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Council For Technical Education and Vocational Training

Narayani Polytechnic Institute

Bharatpur-10, Chitwan

A CLASS NOTE

ON

BUILDING CONSTRUCTION

FOR

DIPLOMA IN CIVIL ENGINEERING (II/I)

(Based on New curriculum 2021)

BY

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CHAPTER 1: INTRODUCTION TO BUILDING CONSTRUCTION

1.1 Definition of building and its uses

A building can be defined as a structure broadly consisting of walls, floors, column, door, windows, ventilators, stairs, lift and roofs, erected to supply covered space for different uses such as residence, education, business, manufacturing, storage, hospitalization, entertainment, workshop etc.
Buildings are designed to meet our basic needs for:

a. **Shelter**: By providing the occupants from weather elements.
b. **Security:** By providing the occupants and their possessions from physical threat
c. **Comfort**: By providing a comfortable thermal, acoustic, and visual environment.

1.2 Building types

Depending upon the character of occupancy or the types of use, building have been classified in following groups as:-

1. **Residential Buildings**: All those buildings in which sleeping accommodation is provided for living permanently or temporary with or without looking of dinning or both facilities are termed as residential buildings. Example: Apartments, Flats, Bungalows, Private houses, Hotels etc.

2. **Educational Building:** These include any building in which education, training and care are provided to children or adults. All those buildings which are meant for education from nursery to university are included in this group.

3. **Institutional Building**: These includes any building which is used for purposes like medical or other treatment or care or persons suffering from physical or mental illness, disease or infirmity, aged persons etc. These buildings normally provide sleeping accommodation for the occupants.

4. **Assembly Building:** This group includes any building where groups of people assemble or gather for amusement, recreation, religious, patriotic, or similar purpose. Example: Cinema Halls, Museums, Place of Worships, Dance Halls, Swimming Pools.

5. **Mercantile Building:** These shall include any building or part of building which is used as shops, stores, market for display and sale of merchandise either wholesale or retail.

6. **Industrial Building**: Any building or part of building in which products or material of all kinds and properties are fabricated, assembled, or proceed. Example: Concrete Plants, Gas plants, Refineries, Sawmills, Power plants etc.

7. **Business Building:** These group includes any building or part or a building which is used for purposes such as transaction of business, keeping of accounts and records etc. Example: Bank, court halls, libraries.

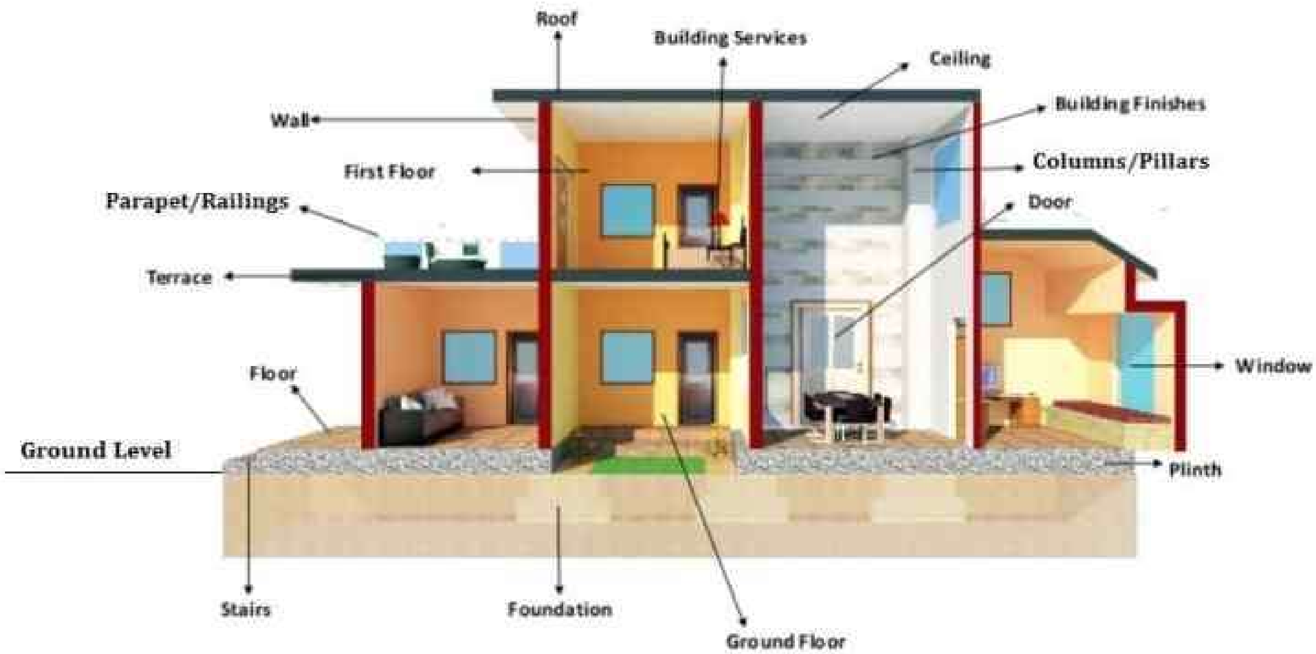
8. **Storage Building**: Any building or part of a building which primarily used the storage or sheltering of goods, wares or merchandise like warehouse, cold storages, garages etc.

9. **Hazardous Building:** This group includes those building structures which are used for the storage, handling, and manufacture or processing of highly combustible explosive material or products which are liable to burn with extreme rapidity and may produce poisonous smoke or gases or may produce explosive which are very toxic and dangerous for life.

1.3 General components of a building

A building can be broadly divided into two parts which are:-

i. **Substructure:** The part of building which are below the surrounding ground.
ii. **Superstructure:** The part which is above the surrounding ground.



The components of building are listed below:-

1. **Foundation:** Foundation is the lowest part of a structure which is below the surface of the surrounding ground level which is in direct contact with sub-strata and transmit all the dead, live and other loads to the soil on which the structure rests.
2. **Plinth:** Plinth is the middle part of the structure of the building between the ground surrounding the building and the top of the floor immediately. Plinth is the part where the substructure ends, and the superstructure starts.
3. **Walls:** The primary purpose of wall is to enclose or divide the floor space in desired pattern. Also, walls are used to provide privacy, security and give protection against sun, rain, cold and other adverse effects of weather.
4. **Column:** Column is a vertical member which is designed for compressive loads and buckling loads. They are structural members which transfer load from beam to footing
5. **Doors, Windows, and Ventilators:** The main function of doors in a building is to serve us a connecting link between internal part and allow the free movement outside the building. Windows are provided for the proper ventilation and lighting of a building. Ventilation moves outdoor air into a building or a room and distributes the air within the building room.
6. **Stair:** A stair is a structure that consists of several steps leading from one floor to another.
7. **Roof:** A roof is the uppermost part of a building whose main function is to enclose the space below and to protect from the effects of weather element such as rain, snow, sun, wind etc.
8. **Building Finishes:** The finishes of several types such as pointing, plastering, distempering, decorative color washing etc. applied on the walls.
9. **Building Service:** Building services include services like water supply, drainage, sanitation, lighting, electricity, air conditioning, fire detection and fire control etc.

1.4 Technical terms used in building

1. **Balcony:** Balcony in a building is horizontal cantilevered projection including a handrail to serve as passage or sitting out place.

2. **Basement:** Basement is the lowermost storey of a building below or partly below ground level that may be used for parking purpose also.
3. **Building Line:** It is a line set up by the local council which is the maximum distance that must be maintained between the building and the street or road boundary.
4. **Beam:** It is a horizontal structural member of a building that transmits the weight above it. Commonly used beams consist of reinforced concrete, running on the main walls of the building at a height above the doors and windows
5. **Chajja or Sunshade:** Chajja (also called as sunshade or weather shed) is the projected element just above the window, which shades the opening, stops rain from entering the room and reduces sky glare while looking out of the room. It's thickness usually tapers from 75 to 100 mm and projection is 300, 450, 600, 750, 900 mm.

6. **Damp Proof Course (DPC):** This is a watertight layer, built into masonry to prevent moisture rising from the ground. A course consisting of some proper water proofing material provided to prevent penetration of dampness or moisture.
7. **Drain:** Drains are the line of pipes including all fittings and equipment such as manholes, inspection chamber, traps used for the drainage of a building.
8. **Footing:** A foundation unit constructed in brick work, masonry, or concrete under the base of a wall or column for the purpose of distributing the load over a large area.
9. **Parapet:** A low wall or railing built along the edge of a roof or a floor.

10. **Set-Back line:** A line usually parallel to the plot boundaries and laid down in each case by the local municipal bodies beyond which nothing can be constructed towards the plot boundaries.
11. **Ground Coverage Ratio:** The quotient obtained by dividing the total plinth on plot area multiplied by 100 .

$$GCR=\frac{\text{Total Plinth}}{\text{area of the plot}} x\ 100$$

12. **Floor Area ratio:** The quotient obtained by dividing the total covered area (plinth area) on all floor multiplied by 100 by the area of the plot.

$$FAR=\frac{\text{Total covered area of all floor}}{\text{area of the plot}} x\ 100$$

13. **Mezzanine floor:** A mezzanine floor is an intermediate floor between main floors of a building, and therefore typically not counted among the overall floors of a building. Often, a mezzanine is low-ceilinged and projects in the form of a balcony.

1.5 General Requirements of parts of building

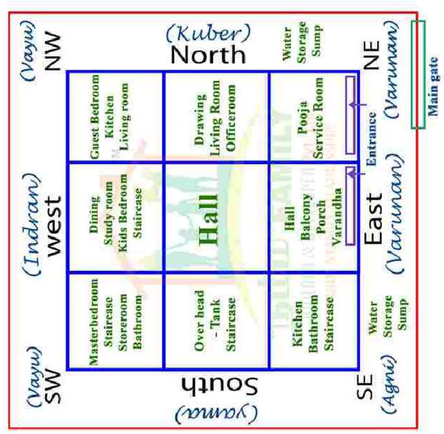
1. **Plinth:**
   a. **Main Building:** The plinth or any part of a building shall be so located with respect to surrounding ground level that adequate drainage of the site is assured. The height plinth shall not be less than **45 cm** from surrounding ground level.
   b. **Interior Courtyard***:* Every interior courtyard shall be raised at least **15 cm above** the level of the center of the nearest street and shall be satisfactorily drained.
2. **Habitable Rooms**
   a. **Size:** The area of habitable room shall not be less than **9.5 m^2** . In case where there is only one room, the minimum width of a habitable room shall be **2.4 m.**
   b. **Height:** The height of the habitable room shall not be less than **2.75 m** in measured from the surface of the floor to lowest point of the ceiling.
   In case of pitched roof, the average height of rooms shall not be less than **2.75** m. The minimum clear head room under a beam, shall be **2.4 m**.
   In case of educational building, ceiling height shall be **3.6 m** for all regions. It could be **3 m** in cold climate. In case of industrial buildings, ceiling height shall be **3.6** m and **3 m** if air conditioned.
3. **Kitchen**
   a. **Size:** The area of kitchen shall not be less than **5m^2** with a minimum width of **1.8m**. A kitchen which is also intended to be used as a dining room shall have a floor area not less than **9.5m^2** with a minimum width of **2.4 m**.
   b. **Height:** The height of the kitchen measured from the floor to the lowest point in the ceiling should not be less than **2.75 m** except for the portion to accommodate floor trap of the floor.
   c. **Other requirements:** Every kitchen should have a window of not less than **1m^2** in area.

4. **Storeroom**
    a. **Size**: The area of a storeroom shall not be less than **3 m^2**.
    b. **Height**: The height of a storeroom shall not be less than **2.2m**.
5. **Garage:**
    a. **Private Garage:** The size of private garage in residential buildings shall not be less than **2.75 m X 5.4m**
    b. **Height:** The height of a garage shall not be less than **2.4m.**
    c. **Other requirements:** The plinth of the garage located at ground level shall not be less than **15cm** above the surrounding ground level.
6. **Mezzanine floor**
    a. **Size:** The minimum size of the mezzanine floor shall not be less than **9.5m^2.**
    b. **Height:** The height of Mezzanine floor shall not be less than **2.20m**, and not more than **2.70m**.
7. **Bathroom and water closets**
    a. **Size:** The size of bathroom shall not be less than **1.8m^2** with a minimum width of **1.2m**. The minimum size of water closet shall be **1.1m^2** with a minimum width of **0.9m**. If it is combines bathroom and water closet, the minimum area shall be **2.8 m^2** with a minimum width **1.2m**.
    b. **Height:** The height of a bathroom or water closet measured from surface of the floor to the lowest point in the ceiling shall not be less than **2.2 m.**
8. **Roof**
    - The roof of building shall be so constructed as to permit satisfactory drainage of rainwater by means of sufficient rainwater pipes of adequate size.
9. **Parapet:**
    - Parapet walls and handrails provided on the edges of roof terrace, balcony, verandah etc. shall not be less than **1m** and more than **1.5m** in height.
10. **Basemen**t
    - The height of basement shall be at least **2.4m** from floor to ceiling.
    - The minimum and maximum height of ceiling shall be **0.9** m and **1.2 m** above the ground level.
    - The basement should be properly ventilated.
    - Adequate arrangement should be made so that surface drainage does not enter the basement.
11. **Stairway**

    The following minimum width shall be provided for each stairway.
    - Residential building up to 3 stories= 0.9 m
    - Other residential building e.g., flats, hostels etc. =1.25 m
    - Residential hotel buildings=1.5 m
    - Assembly buildings like auditorium, theatres, and cinemas=1.5 m
    - Institutional building like hospitals=2 m
    - Educational buildings like schools, colleges=1.5 m

    Other requirements
    - The maximum height of riser shall be 19 cm in case of residential building and 15cm in case of other building. There should not be more than 12 risers per flight.
    - The minimum width of thread shall be 25cm for residential building and 30 cm for other building.
    - Handrails shall be provided with a minimum height of 90 cm from the center of the tread.

1.6 General Rules of Vaastu Shastra



Vaastu shastra is an ancient science which capitalizes on the concept of prosperity. It links person's health and happiness directly with layout and construction of a building. In fact, vastu shastra is the science of the ancient "Vedic Ages" under the guidance of which one can construct building of structure on a particular plot of land. As per their belief the science of vastu shastra controls forces of gravity and magnetic power of the earth.

General rules of vastu shastra to ensure harmonious and prosperous life as follows:

a. **Well:** As far as possible, a well should be dug in the north-east corner of the house and the water from the well should be used for construction.
b. **Open space:** A house can be lucky if there is an open space around the building the whole extent of the house to ensure enough air flow and light.
c. **Shadow of trees:** Heavy and tall trees should be planted in the south, west and south-west of the house. The small plants can be planted in the north, east and north-east. The planted should be planted such that natural light is not blocked.
d. **Kitchen:** Kitchen should be prohibited in northeast direction. Southeast will be best direction to place kitchen.
e. **Staircase:** Northeast direction is worst to construct staircase while southwest is best direction.
f. **Toilet:** The best direction to locate toilet is northwest. Toilet should not construct in northeast direction.
g. **Construct house in south or west direction:** Constructing house in south or west direction is considered auspicious and there is lesser chance of quarrelling, financial crisis etc.
h. **Doors:** It is best if doors face north or east. Similarly, doors should open inside.
i. **Windows:** No window should face towards south-western side to avoid bad luck and negative energy.
j. **Foundation:** While digging foundation, it should be started from the east, go to the north, then to the west and lastly southwest.

CHAPTER 2: Foundation and its types

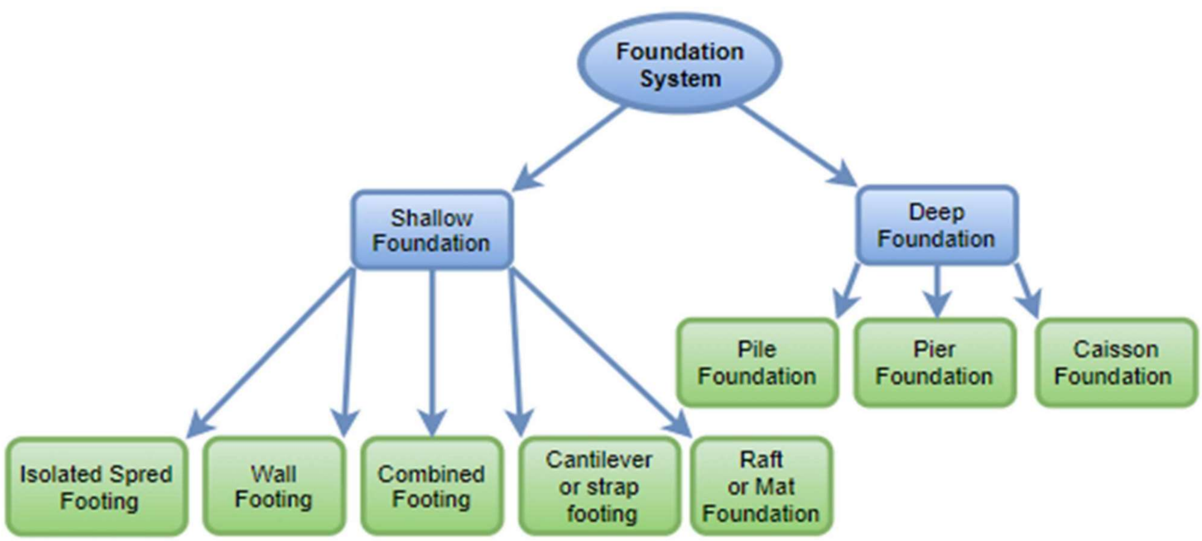
2.1 Concept of Foundation and its purposes

Foundation is defined as that part of the structure that supports the weight of the structure and transmit the load to underlying soil or rock. The soil ground on which the foundation rest is called the foundation bed.

Foundation is provided for the following purposes.

- To distribute the total load coming on the structure on large area to avoid over loading of the soil beneath.
- To prepare a level surface for concreting and masonry work.
- To take the structure deep into the ground and thus increase its stability, preventing overturning.
- Foundation distributes the uneven load of superstructure to the subsoil evenly.
- It provides safety to the structure against undermining or scouring due to animals, flood etc.
- To prevent or to minimize crack due to movement of moisture in case of weak or poor soils etc.
- Foundation supports the structure.

2.2 Types of Foundation



1. **Shallow Foundation**

   When a depth of foundation is less than the width of foundation then it is known as shallow foundation. Shallow foundation placed no more than 6 ft depth from the lowest finished floor.

   A shallow foundation is used when

   - The sufficient bearing capacity of soil available at shallow
   - Foundation material or strata do not result in undue settlement.

   Types of shallow foundation are

   a. **Isolated Spread Footing (Single Footing):** The foundation which is provided under single column is called as isolated footing. It may be square, circular, or rectangular in shape in plan.

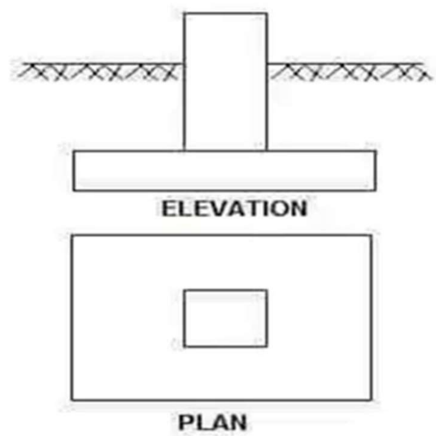
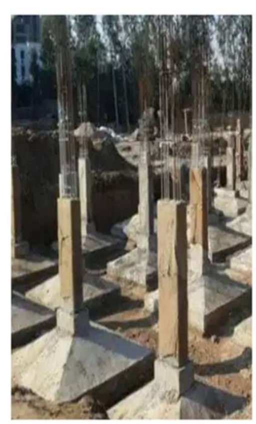


Fig :Isolated spread footing

Types of isolated footing

Single footing

stepping footing



Sloped footing

b. **Wall Footing (Strip Foundation):** The footing which is provided to support wall is known as strip foundation. These footing have length much greater than its width(L>>B)

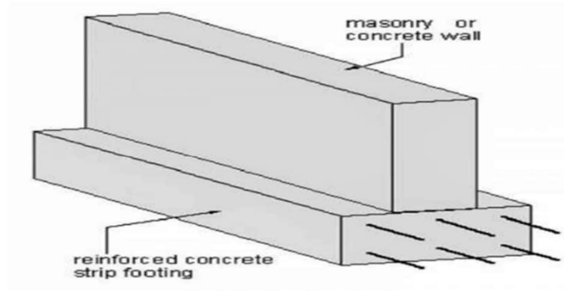
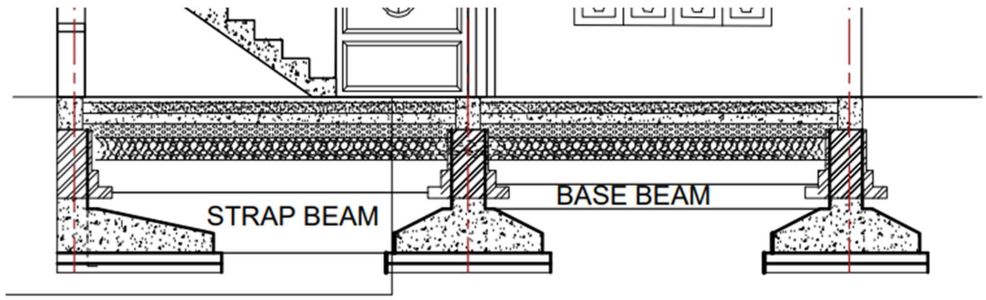
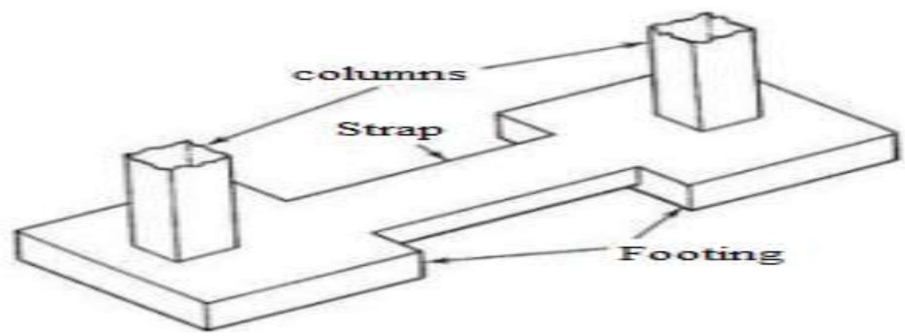


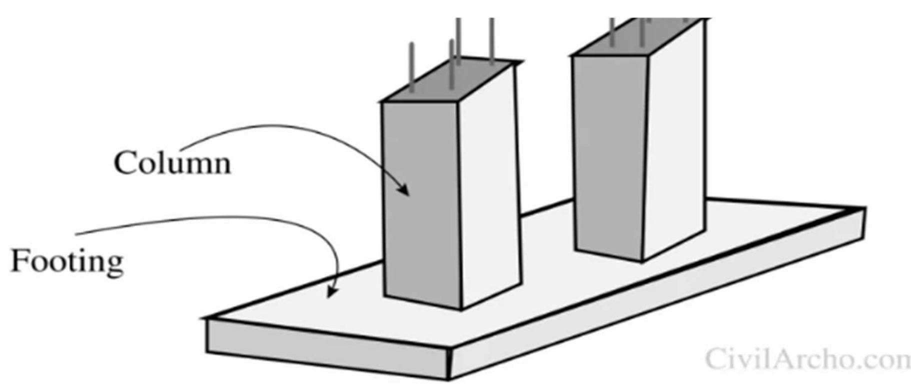
Figure: Wall or Strip footing

c. **Strap Footing(Cantilever footing):** A foundation which consists of two or more isolated foundation connected by a beam is called strap foundation.

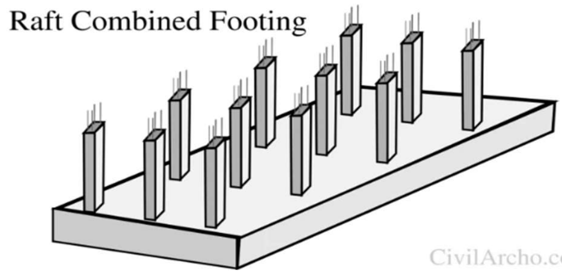




d. **Combine Footing:** Combine footing is provided to support two or more column in a row. It is provided when two or more column is too close.



e. **Raft or Mat foundation:** Raft or mat foundation is a large foundation or slabs supporting several columns as well as wall under structure. This type of foundation is used when the allowable soil pressure is low or where the columns and wall are so close that individual foundation would overlap or nearly touch each other.

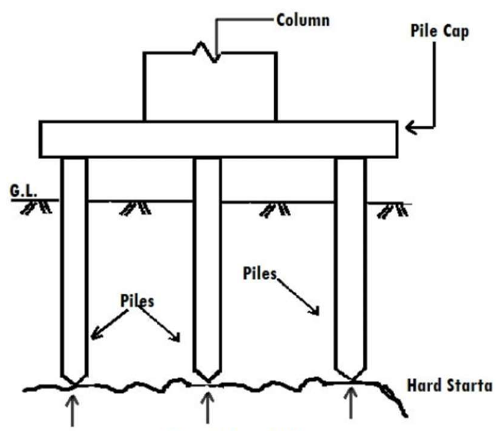


2. **Deep foundation (depth to width ratio>1)**

   A deep foundation is a foundation that transmits the load of a structure of strong soil beds or rock beds available in great depth. When the soil at or near the ground surface is not capable of supporting a structure, deep foundations are required to transfer the loads to deeper strata.

   Types of deep foundation are:

   1. **Pile foundation:** Pile foundation is that type of deep foundation in which the loads are taken to a low level by means of vertical members which may be of timber, concrete, or steel. Pile foundation is a common type of deep foundation. It is used to transmit foundation loads to a deeper soil or rock strata when the bearing capacity of soil near the surface is low.

