public buildings, hospitals bathrooms, etc. it requires more time to finish terrazzo flooring.

15.3.7 Timber floor covering

Timber floor covering is the oldest type, but nowadays it is used for some special-purpose floors such as theatres, dancing halls, carpentry rooms and hospitals. It is preferred in hill places because of its good thermal insulation properties. It possesses natural beauty and has enough resistance to wearing. But prevention from dampness is very important in the case of timber flooring. Timber floor covering may be carried out in the following types:

a. *Strip floor covering:* This is made up of narrow and thin strips of timber which are joined to each other by tongue and groove joints.

b. *Planked floor covering:* In this type of construction, wider planks are employed and these are joined by tongue and groove joints.

c. *Wood block floor covering:* It consists of wooden blocks which are laid in suitable designs over a concrete base. The thickness of a block is 20-40 mm and its size varies from 20 X 8 to 30 X 8 cm. The blocks are properly joined together with the ends of the grains exposed.

d. *Parquet floor covering:* This is the same type of wood block flooring where thin blocks (max. 10mm) are used instead of thicker ones.

15.3.8 Tiled floor covering

Tiled flooring has become the most popular one now a days and extensively used in all types of buildings including public, semi-public, residential, commercial and industrial buildings. The prime advantages of this flooring are shorter time of installation, pleasing appearance and durability. Tiles are laid directly on the concrete or other hard base with a thin layer of mortar. Adhesives are also available to paste these on surfaces. Flooring tiles are available in sizes from 20cm x 20cm to 120 x120 and also in any shades and designs.

For laying tiles on ground or basement, first the ground for receiving the floor is levelled, well watered and rammed. Then a sub grade of 10 to 15 cm thick lime or cement concrete is placed. Then a layer of 1:3 cement mortars is spread over it and levelled it. After it hardened for few hours, neat cement slurry is poured over it. Then tiles are placed over it with utmost care using cement paste applied on its sides. After 2-3 days, joints are rubbed off and cleaned. For upper floors, normally on RCC floors, sub grade with cement concrete is not required.

Tiled flooring provides a non-absorbent, decorative and durable surface. Installation is fast and possible to repair in patches. These are generally costly compared to other floorings. Terracotta (earthen ware) tiles, ceramic tiles, vitrified tiles, glazed tiles, cement concrete tiles and terrazzo are the important varieties of tiles used in tiled flooring.

15.3.9 Marble floor covering

Naturally available marble slabs are directly laid over a sub grade set in lime or cement mortar. Then it is polished with carborandum stones. Though it is costly, it has the properties of hardness, durability and aesthetic appearance. This flooring is adopted in superior type of constructions and places where sanitation and cleanliness are important like hospitals, theatres, places of worships and toilets etc.

15.3.10 Granite floor covering

Granite slabs are also naturally available in different colors and textures. These are laid in the similar way of marble and possess better qualities than marble.

15.3.11 Rubber floor covering

These are used in public and industrial buildings because of their good wearing qualities. It has good elasticity and noise insulation properties. It is made of pure rubber mixed with cotton fibre, granulated cork or asbestos fibre and the desired colouring pigments. The thickness of rubber sheets or tiles varies from 3 to 10 mm and it is available in many designs and patterns. The tiles or sheets and can be cemented over the dry base of concrete or wood by means of special adhesives. The rubber floor coverings are expensive but provide a durable wearing surface.

16.3.12 Linoleum floor covering

Linoleum is the floor covering which is generally laid over wooden or concrete floors. It is the fabricated form of a mixture of resins, linseed oil, gums, pigments, wood flour, cork dust and filler materials. It is available in the market in rolls of width about 2-4 m. The thickness varies from 2 to 6 mm. These tiles are also manufactured in various sizes, shapes and patterns. This can be laid over the floors or pasted with adhesives on the floors. Also linoleum coverings are prepared over wooden bases and nailed over the timber floor bases.

This flooring provides an attractive, resilient durable and economical surface. It offers a surface that can be easily washed and cleaned. Being moderately warm with cushioning effect, linoleum provides comfortable living and working conditions. It offers adequate insulation against noise and heat.

But it is subjected to rotting when kept wet for enough time and its use is not suitable for basements. It has poor resistance against fire, being combustible in nature. This covering when applied over a wooden base may get torn under excessive sub-floor traffic.

17.3.13 Glass floor covering

It is used when it is desired to allow light to the floor below. Structural glass is available in the form of slabs or tiles of thickness 10 to 30 mm. They are fitted within frames of different types. The members of the frame are designed in such a way that the glass floor covering can take up the superimposed loads without breaking. This type of floor covering is not common.