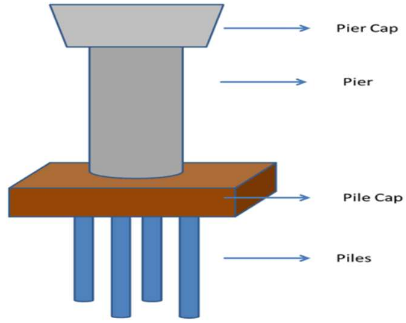


Bearing Piles

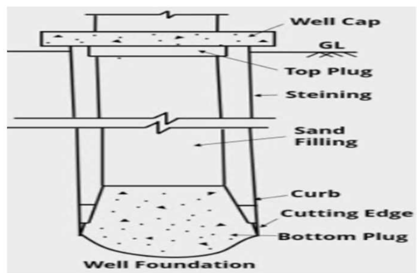
   2. **Pier Foundation:** It is the type of deep foundation which consists of cylindrical column of large diameter to support and transfer large gravity loads to the earth below.

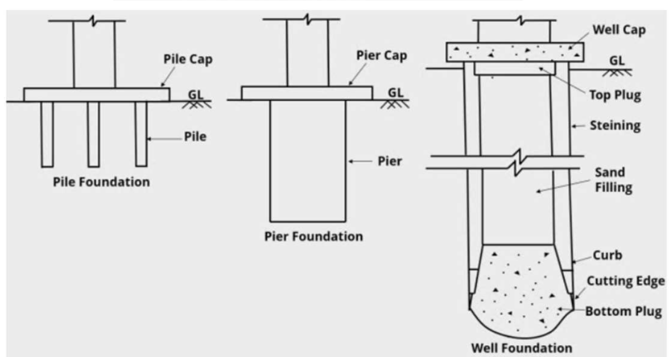
      It consists of vertical shaft up to hard bed and filling them with concrete. The diameter of shaft and their center to center (c/c) spacing depends upon the loading condition, nature of soil and depth at which hard soil is situated. It is used in sandy soil or soft soil. Its types are

      i. Masonry or concrete pier
      ii. Drilled pier



3. **Well or Caisson Foundation:** The well or caisson foundation is such type of foundation which is box like structure circular or rectangular in plans which are sunk from surface of either land or water in desired depth. It is much larger in diameter than pier foundation.
   It is used as bridge pier. It is also used where foundation under water is done.





A. Construction detail of spread foundation for wall and thumb rule (As Per NBC 202:2015)

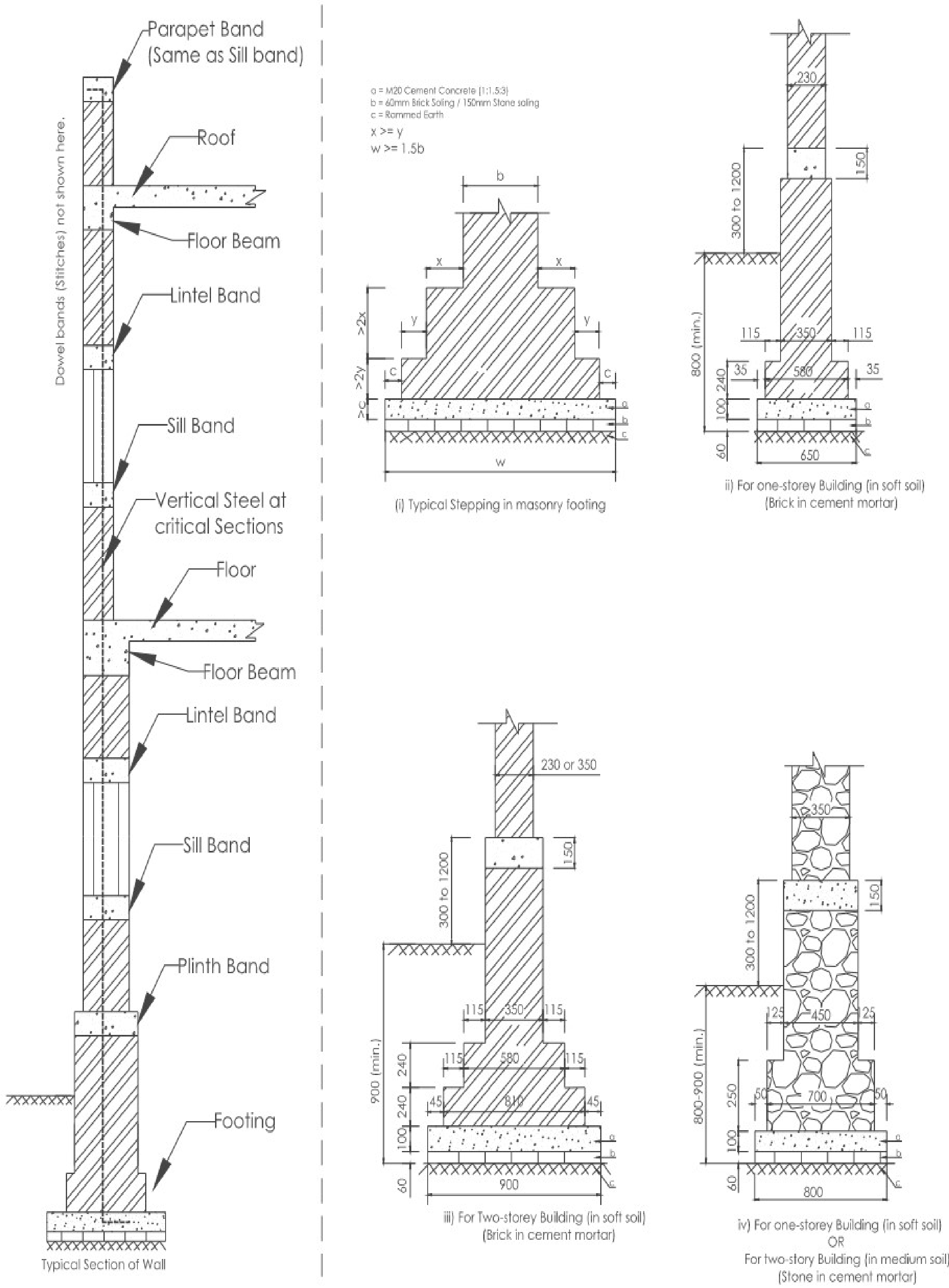


Figure 1-1: Wall Section and Stone/Brick Wall Footing Details

B. Design of foundation (for Numerical For square Footing)

i. Depth of foundation (D_f)

Depth of foundation depends on the character of sub soil and magnitude of load on the structure. minimum depth is calculated by **Rankine's formula**

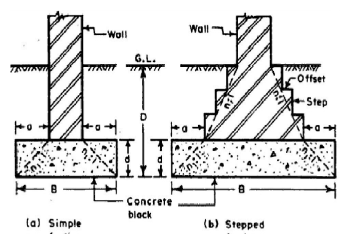
$$D_f = \frac{Po}{\gamma}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)^2$$

where,
D_f = minimum depth of foundation
P_o= Safe bearing Capacity of soil
γ = unit weight of soil (KN/m3)
Φ = angle of repose of soil

ii. Depth of concrete block (d)

$$\textbf{Depth (d)} = \sqrt{\frac{3Px^2}{m_r}} \text{ or } d = \frac{5}{6} \times t$$

Where,
t = thickness of wall
d = depth of concrete bed
x = projection of concrete block
m_r = safe modulus of rupture of concrete in KN/mm^2
P = net upward pressure in KN/m^2



iii. Width of footing (Breadth of concrete bed) (B)

$$A = \frac{W}{Po}$$

$$B = \sqrt{A} \text{ (for Square Footing)}$$

Where,
A = Area of the footing
B= Width of footing in meter
P_o= Safe bearing Capacity of soil
W = total load including self-weight of footing KN/m^2

iv. Minimum width of concrete bed (B_{min})

B_{min} = 2b +2X

Where,
b = width of wall
x = offset of concrete block generally taken as 0.15m

Greater value obtained from (c) and (d) above is taken as the final width of concrete bed.

v. Draw the net sketch of foundation section with the calculate sizes. Some values should be assumed as standard value.

1. **Value of angle of internal friction**

S.N	Type of soil	Angle of internal Friction
(i)	Loose earth	30° to 45°
(ii)	Compact Earth	50°
(iii)	Dry Sand	25° to 35°
(iv)	Moist Sand	30° to 45°
(v)	Wet Sand	15° to 30°
(vi)	Clays	25° to 45°
(vii)	Gravel	30° to 40°

2. **Modulus of rupture of various grade of concrete mix**

S.N	Type of Concrete	(m_r) in N/mm^2
(i)	Pure lime and surkhi concrete (1 mortar : 3 stone ballast)	0.155
(ii)	Moderately hydraulic lime and sand concrete (1 mortar : 3 Stone ballast)	0.155
(iii)	1:4:8 PCC ($M_{7.5}$)	0.246
(iv)	1:3:6 PCC (M_{10})	0.352
(v)	1:2:4 PCC (M_{15})	0.527

Solved Numerical

1. **Design the foundation for a brick pillar 600 mm X 600 mm in section and stress to 1000 KN/mm^2 of the pillar section. Safe bearing capacity of soil may be taken as 155 KN/m^2. Take weight of soil (ɣ) as 19.2KN /m^3 and its angle of repose (ϕ) = 30°.**

   Solution:

   Given,

   Size of Brick Pillar (B xB) = 600 x 600 mm^2

   Stress due to Brick pillar(W)= 1000 KN/mm^2

   Safe bearing capacity of soil(Po) = 155 KN/mm^2

   Unit weight of soil (ɣ) = 19.2 KN /m^3

   Angle of Repose (ϕ) = 30°

i. Width required for footing (B) = $\frac{W}{Po}$

$$= \frac{1000 \text{ KN/mm2}}{155 \text{ KN/mm2}}$$

$$= \frac{396000000 \text{ KN/m}}{155\, x10^6 KN/m^2} \quad (1mm^2 = 10^{-6}\, m^2)$$

$$= 2.55 \text{ m}$$

$$\therefore A_1 = 2.55 \text{ m}$$

∴ Width of the footing (B_1) = $\sqrt{2}.55$ = 1.60m (Assume Square footing)

ii. Width of the at bottom course = 2x600 mm = 1.2m

iii. Projection of concrete block on either side at bottom of the course (x) = $\frac{(1.6-1.2)}{2}$

∴ X =0.2m

iv. For depth of concrete block

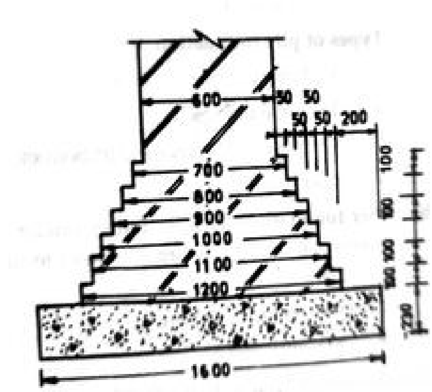
Assume grade of concrete for bed block be M_{10} (1:3:6)

∴ m_r = 0.352 KN/mm^2 = 352 KN/m^2

We know,

$$\text{Depth (d)} = \sqrt{\frac{3Px^2}{m_r}}$$

$$= \sqrt{\frac{3\ X\ 155\ X\ 0.2^2}{352}}$$



$\therefore$ d = 0.228 ≈ 0.23 = 230mm

Alternately,

$d = \frac{5}{6} \times t$

$d = \frac{5}{6} \times 600$

d = 500mm

v. Depth of foundation (D_f)

We know,

$$D_f = \frac{Po}{\gamma} \left(\frac{1-\sin\phi}{1+\sin\phi}\right)^2$$

$$= \frac{155}{192} \left(\frac{1-\sin 30}{1+\sin 30}\right)^2$$

$$= \frac{155}{192} \times \frac{1}{9}$$

$\therefore D_f$ =0.897 m

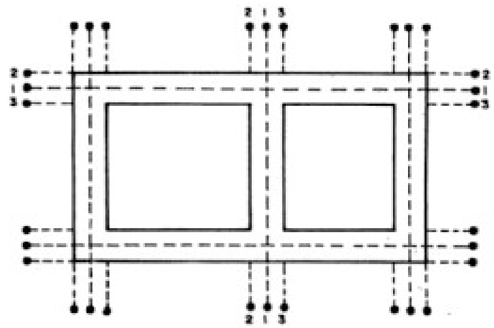
Unsolved Numerical

Design a wall footing which is rest on sandy soil with angle of internal friction 30 degrees and S.B. c of a soil is 15 tons/ m^2 the unit weight of soil is 1600 kg/m^3, wall thickness is 30 cm and load per meter length of soil is 12.4766 tons/m.(CTEVT 2065).

2.1 Earthwork

A. **Setting out of Foundation**

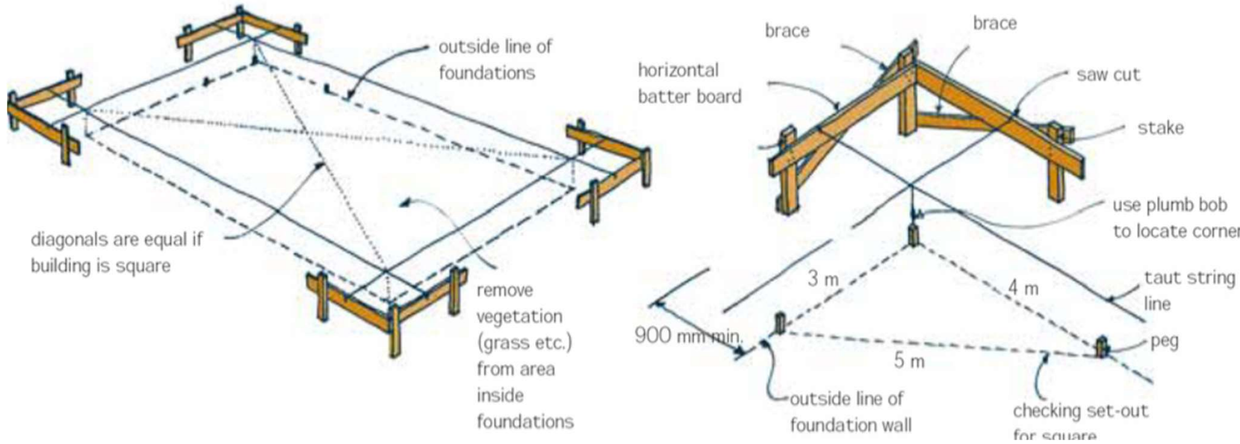
Setting out of building foundation trenches is the process of laying down the excavation line and centerline on the ground based on the foundation plan. The setting out process is also called as ground tracing that is performed before commencing the excavation process. Once the design of foundation is complete, a setting out plan or foundation layout is prepared for a suitable scale and the plan is dimensioned accordingly.



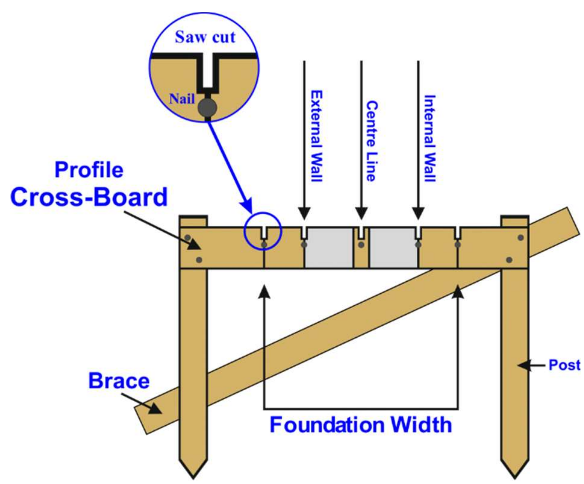
Procedure and requirements in setting out foundation trenches are explained below.

Procedure for setting out building foundation

- The initial step is to mark the corners of the building. After which, the lengths of the sides are checked by diagonal measurements.



- The axial lines (center lines) of the trenches are marked with the help of profiles, sighting rails, strings, and pegs.



- The trench positioning is controlled by outline profile boards. Profiles are set 2m away from the outline so that they do not interrupt the excavation process.
- The offsets are measured from axial lines and the front lines are placed in their correct position relative to local requirements.
- The cross walls positioning is performed by measuring along the main walls and squared from these walls as required. The total width of trenches must be carefully outlined during this process.

Requirements for setting out building foundation

The setting out must establish the following requirement.

- The size of the excavation
- The shape of excavation
- The direction
- The width of the walls
- The position of the walls

The following points should be observed while setting out trenches:

- To set out foundation plan, nails, pegs, profiles, strings, and lime are used.
- To correctly determine the position of trenches, the sight rails must be properly erected at the corners of the building.
- Accurate center lines or axial lines can be determined and marked by using a theodolite.
- To the nails or pegs on the profiles, strings are tied and stretched to achieve horizontal control of dimensions.
- At 1 meter from the edges of excavation vertical reference pillars are erected. Hence vertical control is achieved during building construction.
- A standard datum is previously determined and marked by the surveyor, based on which the levels on the site are obtained. The depth of trenches and other levels should also be regulated by measurements from this point.
- Before placing the concrete into the trenches, the bottom must be properly rammed and compact.
- The width is marked by means of lime powder when the excavation is performed by hand. These markings give accurate cutting
- Centerline is marked when the excavations are performed by a machine.

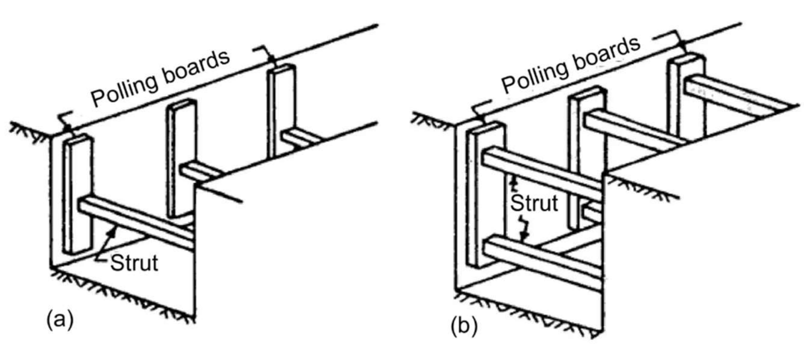
B. Timbering of Trenches

When the depth of trench is large, or when the sub-soil is loose, the sides of the trench may cave in. The problem can be solved by adopting a suitable method of timbering. Timbering of trenches, sometimes also known as shoring consists of providing timber planks or boards and struts to give temporary support to the sides of the trench.

Timbering of deep trenches can be done with the help of the following methods:

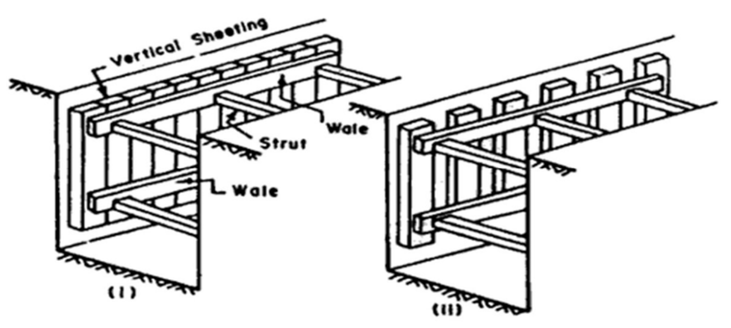
a. Stay bracing:

This method is used for supporting the sides or a bench excavated in firm soil when the depth of excavation does not exceed about 2m. The method consists of placing vertical sheets (called sheathing) or polling boards opposite each other against the two walls of the trench and holding them in position by one or two rows of struts. The sheets are placed at an interval of 2 to 4m and, they extend to the full height of the trench. The polling boards may have width of about 200 mm and thickness of 44 to 50 mm.



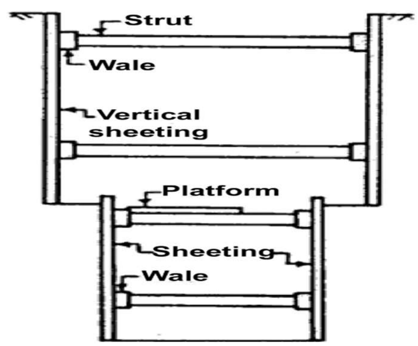
b. Box sheeting:

This method is adopted in loose soils when the depth of excavation does not exceed 4m. A boxlike structure is made using sheeting, Wales, struts, and bracings. The vertical sheets placed near to each other and keeping them in position by longitudinal rows (usually two) of Wales. Struts are then provided across the Wales.



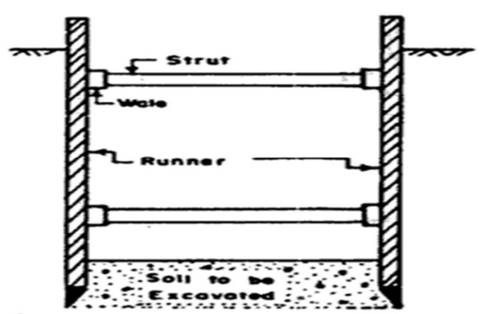
c. Vertical Sheeting

This system is adopted for deep trenches (up to 10 m depth) in soft ground. The method is like the box sheeting except that the excavation is carried out in stages and at the end of each stage, an offset is provided, so that the width of the trench goes on decreasing as the depth increases. Each stage is limited to about 3 m in height and the offset may vary from 25 to 50 cm per stage.



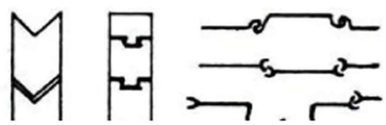
d. Runner System

This system is used in extremely loose and soft ground, which needs immediate support as excavation progresses. The system is like vertical sheeting of box system, except that in the place of vertical sheeting, runners made of long thick wooden sheets or planks with iron shoe at the ends, are provided. Wales and struts are provided as usual. These runners are driven about 30 cm in advance of the progress of the work by hammering.



e. Sheet Pile

This method is adopted when soil to be excavated is soft or loose, depth of excavation is large, width of trench is also large and Sub soil water is present.



C. Construction of foundation under waterlogged trenches (Dewatering)

Excavation of foundation in waterlogged sites poses a great problem for the site engineer. There are various methods of dealing with the situation which depends upon the depth of excavation, depth of water table and many other factors.

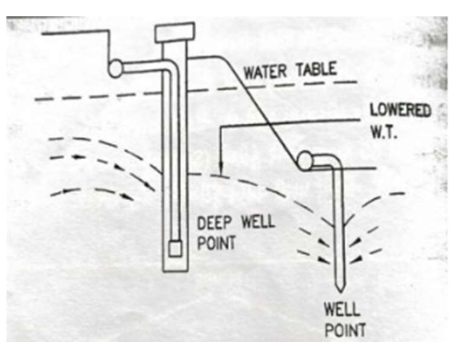
Following methods are adopted while digging foundation trenches in water-logged sites.

a. By constructing drains

This method is adopted in shallow foundation in water-logged ground. In this method, drains of suitable size are constructed by the sides of the foundation trench. The drain collects sub-soil water from the sides and the enclosed area and convey it into a shallow pit or sump well. From the sump, the water is continuously pumped out. This is the cheapest method of draining excavated area and can be easily adopted by using unskilled labor and by using simple equipment.

b. By construction deep wells

In coarse soils, porous rock or in sites where large quantity of subsoil water is required to drained out, (30-60)cm Dia porous rock or in sites where large quantity of subsoil water is required to drained out, (30-60)cm diameter wells are sometimes constructed at 6-15m centers all-round the sites. The water collected in the well is pumped out continuously. This method can be adopted for depth of excavation up to 24m.



c. Freezing Process

This process is suitable for excavations in water-logged soils like sand, gravel, and silt. It is advantageously used for deep excavation such as foundation for bridges. The process consists of forming coffer dam by freezing the soil around the area to be excavated. Freezing pipes containing smaller diameter inner pipes are submerged about 1m center to center along the boundary of the area to be excavated Freezing liquid is then delivered to the freezing pipes by refrigeration plant. his makes the ground around the pipes to freeze and produce a thick wall of frozen earth around the area to be excavated. This process can be applied for up to 30 m depth of excavation.

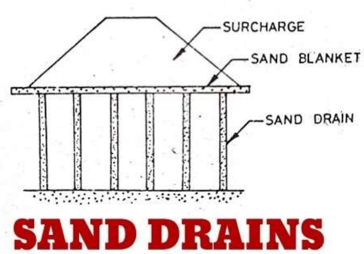
d. By chemical consolidation of soil

In this method, the soft water-logged soils are converted into a semi-solid mass by forcing chemicals like silicates of soda and calcium chloride into the soil. This method is used for small work.

e. Well point system

This is a method of keeping an excavated area dry by intercepting the flow of ground water with pipe well driven deep into the ground. The main components of a well point system are well points, riser pipe, header pipe and the pumps.

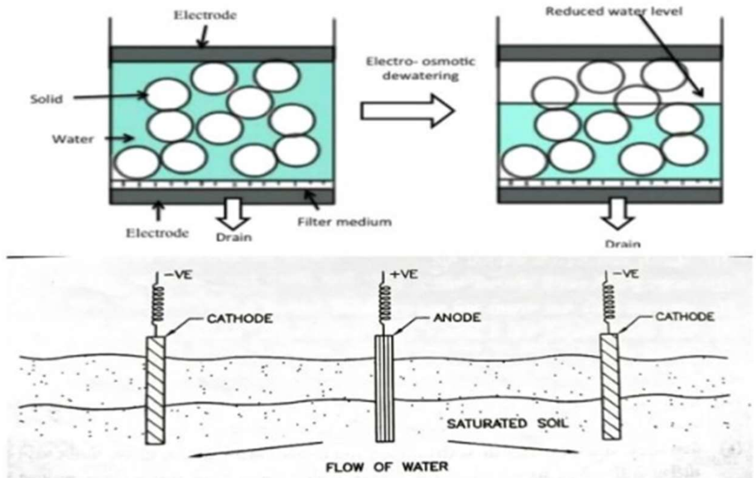
f. By constructing sand drains



Sand drains is highly effective in marshy (दलदल) soils. The diameter of soil drains normally varies between 300 mm to 450 mm. The hole for making the sand drain can be made by driving steel pipe casting into the ground. The drain holes are driven deeper than the marshy layer. The marsh in the pipes is removed by means of jets. Selected type of sand is then filled into the pipes and the pipes are withdraw leaving vertical sand piles in the ground. A thick layer of sand is spread over the entire area to be consolidated. When sand layer is subjected to load, the water from the muck of the marshy soil gets squeezed into the vertical sand drains.

g. Electro-Osmosis

In the process of Electro-Osmosis, steel rod forming the positive electrodes are driven into the soil midway between the well points, which are made to act as negative electrodes. When electric current is passed, the ground water flows towards the negative electrodes and is pumped out. This process requires expensive equipment and hence it is rarely used.



CHAPTER 3: Walls

3.1 Purpose of walls

Masonry is the word used for construction with mortar as a binding material with individual units of bricks, stones, marbles, granites, concrete blocks, tiles etc. The durability and strength of masonry wall construction depends on the type and quality of material used and workmanship.

Wall may be defined as a vertical member, the width (i.e., length) of which exceeds four times the thickness.

Following are the purpose of construction of walls.

a. Walls provide protection against weathering agencies.
b. Walls assure the security.
c. Walls are used for providing support to the floor and roof.
d. Walls are used for privacy.
e. These are used to protect us from heat, cold and other purposes.
f. These are used to divide the available space of the building to fulfill the basic requirements.

3.2 Classification of walls

Wall can be classified into various types on the different criteria.

A. Following are types of walls based on loading condition.

i. Load bearing wall:

It carries loads imposed on it from beams and slabs above including its own weight and transfer it to the foundation. These walls support structural members such as beams, slabs, and walls on above floors above. It can be exterior wall or interior wall. It braces from the roof to the floor.

ii. Non-load bearing wall

Non-load bearing walls only carry their own weight and does not support any structural members such as beams and slabs. These walls are just used as partition walls or to separate rooms from outside. It is known as interior wall (doesn't carry other load than its own load).

iii. Dwarf wall

A dwarf wall is a low wall that is often used as a garden wall, or as the base for the perimeter of a greenhouse or terrace structure. It can be applied to any wall that is less than one-storey in height, but typically dwarf walls are less than 1 meter tall.

iv. Retaining wall

Retaining wall may be defined as a wall built to resist the pressure of liquid, earth filling, or other granular material filled behind it after it is built. It can be used in construction of hill roads, abutments, bridge, dams etc.

v. Breast wall

Breast wall is the wall which is built to sustain the face of a natural bank of the earth. It is the wall built to prevent the soil on a natural slope embankment from sliding down the slope from the harsh weather effects.

vi. Partition wall

A partition wall may be defined as a wall or division made up of bricks, timber, glass, or other materials for the purpose of dividing one room or partition of a room from another.

Objectives

- To divide the whole area into number of rooms.
- To offer privacy for both sight and sound.

B. Following are types of walls based on per material of construction.

a. Brick masonry wall:

The construction of brick bonded together with mortar is termed brick masonry. Brick masonry is a highly durable form of construction. It is built by placing bricks in mortar in a systematic manner to construct a solid mass that withstands exerted loads. There are several types of bricks and several mortars that can be used to construct brick masonry. The bond in brick masonry, which adheres bricks together, is produced by filling joints between bricks with suitable mortar. Special cautions shall be practiced while the mortar is mixed and placed since it greatly affects the performance and durability of the masonry structure.

The brick is mainly used as wall material because it's very easy to use and economical. Size of brick according to NBC is 240 mm (L) x 115 mm (W) x 57 mm (H).

Dimensions of Nepal Standard Brick (mm)				
Length	Breadth	Height	Vertical Mortar Joint	Remark
240	115	57	10	For 10 mm mortar joint

Table 3.1 : Dimensions of a Nepal Standard Birck

Note : Length of Birck = 2 x Width of Birck + 1 Vertical Mortar Joint

b. Stone masonry walls

The construction of stones bonded together with mortar is termed stone masonry. Where they are available in an abundance in nature, on cutting and dressing to the proper shape, they provide an economical material for the construction of various building components such as walls, columns, toothing, arches, beam, etc.

Stone masonry is stronger, durable, and weather-resistant as compared to brick masonry and is in the construction of piers, docks, dams, lighthouses, and other marine structures.

Types of stone masonry

Based on the arrangement of the stone in the construction and the degree of refinement in the surface finish, stone masonry can be classified broadly into the following two categories.

a. Rubble masonry
- Coursed Rubble masonry
- Uncoursed rubble masonry

b. Ashlar masonry
- Fine masonry
- Ashlar Rough-tooled masonry

❖ **Comparison of brick masonry and stone masonry**

i. Generally, brick masonry is cheaper than stone masonry and can be easily constructed.

ii. The minimum, thickness of a wall in stone masonry can be 35 cm whereas, in brick masonry walls of 10 cm thickness can be constructed.

iii. The brick masonry construction proceeds very quickly whereas the stone masonry construction proceeds very slowly, as the bricks are handy whereas stones are not.

iv. Skilled masons are required for stone masonry construction, whereas unskilled laymen can do the brick masonry work.

v. Brick masonry requires less mortar whereas stone masonry requires more mortar which cannot be easily estimated.

vi. Stone masonry is stronger and more durable than brick masonry.

vii. It is not essential to plaster the stone masonry walls whereas brick walls must be plastered or painted when exposed to the open atmosphere.

viii. Bricks are of an absorbent nature and no absorbing moisture makes the buildings damp, but stones are less adsorbent and hence stone masonry walls or buildings are more damp proof.

ix. Brick masonry work cannot be allowed to encounter urine, sewage, etc., without protecting them, whereas this is not the case with stone masonry.

x. Brick masonry is more fire-resistant than stone masonry.

xi. Good ornamental work can be cheaply and easily done in plaster in case of brick masonry, but it is not possible in stone masonry.

xii. Being uniform and regular in shape, proper bond can be easily obtained in case of bricks as compared with stones. Similarly, obtuse, and acute angle joints can be easily provided with brick in masonry than stone masonry.

xiii. Brick absorbs less quantity of heat than stone, therefore in not climates, during nights, stone walls emit more quantity of heat and make sitting in the room uncomfortable.

c. Precast Masonry wall

Precast concrete walls are constructed by casting concrete in a reusable wall mold or form which then cured in a controlled environment, transported to the construction site, and lifted into place. The main function of the precast walls is to speed up the construction process.

Advantages of precast concrete walls

a. Precast concrete walls act as thermal storage to delay and reduce peak thermal loads.

b. The precast concrete wall is used as an interior surface which saves time and money by eliminating the need for separate protection framing and dry wall costs.

c. The precast concrete wall can be used as load-bearing structures and will save cost eliminating the need for an additional structural framing system.

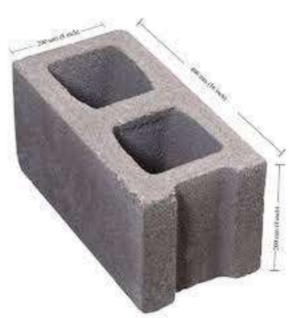
d. Precast concrete walls can be designed to be reused for future building expansions.

e. Precast concrete's durability creates a low maintenance structure, which stands up to critical climate conditions.

f. Precast concrete colors and finishes can be achieved using various aggregate**,** cement, pigments and finishing techniques.

g. Precast concrete walls can be produced with textures including form liner shapes, artwork, and lettering to provide distinctive accent treatments.

d. Hollow Concrete Block



A hollow concrete block is a block made of concrete that has hollow spaces between its walls. It is used to build different types of walls for different purposes like retaining walls, decorative walls, classic walls, etc. Hollow blocks are made of the same ingredients used in poured concrete walls. Hollow concrete blocks are having one or more large holes or cavities which either pass through the block (open cavity) or do not effectively pass through the block (closed cavity) and having the solid material between 50% and 75% of the total volume of the block calculated from the overall dimensions.

Advantages of hollow concrete block masonry

- **a.** Hollow concrete block masonry is the easier and faster construction practice as compared to any other masonry practices.
- **b.** Hollow concrete block masonry reduces the cost of construction labor and construction materials because the use of a larger size of concrete block reduces the number of joints in work.
- **c.** Semi-skilled or unskilled labor can also work in this type of construction.
- **d.** These concrete blocks need low maintenance and are durable.
- **e.** They are eco-friendly materials as industrial wastes, such as fly ash or bottom ash are used as raw materials.
- **f.** Reinforcing the hollow block masonry is possible as there is no additional formwork, or any construction machinery required.
- **g.** Hollow concrete block masonry is highly durable as the concrete is compacted by high pressure and vibration, which gives substantial strength to the block. Adequate curing increases the compressive strength of the blocks.
- **h.** As the hollow concrete blocks are light in weight, they reduce the weight of the structure and hence light structural member or less percentage of steel is required for a given R.C.C building
- **i.** Presence of rough texture on concrete blocks provides good bonding between cement mortar and concrete blocks.
- **j.** It is possible to construct a thin wall by using hollow blocks. Therefore, it helps to save space and increase the floor area or carpet area, i.e., carpet area efficiency is better.
- **k.** In the hollow blocks, the voids or cores can be filled with steel bars and concrete for achieving high seismic resistance.
- **l.** Hollow concrete blocks have good insulating properties against sound, heat, and dampness.
- **m.** These blocks have low water absorption than conventional bricks. If you want to know how to measure water absorption in bricks then read the water absorption test of bricks.
- **n.** Hollow concrete block can safely resist the atmospheric action. This block doesn't require protecting covering
- **o.** It has good fire resistance.

Disadvantages of hollow concrete block

- **a.** The cost of hollow concrete blocks is higher than the conventional bricks.
- **b.** The house built with hollow blocks without any interior reinforcement is likely to suffer damage during earthquakes.

e. Solid Concrete Block

Solid concrete blocks are made from aggregate, Portland cement and sand. These blocks have a solid material, not less than 75% of the total volume of the block calculated from the overall dimensions. Hence, they are heavy. These blocks provide good stability to the structure. So, these blocks are used for a large work of masonry. They are used in the load-bearing walls as well as the non-load bearing walls. Solid blocks are available in large sizes as compared to the conventional bricks. Therefore, less time is required to construct concrete block masonry than brick masonry.

Advantages of solid concrete block masonry

a. The design of solid concrete blocks is flexible and easy to construct.
b. Solid concrete blocks are ideal for foundation and basement wall.
c. Solid concrete blocks are unaffected by termites.
d. Solid concrete blocks provide insulation against cold and hot weather.
e. The solid concrete blocks wall is long lasting, durable and requires less maintenance. These blocks are highly resistive to extreme weather conditions, like high winds, storms, floods, etc.

Disadvantages of solid concrete block masonry

a. Concealed wiring, plumbing etc. are difficult to make.

f. Reinforced brick masonry

Reinforced brick work is the one in which the brick masonry strengthened by the provision of steel bars, steel flats, hoop iron and extended mesh. The reinforced brick masonry is capable of resisting both compressive as well as tensile and shear stress. Because of its ability to resist lateral forces, reinforced brick masonry is extensively used in seismic areas. It is essential to use first class bricks, rich and dense cement mortar in the reinforced brick work.

Reinforced brick work is used in following circumstance:

- When brick wall is to carry heavy compressive load.
- When brick work must bear tensile and stresses.
- When brick work is to be carried out on soil which is susceptible to large settlement.
- When brick work is to resist lateral load.
- When it is required to increase the longitudinal bond.
- When brick work is to be used in seismic areas.

6. Composite Masonry in Stone and Brick

In this type of wall, stone slabs are used in the face work and brick masonry is used as backing. Stones used may be natural or artificial. The stones are secured to the backing either by means of metal cramps or by projecting the headers in the face work well inside the backing. The different types of composite masonry are described below.

a. Brick backed ashlar
- Backing consists of brick laid in courses with proper bond.
- The ashlar may be rough tooled and used in facing by using cement mortar.

b. Brick back stone slab masonry
- Backing consists of brick laid in courses with proper bond.
- Fine dressed stone slabs are used with cement mortar.
- It is preferable to use metal cramps to connect the facing and backing masonry of wall.

c. Rubble backed brick masonry
- Widely used in places where rubble stone is easily available.
- Facing of wall may be done in brick laid courses.
- Each alternate brick courses consist of quoin header.

3.3 Partition Walls

Partition wall is a non-load bearing wall or divider, provided for the purpose of separating one room or part of a roof from another. Partition walls are constructed of bricks, wood, concrete, glass, etc. materials.

Objectives
- To divide the whole area into number of rooms.
- To offer privacy for both sight and sound.

Requirements of good partition wall
- It should be thin in section to utilize maximum floor area.
- It should provide adequate privacy in rooms for both sight and sound.
- It should use durable, light, and strong material.
- It should be simple, easy, and economical in construction.
- It should be strong enough to carry its own load.
- It should resist fire.
- It should resist heat and damp.
- It should resist insect and fungus attack.
- It should be strong enough to support sanitary fitting and heavy fixtures.

Types of Partition Walls Based on use of material

1. Brick Partition

Bricks partitions are always half-brick thick. Brick partition is fire resistant and soundproof. They are three types.

i. Plain Brick Partition

These partitions are made by laying bricks in stretcher bond. The wall is 100 mm thick, and its maximum height is only 2 m, and the maximum length is 6 m. Plastering on both sides is also required.

ii. Reinforced Brick Partition Wall

These partitions are also half-brick thick, but reinforcement of wire mesh, iron hoop, or 6 mm steel bars are provided at every fourth or fifth coarse of bricks. It is stronger and more durable than a plain brick partition.

iii. **Brick- Nogged Partition**
This type of partition wall consists of wooden framework whose interspaces are filled with half brick masonry. The framework consists of head, sill, vertical and horizontal members.

2. **Hollow blocks and clay blocks partition**
Hollow concrete block partitions are built of individual units of concrete. Clay blocks used are well prepared from clay or terra- cotta, and they are either solids or hollow. Hollow clay blocks of section 30*20 cm with thickness varying from 5 to 15 cm can also be used. The blocks are provided with grooves on top, bottom and sides, surface is kept glazed in different colors.
3. **Concrete partition**
It can be either precast or cast in-situ. Special concrete posts are used for the construction of precast concrete partition wall.
4. **Glass Partition**
Glass partition walls are made up of sheet or hollow glass blocks. It provides sensible aesthetics, permits light weight. This kind of wall is damp, sound, and fireproof. It is simple to wash and maintain. Sheet of glass is fixed in the framework of wooden or metal.
5. **Timber or Wooden Partition**
Timber partition walls are lighter in weight and simple to construct. It is neither sound-proof not fire-proof. This partition wall is not appropriate for damp locations.
6. **Strawboards Partition**
It is Useful where removal of partition is frequent. It is Made of compressed straw covered thick paper or hardboard. It is easy to construct and has heat and soundproof.
7. **Metal Partition**
Metal partition wall are light in weight, fireproof and strong. It is easy to construct and shift. Insulated material is filled into hollow spaces.
8. **Asbestos Cement Partition**
Asbestos cement partitions are lightweight, impervious, durable, watertight and fire-proof. Asbestos cement sheets are made of asbestos cement and fixed into timber framework. Sheets are placed in position and joined by cement mortar. Mostly adopted in works of temporary character.
9. **Portable Partition**
These partition which provides temporary walls. The portable wall partition has two full panel end members which provide support, rigidity, privacy, and noise reduction. They fold and are on wheels enabling mobility and ease of storage.

3.4 Mortars

Mortar is a bonding agent which is generally produced by mixing cementing or binding material (lime or cement) and fine aggregate (sand, surki, sawdust, etc.) with water.

Function of mortar

- It binds together stones or brick properly.
- Holds coarse aggregate together to form a solid masonry.
- In stone masonry and brick masonry, it fills up empty joint.
- Used for pointing and plastering of the structure.
- It provides a durable and weather resisting layer between different courses of masonry structure.
- Provide aesthetic qualities to the structure using color and type of joints.

Properties of good mortar

- The mortar should be easily workable.
- It should be sufficiently plastic.
- It should be capable of retaining sufficient water during its application.

- It should not develop any cracks on drying.
- It should set and harden quickly to achieve speed in construction.
- It should be economical to make without compromising any essential qualities.
- It should not react with masonry units to affects their strength and durability.
- It should be strong and durable after drying and hardening

Types of mortar

Depending upon the materials used for mortar mixture preparation, the mortar could be classified as follows.

i. **Cement Mortar**

Cement mortar is a type of mortar where cement is used as binding material and sand is used as fine aggregate. Depending upon the desired strength, the cement to the sand proportion of cement mortar varies from 1:2 to 1:6.

ii. **Lime Mortar**

Lime mortar is a type of mortar where lime (fat lime or hydraulic lime) is used as binding material and sand is used as fine aggregate. The lime to the sand proportion of cement mortar is kept 1:2. The pyramids at Giza are plastered with lime mortar.

iii. **Gauged Mortar**

Gauged mortar is a type of mortar where cement and lime both are used as binding material and sand is used as fine aggregate. Basically, it is a lime mortar where cement is added to gain higher strength. The process is known as gauging. The cement to the lime proportion varies from 1:6 to 1:9. Gauged mortar is economical than cement concrete and possess higher strength than lime mortar.

iv. **Surki Mortar**

Surki mortar is a type of mortar where lime is used as binding material and surki is used as fine aggregate. Surki mortar is economic.

v. **Mud Mortar**

Mud mortar is a type of mortar where mud is used as binding material and sawdust, rice husk or cow-dung is used as fine aggregate. Mud mortar is useful where lime or cement is not available.

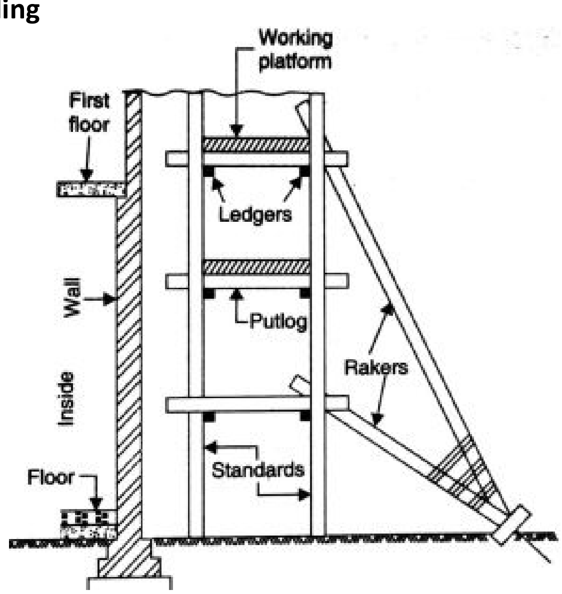
Preparation of Mortar

i. Take one bag of cement, which has a volume of nearly 0.035 m^3.
ii. Measure quantity of dry sand using batching box. Batching box has a volume of 0.035m^3.For example if you are preparing a cement mortar of the ratio 1:3(i.e., 1 part cement and 3 parts sand), then for one bag cement take 3 boxes of sand.
iii. First spread the measured amount of sand on watertight platform or a steel through.
iv. Spread the cement over the sand
v. Then mix them dry by turning over and over, backward, and forward several times by a shovel, till the mixture looks uniform in color.
vi. Out of this dry cement and sand, take out only that amount of mix which ca be used within 30 minutes, and form it inti s heap.
vii. Make a small depression on top of the heap.
viii. Add required amount of water to give it required consistency, to the center of the heap.
ix. Mix the whole mass thoroughly for 5 to 10 minutes by means of a shovel.
x. Water of amount 70% of weight of cement is just sufficient to give it necessary consistency for 1:3 mortar.

3.5 Scaffolding

Scaffolding is a temporary structure to support the original structure as well as workmen used it as a platform to carry on the construction works. Types of scaffolding varies with the type of construction work. Scaffolding is made up of timber or steel. It should be stable and strong to support workmen and other construction material placed on it.

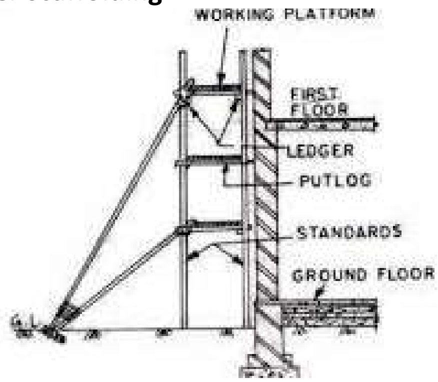
Component/parts of scaffolding



a. **Standards:** These are the vertical members of the framework, supported on the ground or drums, or embedded into the ground.
b. **Ledgers:** The horizontal supporting members running parallel to the wall.
c. **Braces:** Braces are diagonally fixed on standards.
d. **Putlogs:** Putlogs are placed one end on ledgers and other ends right angles on the wall. This is a transverse member.
e. **Transoms:** Transoms are a type of putlogs supported on ledgers on both sides.
f. **Bridle:** This is a member used to bridge a wall opening; supports one end of the putlog at the opening.
g. **Boarding:** Boarding is a horizontal platform supported on putlogs and is used for the support of workmen and materials at the time working.
h. **Guard rail:** This is a rail, provided like a ledger, at the working level.
i. **Toe board:** These are boards, placed parallel to ledgers, and supported on putlogs, to give protection at the level of the working platform.

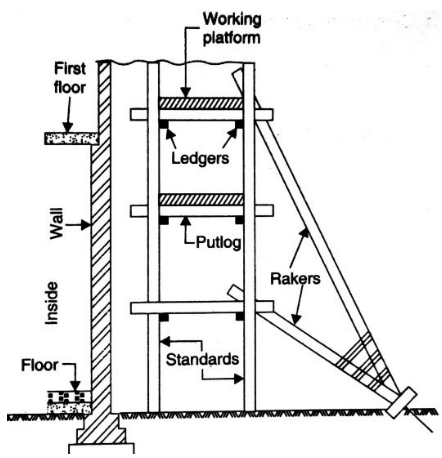
❖ **Types of scaffolding**

1. **Single scaffolding or Bricklayer scaffolding**



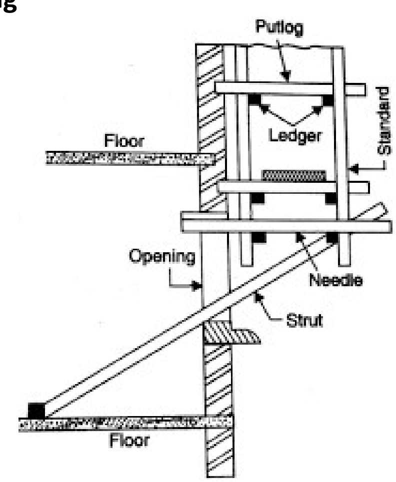
Single scaffolding is generally used for brick masonry and is also called as brick layer's scaffolding. Single scaffolding consists of standards, ledgers, putlogs etc., which is parallel to the wall at about 1.2 m. Distance between the standards is about 2 to 2.5 m. Ledgers connect the standards at vertical interval of 1.2 to 1.5 m. Putlogs are taken out from the hole left in the wall to one end of the ledgers. Putlogs are placed at an interval of 1.2 to 1.5 m.

2. **Mason or double scaffolding**



Double Scaffolding is generally used for stone masonry so, it is also called as mason's scaffolding. In stone walls, it is hard to make holes in the wall to support putlogs. So, two rows of scaffolding are constructed to make it strong. The first row is 20 – 30 cm away from the wall and the other one is 1m away from the first row. Then putlogs are placed which are supported by both frames. To make it stronger rakers and cross braces are provided. This is also called as independent scaffolding.

3. **Cantilever or needle scaffolding**



This a type of scaffolding in which the standards are supported on series of needles and these needles are taken out through holes in the wall. This is called single frame type scaffolding. In the other type needles are strutted inside the floors through the openings and this is called independent or double frame type scaffolding. Care should be taken while construction of cantilever scaffolding.

4. **Steel Scaffolding**

Steel scaffolding is constructed by steel tubes which are fixed together by steel couplers or fittings. It is very easy to construct or dismantle. It has greater strength, greater durability, and higher fire resistance. It is not economical but will give more safety for workers. So, it is used extensively nowadays.

5. **Suspended Scaffolding**

In suspended scaffolding, the working platform is suspended from roofs with the help of wire ropes or chains etc., it can be raised or lowered to our required level. This type of scaffolding is used for repair works, pointing, paintings etc.

6. **Trestle Scaffolding**

In Trestle scaffolding, the working platform is supported on movable tripods or ladders. This is generally used for work inside the room, such as paintings, repairs etc., up to a height of 5m

3.6 Shoring

Shoring is the construction of a temporary structure to support temporarily an unsafe structure. These support wall laterally. Shoring can be used when walls bulge out, when crack due to unequal settlement of foundation and repair are to be carried out to the cracked wall, when an adjacent structure need pulling down, when opening are to be newly made or enlarge in a wall.