18.3.14 Plastic or PVC floor covering

The plastic tiles are made of PVC (Poly Vinyl Chloride). Plastic or thermoplastic tiles can be economically used as floor covering on the concrete floor base. It is not preferred over wooden floor base as the preparation of the wooden surface for receiving the tiles is very costly.

Plastic floor covering are used in all types of buildings like offices, hospitals, shops, schools

19.3.15 Magnesite floor covering

Magnesite flooring is known as composition flooring or joint less flooring. It is composed of a dry mixture of magnesium oxide, a pigment and inert filler materials, e.g., wood flour, asbestos or sawdust. Liquid magnesium chloride is

Chapter 16

BASIC INFRASTRUCTURE SERVICES

16.0 Introduction

A number of allied services are required apart from those discussed in the previous chapters, for the successful functioning of the different types of buildings. These are ventilation, lighting, thermal insulation, sound proofing, air conditioning, vertical transportation, plumbing and fire fighting equipments etc. Some of these topics are discussed in the following sections. Vertical transportation is an important service to be designed with due care especially in multi storied buildings for the circulation of traffic both in normal use and in emergencies. The various measures of vertical transportation are staircases, ramps, elevators or lifts and escalators. MEP and HVAC are also discussed in the following sections.

16.1 MEP

Mechanical, Electrical and Plumbing **(MEP)** refers to these aspects of building design and construction. **MEP** design is important for planning, decision making, accurate documentation, performance, cost-estimation, construction, and operating/maintaining the resulting facilities. Various systems in MEP are given below.

1. Mechanical

Mechanical systems most commonly relate to heating ventilation and air conditioning (HVAC) systems, but they can also relate to transportation systems such as elevators and escalators, elements of infrastructure, industrial plant and machinery, and so on.

Heating ventilation and air conditioning can be used in buildings to:

- Regulate internal temperatures.
- Regulate internal humidity.

2. Electrical

Electrical systems might include:

- Power supply and distribution.
- Interior and exterior lighting.

- Control systems.
- Information and telecommunications systems.
- Security and access systems.
- Detection and alarm systems.

3. Plumbing

Plumbing refers to any system that allows the movement of fluids, typically involving pipes, valves, plumbing fixtures, sanitary fixtures tanks and other apparatus.

Plumbing systems might be used for:

- Potable cold and hot water supply.
- Water recovery and treatment systems.
- Rainwater, surface and subsurface water drainage.
- Heating and cooling.
- Waste removal.
- Fuel gas piping.

16.2 HVAC

HVAC system is a **H**eating, **V**entilation, and **A**ir-**C**onditioning system. This is the system or combination of system used to provide a comfortable temperature in buildings and maintain high levels of air quality. The objective of an HVAC system is to ensure that the indoor environment is both safe and comfortable for humans. Safety here mainly concerns with the *Indoor Air Quality* or IAQ. Indoor Air Quality demands indoor air should have enough oxygen and be free of noxious gases.

Heating is the process of generating heat (i.e. warmth) for the building. This can be done via central heating with a boiler, furnace, or heat pump to heat water, steam, or air in a central location such as a furnace room in a home. The heat can be transferred by convection, conduction, or radiation.

Pipes are used to transport the heat to the rooms with heated water or steam. Most modern hot water boiler heating systems have a circulator, which is a pump, to move hot water through the distribution system. The heat can be transferred to the surrounding air using radiators, hot water coils or other heat exchangers. The radiators are mounted on walls or installed within the floor to produce floor heat.

The use of water as the heat transfer medium is known as hydronics

Ventilation is the process of exchanging or replacing air in any space to provide high indoor air quality. This involves temperature control, oxygen replenishment, and removal of moisture, odours, smoke, dust, airborne bacteria, carbon dioxide, and other gases. Ventilation removes unpleasant smells and excessive moisture, introduces outside air, keeps interior building air circulating, and prevents stagnation of the interior air. Methods for ventilating a building may be divided into *mechanical/forced* and *natural* types.

a) Mechanical, or forced, ventilation is provided by air handler units (AHU) and used to control indoor air quality. Excess humidity, odours, and contaminants can often be controlled via dilution or replacement with outside air. Kitchens and bathrooms typically have mechanical exhausts to control odours and sometimes humidity.

Ceiling fans and table/floor fans circulate air within a room for the purpose of reducing the perceived temperature by increasing evaporation of perspiration on the skin of the occupants. Because hot air rises, ceiling fans may be used to keep a room warmer in the winter by circulating the warm stratified air from the ceiling to the floor.

b) Natural ventilation is the ventilation of a building with outside air without using fans or other mechanical systems. It can be via operable windows, louvers, when spaces are small. In more complex schemes, warm air is allowed to rise and flow out high building openings to the outside (stack effect), causing cool outside air to be drawn into low building openings. Natural ventilation schemes can use very less energy. But in warm or humid climates, maintaining thermal comfort solely via natural ventilation may not be possible.

Air Conditioning

Air conditioning is the process of treating air so as to control simultaneously its temperature, humidity, purity, distribution, air movement and pressure to meet the requirements of the conditioned space such as comfort and health of human beings, needs of industrial processes and other needs in the buildings.

Purposes of air conditioning

a) It is required to preserve and maintain the health, comfort and convenience of the occupants in residential buildings.

b) It is required to preserve the quality of the products and to maintain the working of industrial processes such as artificial silk and cotton cloth etc.

c) In the commercial buildings like theatres, offices, shops, banks, stores, restaurants etc., air conditioning is required to improve the working atmosphere and maintain comfort within these concerns.

16.2.2 HVAC - An integrated approach

With the advent of new, innovative technologies, the new generation of HVAC (Heating, Ventilation, and Air Conditioning) systems has become both energy and cost efficient. The basic operations of heating/cooling, ventilation and air conditioning are brought together in single or connected systems in buildings. Though the equipments used for achieving these are different, or location of the equipments in the building are centralised or local, the ultimate concern of indoor air quality is fulfilled in an integrated manner in modern HVAC systems.

16.2.3 Classification of HVAC systems

The major classification of HVAC systems based on location of primary equipment is *central system* and *decentralized or local system.*

Central system: in which the primary equipment location to be centralized as conditioning entire building as a whole unit.

Decentralized or local system: in which equipment separately conditioning a specific zone as part of a building.

Therefore, the air and water distribution system should be designed based on system classification and the location of primary equipment. The criteria as mentioned above should also be applied in selecting between two systems.

16.2.4 Types of HVAC systems

Important types of HVAC systems available are

1. Split HVAC system

The most common types of HVAC systems are the heating and cooling split systems. The system has two main units, one for heating and one for cooling. They usually contain one indoor unit such as a furnace and one outdoor unit such as a central air conditioner often located outside. This system uses a traditional thermostat to manage the temperature, and is able to keep most houses at your desired temperature.

These types of HVAC units have a cooling system outside, which uses refrigerant, compressors and coils to cool air, and a fan to blow out hot air. These are usually the large AC units placed outside the home, which run during the summer.

2. Hybrid Split System

Hybrid **Split System** is a similar to the split HVAC system and is very energy efficient in comparison due to the fact that they have an electric hybrid heater system. This gives the homeowner the ability to choose between gas power or electric power to heat a home. These split hybrid heating and cooling systems are great for climates the temperature can be chosen during colder months. This HVAC system is also controlled by a thermostat located within the home and forces air through the ducts.

3. Ductless- mini split system

A **ductless HVAC system** has multiple inside units located in each room that can be controlled separately for heating and cooling. The mini split units are mounted on room walls and connect to a compressor located outside of the home. Mini split units are easier to install than a central AC system but usually more costly.

Another benefit is energy conservation, since individual rooms that are being used are being heated or cooled it keeps exterior or unused rooms from wasting energy.

4. Packaged Heating and Air System

It is a combination unit that contains both the heating & air unit all in one. This HVAC type is usually installed in the attic or on top floor in a storage space of multi storied buildings. It is able to cool and heat a home with one unit and is incredibly energy efficient. It's often used in areas where warmer climates are common. The heat is electrically generated in this system.

16.3 Elevators or lifts

Elevator or lift is an appliance designed to transport persons or materials between two or more levels in a vertical or substantially vertical direction by means of a guided car or platform. Elevators are used in buildings having more than three storeys. They are either electric traction elevators or hydratulic elevators. Electric traction elevators are used exclusively in tall buildings. Hydraulic elevators are generally used for low-rise freight service which rises up to about six storeys. Hydraulic elevators may also be used for low-rise passenger service.

16.3.1 Types of elevators

1. Traction Elevators.

Traction elevators are lifted by ropes, which pass over a wheel attached to an electric motor above the elevator shaft. These elevators are used for mid and high-rise applications and have much higher travel speeds than hydraulic elevators. A counter weight makes the elevators more efficient by offsetting the weight of the car and occupants so that the load on motor comes less.

The different components of an electric traction elevator are the car or cab, hoist wire ropes, driving machine control equipment, hoist way rails, counter weight, machine room and lift pit. The car is the load carrying element of the elevator and a cage of light metal supported on a structural frame, to the top of which the wire ropes are attached. The ropes raise and lower the car in the shaft. The ropes pass over a grooved, motor-driven sheave and are fastened to the counter Weights. The paths of both the counter weights and the car are controlled by separate sets of T-shaped guide rails. The control and operating machinery may be located in a penthouse (machine room) above the shaft or in the basement. Safety springs or buffers are placed in the pit, to bring the car or counter weight to a safe landing.