Objective of shoring

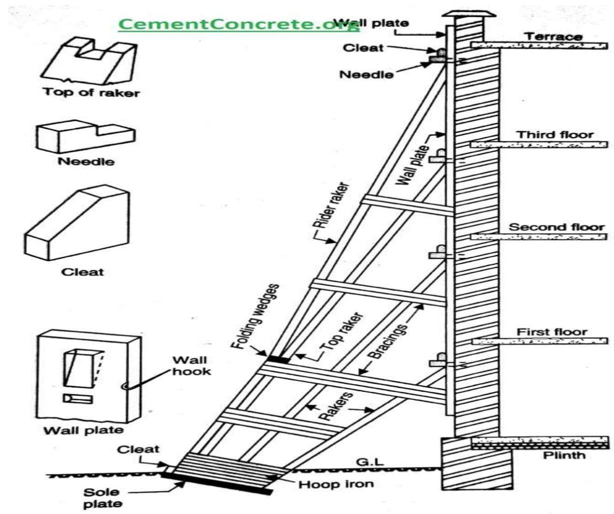
The main objective of shoring may be summarized as below.

- Defective parts of the building are to be dismantled and rebuilt.
- Support upper part of the wall during formation of large openings on the wall.
- Avoid failure of structure while removing adjoining structure.
- Intermediate building to be dismantled.
- Give support to the wall of building develops sign of bugling.

Types of shoring

There are three different types of shores

1. **Raking shores**



Raking shoring is also called inclined shoring. In this method, inclined members known as rakers are used to give lateral supports to walls.

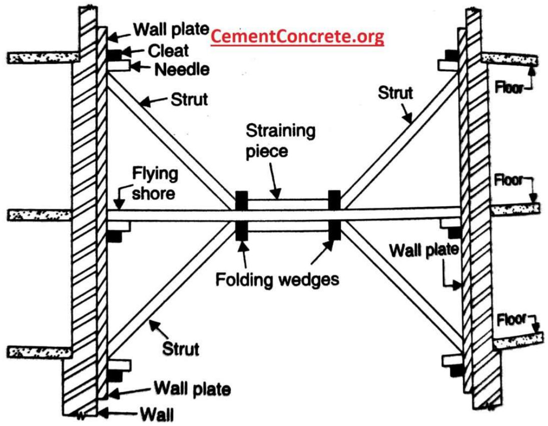
A raking shore consists of the following components:

- Rakers
- Wall plate
- Needles
- Cleat
- Bracing
- Sole plate

The following points are to be kept in view for the use of the raking shores:

i. Rakers are to be inclined in the ground at 45° . However, the angle may be between 45° and 75°.
ii. For tall buildings, the length of the raker can be reduced by introducing rider raker.
iii. Rakers should be properly braced at intervals.
iv. The size of the rakers is to be decided based on anticipated thrust from the wall.
v. The center line of a raker and the wall should meet at floor level.
vi. Shoring may be spaced at 3 to 4.5m spacing to cover longer length of the bar.
vii. The sole plate should be properly embedded into the ground on an inclination and should be of proper section and size.
viii. Wedges should not be used on sole plates since they are likely to give way under vibrations that are likely to occur.

2. **Flying Shores**



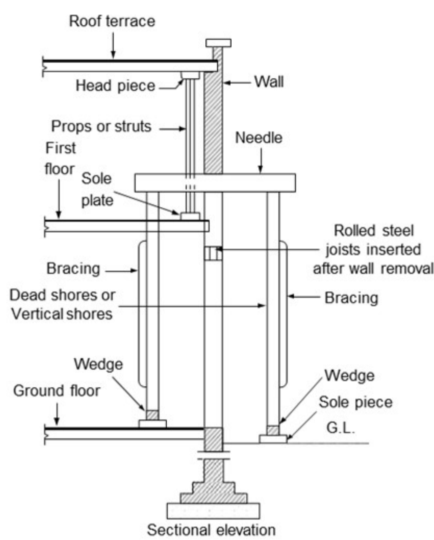
Flying shoring is also commonly referred to as horizontal shoring. Flying shores is a system of providing temporary supports to the party walls of the two buildings where the intermediate building is to be pulled down and rebuilt. All types of arrangements of supporting the unsafe structure in which the shores do not reach the ground come under this category.

The major components of flying shores are:-

- wall plates
- Needles
- Cleats
- Horizontal struts (commonly known as horizontal shores)
- Inclined struts

A horizontal strut is placed between the wall plates and is supported by a system of needle and cleats. The inclined struts are supported by the needle at their top and by straining pieces at their feet. The straining piece is also known as straining sill and is spiked to the horizontal shore. The width of straining piece is the same as that of the strut.

3. **Dead Shores**



Dead shore is also called vertical shoring. Dead shore is the system of shoring which is used to render vertical support to walls and roofs, floors, etc. when the lower part of a wall has been removed for the purpose of providing an opening in the wall or to rebuild a defective load bearing wall in a structure. The dead shore consists of an arrangement of beams and posts which are required to support the weight of the structure above and transfer same to the ground on firm foundation below.

3.7 underpinning

The placing of new foundation below an existing foundation or the process of strengthening the existing foundation is known as the underpinning of foundations.

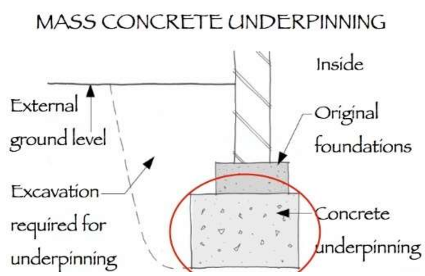
Following are the situations demanding underpinning:

- **a.** A building with deep foundations is to be constructed adjoining to an existing building.
- **b.** The settlement of existing foundation has taken place, resulting in serious cracks in the wall.
- **c.** The basement is to be provided to an existing building.
- **d.** The existing foundations are to be deepened to rest them on a soil of higher bearing power.

Methods of underpinning

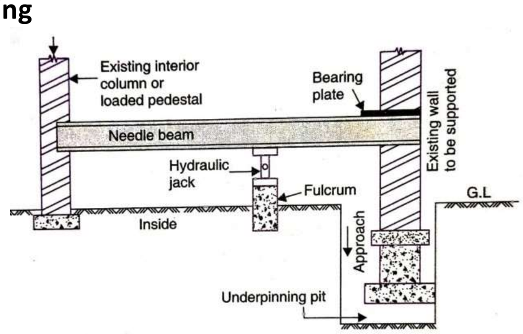
Following are the methods of underpinning:

a. Mass Concrete Underpinning/Mass Pour



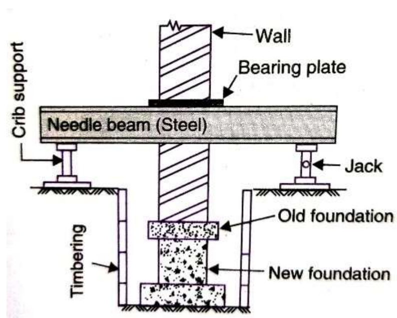
This underpinning method is used where a lot of digging is not required. A concrete foundation is poured to increase the strength of the base. This is a very easy underpinning method and doesn't require heavy machinery. Also, it is a very cost-effective method.

b. Beam and Base Underpinning



In this method, a traditional mass concrete base is used and is supported by beams so that the foundation is strong. In this kind of underpinning, the foundation's weight will be taken care by the beam that will be either constructed above or below the concrete base.

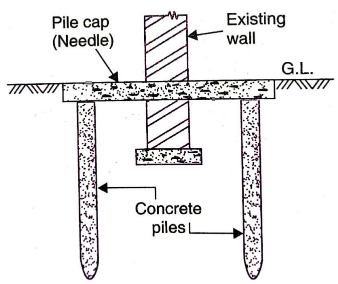
c. Pit underpinning method



(a) Vertical section

The pit technique of underpinning is often performed by methodically digging the area in phases. To do this, the old wall was cut into sections with widths ranging from 1.20 to 1.50 meters. At the predetermined locations, holes are cut out of the existing wall. After that, needles that have bearing panels attached to them are placed through all these perforations and stabilized by jacks. After this, excavation will begin, first to a depth equal to the level of the existing foundation, and later to the desired depth.

d. Pile underpinning method

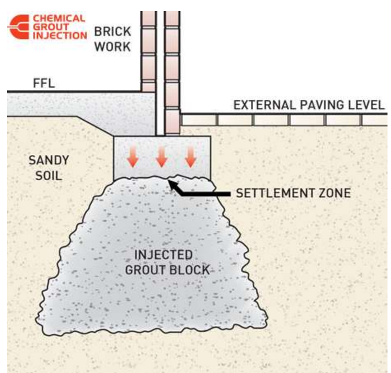


In some circumstances, such as those involving swampy areas, severe loads on already-existing structures, and loads that need to be shifted to a deeper depth, the pit approach may not be feasible or cost-effective.

Using a pile technique might be used in these instances. The piles are positioned on each side of the current wall in this way. The pile caps act as needles and are inserted into the wall. As a result, the pressure is taken off the current wall.

This approach is very helpful in clayey soils, as well as locations that are prone to waterlogging, and walls that are required to handle large loads. Pile driving occurs concurrently with the construction of light buildings, followed by the installation of clamps or cantilever needles.

e. Chemical underpinning method



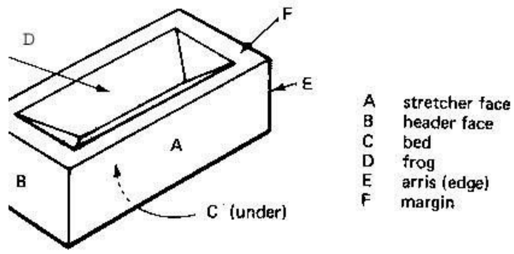
Chemicals are used in this technique for the purpose of consolidating the foundation dirt. Under the foundation, perforated pipes serve as a motor that moves in an angled direction. The slopes are designed in such a way that the whole region is under the current footing corners beneath the section that was reinforced.

Injecting a sodium silicate in a mix of water via the pipes is the next step once the pipes have been placed. The procedure involves two injections. Calcium chloride is pumped via the pipes while they are being removed. These two compounds react chemically, leading to soil consolidation as a byproduct. If we have granular soil, this technique will work .

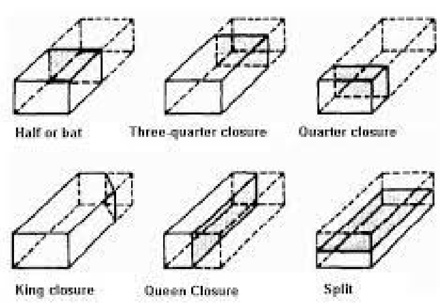
CHAPTER 4: BRICK MASONARY

The construction of brick with mortar which harden by heat is termed as brick masonry.

4.1 Definition of some terms in brick masonry



a. **Course**
   A course is a horizontal layer of bricks.
b. **Bed**
   It is the surface of stone perpendicular to the line of pressure. It indicates the lower surface of bricks or stones in each course.
c. **Back:** The inner surface of a wall which is not exposed is called the back. The material forming the back is known as backing.
d. **Face:** The exterior of wall exposed to weather is known as face. The material used in the face of the wall is known as facing.
e. **Hearting:** It is the interior portion of a wall between the facing and backing.
f. **Head:** It is a brick or stone, which lies with its greatest length at right angles to the face of the work. Continue.
g. **Stretcher:** It is a brick or a stone which lies with its longest side parallel to the face of the work.
h. **Bond:** The method of arranging bricks so that the individual units are tied together.
i. **Quoins:** The stones used for the corners of walls of structure.
j. **Bat:** It is a portion of a brick cut across the width.



k. **Closer:** It is the portion of a brick cut in such a manner that its one long face remains uncut.
l. **Queen Closer:** It is the portion of a brick obtained by cutting a brick lengthwise into two portions.
m. **King closer:** It is the portion of a brick obtained by cutting off the triangular piece between the center of one end and the center of one side.
n. **Frog:** It is an indentation or depression on the top face of a brick made with the object of forming a key for the mortar.
o. **Sill:** It is a horizontal stone, concrete, or wood, employed for the purpose of shedding off rainwater from the face of wall immediately below the window opening.

- **p. Jambs**: an upright piece or surface forming the side of an opening (as for a door, window).
- **q. Soffit**: the underside of a part or member of a building (as of an overhang or staircase).
- **r. Pilasters:** an upright architectural member that is rectangular in plan and is structurally a pier but architecturally treated as a column and that usually projects a third of its width or less from the wall.

- **s. Toothing:** Bricks left projecting in alternate courses for the purposes of bonding future masonry work.

4.2 Construction of brick wall

A. Procedure of laying bricks in wall

Here are the basics to get started on building a brick wall. Make sure you have the following materials (and permissions):

- i. Trowel
- ii. Hammer
- iii. Spirit Level
- iv. Shovel
- v. Bricks (soaked brick)
- vi. String and nails
- vii. Plum bob

1. **Prepare the materials**
   Work out how many bricks you are going to need before starting. Either estimate or calculate based on their size. Do not neglect to include the thickness of the mortar, which tends to be approximately 10mm.
2. **Mix the mortar**
   Using a shovel or mortar mixer on a tarp, mix the amount of mortar you think you will need. Five parts sand to one part cement should do. Mix this with water until the mixture has a smooth, creamy texture.
3. **Create a foundation**
   Dig a trench for the foundation you intend to lay. It should be at least a foot deep and wide. Fill this with mortar and check to ensure you have a solid, level base for the brick wall.
4. **Create a string line**
   Using string and other material, create a straight line where you wish to build this brick wall. Bear in mind you can also lift this line off the ground later if you want to make sure your wall is being built straight.
5. **Lay the mortar**
   Once the foundation has dried, place a layer of mortar where the string runs along the ground. This should be a little bit thinner than the individual bricks you will lay, as the mortar will spread when you put the bricks on top of it.
6. **Start laying the bricks**

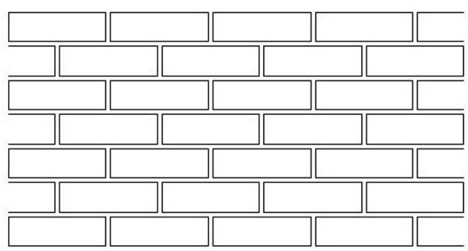
Lay the bricks down end to end on the mortar, putting approximately 10mm of mortar between each brick to act as a binder. Wait for these to dry. The brick courses should be laid truly horizontal and should have truly horizontal (sprit level) and should have truly vertical joints (Plum Bob). Joints should not repeat in a vertical line up to fourth course.

7. **Cut the bricks for the second row**
   For the second row, you will want to offset the bricks by half a brick. If the wall is not a loop, you will need to cut one of the bricks in half for each row. Do this with a chisel, giving it a swift tap in the middle of the brick, using a hammer.
   Continue this upwards until you have enough as many rows as you need. Generally, the height of brick masonry construction in a day should be less than 1.5m. The maximum difference in rise of the wall between the different portions should not be more than one meter.
   The mortar joints should be stuck flush and finished if no plastering or pointing is to be done.
   To ensure continuous bond between the old and the new, the walls should be stopped with a toothed end or racked. Finished brickwork in lime mortar should be cured for a period of 2 to 3 weeks. This period can be reduced to 1 to 2 weeks in case of brickwork with cement mortar. To carry out the brickwork at higher level, a single scaffolding is used.

B. Types of bonds in brick wall

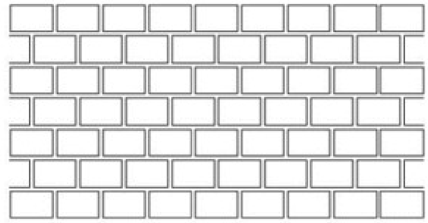
It is the method of arranging the bricks in course so that individual units are tied together, and the vertical joints of the successive course do not lie in same vertical line. The most used types of bonds in brick masonry are:

a. Stretcher bond



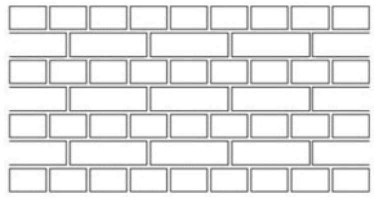
- Stretcher bond is the one in which all the brick are laid as stretcher on the focus of walls.
- Stretcher bond, also called as running bond, is created when bricks are laid with only their stretchers showing, overlapping midway with the courses of bricks below and above.
- Stretcher bond in the brick is the simplest repeating pattern.
- They are suitably used only for one-half brick thick walls such as for the construction half brick thick partition wall.
- Walls constructed with stretcher bonds are not stable enough to stand alone in case of longer span and height

b. Header bond



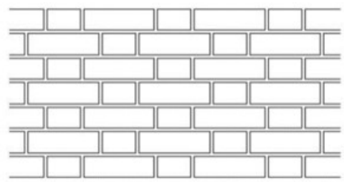
- Header bond is one in which all the bricks are laid as header on the faces of walls.
- Header bond is also known as heading bond.
- Header bond is used for the construction of walls with full brick thickness.
- In header bonds, the overlap is kept equal to half or one fourth width of the brick.

c. English Bond



- English bond in brick masonry has one course of stretcher only and a course of header above it, i.e., it has two alternating courses of stretchers and headers.
- Headers are laid centered on the stretchers in course below and each alternate row is vertically aligned.
- To break the continuity of vertical joints, quoin closer is used in the beginning and end of a wall after first header.

d. Flemish Bond



- In this type of bond, each course is comprised of alternative headers and stretchers.
- Every alternative course starts with a header at the corner.
- Quoin closers are placed next to the header in alternative courses to develop the face lap.
- For the breaking of vertical joints in the successive courses, closers are inserted in alternative courses next to the header.
- The disadvantage of using Flemish bond is that construction is difficult and require greater skill to lay it properly as all vertical mortar joints need to be aligned vertically for best effects.

Types of Flemish bond

i. **Double Flemish Bond**: This type of bond has the same appearance both in front and back elevations, i.e., each course consists of alternate header and stretcher. This type of bonding is comparatively weaker than English bond.

ii. **Single Flemish Bond:** This type of bond is a combination of English bond and Flemish bond. In this type of construction , front exposed surface of wall consists of Flemish bond and the back surface of the wall consists of English bond in each course. The main purpose of using single Flemish bond is to provide greater aesthetic appearance on the front surface with required strength in the brickwork with English bond.

Comparison of English Bond and Flemish bond

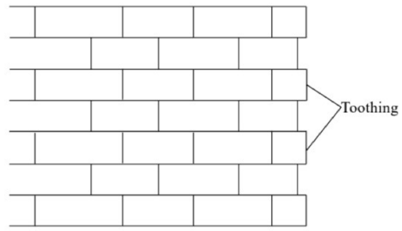
Sr No.	*English Bonds*	*Flemish bond*
1	This bond consists of headers and stretchers laid in alternative courses.	This bond consists of headers and stretchers laid alternatively in each course.
2	It is strongest of all the bonds.	It is less strong for walls having thickness more than 13 ½ inches.
3	It provides rough appearance especially for one brick thick walls.	It provides good appearance for all thickness of walls.
4	There are no noticeable continuous vertical joints in the structure built in this bond.	There are partly continuous vertical joints in the structure built in this bond.
5	Much attention is not required in providing this bond.	Special attention is required in providing this bond.
6	Progress of work is more.	Progress of work is less.
7	It is costly because the use of brick bats is not allowed.	It is economical because brick bats are allowed for forming this bind.

C. Precautions in brick work

i. The length and width of the walls should be according to the drawings.
ii. The quality of bricks should be good having required strength and should not show any efflorescence (salt on face).
iii. The sand should not have fine grains and be free from silt etc. The sand used for brick mortar should be of required FM (Coarser) with no silt.
iv. The mixing of mortar should be proper with required quantity of water. It should not be dry or liquid.
v. The opening of doors and windows should be left simultaneously, not by dismantling. The actual size of each window and door opening should be kept more than 1 inch clear.
vi. The bricks are soaked in water before use otherwise these will absorb water from the mortar and the bonding will be weak.
vii. The frog or depression side of the brick should be upwards.
viii. Minimum number of bats is used.
ix. Bricks are absolutely aligned horizontally and in a straight line. This can be checked by a stretched string across the face.
x. The bricks are vertically aligned which can be checked with a plumb bob.
xi. The courses or layers of bricks are level. This can be checked with a spirit level.
xii. The thickness of joints is not more than 1 cm.
xiii. The joints should be filled with mortar fully without any gaps.
xiv. The joints are pushed inside when cement mortar is still wet so that later plastering can be done effectively.
xv. Brick work should be kept wet for seven days so that the mortar may gain its full strength.
xvi. There are no continuous vertical joints.
xvii. Bricks, sand, and cement used in brick work should be according to their specifications.

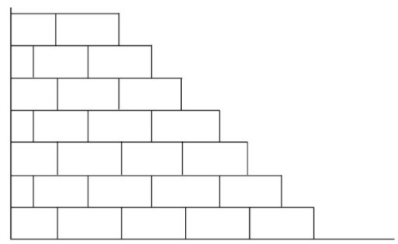
D. The methods of bonding new brickwork with old brickwork are :

i. Toothing:



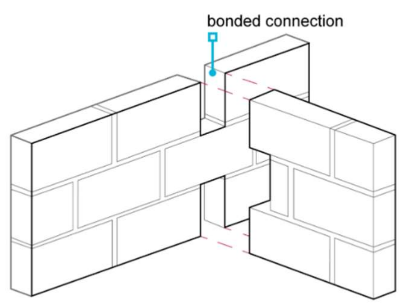
The process of leaving recesses in the alternate courses of the wall at the desired place is called toothing. It becomes essential to provide recesses when it is proposed to connect a partition wall to the main wall of the building. The depth of the recess is kept as 5 cm and length depends upon the thickness of the partition wall. The method is adopted for providing a proper bond between the existing and new walls.

ii. Racking back:



The process of leaving an off set of 5 cm in each course of a wall is called racking back. When the full length of the wall cannot be completed at one time, offsets are left in each the course of the completed portion of the wall. The next day, the surface is cleaned and wetted with water before completing and joining other portions.

iii. Block Bonding:



When a new cross wall is to be joined to the old main wall, then a number of rectangular recesses are cut in the main wall. The recesses are cut equal in width to that of the cross wall, three courses in height and half a brick in-depth after leaving a space of three courses between them. The new wall is then bonded into the main wall after clearing the recesses from all dust and old mortar.

E. Expansion and contraction joints in brick work

i. Expansion Joint

An expansion joint separates brick masonry into segments to prevent cracking caused by changes in temperature, moisture expansion, elastic deformation, settlement, and creep. Expansion joints may be horizontal or vertical.

Expansion joints in masonry walls are provided if length exceeds 30m.

Spacing of expansion joints

Material	Normal spacing	Joint thickness
Clay brickwork (2)	12m (Spacing up to 15m may be possible if sufficient restraint is provided - consult designer)	15mm
Calcium silicate	7.5-9m	10mm
Concrete brickwork (1)	6m	10mm
Concrete blockwork (used in outer leaf)	6m	10mm
Stone	12m	15mm

Note:
It is not normally necessary to provide movement joints to the internal leaf of cavity walls, but it should be considered for rooms with unbroken lengths of wall in excess of 6m.

The first joint from a return should be not more than half the dimension indicated in the table. Movement joints are not acceptable in solid party or separating walls; however, where cavity wall construction is adopted, offset movement joints with a solid rubber compressible strip may be acceptable.

(1) Where openings are over 1.5m, masonry bed joint reinforcement should be considered
(2) For unrestrained masonry such as parapets and free standing walls, vertical joint spacing should be reduced to 5m - 6m centres.

ii. **Contraction Joints**

A control joints or contraction joints that is place in the concrete or masonry wall to control cracking. A contraction joint is formed, sawed, or tooled groove in a concrete structure to create a weakened plane to regulate the location of cracking resulting from the dimensional change of different parts of the structure. The joints are made when there is chance of cracks or where the concentration of stress is expected so that the structure does crack, the location will be known. The crack may be due to temperature variation or drying shrinkage or other measure.

4.2 Miscellaneous

A. Soaking of brick

When an object becomes thoroughly wet by immersing it into the liquid it is called soaking. To make brick thoroughly wet i.e., saturated by immersing in water, it is called soaking of bricks.

The brick by nature is porous and hence it has a tendency to absorb the water or moisture. Porosity is the ability to release and absorb moisture, and it is important and useful properties of brick.

When brick is soaked in water, the brick absorbs water and release air so that when it is used in masonry and placed over the wet mortar, it will no more absorb any water from the wet mortar. However, if it is dry i.e., not soaked in water, it will start absorbing water from the mortar. Thus because of loss of water from mortar, hydration of cement will not take place and mortar will not gain strength. Thus, it will fail to make a strong bond between bricks and mortar. Ultimately, it will make the bonding of masonry wall weak. Soaking also helps to remove dirt, dust, sand and particularly any other soluble salts, which cause efflorescence.

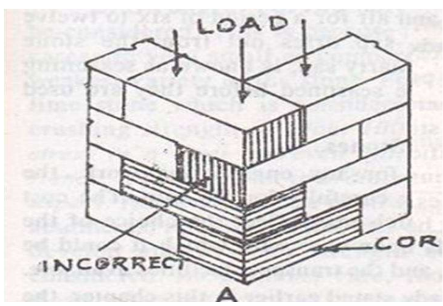
Bricks should be soaked in water before use for a period so that the water penetrates the entire depth of the bricks. Normally it is suggested to soak bricks for at least 12 hours. Soaking of bricks should be continued till air bubbling ends.

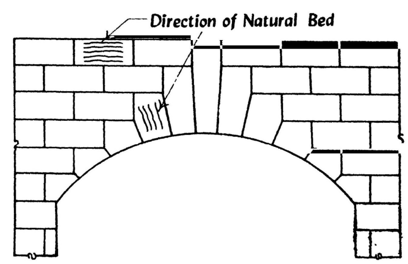
The best way to do this is to use the drums for soaking of brick. Put bricks in drum or tank and fill it completely with water and allow soaking happening.