There are traction elevators without gear box (gearless traction lift) and with gearbox (geared traction lift).

2. Hydraulic Elevators.

Hydraulic elevators are supported by a piston at the bottom of the elevator that pushes the elevator up when an electric motor forces oil or another hydraulic fluid into the piston. The elevator goes down as a valve releases the fluid from the piston. They are used for low-rise applications of 2-8 stories and travel at a maximum speed of 60m per minute. The machine room for hydraulic elevators is located at the lowest level adjacent to the elevator shaft.

16.3.2 Definitions

Lift: is an appliance designed to transport persons or materials between two or more levels in a vertical or substantially vertical direction by means of a guided car or platform.

Passenger Lift: A lift designed for the transport of passengers.

Hospital Lift: (Stretcher lift) A lift normally installed in a hospital and designed to accommodate one number bed/stretcher along its depth with sufficient space around to carry a minimum of three attendants in addition to the lift operator.

Goods Lift: A lift designed primarily for the transport of goods, but which may carry a lift attendant or other persons necessary for loading unloading of goods.

Service Lift: A passenger cum goods lift meant to carry goods along with people.

Fireman's Lift: The fire man's lift has the following standards. Lift car area shall not less than 1.44m2 and with minimum capacity of 544Kg (8 persons). Doors are to be with automatic operation and have a minimum fire resistance of one hour.

16.3.3 Design considerations

The important considerations of design of lift system are the following.

a) Number of floors to be served.

b) Floor-to-floor distance

c) Population of each floor

d) Maximum peak demand; this demand may be unidirectional, as in up or down peak periods, or a two way traffic movement.

Kerala Municipality Building Rules 1999 stipulates every Hospital/ Medical building exceeding three floors and all other building with more than four floors should have at least one lift. There shall be a minimum of one lift for first 4000 square meters and at the rate of one additional lift for every 2500 of square meters of total floor area.

16.3.4 Design parameters

A lift installation for the office building is normally designed based on three main factors.

Population: The total building population and its future projections are required for design of lift systems. The probable population density may be obtained from the building owner. In the absence other data, an average of one person per $5m^2$ is assumed.

Quantity of service (Handling Capacity): It is the measure passenger handling capacity of a vertical transportation system. The following passenger handling capacities for various buildings is as follows.

Type of Building	Handling Capacity
Office – diversified tenants	10 to 15 percent
Office – single tenant	10 to 25 percent
Residential	7.5 percent

Quality of service (or interval): is related fundamentally to the time interval a passenger has to wait. It can also be said as the expected interval (in seconds) between the arrivals of elevators in the main floor. For a large building, the quality of service can be categorized as

a) average interval 20-25 seconds - excellent

b) average interval 35-40 seconds - fair

c) average interval 45 seconds – poor

d) average interval over 45 seconds - unsatisfactory

16.3.5 Location of elevators

The most efficient method of locating elevators to serve an individual building is to group them together. A group has a lower average interval between car arrivals than a single elevator. Groups should be located:

a) For easy access to and from the main building entrance.

b) Centrally for general ease of passenger journey

If the building has areas which give long distance to the central group elevator, then it may be efficient to provide an additional elevator for local areas.

16.4 Ramps

Ramps are sloping surfaces used to provide an easy connection between the floors or access from ground to the floors. They are especially useful when large number of people or vehicles have to be moved from floor to floor. They are usually provided at places such as garages, railway stations, stadiums, town halls, office buildings and exhibition balls. As per the prevailing building bye laws, ramps are to be provided in all public buildings and residential apartments for the use of physically challenged persons in lieu of steps/stairs. Sometimes they are provided in hospital buildings so as to facilitate the movement of stretchers and wheel chairs from one floor to other floor.

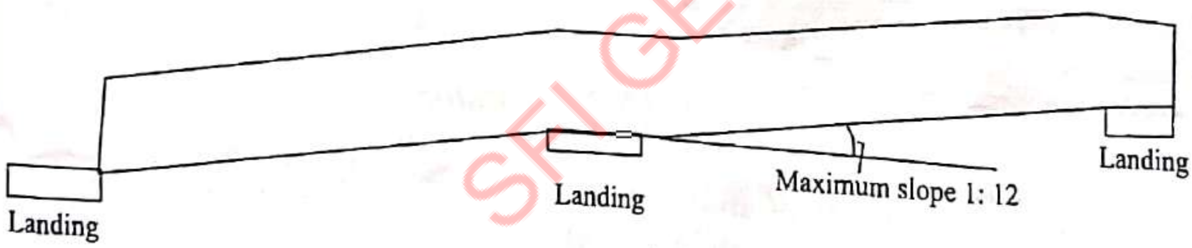


Fig. 16.1 Ramp

Ramps should be constructed with a non-slippery surface. Ramps are generally given a slope of 15 per cent. But a slope of 8 to10 per cent is usually preferred. The ramps need not be straight for the entire length. It can be curved, zigzagged or spiral. But a straight and level landing of minimum length 1.1m is provided at door steps or places where direction of ramp changes. Ramps and landings should be designed for a live load of at least 4 KN/m^2. Minimum width of pedestrian ramps is 1.2 m. Landings should be at least as wide as the ramps. Powered ramps, or moving walks, carrying standing passengers are set to operate on slopes up to 8° at speeds up to 60 m/min and/or slopes up to 15° at speeds up to 47 m/min.

16.5 Escalators

Escalators are power driven, inclined and continuous stairway used for raising or lowering passengers. These are used to move large number of people from floor to floor of buildings. Escalators are installed at commercial centres, shopping malls, air ports, railway stations and in other public buildings where heavy people movement is expected. These stairs have continuous operation without the need of operators. Escalators with electronic sensors are also available which operate automatically only when people approach to use it so as to save energy. Escalators have large capacity with low power consumption. Escalators are in the form of an inclined bridge spanning between the floors.

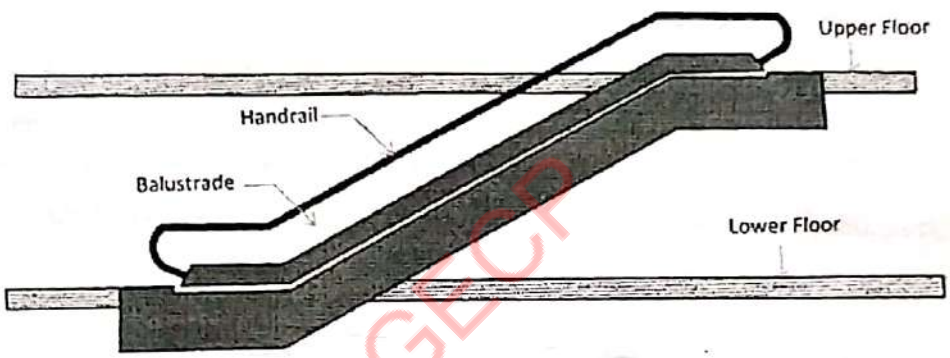


Fig. 16.2 Escalator

The components of an escalator are a steel trussed frame-work, hand rails and an endless belt with steps. At the upper ends of an escalator are a pair of motor-driven sprocket wheels and worm gear driving machine. At the lower end also there is a matching pair of sprocket wheels. Two precision-made roller chains travel over the sprockets pulling the endless belt of steps. These steps move on an accurately made set of tracks attached to the trusses with each step supported on four resilient rollers. Escalators are reversible in direction. They are generally operated at a speed of 0.5 to 0.75m/s. Slope of stairs is standardized at 30°. For a given speed of travel, the width of steps decides the capacity of the powered stairs. Normally a design capacity of 3200 to 6400 person per hour is adopted depending upon the width of the escalator. Escalators are installed at where traffic is heaviest and where it is convenient for passengers in a building. In new building design, sufficient space should be allotted for powered stairs and structural framing be made adequately to support them.

Table 16.1 Capacity of escalators

Step width	Theoretical capacity in number of persons/hour		
	0.5 m/s speed	0.65 m/s speed	0.75 m/s speed
0.6m	4500	5850	6750
0.8m	6750	8775	10125
1.0m	9000	11700	13500

Escalators are generally installed as pair. Up going traffic and down moving traffic are carried by this pair of escalators. The arrangement of escalators in each storey can be either parallel or criss cross. Criss-cross arrangement is more compact as it reduces walking distance between stairs at various floors to a minimum. This is why criss-cross arrangement is preferred over parallel arrangement.

16.6 Fire Safety for buildings

The primary goal of fire safety efforts is to protect building occupants from injury and to prevent loss of life and prevent property damage. According to Indian law, minimal fire safety equipment is mandatory for any developed property. These laws are given by the National Building Code (NBC), which is a document containing standardized requirement for the design & construction of most types of building in the country.

NBC stipulates certain norms and regulations in the construction of buildings to ensure fire safety. Some important aspects are

1. According to the height of the building, there shall be sufficient fire way around the building with a minimum width of say. 5m etc. for the entry of fire engines.

2. There shall be alternate fire stairs and lifts apart from the common stairs and lifts depending upon the floor area of the building.