CHAPTER 5: STONE MASONRY

5.1 Glossary of terms used in Stone masonry

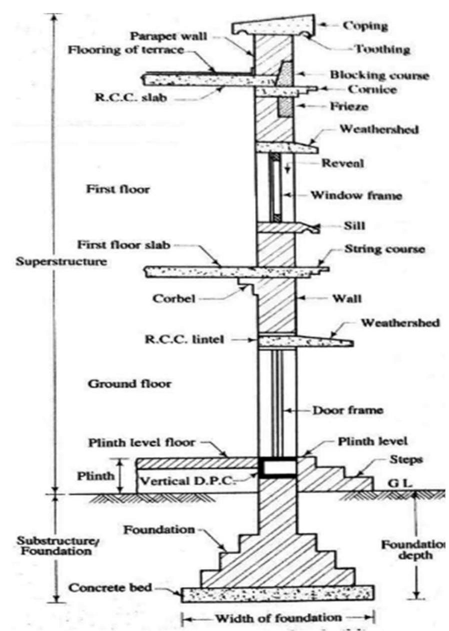
1. **Natural bed and bedding plane:**
The plane along which stones can be easily split is known as bed of stones.
In stone masonry work, the stone should be used in such a way that the direction, of applied is perpendicular to the natural bed of stone. In other words, the position of stone blocks in wall should be same in which they were originally deposited. This position gives them maximum strength to the stone works in walls.
In this case of arches, the bedding plane should be radial and at right angles to the face of the arch. Such an arrangement causes the thrust of arch act normal to the direction of natural bed.
In the case of cornices and strong courses stone remain unsupported. In this case natural bed of stone should be kept vertical



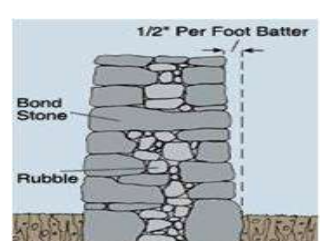


Natural bed of stone

2. **String course:**
It is a horizontal course of masonry projecting from the face of the wall and is generally at every floor or sill level throughout the length of the wall. It is intended to improve the elevation of the structure.

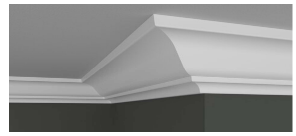


3. **Corbel:**
It is the extension of one or more courses of brick stone from the face of a wall. The projection of courses which is generally ornamental in shape, serves as a support for wall plate etc. the elevation of the structure.
4. **Cornice:**
It is a horizontal molded projection provided near the top of a building or at the junction of a wall and ceiling It not only increases the architectural beauty of the structure but also serves as a barrier for shedding rainwater off the face of the wall.
5. **Blocking course:**
It is a course of stone masonry provided immediately above the cornice to check the tendency of the cornice to overturn and incidentally it adds to its appearance.
6. **Bond stone:**
It is also known as a bonding stone (through stone) which is a large stone that passes through a wall from one side to the other. The purpose of the bond stone is to lock the layers of the wall together and

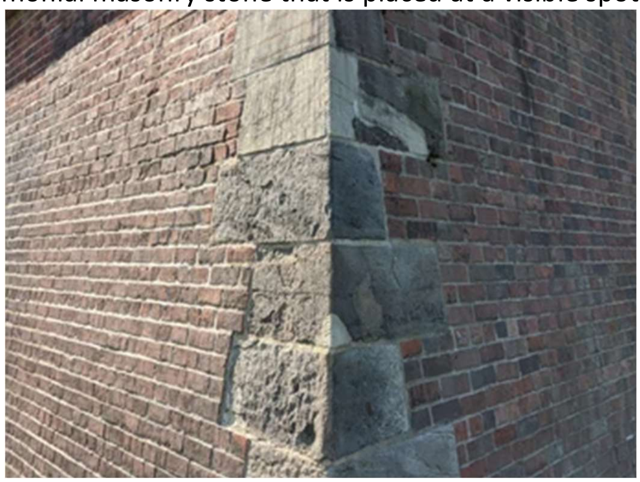


reinforce the structure. Bond stones are provided to interlock the two faces and should extend up to the full thickness of the wall if the wall is less than 60 cm in thickness in uncoursed rubble masonry.

7. **Parapet:**
   It is a term applied to a low wall built around a flat roof to function as a protective solid balustrade for the users of terrace (flat roof). In a pitched roof, a parapet wall is provided to conceal the gutter at roof space level and for imparting an architectural effect to the structure.
8. **Coping**
   Coping is a covering placed on the exposed top of an external wall. It is provided to prevent the seepage of water through the joints of the topmost course of the wall. It may be of concrete, stone, brick, or terra-cotta.
9. **Molding**
   A projecting or recessed part is used to give shadows to a wall, arch, or other surfaces



10. **Cornerstone:**
    A cornerstone is a ceremonial masonry stone that is placed at a visible spot building's exterior.



5.2 Classification of stone masonry

Stone masonry can be broadly classified in the following two types:

- **A.** Rubble Masonry
- **B.** Ashlars Masonry

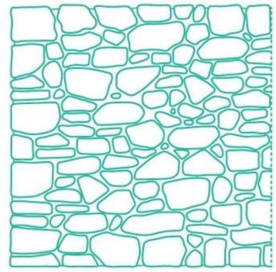
A. Rubble Masonry

In this masonry, the stone of irregular shape and size are used which are taken from quarrying. The strength of rubble masonry mainly depends up on quality of the mortar used. The thickness of joint is not uniform. This masonry is cheaper as it doesn't require dressed stone. Rubble masonry is further divided into.

a. Random Rubble Masonry:

Masonry constructed using undressed or partially dressed stones in a random order is called random rubble masonry. There are two types of random rubble masonry.

i. **Uncoursed Random Rubble Masonry:**

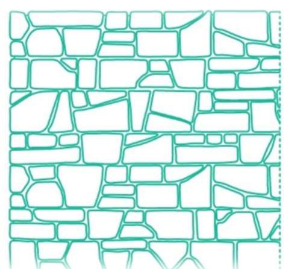


The random rubble masonry constructed without forming courses is uncoursed random rubble masonry. It is mostly used for the construction of walls with a low height.

Some of the features of this masonry are.

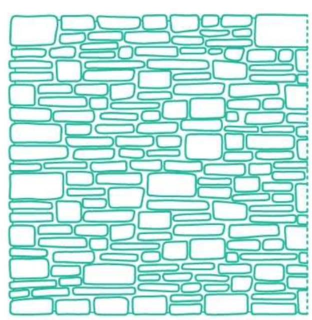
- It is the cheapest and roughest type of masonry.
- It has varying appearance.
- Corners of stones are slightly knocked off before using.
- To increase the strength of this masonry, large stones are used at corners and jambs.
- Through stone is used in every square meter for joining faces and backing.

ii. **Coursed Random Rubble Masonry:**



The masonry in which stones are laid in courses and layers of equal height is called coursed random rubble masonry. It is used in the construction of go-downs, boundary walls etc. Commonly hammer dressed stones used in this masonry.

b. Squared Rubble Masonry



The type of masonry in which face stones are squared on all joints and beds by dressing before laying is called square rubble masonry. There are two types of square rubble masonry which are explained below.

i. **Coursed Square Rubble Masonry**: The square rubble masonry in which stones are laid in courses is called coursed square rubble masonry. It is used for construction of hospitals, schools, market, modern residential building. It is also used in hilly areas where the availability of quality stones is common.

Some features of this masonry are

- It is a superior variety of rubble masonry

- Stones used are squared on all joint and beds and laid in courses.
- Stones are laid in courses of equal layers.
- Joints are uniform.

ii. **Uncoursed Square Rubble Masonry**: The square masonry in which stones are laid without making courses is called uncoursed square rubble masonry. It is mostly used in the construction of ordinary buildings in the hilly areas where the availability of quality stones at cheap rate is common.

c. **Dry Rubble Masonry**

The rubble masonry constructed without using mortar or other binding agents is called dry rubble masonry. Undressed or partially dressed stones are used in this masonry. It is suitable for construction the walls of height less than 6m.

B. Ashlar Masonry

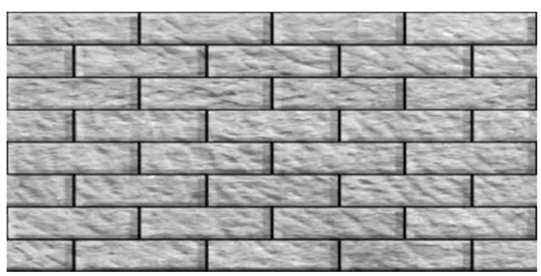
The stone masonry constructed using finely dressed stones is called ashlar masonry.

Some features of ashlar masonry are

- The courses are of uniform height.
- All the joints of this masonry are regular, thin and have a uniform thickness.
- Ashlar masonry is mostly used in the construction of heavy structures, architectural buildings, high piers and abutments of bridges.

Types of ashlar masonry are:

a. **Ashlar Fine Masonry**



This is the finest type of masonry where perfectly dressed stones are used. The height of the courses is never less than 30cm & generally, all the courses are kept at the same height. The stones are generally laid as header & stretcher alternately.

b. **Ashlar Rough Tooled**

In this type, the exposed faces should have a fine chisel drafting. The Thickness of mortar joints does not exceed 6mm. The size, angle, edges, etc. are maintained in an order like that for dressed ashlar. It is also known as bastard ashlar.

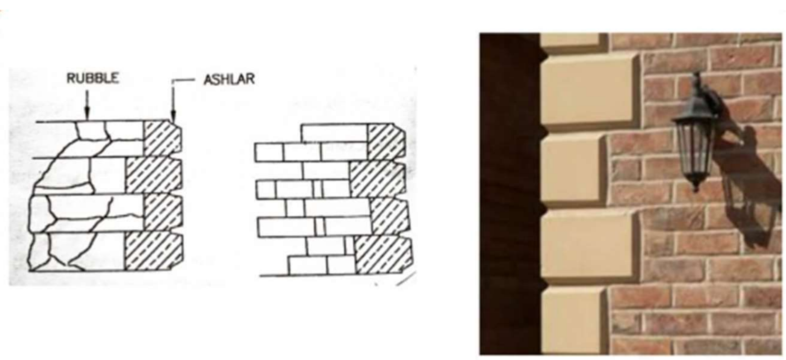
c. Ashlar rock, quarry faced

This masonry type has a 25 mm wide strip made by a chisel placed around the perimeter of every stone. The remaining portion of the face is left in the same form as it is received.

d. Ashlar Chamfered

This masonry is like the one described above with the only difference that the edges around the exposed faces of stone are leveled off at an angle of 45° for the depth of 25 mm or more.

e. Ashlar Facing



Ashlar facing

Ashlar facing masonry is provided along with brick or concrete block masonry, to give a better appearance. Face stones are rough tooled. The height of the stone should not be less than 20 cm. The backing is made up of brick, concrete, etc.

5.3 Construction of Stone Masonary

i. Stone used in good masonry should be well seasoned, hard, tough, compact, and uniform in texture and should be free from defects like crack, flaws, cavities and patches of soft or loose material.
ii. All stones should be laid upon their natural bed.

iii. Stone masonry may be constructed in lime or in cement mortar about plinth level, but in damp proof construction or waterlogged site or in basement, lime or in hydraulic lime or cement mortar with surkhi should be used in foundation and up to plinth level.
iv. Proper bond should be maintained throughout the masonry. The construction should be well supervised.
v. The facing and backing of the wall should be well bound by through stones.
vi. Quoins used to form the jams for doors or windows opening should be of full height of the course.
vii. Toothing should not be allowed in stone masonry.
viii. The hearting of the masonry should be properly packed with the chips and mortar avoid hollow being left.
ix. The vertical joints should be staggered as far as possible.
x. Stones to be used in the work should be well wetted before use.
xi. The masonry should not be subjected to tensile stress.
xii. When it is desired to construct over old or dry surface, it should be well cleaned and wetted before starting new construction.
xiii. The exposed joints in stone masonry should be properly pointed.
xiv. The entire work should be cured well i.e., it should be kept well wetted for at least two weeks.

CHAPTER 6: DAMP AND WATER PROOFING

6.1 Causes and method of damp Proofing

One of the important requirements of a building is that it should remain dry, that is damp proof. Dampness in building may occur due to bad design, faulty construction, and use of poor quality of materials. If this condition is not satisfied, it is likely that the building may become unhygienic to the inhabitants and unsafe from the structural point of view, because dampness breeds germs of certain diseases and disintegrates the structure.

The excess or penetration of moisture content inside the building through its walls, floors, or roof is known as **dampness.**

The treatment given to prevent leakage of water from roof is generally termed as water proofing whereas the treatment given to keep the walls, floors and basement dry is termed as **damp-proofing.**

Effects of dampness

The various defects caused by dampness in buildings may be summarized as under.

- It causes efflorescence which may ultimately result in disintegration of brick, stones, tiles etc.
- It may result in softening and crumbling of plaster.
- It may cause bleaching and flaking of paint with the formation of color patches.
- It may result in the warping, buckling, and rotting of timber.
- It may lead to the corrosion of metals.
- It may deteriorate electrical fittings.
- It reduces life of structure of structure.
- It promotes growth of termites.
- It breeds mosquitoes and creates unhealthy living condition for the occupants.

Causes and sources of dampness

In brief some major causes of dampness are:

a. **Rain penetration:**
Properly constructed walls offer considerable resistance to rain penetration, but penetration takes place through the joints and porous or stones. Rain penetration is also possible through the roof components, cracks and joints between the walls and the roof.

b. **Level of site:**
Structure built on a higher ground can be drained off easily and hence they are less liable to dampness. But low-lying areas cannot be easily drained off and thus causes dampness in the structure.

c. **Drain ability of the site**
Gravel and sandy soil allow water to pass through easily whereas clay soils retain moisture and causes dampness due to capillary rise.

d. **Climatic condition:**
Dampness is also caused due to condensation of moisture present in the atmosphere under very cold climate. Condensation of the atmosphere moisture can be identified by the drops of moisture present on the ceilings, walls, floors etc.

e. **Defective orientation:**
The buildings having its walls subjected to direct showers of rain or getting less direct sun rays, due to defective orientation is liable to dampness.

f. **Moisture entrapped during construction:**
Walls while being constructed are in wet condition. There may persist moisture for a long period after the construction is over, due to the use of salty or alkaline water, which causes dampness in the building.

g. **Defective materials:**
Dampness is also caused due to soakage of moisture by the defective materials like porous bricks, soft stones etc. especially when they are used in external walls.

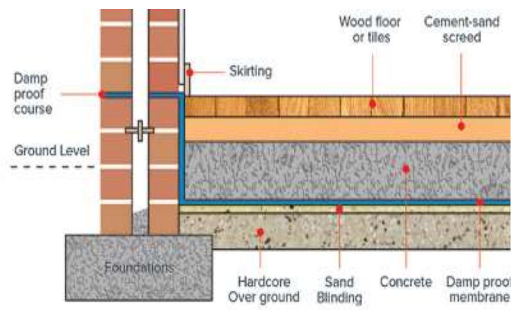
h. **Defective construction:**
In case, there is any leakage in the sewers, down water pipes, kitchen, bathrooms etc. it will be causing dampness in the building.

i. **Inadequate slope to flat roofs:**
If slope of the roof is not adequate to drain off rainwater effectively, storage of water may take place at the roof and water may seepage into the building.

6.2 Methods of Damp Proofing

Following methods are generally adopted to prevent the defect of dampness in a structure.

1. **Membrane Damp Proofing**



The membrane damp proofing is one of the types, where the water repellent material is used in the membrane or protective layer of the proofing. This proofing method is applied between the source of dampness and the structure adjoining it. This type of layers is commonly known as damp proof course (DPC). The damp proofing materials used for proofing are cement concrete, bituminous felts, epoxy, mastic asphalt, plastic, silicon, metal sheet plastic or polythene sheets and polymers. These materials create a stud formation on the walls, ceiling, and floor, developing an air gap between the source and structure. This air gap evaporates the water or the moisture seeping through the structure by leaving the wall unobstructed. The proofing is applied either horizontally or vertically, depending on the source of dampness.

2. **Integral Damp Proofing**

This type of proofing course includes compounds for proofing mixed with concrete to increase the permeability. The proofing compounds are available in liquid and powder form. The integral damping compounds made from clay, lime or sand have extraordinary properties that fill the empty spaces in the concrete and make the structure more resistant to moisture. Some of the engineering consultants use calcium chloride, alkaline silicates, and aluminum sulphate to produce waterproof concrete and damp proofing to the walls and floors. However, the amount of waterproofing compounds added to the concrete depends on the manufacturer's requirements

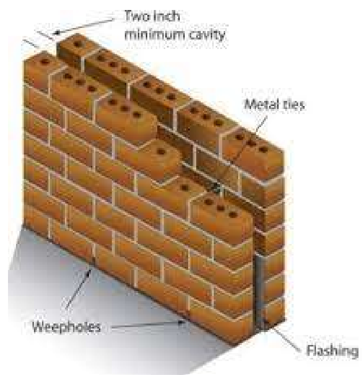
3. **Surface Treatment**

Thirdly, the surface treatment is essential to make the walls and floors less permeable for the moisture to find its way through the pores. So, filling these pores through the surface treatment prevents moisture from entering the structures. So, the structural engineers use water repellent chemicals like stearates and calcium and aluminums oleates in the surface treatment process. Paints, varnishes, bituminous solution, and cement coating fall under surface treatment, and most of the structural design consultants use lime-cement plaster for surface treatment. The lime-cement surface treatment includes compounds like lime, cement, and sand in the ratio of 1:1:6, which offers effective damp proofing for the building.

4. **Guniting**

- This consists of depositing a layer of rich cement mortar by pressure over the surface to be waterproofed. The operation is carried out by use of a machine known as a cement gun.
- Cement and sand usually taken in proportion of 1:3 to 1:4 are then fed onto a machine. That mixture or mortar is then finally shot on the clean prepared surface with a cement gun under a pressure of 2 to 3 kg/cm^3.
- Nozzle of the cement gun is hold at a distance of 75 to 90 cm from the working face of wall.
- The quantity of water in the mix can be controlled by means of regulating valve provided in the water supply hose attachment. Since the material is applied under pressure it ensures dense compaction and better adhesion of rich cement mortar and hence the treated surface becomes waterproof.

5. **Cavity wall construction:**



- In these methods of damp preservation in which main wall of the building is shielded by outer skin wall, leaving a cavity between these two walls.

6. **Pressure grouting**
   - The mixture of cement, sand, and water under pressure into the cracks, voids or fissures present in the structural component or the ground.
   - In general, the foundation is given this treatment to avoid the moisture penetration.
   - This technique also used for repairing structures, consolidating ground to improve bearing capacity, forming water cut-offs to prevent seepage etc.

6.3 Material used for damp proofing

Property of the material used for damp proofing

An effective damp proofing material should have following properties.

- It should be impervious.
- It should be strong and durable and should be capable of withstanding both dead as well live load without damage.
- It should be dimensionally stable.
- It should be free from deliquescent salts like sulphates, chlorides, and nitrates.
- The material should be reasonably cheap .
- The material should be such that it is possible to carry out leak proof joining work.

Classification of material

The material commonly used to check dampness can be divided into the following four categories.

i. **Flexible material:** Material like bitumen, plastic sheet etc.
ii. **Semi-rigid material:** Material like mastic asphalt or combination of material or layer.
iii. **Rigid material:** Material like first class bricks, stones, slates, cement concrete etc.
iv. **Grouting material:** Grout consists of cement slurry and acrylic based chemical/polymers.

Some material used for damp proofing are

a. Hot bitumen

- This is flexible material and is placed on the bedding of concrete or mortar in hot condition.
- This material should be applied with a minimum thickness of 3mm.

b. Mastic asphalt

- This is semi rigid material, and it forms an excellent impervious layer for damp proofing.
- It is made by mixing bitumen, sand, and mineral filler.
- It is liable to squeeze out in very hot climates under very heavy pressure.

c. Bituminous felts

- This is a flexible material.
- It is easy to lay and is available in rolls of normal wall width.
- It is laid on a layer of cement mortar.
- An overlap of 100mm is provided at the joints and full overlap is provided at all corners.
- It is liable to squeeze out under heavy pressure and it offers little resistance to sliding.
- The material is available in rolls, and it should be carefully unrolled, especially in cold weather.

d. Metal Sheets

- The sheets of lead, copper, aluminum is used as DPC.
- The lead is flexible material. The thickness of lead sheets should be such that its weight is not less than 200 N/m^2 .
- It is impervious to moisture, and it does not squeeze out under ordinary pressure.
- The surface of lead coming in contact with lime and cement are likely to be corroded and hence a coating of bitumen paint of high consistency should protect the metal.
- The copper is rigid material. It possesses higher tensile strength than that of lead.
- Copper sheet of 3mm thickness is embedded in cement lime mortar.
- Aluminum sheets can also be used for damp proofing. But they should be protected with a layer of bitumen.

e. Combination of sheets and felts

- A lead foil is sandwiched between asphalt and bituminous felt.
- This is known as the lead core and it is found to be economical, durable, and efficient.

f. Stones

- The two course of sound and dense stones such as granite, slates etc. laid in cement mortar with vertical breaking joint can work as an effective damp proofing course.
- The stones should extend for full width a damp proofing course.

g. Brick

- The dense bricks, absorbing water less than 4.5 % of their weight, can be used for damp proofing at place where the damp is not excessive.
- The joints are kept open.

h. Mortar

- Cement mortar of 1:3 is used as binding layer for DPC.
- Small quantity of lime is added to increase the workability.
- 75 gram of soap is dissolved per liter of water for preparing mortar.
- This mortar can be used for plaster of outer walls.

i. Cement Concrete

- A cement concrete layer in proportion 1:2:4 is generally provided at the plinth level to work as a damp proofing course.
- The depth of cement concrete layer varies from 40mm to 150mm.
- The layer prevents water raise in wall by capillary action.

j. Plastic Sheets

- The material is made of black polythene having a thickness of about 0.55mm to 1mm with usual width of wall and it is available in roll length of 30m.
- This treatment is relatively cheap, but it is not important.

6.4 Damp Proof Treatment in Various Element of House

A. Foundation

Foundation depending upon the depth of the ground level, the treatment to be given to the foundation can be subdivided into the following four categories.

a. Treatment to foundation on ordinary soil.

Building foundations on ordinary soil where the sub-soil water is not high are also liable to get damp. Brick being porous, brick masonry below the ground level can absorb moisture from adjacent ground. This moisture travels up from one course to another by capillary action and can make the wall damp for a considerable height. This can be checked by providing DPC at appropriate place. In case of building without basement, the best portion for damp proof course lies at plinth level. In case of structure without plinth, DPC should be provided at least 150mm above ground level. If the damp proof course is laid just at the ground level, earth, dust, or leaves might accumulate outside the wall and by the passage of time the level of outside earth may be raised above the DPC level. In such case, moisture can travel from outside ground level to brickwork above DPC and hence the purpose of providing DPC will not be served.

b. Treatment to foundation on damp soil

In case of building constructed on damp soil in wet areas, both the walls as the ground floor are liable to become damp due to capillary rise of moisture from ground. In such cases, the DPC is laid over the entire area of ground floor including wall thickness. Bitumen felts can be used for damp proofing treatment.

The sequence of operations for laying DPC can be divided in the following steps.

- Apply hot bitumen at the rate of 1.5kg/m^2 over the prepared surface to serve as prime coat.
- Lay bitumen felt in single layer over the primer coat.
- Apply hot bitumen at the rate of 1.5kg/m^2 over the bitumen felt to serve as finishing coat.

Immediately after laying, the DPC is protected with a course of brick laid flat on a cushion of fine sand. This prevents damage to DPC specification on account of droppage of sharp-edged implement or other material during construction.

c. Treatment to basements in ordinary soil

- In sites where sub soil water table is low or, where the hydrostatic pressure is not much, the treatment consists in providing a horizontal DPC over the entire area of basement floor and then extending it in the form of vertical DPC on the external faces of the basement walls.
- The DPC material thus functions like a waterproof tank on the external faces of the basement and keep it dry.
- It is common, to use bitumen felts in multiple layers for damp proofing treatment to basements. For normal duty treatment or in places where moisture ingress is not considered excessive, two layer of bitumen felts are used.
- In case of heavy-duty treatments or in places where heavy moisture ingress is encountered, three layers of bitumen felts are used.

- The sequence of operations for laying DPC in basement for normal duty treatment can be divided in the following steps.
    - ✓ Apply hot bitumen at the rate of 1.5kg/m^2 over the prepared surface to serve as **prime coat**.
    - ✓ Lay **bitumen felt** in single layer over the primer coat.
    - ✓ Apply hot bitumen at the rate of 1.5kg/m^2 over the bitumen felt.
    - ✓ Lay another layer of bitumen felt in single layer over the hot bitumen layer.
    - ✓ Apply another hot bitumen at the rate of 1.5kg/m^2 over the bitumen felt to serve as finishing coat.

d. Treatment to basement in damp soil

Ground water always produces hydrostatic pressure and such poses great problem in the design of basement. In sites where the ground water table is high, the problem of damp-proofing of basement can be tackled by one of the following three method.

- By providing foundation drains and DPC
- By providing RCC floor and wall slab and DPC
- Water proofing treatment by using grout consisting of cement mortar admixed with acrylic based chemicals along with rough stone slabs.

B. Walls

- Wall can get damp due to penetration of moisture from its external face to internal one, due to porosity of bricks and mortar joints. Various treatments given to exposed surface of walls to prevent dampness include pointing, plastering, painting etc. It is observed that plaster made of cement, lime and sand mixed in proportion of 1:1:6 serves as very effective rendering to protect the wall against dampness in normal weather conditions.
- In areas of heavy rainfall, cement plaster 1:4 mixed with water proofing compounds like pudlo, permo etc. In exposed brick work, dampness can be prevented by painting the surface with waterproof cement paint or with colorless liquid water proofing compound.

C. Floors

- For location where ground water moisture is not present, subsoil is rammed well.
- 7.5 to 10 cm sand layer is spread over total area of floor.
- Stone soling may be made and 7.5 to 10 cm layer of concrete 1:3:6 may be provided.
- Over this base flooring may be laid.
- If ground water is there, membrane DPC over total area is laid.
- Membrane can be mastic asphalt.
- Layer of brick is laid over DPC to protect it from damage.
- Before laying bitumen felt, a coat of hot bitumen at a rate of 1.5kg/m2 is applied over the foundation concrete to serve as primer coat.
- After laying bitumen felt, finishing coat of hot bitumen is applied at a rate of 1.5kg/m2 over felt.

D. Roof

1. Treatment to flat roof

- DPC for flat roofs, parapet walls, coping and pitched roofs are also made with suitable DPC material.
- Flat roofs required relatively heavier and costlier water proofing treatment as compared to slope roofs.
- The water proofing treatment for the roof may consist in laying bitumen felt directly over the surface of the roof slab after painting the roof top with hot bitumen.
- Depending upon the requirement, the treatment with felts may be with 4 courses, 6 courses and 8 courses.

- Commonly adopted water proofing treatment for flat roofs is providing a grading of selected material over the roof slab.
  - ✓ laying of cement concrete
  - ✓ laying of cement concrete with tiles
  - ✓ laying of mud with tiles
  - ✓ laying of brick cement grout with chemicals

2. Treatment of pitched roof

Rain may penetrate through a sloped roof because of

- ✓ Insufficient roof slopes
- ✓ Insufficient overlapping of roof covering
- ✓ Inadequate rainwater gutters.

Design and installation of rainwater gutter needs extra attention with respect to its capacity, position, fixing etc.

DPC provided in the gutter should extend up to surface of the parapet wall and should be taken into partly the body of the wall.

E. Parapet Wall

- If the flat roof has a parapet and there are cracks in it or its plaster is very porous or defective, rainwater may find and easy access to the wall below and make the wall and some portion of the ceiling damp.
- Rainwater may also leak through cracks at the junction of the parapet.
- The parapet wall is further protected by providing coping of brick, concrete, or stone on its top.

CHAPTER 7: CONCRETE AND CONCRETE CONSTRUCTION

7.1 Concrete and grades of concrete

Concrete is a composite material, composed of fine and coarse aggregate bonded together with cement that hardens over time. Grade of concrete is defined as the minimum strength at which concrete must possess after 28 days of construction with proper quality control. Grade of concrete is denoted by prefixing M to the desired strength in Mpa (N/mm^2).

Let us take an example of M20, in the designation M20 of the mix letter M represents the mix and the figure 20 represents the specified characteristics strength of 15x15x15 cm^3 cube at 28 days expressed in N/mm^2.

Grade of Concrete	Concrete Mix Ratios	Compressive Strength (MPa - N/mm^2)
Initial Grades/Normal Grade of Concrete		
M5	1:5:10	5 MPa
M10	1:3:6	10 MPa
M15	1:2:4	15 MPa
M20	1:15:3	20 MPa
Mid Grades/Standard Grades of Concrete		
M25	1:1:2	25 MPa
M30	Design Mix	30 MPa
M35	Design Mix	35 MPa
M40	Design Mix	40 MPa
M45	Design Mix	45 Mpa
Higher Strength Concrete Grades		
M50	Design Mix	50 MPa
M55	Design Mix	55 MPa
M60	Design Mix	60 MPa
M65	Design Mix	65 MPa
M70	Design Mix	70 MPa

7.2 properties of concrete

Strength, durability, and workability may be considered as the main properties of concrete. In addition, good concrete should be able to resist wear and corrosion and it should be water-tight, compaction and economical.

Concrete is the most used construction material because of its following properties.

- It has relatively high compressive strength.
- Fresh concrete can be easily handled and molded in any shape and size.
- It has better resistance to fire.
- It has long service life with low maintenance cost.
- Most economical structure material for the construction of dam and footing.
- It is easily workable.
- It can be pumped and hence it can be laid in the difficult position.
- It is strong and durable.
- It has minimal weathering effect.
- It has very low permeability.
- It is resistance to chemical attack

7.3 Workability of concrete

Despite all its importance, workability is the most elusive property of concrete and is quite difficult to define and measure. Concrete is said to be workable if it can be easily mixed, handled, transported, placed in position and compacted. Lubricating effect of the cement-paste which in turn is solely governed by the degree of dilution, affects the workability of a concrete mix. A workable concrete mix must be fluid enough so that it can be compacted with minimum labor.
A workable concrete dose not result in bleeding or segregation. Bleeding of concrete takes place when the excess of water in the mix comes up at the surface and segregation is caused when coarse aggregate tend to separate from the fine aggregate.
Workability of a concrete mix is appreciably affected by the following.

a) **Water cement ratio:**
Higher the water/cement ratio, higher will be the water content per volume of concrete and concrete will be more workable.
b) **Size of Aggregates:**
Larger the size of the aggregate, lower will be the workability of a concrete and vice versa.
c) **Shape of Aggregates:**
The shape of aggregates affects the workability of concrete. It is easy to understand that rounded aggregates will be easy to mix than elongated, angular and flaky aggregates due to less frictional resistance.
d) **Mix Proportions of Concrete:**
Mix proportion of concrete tells us the ratio of fine aggregates and coarse aggregates with respect to cement quantity. The more cement is used, concrete becomes richer, and aggregates will have proper lubrications for easy mobility or flow of aggregate sand hence higher will be the workability.
e) **Cement Content of Concrete:**
Cement content affects the workability of concrete in good measure. More the quantity of cement, the more will be the paste available to coat the surface of aggregates and fill the voids between them. This will help to reduce the friction between aggregates and smooth movement of aggregates during mixing, transporting, placing, and compacting of concrete.
The workability of concrete can be measured by one of the following three tests.
   i. Slump test
   ii. Compaction fact
   iii. Vee-Bee test

7.4 Methods of Proportioning Concrete Mix

The aim of evolving different methods of proportioning concrete is to get strongest and the densest mix with least amount of cement.
The different methods of proportioning concrete are

a) **By arbitrary standards**
   - The general expression for the proportions of cement, sand and coarse aggregate is 1 : n : 2n by volume.
   - 1 : 1 : 2 and 1 : 1.2 : 2.4 for very high strength
   - 1 : 1.5 : 3 and 1 : 2 : 4 for normal works.
   - 1 : 3 : 6 and 1 : 4 : 8 for foundations and mass concrete works

b) **Minimum void method**
The quantity of sand used should be such that it completely fills the voids of coarse aggregate. Similarly, the quantity of cement used to show such that it fills the voids of sand, so that a dense mix the minimum voids is obtained. In actual practice, the quantity of fine aggregate used in the mix is

about 10% more than the voids in the coarse aggregate and the quantity of cement is kept as about 15% more than the voids in the fine aggregate.

c) By trial or by maximum density method

This method is based on the principle, that a concrete mix which is formed by so proportioning its aggregate as to give heaviest weight for same volume, yield the densest concrete. Hence in this method a box is filled with varying proportions fine and coarse aggregates. The proportion which gives the heaviest weight is adopted for the work.

d) Fineness modulus method

The fineness modulus of an aggregate is the term used to indicate the average size of particle in the aggregates. It is represented in the form of an index number. Thus, the coarser the aggregate, the higher will be the value of fineness modulus.

In this method the samples of both coarse and fine aggregates are passed through a set of nine standard sieves and the percentage of the sample retained on each of the sieves is determined. The total of these percentage divided by 100 gives the fineness modulus of the sample.

e) Water cement ratio

Abram, as a result of experiments, established that the proportion of water to cement in any mixture has the greatest influence on the strength of the concrete.

According to water cement ration law " *for any given condition of test, the strength of well compacted concrete with good workability is dependent only on the water cement ratio*".

- The lower water content produces stiff paste having greater binding property and hence the lowering the water-cement ratio within certain limits results in the increased strength.
- Similarly, the higher water content increases the workability, but lower the strength of concrete.
- The optimum water-cement ratio for the concrete of required compressive strength is decided from graphs and expressions developed from various experiments.
- According to Abram's Law water-cement law, lesser the water-cement ratio in a workable mix greater will be the strength.

7.5 Mix Design

The aim of mix design is to determine the proportions in which cement, fine aggregate, coarse aggregate, and water should be mixed to produce concrete of required strength, workability and durability with minimum cost.

When the task of deciding the proportion of the constituents of concrete is accomplished by use of certain established relationships the concrete thus produced is termed as design mix concrete.

When the proportions of cement aggregate and water are adopted based on arbitrary standard the concrete produced is termed as nominal mix concrete.

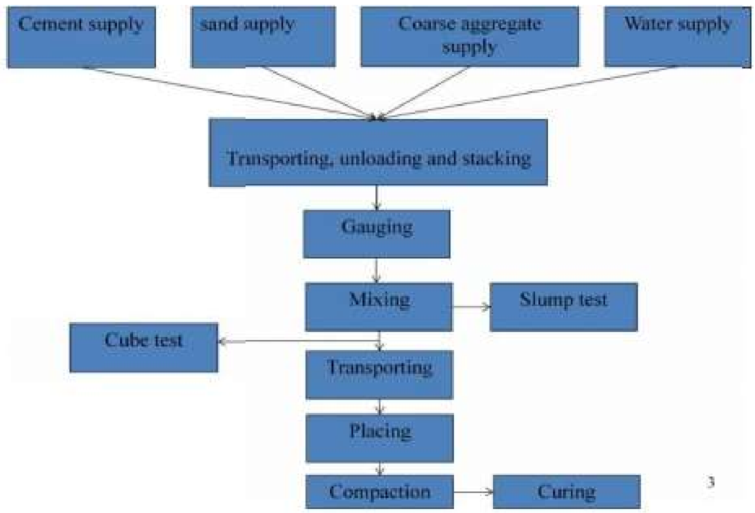
a) Design mix concrete:

The basic assumption in design mix concrete is that compressive strength of concrete is dependent almost entirely on the water cement ratio. The design of the concrete mix can be carried out by following method laid in the code.

b) Nominal mix concrete:

Nominal mix concrete is used in works where the quality control requirement for design mixes is difficult to be implemented. As explained earlier, nominal mix concrete can be produced by taking cement, fine aggregate, and coarse aggregate in the ratio of 1:n:2n for normal work. However, the ratio of the coarse aggregate to fine aggregate can vary from $1{:}1\frac{1}{2}$ to $1{:}2\frac{1}{2}$ in situation where denser or more workable concrete is to be produced.

7.6 Concreting Process



The operation involved in the production and execution of the item of concrete can be broadly divided in following stages:

1. **Batching of materials:**

   To ensure uniformity in the quality of concrete it is necessary that all material that go into its production are measured accurately within permissible tolerances. Batching of material can be done manually or by using batching plant. The choice of system to be adopted for hatching depends up on the magnitude of concreting work involved and the rate at which concrete is required to be produced.

   While batching cement is always measured by weight, the weight of one bag of cement is taken as 50 kg. Fine and coarse aggregate are measured by volume in case of manual batching and by weight in case of mechanical batching i.e., by batching plant.

2. **Mixing of concrete:**

   The purpose of mixing is to ensure that mass homogeneous, uniform in color and uniform in consistency.

   There are two different types of concrete mixing.

i. **Hand Mixing**

- It is done manually.
- Used when quantity of concrete needed for the work is small.
- Sand in cement in appropriate proportion are mixed first on a cleaned hard surface or on a steel plate.
- Coarse aggregate is then added and whole mixture is mixed thoroughly with the shovels.
- The predetermined amount of water is added in the mixture.
- The mass is then turned till the concrete obtained is homogeneous.
- As compared to machine mixing it cannot give homogeneous and uniform concrete.

ii. **Machine Mixing**

- In this method, first coarse aggregate is put into the machine drum then fine aggregate and cement is added.
- Machine is started to revolve to mix the material in dry state.
- Then gradually water is added with the pipe or jar into the mixture in require water cement ratio.
- Drum is rotated for 1 to 2 minutes for thoroughly mixing of concrete after mixing water.
- It is an effective and economical way of mixing in which homogeneous and uniform mixing can be ensured.

- It is further divided into the following types.
    - **Continuous mixers:** Continuous mixers are employed in massive construction where large and continuous flow of concrete is desired. The process of feeding the mixing is more or less automatic. The machine requires careful supervision to obtain the concrete mix of desired consistency.
    - **Batch mixing:** In this method, the desired proportions of materials are fed into the hopper of a drum in which the materials gets mixed by the series of blades or baffles inside the mixer.

      Batch mixers are further classified as
        - ✓ **Tilting type mixers:** The mixer consists of a conical or bowl-shaped drum with inside vanes. These vanes revolve on an inclined axis. It discharges mix by tilting its drum without segregation. This mixer is preferable for mixes of low workability and having large size aggregate.
        - ✓ **Pan mixers:** This mixer is static type. It is fixed and stationary and hence used either at a central mixing plant or at large concrete project or in the laboratory.
        - ✓ **Non-tilting type mixers:** In this type of mixer, the drum cylindrical and always rotate about a horizontal axis. The discharge of mixed is obtained either by inserting chute into the drum or reversing of rotation of drum. Concrete is liable to segregate in these types of mixers due to the slower rate of discharge.
        - ✓ **Transit Mixers:** Transit mixers are mounted in a truck. These mixers is fed with aggregate and cement from a batching plant and add water to mix concrete. The drum of these mixers revolves 70-100 revolutions for complete mixing of concrete.

3. Transportation of Concrete

After mixing of concrete, it should be transported and placed at the site as quickly as possible. Segregation and drying should be avoided while transporting the concrete after mix. For most of the small jobs, concrete mix is transported manually with the help of wheelbarrows or even in a pan carried manually. For any medium to large projects, mechanical equipment is used to transport concrete from mixer to the formwork where it must be laid in the final shape.

Depending up on the type of work and equipment available various methods of transporting concrete can be employed.

a) Pan method: This method of concrete transportation can be employed for small jobs, where the quantity of concrete required is small and labor are available at a cheaper rate.

b) Bucket conveyors: Bucket conveyors are used to transporting concrete in the vertical direction from bottom to top.

c) **Dumpers and trucks:** These are a special type of trucks. These dumpers are suitable to transport concrete for relatively longer distance without segregation and setting. Tipping lorries are also used to transport concrete.

d) **Belt Conveyors:** Belt conveyors are very convenient in the movement of concrete easily to different parts at site. It can transport concrete continuously and is suitable for a hot climate. When other methods of transportation are not feasible, belt conveyors are best for the alternate solution.

e) **Concrete Pumps:** Concrete is transported through pumps in tunnel construction. The Guniting and shortcreting are specially done through pumps in high pressure.

f) **Builders Hoist:** Nowadays at multistory building sites up to 150m hoists are used to transport the concrete.

g) **Cranes:** Cranes are commonly used to transfer concrete from the mixer or a place of delivery to the form of work where it has to be laid. It is very suitable transferring system as it can take concrete to the right location where it is required.

4. **Placing of concrete**

Concrete should be placed and compacted immediately after mixing. The arrangement for the conveyance of the concrete mix should be so planned that the mixed mass is used within **30 minutes**. This is necessary to prevent the danger of concrete getting its initial set.

Concrete should not be placed from heights more than **1m** and before placing concrete shuttering should be checked.

5. **Compaction of concrete**

Concrete mixes are a heterogeneous mixture of cement, aggregates and water in a stiff state containing large voids and entrapped air. Consolidation can be carried out through compaction to remove air voids.

Compaction is achieved by the use of mechanical compaction or hand compaction

i. **Hand compaction:**

Hand compaction may be done by rodding, tamping or hammering. Tamping is usually adopted for compacting concrete for slabs or other such surfaces. Roding is done for thin vertical members. Hammering is done for massive plain concrete works and for compacting an almost dry concrete, the surface is beaten with heavy flat bottom rammers till the film of mortar start appearing on the surface.

ii. Mechanical Compaction:

Mechanical compaction is achieved using mechanical vibrators.

- **Internal Vibrators:** Internal vibrators are also called needle vibrator. It consists of three parts. The power unit, flexible tube and vibratory head. They are introduced into the fresh concrete to vibrate and given a compacting effect to the concrete. Power is given to vibrator either by petrol engine or electricity input. Flexible rubber tube connects a power connecting device and the vibrating needle.

- **Plate Vibrators:** They are used to compact with lesser thickness. This vibrator falls under the category of a surface vibrator. It is extensively used in slab construction.

- **Vibrating Screen:** The vibrating screen is also the type of surface vibrators capable of compacting large section of concrete surface giving neat shape to the concrete. They are used in finishing bridge decks and also concrete pavement of roads, aprons and parking areas.

- **Form Vibrators:** These vibrators are external vibrators and are attached to the outside of the concrete formwork. These are used in compaction of precast concrete.

- **Concrete Rollers:** Large static rollers are also used for compacting plum concrete.

6. **Curing of concrete**

Curing of concrete is one of the essential requirements of process of concreting. Curing is process of keep the set concrete damp for some days to enable the concrete gain more strength. If concrete is left in contact with water, it will continue to gain strength for many months. Otherwise, all free water evaporates, and no further hydration can continue. Curing ensures that water for hydration is available as long as possible.

Curing Method

- **i.** Spraying surface of concrete with water.
- **ii.** Protecting exposed surface from wind and sun by windbreaks and sunshades.
- **iii.** Covering surfaces with wet hessian and sprinkling the water.

Columns, walls or other vertical members are usually cured by wrapping gunny bags.

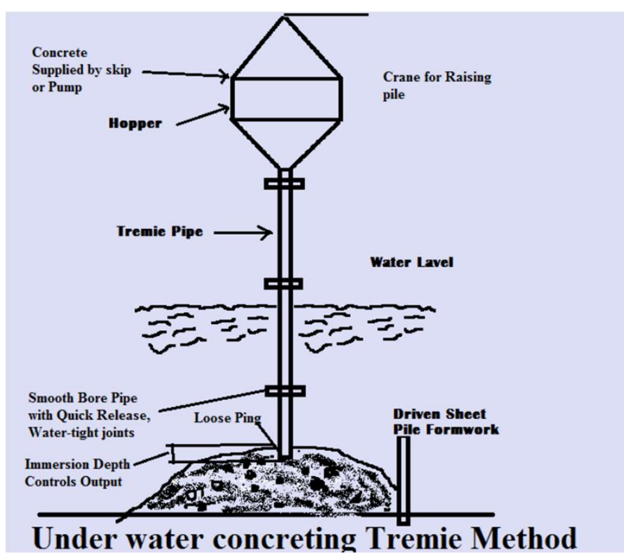
7.7 Concreting under Water

The deposition of concrete under water is a complicated problem. When it is necessary to deposit concrete under water, we should give attention while selecting the methods, equipment, materials, and proportion of mixed to be used.

- The water cement ratio shall not exceed 0.6 or smaller depending on the grade of concrete.
- For aggregate 40mm maximum particle size, the cement content shall be at least 350 kg/m^3 of concrete.
- Concrete cast under water should not fall freely through water.
- Concrete shall be deposited continuously until it is brought to the required height.

Method adopting for depositing concrete under water are

a. **Tremie**



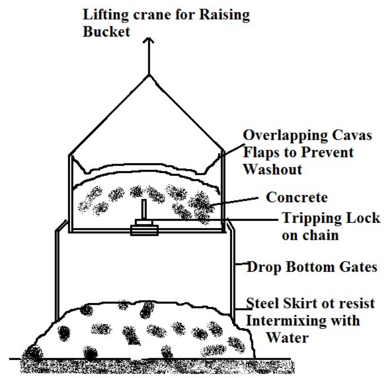
- Concrete is placed through the vertical pipe.

- The top section of the tremie shall be a large enough to hold one entire batch of mix.
- The tremie pipe shall not be less than 200mm in diameter and shall be large enough to allow a free flow of concrete and strong enough to withstand the external pressure of water.
- While placing concrete, the lower end of pipe is inserted sufficiently deep into the concrete which has been placed previously but has not set.
- The concrete emerging from the pipe pushes the material that has already been placed to the side and upwards and thus does not come into direct contact with water

b. Direct placement with pump

- As in the case of the tremie method, the vertical end piece of the pipeline is always inserted sufficiently deep into the previously cast concrete and should not move to the side during pumping.

c. Drop Bottom Method



Bucket Placing Method

- The top of the bucket shall be covered with a canvas flap.
- The bottom doors shall open free downward and outward when tripped.
- The bucket shall be filled completely and lowered slowly to avoid backwash.
- The bottom doors shall not be opened until the bucket resets on the surface upon which the concrete is to be deposited and when discharged shall be withdrawn slowly.

d. Bags

- In this method the jute sacks or coarse cloth bags of minimum capacity of 0.028 m^3 are filled about 2/3 with concrete and the spare part of the bag is turned down and tied securely.
- The properly filled bags are lowered into the water and placed carefully with the help of divers so that the whole mass is interlocked.
- Bag used for this purpose shall be free from harmful materials.

7.8 Placing under cold weather

- Concreting work done at a temperature below 6°C is termed as cold weathering concrete. If the concreting is done at freezing temperature, it will have harmful effect on the properties of concrete. Thus, cold weather adversely affects the setting and hardening of concrete and hence delays the development of ultimate strength in concrete.
- The strength after 28 days may be only 50% of the ultimate strength if concrete is cured at 0°C and it may be only 30% of its ultimate strength if it is cured at -10°C . However, while concreting in cold weather, precaution is taken to keep the temperature of concrete above a minimum value both while placing the concrete in position in the formwork as well as while curing it.
- Besides this it is necessary to insulate the formwork by fixing boards or tarpaulins etc. on the outside of the formwork battens.

- In moderate or less severe conditions the problem can be tackled by increasing the quantity of cement in the mix or by use of rapid hardening cement or by use of high alumina cement.
- Use of accelerators like calcium chloride is also sometime advocated to produce increased internal temperature during setting and hence to achieve early setting of concrete.
- However, the method commonly adopted for concreting in cold weather is to heat up the aggregates or water or both with view to keep the temperature of the resultant concrete less than 38°C .
- Pre-heating of mixing water is the most effective in this regard. The water is heated to have temperature of at the time of mixing.
- Aggregate should be heated only up to 15°C in case the temperature of the mixing water is 60°C.
- Similarly, adequate temperature for concrete in cold weather can be obtained by increasing the temperature of only sand to about 40°C if mixing water is taken as 60°C .
- In cold weather all concrete surfaces should be covered as soon as the concrete is placed in position with a view to keep the heat in and to provide necessary protection from outside frost. This is achieved by covering the concrete surface with dry blankets of straw, cement bags etc.

7.9 Placing concrete in hot weather

When the temperature of freshly mixed concrete approaches approximately 77 degrees Fahrenheit adverse site conditions can impact the quality of concrete. Ambient temperatures above 90 degrees Fahrenheit and the lack of a protected environment for concrete placement and finishing (enclosed building) can contribute to difficulty in producing quality concrete.

The precautions required to ensure a quality end product will vary depending on the actual conditions during concrete placement and the specific application for which the concrete will be used. In general, if the temperature at the time of concrete placement will exceed 77 degrees Fahrenheit a plan should be developed to negate the effects of high temperatures.

The precautions may include some or all the following:

- Moisten subgrade, steel reinforcement, and form work prior to concrete placement.
- Erect temporary wind breaks to limit wind velocities and sunshades to reduce concrete surface temperatures.
- Cool aggregates and mixing water added to the concrete mixture to reduce its initial temperature. The effect of hot cement on concrete temperature is only minimal.
- Use a concrete consistency that allows rapid placement and consolidation.
- Protect the concrete surface during placement with plastic sheeting or evaporation retarders to maintain the initial moisture in the concrete mixture.
- Provide sufficient labor to minimize the time required to place and finish the concrete, as hot weather conditions substantially shorted the times to initial and final set.
- Consider fogging the area above the concrete placement to raise the relative humidity and satisfy moisture demand of the ambient air.
- Provide appropriate curing methods as soon as possible after the concrete finishing processes have been completed.
- In extreme conditions consider adjusting the time of concrete placement to take advantage of cooler temperatures, such as early morning or nighttime placement.
- With proper planning and execution concrete can be successfully placed and finished to produce high quality durable concrete at temperatures of 95 degrees Fahrenheit or more.

7.10 Causes of failure of reinforced concrete structure

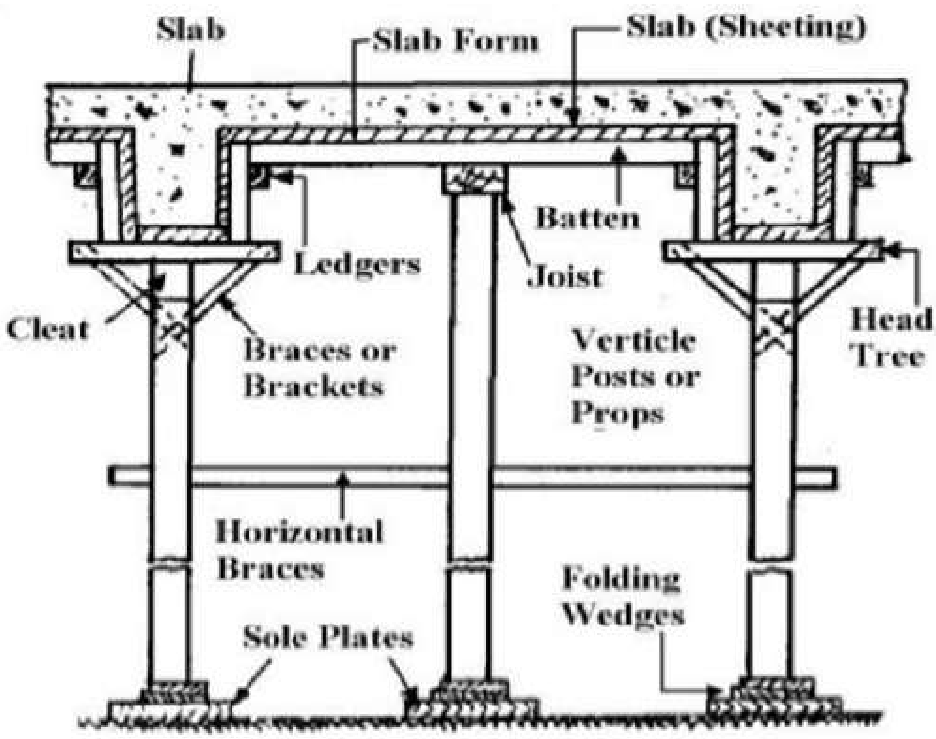
A reinforced concrete member can fail mostly in the following cases.