3. Non-combustible materials should be used for construction of buildings, and the internal walls of staircase enclosures should be of brick work or reinforced concrete or any other material of construction with minimum of 120 min rating.

4. Emergency power supplying distribution system for critical requirement for functioning of fire and life safety system particularly for the operation of fire pumps, lifts, emergency exit lighting, signage lighting, fire alarm system, public address system and for fire control room.

5. Sufficient exclusive storage of water at ground water tank and at terrace with capacity depends on floor area of building.

6. Landings of fire stair shall abut with external wall and openings shall be closed with breakable glass.

7. Sufficient space shall be kept free at terrace for rescue operations and helipads are mandatory for high rise buildings.

16.5.1 Fixed Fire Extinguishing Systems/Installations

Portable firefighting equipment like fire extinguishers, as well as mobile firefighting equipment like Fire Tenders and other vehicle-mounted fire fighting appliances, can be used for tackling fires whether inside a building or in the open land. On the other hand, for tackling fires particularly inside buildings, structures or in specific areas, fire extinguishing systems installed permanently within the premises will be required for providing adequate fire protection.

These fixed fire extinguishing systems/installations can be based on various extinguishing media used for protection, as stated below:

(a) Systems/Installations based on water:

(i) Hydrant Installations;

(ii) Automatic Sprinkler Installations;

(iii) Automatic Water Spray Installations;

(iv) Automatic Deluge and Drencher Installations.

(b) Systems/Installations based on foam:

(i) Automatic foam installations using low expansion foam;

(ii) Automatic foam installations using medium expansion foam;

(iii) Automatic foam installations using high expansion foam.

Chapter 17

GREEN BUILDINGS

17.1 Introduction

Right from the pre historic man who constructed the hut for the first time to the great builders of modern world, have exploited the nature and its resources and disturbed the natural habits of other birds and animals. Now tremendous damages have been inflicted on our planet by the construction of various types of buildings using sand and water from the rivers, stones from the mountains, cement manufactured from the ingredients dug from the land etc. Also carbon emission from the buildings and due to manufacture of construction materials warm up the air and space. This global warming leads to changes in climate, changes in rain fall pattern, rise of sea level, acid rain, ozone layer depletion etc. On realizing the environmental responsibilities, many efforts were put forth and one such intelligent initiative is the concept of "Green Buildings".

Green Buildings have a new approach to save water, energy and material resources in the construction and maintenance of the buildings and can reduce or eliminate the adverse impact of buildings on the environment and occupants.

"A green building is one which uses less water, optimises energy efficiency, conserves natural resources, generates less waste and provides healthier spaces for occupants, as compared to a conventional building"

Green Buildings are Eco Friendly Structures. This helps the earth and people to retain nature to a maximum extent possible in three ways with reference to the location of the buildings as below.

1. Retain the external environment at the location of the building.
2. Improve internal environment for the inhabitants.
3. Preserve the environment at places far away from the building

17.2 Green Building Materials

The basic concept behind materials used in the construction of green building is the minimum release of green house gases (CO_2) during the production of those materials. Also these materials consume minimum quantities of water, energy and raw materials during production and conveyance. Many of these are made by re-use and recycle methods. Green building materials are reusable, energy efficient, sustainable and environment friendly. Some of the green building materials are discussed in following sections.

1 Earthen Materials

Earthen materials like adobe, cob, and rammed earth are being used for construction purposes. For good strength and durability- chopped straw, grass and other fibrous materials etc. are added to earth. Even today, structures built with adobe or cob can be seen in some remote areas.

2. Engineered Wood

Wood is one of the most famous building materials used around the world. But in the process of conversion of raw timber to wood boards and planks, considerable quantity of wood gets wasted. This wastage can also be used to make structural parts like walls, boards, doors etc. in the form of engineered wood.

Engineered wood contains different layers of wood, usually the middle layers are made of wood scraps, softwoods, wood fibers etc.

3. Structural insulated panels (SIPs)

Structural insulated panels (SIPs) consist of two sheets of oriented strand boards or flake board with a foam layer between them. They are available in larger sizes and are used as walls and partitions for the structure. Because of size, they often need heavy equipment to install however, they provide good insulation.

4. Insulated Concrete Forms

Insulated concrete forms contain two insulation layers with some space in between them. This space contains some arrangement for holding reinforcement bars. After these forms are placed at site with reinforcement, concrete is poured into this space. This will act as wall or partition or any other structure.

They are light in weight, fire resistant, low dense and have good thermal and sound insulation properties.

5. **Cordwood**

If wood is abundantly available at the site of construction, cordwood construction is recommended. It requires short and round pieces of wood which are laid one above the other, width wise, and are bonded together by special mortar mix. They are strong, environmental friendly and also give good appearance to the structure.

3. **Cellulose**

Cellulose is a recycled product of paper waste and it is widely used around the world for insulation purposes in buildings. It acts as good sound insulator and available for cheap prices in the market.

4. Polyurethane

Polyurethane foam is available in the form of spray bottles. They are directly sprayed onto the wall surfaces or to where insulation is required. After spraying it expands and forms a thick layer which hardens later on. They offer excellent insulation and prevent leakage of air.

5. Natural Fiber

Natural fibers like cotton, wool can also be used as insulation materials. Recycled cotton fibers or wool fibers are converted into a batt and installed in preformed wooden frame sections.

6. Fiberglass

Fiberglass is also used for insulation purposes in the form of fibreglass batts. Even though it contains some toxic agents, because of its super insulation property at low cost it is considered as a green building material.

7. Non-VOC paints

Non-VOC paint or green paint is recommended over VOC containing paints. Presence of Volatile Organic Compounds (VOC) in paint reacts with sunlight and nitrogen oxide resulting in the formation of ozone which can cause severe health problems for the occupants.

8. Timbercrete

Timbercrete is a combination between timber waste from various sources and concrete– a green material that is lighter that solid concrete with greater strength and insulating capabilities.

saw mill waste

This green material provides unique thermal qualities that combine thermal mass and insulation makes it suitable for eco-housing. Timbercrete is also bushfire proof, which allows minimal heat transfer and radiation. The other benefit is that this material is very user-friendly.

9. Straw Bale

Straw bale is another green building material which can be used as framing material because of good insulating properties. They also act as soundproof materials. Straw bale can be used as fill material in non-load bearing walls between columns and, in beams framework. Since air cannot pass through them, straw bales also have some resistance to fire.

bales of straw

10. Ferrock

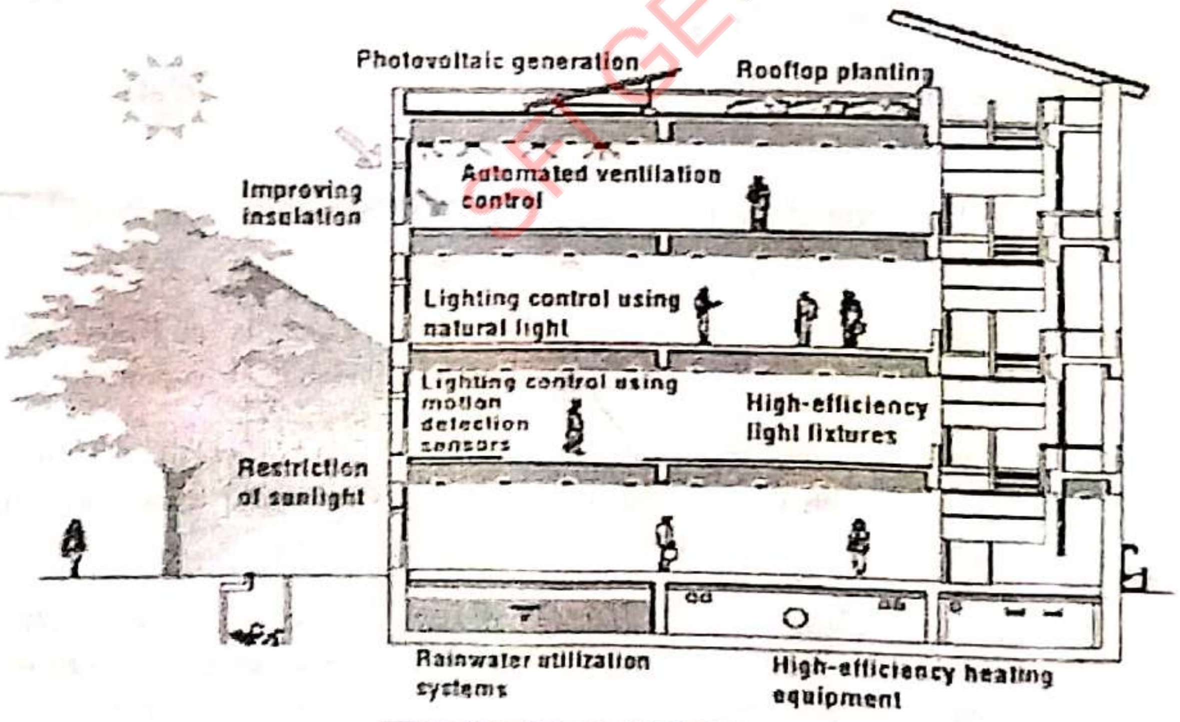
Ferrock is a new material that uses recycled materials including steel dust from the steel industry to create a concrete-like building material. It is stronger than concrete. This unique material actually absorbs and traps carbon dioxide as part of its drying and hardening process. Hence it is not only less CO_2 intensive than traditional concrete, but actually carbon neutral.