- When the member is subjected to excessive tension, to exceed the permissible stress in steel.

- When the loading is such that the compressive stress in concrete exceeds its safe permissible value.
- When the concrete is subjected to excessive shear.
- Because of the slipping of the steel bars from concrete.
- Due to bad quality of material used shrinkage, creep, or thermal effects.
- When the member is subjected to extremes of temperature, aggressive liquids, or gases.

CHAPTER 8: FORMWORKS

8.1 Characteristics of good formwork



Formwork or shuttering is a temporary construction used as a mould for the structures in which concrete is placed, hardens and mature. Formwork is a temporary but rigid structure in which the cast in situ concrete is laid for casting the members to required shape.

A good formwork have following characteristics

- It should be strong enough to withstand all types of dead and live load.
- It should be rigidly constructed and efficiently propped and braced (both horizontally and vertically) so as to retain its shape without undue deflection.
- The joints in the formwork should be tight against leakage of cement grout.
- The formwork should be constructed in such a manner that it may permit the removal of various parts in desired sequence without jarring or damaging the concrete.
- The material of the formwork should be cheap, easily available and should be suitable for reuse several times.
- The formwork should be set accurately to the desired line and levels and should have plain surfaces.
- The formwork should be as light as possible.
- The material of formwork should not warp or get distorted when exposed to sun, rain or water during concreting.
- The formwork should rest on firm base.

8.2 Material for formwork

A formwork is a temporary structure used as mold for the original structure. There are different material available to construct the formwork. The type of material to be used for formwork depends up on the nature of construction as well as the availability and cost of material.
Formwork can be made from timber, plywood, steel, aluminum etc.

a) Timber Formwork

Timber is the most used material for formwork. Timber logs, lumber etc. are used as bracing members from ancient times. So, the timber formwork is also called as traditional formwork. It is most economical material used for formwork.

Advantages

- Timber can be cut into any required size easily.
- Timber is light in weight, and it can be handled easily.
- Timber has good thermal resistance which prevents the damage of concrete in colder regions.
- It is easy to understand the construction method of timber formwork hence, skilled workers are not necessary.
- Timber formwork can be easily dismantled.

Disadvantages

- Dry timber may absorb water from wet concrete which result in the reduction of strength in concrete structure.
- Wet timber having high moisture content compress the wet concrete and forms cracks in the structure and grout may leaked through joints when shrinking occurs

b) Plywood Formwork

Plywood which is a manufactured product of timber is also used for formwork. It consists of number of veneer sheets or plies in layers. Nowadays, the use of plywood formwork provides smooth finish when compared to normal timber formwork. Hence, finishing cost may reduce using plywood. For formwork, special type of plywood called exterior plywood is used. The veneer sheets of exterior plywood are bonded with strong adhesive to make it watertight. The plywood boards are available in thickness from 7mm to 32mm.

Advantages

- Plywood can also be cut into required size easily.
- Plywood is strong, durable, and light in weight.
- Provides smooth finish on the surface.
- Very large size plywood sheets are available which makes the construction of formwork quicker and easier.
- Curved formworks can also be prepared using plywood.
- When compared to timber, it gives a greater number of reuses.

Disadvantages

- When compared to timber it is costly.
- Thin plywood sheets cannot sustain the weight of concrete they may bow out if proper thickness is not provided.

c) Steel Formwork

Steel can also be used as formwork material. It is very costly, but it can be used for a greater number of times than others. They provide excellent finish to the concrete surfaces. For mass structures like dams, bridges etc. steel formwork is so strong and safe.

Advantages

- Steel forms are durable and stronger.

- Provides uniform and smooth surface finish to the structure.
- Great reusability.
- Easy to fix the formwork and easy to dismantle.

Disadvantages

- Cost is very much higher.
- It is heavy and requires lifting equipment for large structure formwork.
- Corrosion will occur when there is a frequent contact with water.
- The size and shapes of forms available are limited.

8.3 Construction of formwork

The construction of formwork normally involves the following operations.

A. Propping and centering

The props used for centering may be of steel, timber posts or ballies. Pillars made up of brick masonry in mud mortar are also sometimes used as props. In case wooden ballies are used props, they should rest squarely on wooden sole plates laid either on ground or on brick masonry pillars in mud mortar. The wooden plate should have area of at least 0.1 m^2 and it should be 40 mm thickness. Double wedges are essentially provided between the sole plates and the timber props with a view to permit accurate adjustment of the shuttering prior to concreting operation and to allow easy removal of shuttering after works.

B. Shuttering

The shuttering can be made up of timber planks, or it may be in the form of panel units made either by fixing plywood to timber frames or by welding steel plates to angle framing. In any case, the shuttering should be constructed in such a manner that the joints should be tight against leakage of cement grout.

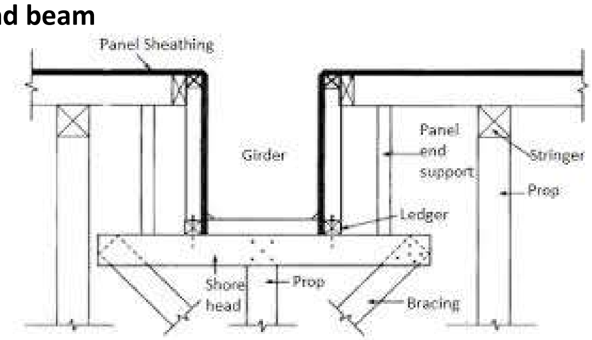
C. Provision of camber

Certain amount of deflection in structure is unavoidable. It is therefore desirable to give an upward camber in the horizontal members of the concrete structure (especially in members having long spans) to counteract the effect of deflection. The provision of desired camber should be made in formwork itself during its erection.

D. Surface treatment

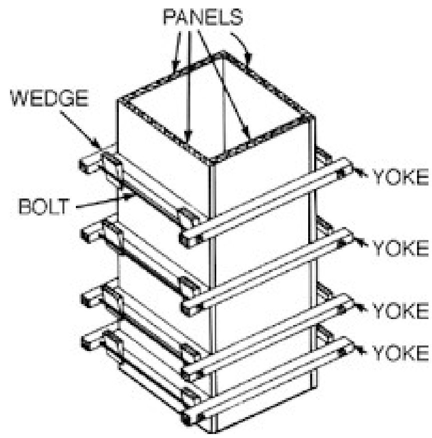
Before laying concrete, the formwork should be cleaned of all rubbish particularly the sawdust shaving and chippings etc. All surfaces of timber shuttering that are to come in contact with concrete should be well wetted with water. This is necessary to prevent the chances of dry shuttering timber absorbing water from the concrete which may cause warping, swelling and distortion of timber besides resulting in defect of honey combing concrete.

Formwork for slab and beam



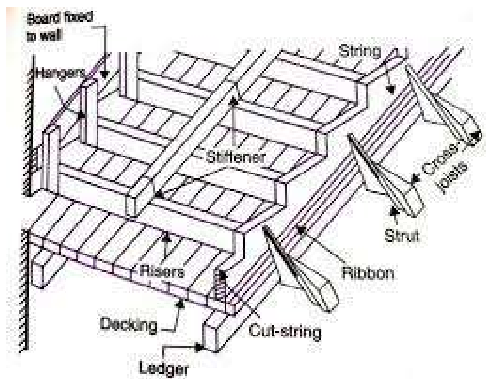
- It consists of sole plates, wages, vertical posts, head tree, battens, ledgers.
- Slab formwork rests on head tree.
- If props heights are more than 8 feet provide horizontal bracing.

Formwork for column



- It consists of side and end planks, yoke, nut bolts.
- Two end and two side planks are joined by the yokes and bolts.

Formwork for staircase



It consists of vertical and inclined posts, inclined members, wooden planks or sheeting, stringer, riser planks.

8.4 Order method of removing formwork

The formwork should be planned and constructed in such a manner that it is possible to remove the different components in the following order of sequence.

a. Shuttering forming vertical faces of walls, beams, and columns sides (which bear no load but are used only to retain the concrete) should be removed first.

b. Shuttering forming soffit to slabs should be removed next.

c. Shuttering forming soffit of beams, girders or other heavily loaded shuttering should be removed in the end.

d. Duration of time up to which the formwork should be kept in place depends up on many factors such as type of cement used, shape and position of the member (whether member is horizontal, vertical, or inclined) loads to be carried by the members and the temperature of the air. In general, rapid hardening cement, warm weather and light loading conditions allow early removal of formwork.

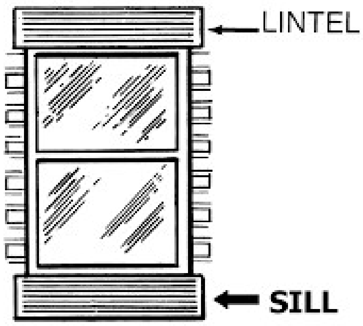
e. Early release of formwork permits its re-use in other areas and these results in economy by way of optimum utilization of material and fast construction.

f. The formwork should under no circumstances be allowed to be removed until the concrete reaches strength of at least twice the stress to which the concrete may be subjected to at the time of removal of formwork.

Type of Formwork	*Minimum Period Before Striking Formwork*
a) Vertical formwork to columns, walls, beams	16-24 h
b) Soffit formwork to slabs (Props to be refixed immediately after removal of formwork)	3 days
c) Soffit formwork to beams (Props to be refixed immediately after removal of formwork)	7 days
d) Props to slabs:	
1) Spanning up to 4.5 m	7 days
2) Spanning over 4.5 m	14 days
e) Props to beams and arches:	
1) Spanning up to 6 m	14 days
2) Spanning over 6 m	21 days

CHAPTER 9: SILL/LINTEL

9.1 Sill/ lintel and their uses



Sill: Sill is a horizontal member usually as wide as the wall provided below windows or other openings. Sill supports the windows.

Lintels and its uses

The Lintel is a horizontal member placed just over the openings of doors, windows, verandas, etc. to support the load of the masonry work over It. Lintel beams provide supports to the openings in building and transfer that load safely to the masonry walls or columns. Their width must be equal to the width of the wall. They are built on the top of openings, and their ends are built in the wall. Arches are also constructed on the place of the lintel. However, as compared to arches, lintel beams are very easy to construct.

9.2 Types of sill/lintels

Based on the material used Sill/lintels may be classified as

a. **Wooden sill/Lintel**
   - Wooden or Timber Lintels are the oldest types of sill/lintels.
   - In hilly areas, where timber suitable for the construction of sill/lintel is easily available, wooden sill/lintel are commonly used.
   - In plains, the use of wooden sill/lintel is very rare on account of high cost of the material.
   - Timber if not properly ventilated, is liable to decay.
   - If the length of the opening is long, then two or more pieces of timber are joined to provide sill/ lintel on the whole opening.
   - Wooden being combustible, wooden sill/lintels cannot be recommended for fireproof construction.

b. **Stone Sill/lintel**
   - These are the most common type, especially where stone is abundantly available.
   - This type of Sill/lintel will be very firm and strong, but it weighs too much.
   - Their thickness is kept approximately 10 cm per meter.
   - They are used up to spans of 2 meters.
   - It is difficult to deploy them its cities as its transportation is a very complex task. Hence, they are not used in urban areas.

c. Brick Sill/lintel

- They are constructed with hard, well burnt, first class brick laid on end or on edge.
- These are used when the opening is less than 1m and lesser loads are acting.
- Its depth varies from 10 cm to 20 cm, depending up on the span.

d. Reinforced Brick Sill/Lintel

- These are used when loads are heavy, and span is greater than 1m. The depth of reinforced brick Sill/lintel should be equal to 10 cm or 15 cm or multiple of 10 cm.
- The bricks are so arranged that 2 to 3 cm wide space is left length wise between adjacent bricks for the insertion of mild steel bars as reinforcement. 1:3 cement mortar is used to fill up the gaps.

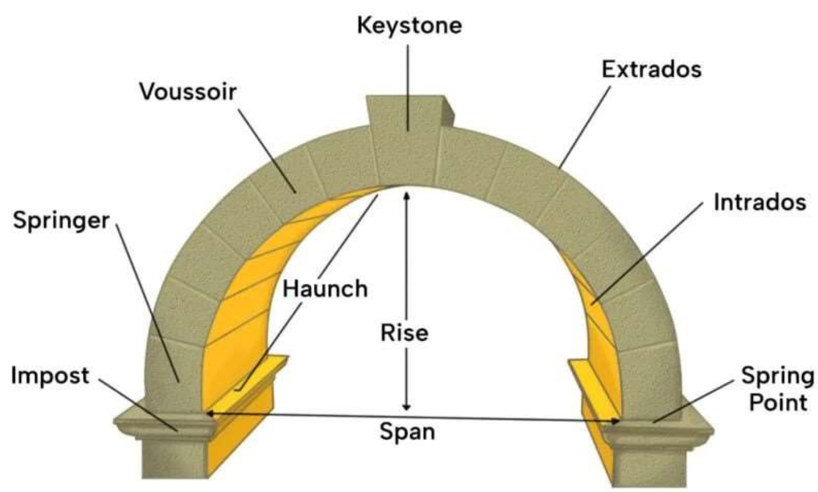
e. Reinforced Cement Concrete Sill/Lintel

- At present, the Sill/lintel made of reinforced concrete are widely used to span the openings for doors, windows, etc. in a structure because of their strength, rigidity, fire resistance, economy, and ease in construction. These are suitable for all the loads and for any span. The width is equal to width of wall and depth depends on length of span and magnitude of loading.

e. Steel Lintel

- These are used when the superimposed loads are heavy, and openings are large. These consist of channel sections or rolled steel joists. We can use one single section or in combinations depending up on the requirement.

9.3 Arch and its uses



An arch is a structure constructed in curved shape with wedge shaped units (either bricks or stones), which are joined together with mortar, and provided at openings to support the weight of the wall above it along with other superimposed loads.

Because of its shape the loads from above gets distributed to supports (Pier or abutment). In common with lintels, the function of an arch is to carry the weight of the structure above the opening. Because of their shape, the blocks support each other by the mutual pressure of their own weight and the structure remains in position by the resistance from the support.

Technical terms used in arch

The various technical terms used in arch work are described below.

i. **Abutment:** Abutment or pier is the part of the wall or pier on which the arch rests.

ii. **Arch ring:** It is a course of stones or bricks having a curve like that of the arch.
iii. **Intrados:** This is the inner curve of arch.
iv. **Soffit:** This is the inner surface of the arch.
v. **Extrados or Back:** This is the external curve of an arch.
vi. **Voussoirs:** These are the wedge-shaped units forming the courses of an arch.
vii. **Crown:** This is the highest point of the extrados.
viii. **Key:** This is the wedge-shaped unit at the crown of an arch.
ix. **Arcade:** This is a row of arches supporting a wall above & being supported by the piers.
x. **Springing Point:** These are the points from which the curve of an arch springs.
xi. **Springing Line:** This is the imaginary horizontal line joining the two springing points.
xii. **Skewback:** This is the inclined or splayed surface on the abutment.
xiii. **Springer:** This is the first voussoir at springing level on either side of an arch & it is immediately adjacent to the skewback.
xiv. **Span:** This is the clear horizontal distance between the supports.
xv. **Rise:** This is the clear vertical distance between the highest point on the intrados & the springing line.
xvi. **Spandrel:** If two arches are constructed side by side, then a curved triangular space is formed between the extrados with the base as horizontal line through the crown. This space is called as spandrel.
xvii. **Haunch:** This is the lower half portion of the arch between the crown & the skewback.
xviii. **Impost:** The projecting course at the upper part of a pier or an abutment to stress the springing line is called the impost.
xix. **Depth or Height:** This is the perpendicular distance between the intrados & extrados.

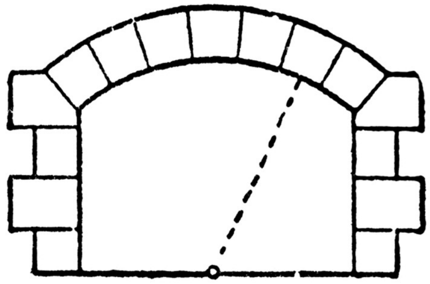
A. Types of arches based on shape

Based on the shape of construction arches are classified into 10 types and they are discussed below.

1. Flat Arch

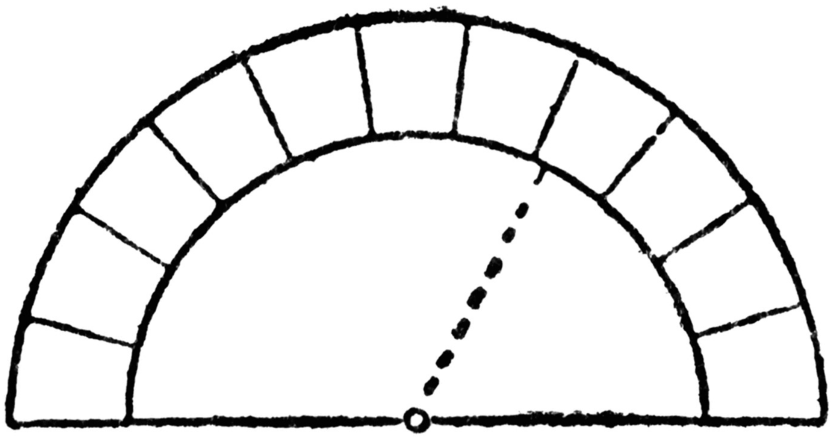
- For flat arch, the intrados is apparently flat, and it acts as a base of equilateral triangle which was formed by the horizontal angle of 60° by skewbacks.
- Even though the intrados is flat, but it is given that a slight rise of camber of about 10 to 15 mm per meter width of opening is allowed for small settlements.
- Extrados is also horizontal and flat. These flat arches are generally used for light loads, and for spans up to 1.5m.

2. Segmental Arch



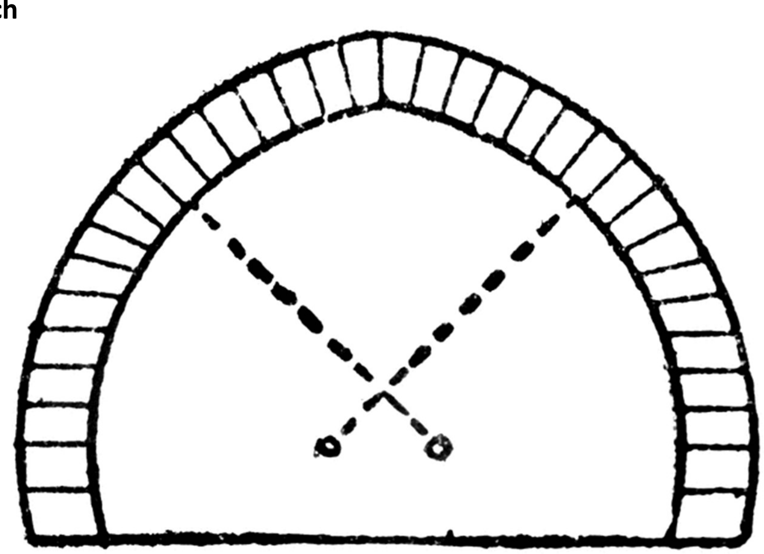
- This is the basic type of arch used for buildings in which Centre of arch lies below the springing line.
- In segmental arch, the thrust Transferred in inclined direction to the abutment.

3. Semi-Circular Arch



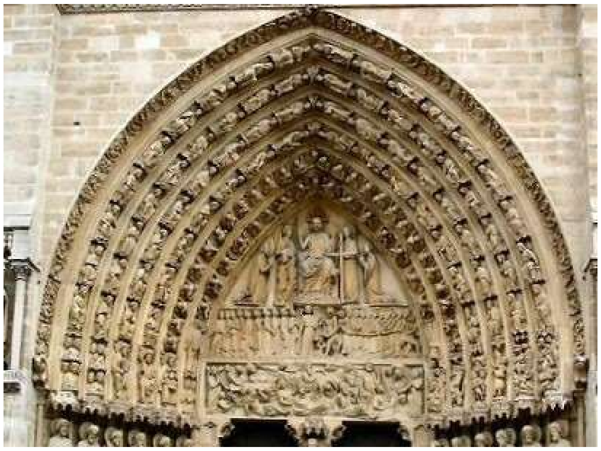
- The shape of arch curve looks like semi-circle and the thrust transferred to the abutments is perfectly vertical direction since skewback is horizontal.
- In this type of arch, the Centre lies exactly on the springing line.

4. Horseshoe Arch



- Horseshoe Arch is in the shape of horseshoe which curves more than semi-circle.
- This is generally considered for architectural provisions.

5. Pointed Arch



- The other name of pointed arch is Gothic arch.
- In this type of arch two arcs of circles are met at the apex hence triangle is formed.
- This may be either isosceles or equilateral.

6. Venetian Arch

- Venetian arch is also pointed arch, but its crown is deeper than springing's.
- It contains four Centre's, all located on the springing line.

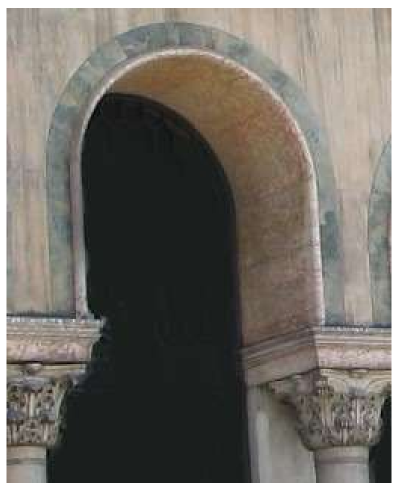
7. Florentine Arch

- Intrados of arch is in the shape of semi-circle and rest of the arch is similar to Venetian arch.
- It has three Centre's, all located on the springing line.

8. Relieving Arch

- Relieving arch is constructed above flat arch or on a wooden lintel to provide greater strength. In case of relieving arch, we can replace the decayed wooden lintel easily without disturbing the stability of structure.
- The ends of this arch should be carried sufficiently into the abutments.

9. Stilted Arch



- Stilted Arch consists of a semi-circular arch with two vertical portions at the springing's.
- The Centre of arch lies on the horizontal line through the tops of vertical portions.

10. semi-elliptical

- This is a type of arch of semi-ellipse shape and having three or five Centers.

B. Types of Arches based on number of Centers

Based on number of centers the arches are classified as:

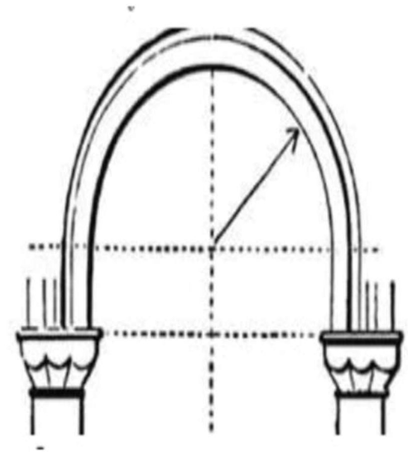


Fig: One centered arch

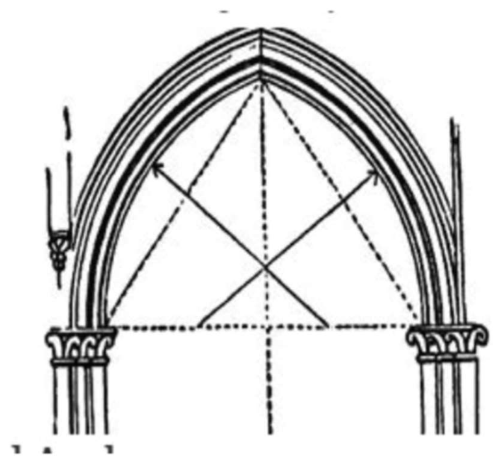


Fig: Two centered arch

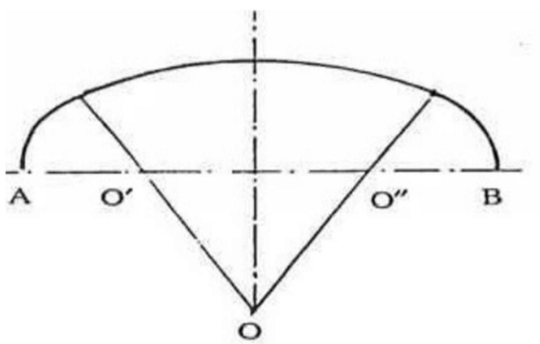


Fig: Three centered arch

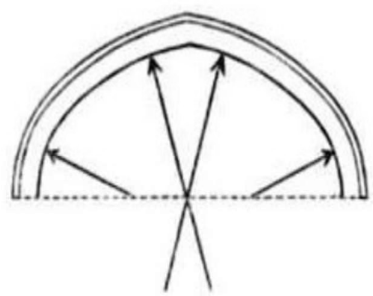


Fig: Four centered arch

1. **One-centered Arches**
   - Segmental, semi-circular, flat, horse-shoe arches and stilted arches are one centered arch.
   - In some cases, perfectly circular arch is provided for circular windows which is called as bull's eye arch is also come under these categories.
2. **Two Centered Arches**
   - Pointed or gothic or lancet arches are generally come under this type.
3. **Three centered arches**
   - Semi elliptical and Florentine arches are generally having three number of centers
4. **Four Centered Arches**
   - Venetian arch is a typical example for four-centered arch. Tudor arch is also having four centers.