11. Stones

Slate/stone— These natural materials are excellent green choices but are very expensive due to both material and labor considerations but can be cheap at the places where they are easy available. They have a very long life.

12. Fiber cement

This material is made from wood, sand, and Portland cement. Fiber cement offers excellent durability and fire resistance and is less expensive than many common wood choices.



Conceptual Drawing of Green Building

17.3 Energy and water management systems

Optimization of energy and water consumption is the key factor in green buildings. There are efficient measures adapted in reducing the use of these resources. Those are explained below.

17.3.1 Energy systems in green buildings

In modern world, 30-40 percent of energy is consumed by the buildings. It is predicted that this may increase up to 48 percent by 2025. This warrants green buildings to achieve energy efficiency. There are many methods to improve building's energy efficiency.

1) The solar energy on a green building is trapped to supplement the conventional energy. Use of photo voltaic cells convert solar energy.

2) The natural light is allowed to enter in the intermediate floors to minimize the usage of electricity.

3) Sunlight is restricted by the high grown trees outside the lower floors of the building.

4) High efficiency light fixtures like LED lamps make a pleasant lighting apart from saving the energy.

5) Installation of motion detectors for lighting control which makes light to glow only when area is occupied.

6) High-efficiency windows and insulation in walls, ceilings, and floors are used for the benefit of better temperature control.

7) The HVAC system must have a correctly designed distribution system to minimize the amount of airflow (and thus energy) necessary to heat and cool the building.

8) Allowing building occupants to individually control heating and cooling in their living or working spaces is an effective way to reduce energy use.

9) New innovations in insulation can reduce the energy used in manufacturing insulation and allow insulation to be recycled or biodegradable. Mineral, fibrous, and cellulose-derived materials are now available for insulation purposes.

10) Weather-stripping, maintaining entry door closers and installing storm windows reduces the energy demand.

17.3.2 Water management in green buildings

Concept of optimal use of water in green buildings starts right with the planning stage of such building. The green building by its design and layout shall not disrupt the natural water flows, it should orient and stands just like a tree. Rain falling over the whole area of the building shall be harvested in full either to replenish the ground water table or to be utilized in the services of the building. Also water conservation methods are adopted throughout the construction phase of the building. Techniques like membrane curing are practiced to minimise the water required for curing of concrete elements during construction.

In simple words, water efficiency means reducing the usage of water and minimizing the waste water.

An integrated system approach to building water management allows the best allocation of potable water from municipal sources. And not only to regulate the inflow of water and recycling of water throughout the building system, but also decrease the outflow of water through efficient wastewater and infiltration processes. Water management comprises all aspects of the water cycle from start to finish. The following figure explains water flow in a conventional building and green building.

a) **Conventional Building**

b) **Green Building**

Fig. 17.3 Water Floor Diagrams

Blackwater is the mixture of urine, feces and flush water along with anal cleansing **water** (if **water** is used for cleansing) and/or dry cleansing materials.

Water coming from domestic equipment other than toilets (e.g., bathtubs, showers, sinks, washing machines) is called **greywater**.

In conventional buildings, potable water turns into black or grey water and rain water runs off.

But in green buildings, Potable water turns into greywater is recycled and used it again. Little portion of potable turned to black water and dispose d off. Rain water is stored and used again. This is the system where water efficiency achieved.

The other aspects of water management in green building are the following.

1) Rain water harvesting facilities to utilize the water for the services of the building are provided with sufficient capacity.

2) Plumbing arrangements are done in such a way that potable water is used for potable purpose only.

3) Dual plumbing is system adopted one for potable and other for recycled/flush water.

4) The toilets shall be fitted with low water consuming flushes.

5) Wash taps are controlled with motion sensors which reduces the use of water in unwanted times.

6) Grey water from kitchenette, bath and laundry shall be treated and reused for irrigation or in cooling towers of air- conditioning.

7) Water efficient toilets which use 2-3 litres of water for flushing compared to the conventional flushes.

8) Vacuum toilets which normally used in aircrafts are becoming common in public rest rooms and commercial buildings.

9) Waterless toilets (Composting toilets) which do not require water to transport human excreta. These toilets have pit or space below the toilet for composting excreta.

10) Water efficient urinals are used in offices and, hotels, theatres etc. use as less than 2.8 Litre of water per flush. Most of them use oil barriers instead of water seal in flushes to prevent odour escaping from urine.

11) Using Water efficient appliances like washing machines and dish washers.

Questions

1. What is importance of green building?
2. Explain any four green building materials.
3. Write short notes on the energy systems and water management in green buildings.