5. **Five centered arches**
   - A good semi-elliptical shape arch contains five centers.

C. Types of Arches based on Workmanship and Construction Materials

Based on material used for construction and workmanship, arches may be classified as:

1. **Stone Arches**

   Based on workmanship, these are sub divided into two sub-types.

   i. **Rubble arches:** Rubble arches are very weak and used only for inferior work. These are used up to spans of 1m. These are made of rubble stones which are hammer dressed, roughly to shape and size and fixed in cement mortar.

   ii. **Ashlar Arches:** In this type, the stones are cut to proper shape of voussoirs (a wedge-shaped or tapered stone used to construct an arch) and fully dressed, joined with cement mortar. Ashlar stones are also used to make flat arches.

2. **Brick Arches**

   Brick arches are also sub divided into

   i. **Rough brick arches:** These are constructed with ordinary bricks without cutting to the shape voussoirs. The arch curve is provided by forming wedge shaped joints with greater thickness at extrados and smaller thickness at intrados. So, it looks unattractive. That's why it is not recommended for exposed brick works.

   ii. **Axed brick arches:** The bricks are cut into wedge shape with the help of brick axe. So, these are roughly dressed in shape and size. Hence, Arch formed by these axed bricks is not very pleasant.

   iii. **Gauged brick arches:** In this type of arch, bricks are cut to exact shape and size of required voussoir with the help of wire saw. The bricks are finely dressed, and these bricks are joined by lime putty. But, for gauged brick arches only soft bricks are used.

   iv. **Purpose made brick arches** The bricks are manufactured, matching with the exact shape and size of voussoirs, to get a very fine workmanship.

3. **Concrete Arches**

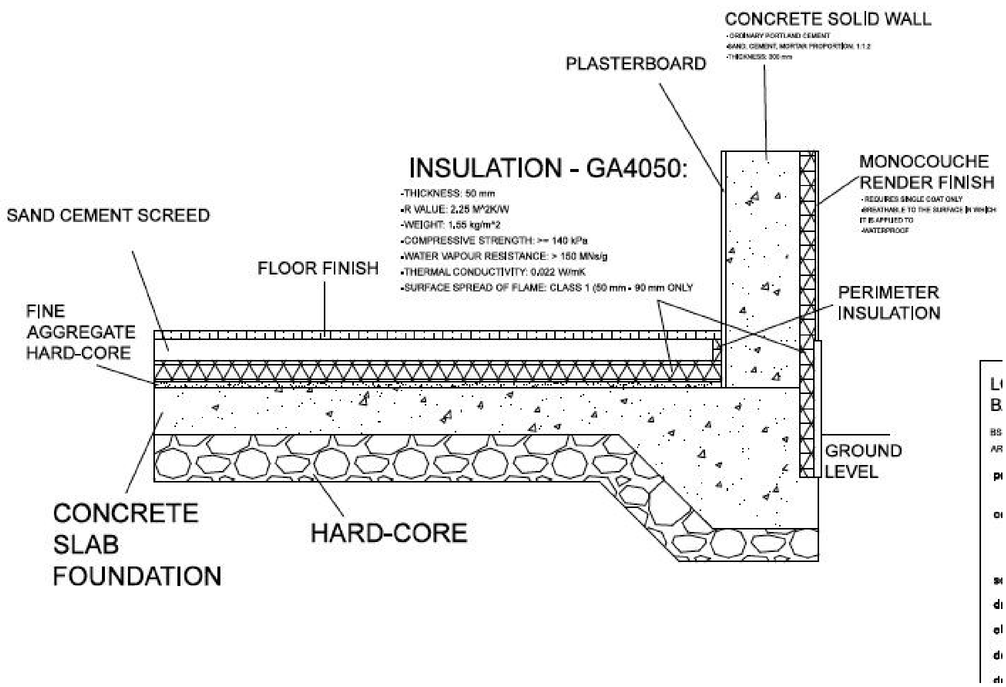
   Concrete arches are of two types:

   i. **Precast concrete block arches**: In Precast concrete block arches the blocks are cast in molds to the exact shape and size of voussoirs. For key stone and skewbacks special molds are prepared. These will give good appearance because of exact shape and size. Cement concrete of 1:2:4 is used.

   ii. **Monolithic concrete block arches**: Monolithic concrete block arches are suitable for larger span. These are constructed form cast-in-situ concrete. These may be either plain or reinforced, depending upon the span and magnitude of loading. Form work is used for casting the arch. The curing is done for 2 to 4 weeks.

CHAPTER 10: FLOOR AND FLOOR FINISHES

10.1 Glossary of terms



1. **Floor Finishes**

To sub-divide the portion between plinth level or basement level and roof level, the solid constructions are carried out. These constructions are known as the floors and the exposed top surfaces of floors are termed as flooring.

Ground floors or basement floors, which directly rest on the ground, do not require the provision of a floor. But they are provided with suitable type of flooring.

Requirements of good floor finish:

a) Adequate strength and stability
b) Adequate fire resistance
c) Sound insulation
d) Damp resistance
e) Thermal insulation
f) Easy to clean
g) Economical

Purpose of flooring

a) Provide level surface with sufficient strength.
b) Supporting the occupants of building.
c) Exclude passage of water and water vapor.
d) Provide resistance to heat loss through the floor.
e) Provide sound insulation, adequate fire resistance, and thermal insulation.

Factors to be considered before selecting the types of material for floor finishing

a) **Appearance:** The flooring material should be of desired appearance.
b) **Cleaning:** It can be easily and effectively cleaned. It should have effective resistance against absorption of oil, grease etc.

c) **Comfort:** It should give comfort when used. It must possess reasonably good thermal insulation; it imports comfort to the residents of the building.

d) **Cost:** The cost of flooring material should be reasonable as compared to other utility of buildings.

e) **Damp resistance:** The flooring material should offer sufficient resistances against dampness.

f) **Durability:** It should be durable and strong enough to impart resistance to wear, tear, chemical action, temperature changes, etc.

f) It should offer sufficient fire resistance.

g) It should be such that required minimum maintenance.

h) **Noise:** Floor finishing material giving less noise should be preferred.

i) **Slipperiness:** The surface of floor should be smooth, but it should not be too slippery.

2. **Base course**
   Base is the prepared surface on which floor topping or under layer is laid. The layer of material provided for this purpose is known as base course.
3. **Under layer**
   Layer of material provided in between the base and floor topping.
4. **Topping**
   Topmost layer of floor provided over the under layer/base course, in the absence of under layer.
5. **Rubble filling**
   When the subsoil conditions are not favorable and monolithic construction is desired, then, a 5cm to 10cm thick hard core of dry brick or rubble filling is laid in Monolithic Concrete Flooring.

10.2 Types of Floor Finishes

1. **Cast-In-Situ Concrete Flooring**

- This is commonly used for residential, commercial and even industrial building, since it is moderately cheap, quite durable and easy to construct.
- The floor consists of two components.
  a. Base concrete, and
  b. topping or wearing surface.
- The two components of the floor can be constructed monolithically (i.e.. topping laid immediately after the base course is laid) or non-monolithically.
- According to the method of finishing the topping, cement concrete floor can be classified into the following two types.
  a. Non-monolithic or bonded floor finish concrete floor
  b. Monolithic floor finish concrete floor.

A. A Bonded floor finish concrete floor

Non-monolithic or bonded floor finish concrete floor: The type of cement concrete floor in which the topping is not laid monolithically with the base concrete is known as non-monolithic or bonded floor finish concrete floor.

Method of construction

- The earth is consolidated.
- 10 cm thick layer of clean sand is spread.
- 10 cm thick Lime Concrete (1:4:8) or Lean Cement Concrete (1:8: 16) is laid thus forming base concrete.
- The topping [4cm thick Cement Concrete (1:2:4)] is laid on the third day of laying base.
- This type of construction is mostly adopted in the field.

B. Monolithic

Monolithic floor finish concrete floor: The cement concrete floor in which the topping consisting of 2cm thick cement concrete (12:4) is laid monolithically with the base concrete is known as monolithic floor finish concrete floor.

Method of construction

- The surface of muram or earth filling is leveled, well-watered and rammed.
- 10 cm layer of clean and dry sand is spread over.
- When the sub soil conditions are not favorable and monolithic construction is desired, then, 5 cm to 120 cm thick hard core of dry brick or rubble filling is laid.
- 10 cm thick layer of base concrete consisting of cement concrete (1:4:8) or lean cement concrete (1:8:16) is laid.
- The topping (2cm thick layer of cement concrete(1 :2:4)) is laid after 45 minutes to 4 hours of laying base concrete.

2. Terrazzo flooring

- Terrazzo flooring is another type of floor finish that is laid in thin layer over concrete topping It is very decorative and has good wearing properties. Due to this, it is widely used in residential buildings, hospitals, offices, schools, and other public buildings.
- Terrazzo is a specially prepared concrete surface containing cement (white or grey) and marble chips (of different colors) in proportion to $1{:}1\frac{1}{4}$ to 1:2.
- When surface has set, the chips are exposed by grinding operation. Marble chips may vary from 3 mm to 6 mm size.
- Colour can be mixed to white cement to set desired tint. The flooring is, however, more expensive.
- The sub-base preparation and concrete base laying is done in a similar manner, as explained for cement concrete flooring.
- The top layer may have about 40 mm thickness, consisting of
    1. 34 mm thick cement concrete layer (1:2:4) over the base concrete.
    2. About 6 mm thick terrazzo topping.
- Before laying the flooring, the entire area is divided into suitable panels or predetermined size and shape. For this, aluminum or glass strips are used. The strips have the same height as the thickness of the flooring (i.e., 40 mm). The strips are jointed to the base concrete, with the help of cement mortar, and their tops are perfectly set to level and line. Alternate panels are filled. The width of the strips maybe 15 to 2.0 mm.

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

3. Stone (Marble and Kota) flooring

I. **Marble flooring**

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

II. **Kota flooring**

- Kota Stone is a naturally available, fine-grained variety of limestone originated from Kota, Rajasthan.
- It’s fascinating natural look, durability and low cost makes it the most extensively used material in both the interiors and exteriors of houses and commercial areas.

- Kota is well known for its shiny appearance and charming colours, and ages beautifully over time. It is available in different shapes and sizes and can easily blend with any home decor.
- In fact, the material is quite an asset in the construction industry in terms of its unique characteristics it possesses.
- Kota stone is used in two finishes i.e., rough dress and polished finish.
- It is an excellent building one for Pathways, Corridors, Driveways, Commercial buildings. It is also used in chemical Industries due to its resistant properties.

Advantages/ benefits of using Kota stone flooring

- Kota Stone flooring is hard, tough, non-porous and a homogeneous material which can be widely used in different areas.
- Kota Stone flooring is not water absorbent and is anti-slip hence is the most perfect and hygienic flooring for humid areas.
- Kota is resistant enough to fit to any climatic conditions-dry, humid, or cold.
- They are available in slabs and tiles form and can be set in any pattern of flooring and extremely cost effective as compared to other stones.
- Kota Stone is available in natural shades, and it can be cut in to any size and shape as per the requirement.
- Look at the natural shades of Kota floor
- Kota stone floors are heavy, and they are set on strong base of base coat.
- Kota Stone is the ideal flooring material in the building and outside the building to impart a stronger and luxurious look to the floors.
- It is the cheapest stone s among the other natural stones.
- Kota stone are available in different sizes slab/ tiles of 30 * 30 , 40 * 40 , 30 * 60 , 40 * 60 , 60 * 60 , 50 * 50 , 55 * 55 , and 60 * 90 centimeters.
- A Kota stones can be used in Exteriors, Pathways, Corridors, Driveways, and Balconies etc.
- The stone can be polished again if a fresh appearance is desired.
- It is a very good reflector of heat making it comfortable to walk on.
- It forms a heavy and strong base for kitchen countertops. In many cases granite or marble slab counters are fixed on top of the Kota stone base.
- Suitable for wall cladding

Disadvantages of Kota stone

- It is not available in big slab sizes like marble or granite. Kota is a variety of limestone which is very fragile hence it is available in smaller sizes.
- Kota is not acid and alkali resistant and can be stained easily.
- Continuous usage of Kota stone might result in flaking. However, if it is well maintained and polished regularly flaking of the stone might be prevented.
- Its surface finish is not so lustrous as marble or granite.
- The stone does need regular maintenance, but care should be taken not to drag heavy furniture over it.

4. PVC flooring

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

5. Glazed tiles flooring

- The glazed tiles were only used for walls, at the initial stages. Glazed ceramic tiles are mainly manufactured by two processes.

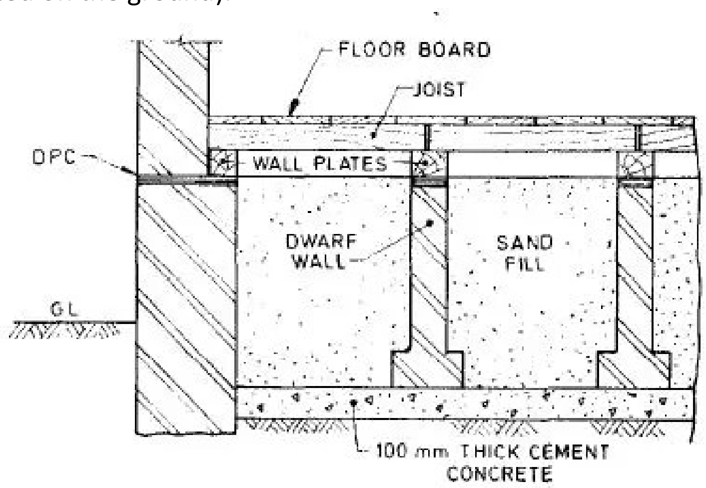
  Step 1: With the help of special white clay that is fired at a temperature of 1200 degree Celsius, the body of the tiles are made. These final elements are called biscuits.

  Step 2: The biscuits are accompanied by glazing and decorations if any and are fired in the oven.
- The glazes in ceramic tiles can be of two types:
  a. Earthenware glazes, and
  b. Colored enamels.
- The colored enamels are also of different types.
  a. Bright or glossy surface
  b. Eggshell, vellum finishes
  c. Matt finishes

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

6. Timber flooring

- Timber flooring is used carpentry halls, dancing halls, auditoriums, etc.
- One of the major problems in timber flooring are the damp prevention.
- This can be done by introducing D.P.C. layer below the flooring.
- Timber floors can either be of 'suspended type' (i.e., supported above the ground) or 'solid type (full supported on the ground).



- The sketch of suspended' or 'supported' timber flooring is shown in figure above. The hollow space between the flooring and over site concrete is kept dry and well-ventilated by providing air bricks in the outer walls and voids in the sleeper wall.
- The flooring consists of boarding supported on bridging or floor joints of timber, which are nailed to the wall plates at their ends.
- Sleeper walls are not spaced more than 1.8 to 2 m.

Where the problem of dampness is not acute, timber floors may be supported on the ground all along.

- For this type of construction, base concrete is first laid in 15 to 20 cm thickness. Over it, a layer of mastic asphalt is applied. Wooden block flooring is then laid over it.
- Wooden blocks are short but thick (with sizes 20 x 8 cm to 30 x 8 cm and thickness 2 to 4 cm) and are laid in suitable designs.
- To fix the wooden floor on concrete slabs, longitudinal nailing strips, with beveled section, are embedded in concrete at suitable interval.

7. Tiles flooring

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

10.3 Specials Emphasis on Level / Slope / Reverse Slope

- Whenever you need to drain the water off your floors, whether it is your bathroom floor or any other wet area of your home, the proper slope of flooring helps to run the water off efficiently.
- An incorrect floor slope can cause water to run in the wrong direction, instead of gently sloping towards the drain.
- The Slope of a surface means the surface of which one end or side is at a higher level than another, a rising or falling surface:
- There are floor surfaces in an apartment or homes that require slope. Each surface given below needs a different slope:

  a. Bathrooms
  b. Toilets
  c. Balconies
  d. Kitchen
  e. Staircase
  f. Terrace
  g. Drains & plumbing lines

- Apart from floor surfaces, windowsill and Chajja also have a slope requirement. But we would be focusing on the slope of the flooring in this chapter. Slope requirement also depends on two factors.
  a. Floor Finish's undulation level
  b. Rate of water draining requirement.

- The below table shows slope requirements against the above factors.

Floor Finish's undulation

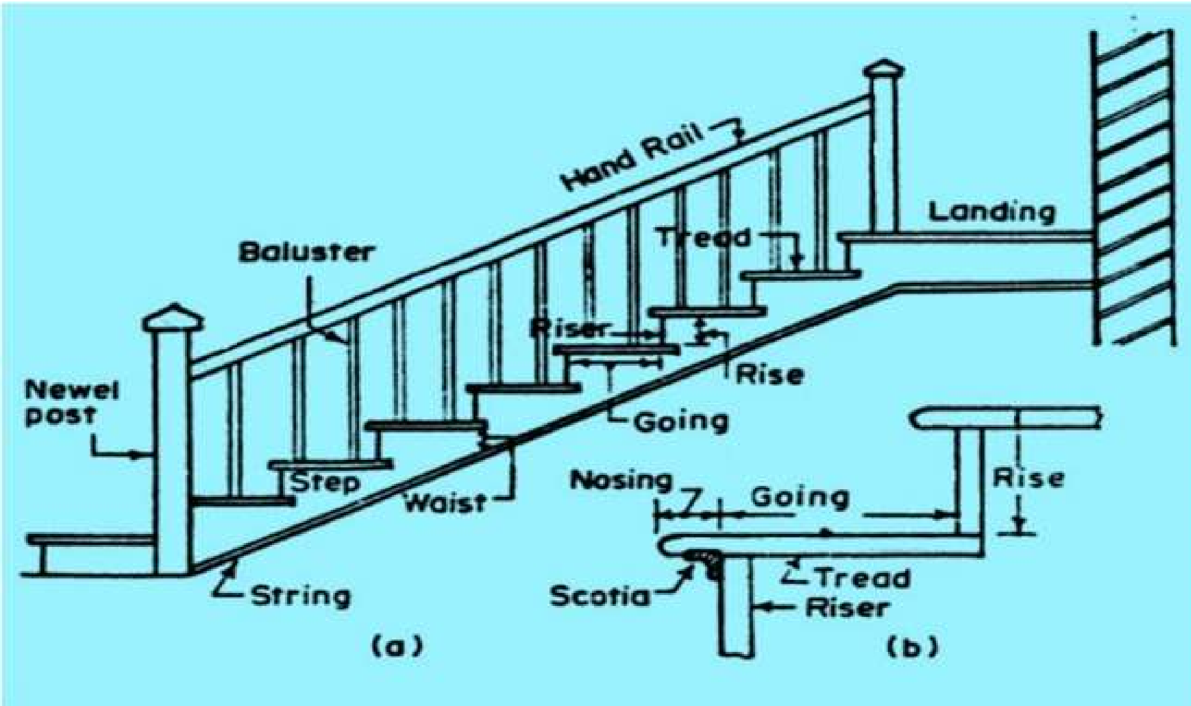
Rate of draining requirement	High Ex: Concrete screed finish	Low Ex: Tiling
High Ex: Toilets	High Slope	Moderate Slope
Low Ex: Car Parking	Moderate Slope	Low Slope

- The slope may be mentioned in two ways, in ratio (ex: 1:100 or 1 in 100), or in percentage (ex: 1%). The below table gives the slope requirement for assumed floor finish.

S.n	Area	Floor Finish	Slope in ratio	Slope in %
1	Toilets – wet area	Ceramic Tiling	1 in 60	1.67%
2	Toilets – dry area	Ceramic Tiling	1 in 80	1.25%
3	Utilities & Balconies	Ceramic Tiling	1 in 100	1%
4	Terrace	Ceramic / Clay tiles	1 in 120	0.83%
5	Basements & Car parks	VDF / IPS	1 in 150	0.67%
6	Roads	VDF / IPS / Pavers	1 in 150	0.67%
7	Concrete Drains	Concrete / Plaster	1 in 200	0.5%
8	Plumbing lines	PVC	1 in 250	0.4%

- In case of change in floor finish, slope must be decided suitably.

CHAPTER 11: STAIRS AND ROOF



11.1 Glossary of terms

The common technical terms used in stair construction are briefly discussed below.

a) **Staircase:** It is an important component of a building providing access to different floors and roof of the building. It consists of a flight of steps and one or more intermediate landing slabs between the floor levels.
b) **Steps:** A portion of a stairway comprising the tread and riser which permits ascent or descent from one floor to another.
c) **Tread:** The horizontal upper part of a step on which foot is placed in ascending or descending stairway.
d) **Riser:** The vertical portion of a step providing support to the tread.
e) **Flight:** A series of steps without any platform, break or landing in their direction.
f) **Landing:** A platform or resting place provided between two flights.
g) **Nosing:** The outer projecting edge of a tread is termed as nosing. Nosing is usually rounded to give good architectural effect to the treads and make the stair-case easy to negotiate.
h) **Going:** The run of step in a stair or the width of the tread between two successive treads.
i) **Handrail:** It is the member of stair at the top of the baluster and act as support of the hand.
j) **Newel:** It is a wooden or metallic post supporting the handrail and is usually provided at the hand, foot or at point where the balustrade changes its direction.
k) **Stringer:** They are the sloping member which support the step in the stair. They run along the slope of the stair.
l) **Baluster:** They are the vertical members to support the handrail and placed between steps and handrail.
m) **Line of nosing:** It is an imaginary line touching the nosing of each tread and is parallel to the slope of the stair.
n) **Pitch:** It is the angle which the line of nosing of the stair makes with horizontal.

- **o) Soffit:** It is under surface of stair.
- **p) Winders:** Radiating steps for changing direction of a stair.
- **q) Waist Slab:** Waist slab refers to a slab of the stair that is slanting from the floor slab to the landing slab. This can be imagined like a ramp – not including the steps.

11.2 Classification of staircase based on material

The commonly adopted materials in the construction of stairs are wood, stone, steel, cast iron, plain concrete or reinforced concrete, brick work or reinforced brick work.

a) Wooden Stairs:

Timber (wood) is mainly used for stair construction where fire-resistance is not of much consideration. Timber stairs are cheap, easy in construction and maintenance and light in weight. Timber stair constructed from fire-resisting hard wood, like oak, teak, mahogany etc., using minimum thickness of various members as 5cm. is found to serve the requirements of a fire-resisting stair to a great extent.

b) Stone Stairs

Stair made from hard, strong, resistance to wear stones are found to be durable and fire resisting. They are commonly constructed in workshop, warehouse, and other public building. Their usage in residential building is generally restrict to outside stairs. Being heavy, stone stairs require stable support to avoid the danger of damage due to settlement of supporting walls.

c) Metal Stairs

They are usually fabricated from steel and cast iron and their use in generally restricted to factories, godowns etc. In its simplest form, a metal stair consists of steel stringer to which steel angles are riveted or welded and metal treads are provided over them. Sometimes concrete is filled in steel grating to form the tread.

d) Reinforced concrete stairs

Reinforced concrete stairs predominate the stairs made from wood, stone, or metal. This is because of the various advantage RCC. has over other materials. Reinforced concrete is perhaps the most suitable of all the said materials for the construction of stairs .RCC stairs can be molded in any desired form to suit the requirement of the architect. Reinforced concrete stairs can be precast or cast in situ.

The various advantage of reinforced concrete stairs are given below:

i. They have requisite fire resistance qualities to a great extent.
ii. They are durable, strong pleasing in appearance and can be easily rendered non slippery.
iii. They can be designed for greater widths and longer spans.
iv. They can be easily cleaned.
v. The cost of maintenance is almost nil.
vi. In a frame structure of reinforced concrete, RCC stair in perhaps the only choice.

Location of stair

A stair is a set of steps leading from one floor to another. The room or enclosure of the building in which the stair is located is known as a staircase. Stair may be made from timber, brick, stone, metal and plain and reinforced cement concrete.

Primary function of stair

- Provide an access from one floor to another floor.
- Provide a safe means of travel between the floors.
- Provide a degree of insulation where part of a separating element between compartments in a building.

- Provide an easy means of travel between floors.
- Provide a suitable means of escape in case of emergency such as fire, earthquake etc.
- Provide a means of conveying fittings and furniture between floor levels.

11.3 Planning and layout of staircase

Requirement of good stair

Any well-planned stair should meet the following criteria for easy, quick and safe ascent/descent:

a) **Location**:
It should be located to get sufficient light and ventilation with easy access from different corner of the building.

b) **Width of stair**: It should be wide enough to carry the user without much crowd or inconvenience. Width of stair depends on up to its location in the building and the type of building itself. Normally the widths of stair public and residential building are 1.8m and 90 cm, respectively.

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

d) **Pitch of stair**
Pitch of the stair should be made flatter by introducing landing. In general, the pitch never exceeds 40 degree and should not be flatter than 25 degrees.

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

f) **Balustrade**
The open well stairs should be provided with balustrade to minimize the danger of accidents.

g) **Material construction**
The material used for construction of stair should be such as to provide sufficient strength and fire resistance.

h) **Landing**
Width of landing should not be less than width of the stair flight at any case.

i) **Winders**
The introduction of winders in stair should be avoided as far as possible. They are liable to be dangerous and involve extra expenses in the construction.

- **Fixing of Going and Riser**

The rise and tread of every step in a stair should be uniform dimensions throughout. The ratio of the going and the rise, of the step should be so proportioned as to ensure a comfortable access to the stair way.

- T+2R= (60-64)cm
- T*R=400-426 cm^2
- T+R=40-45 cm

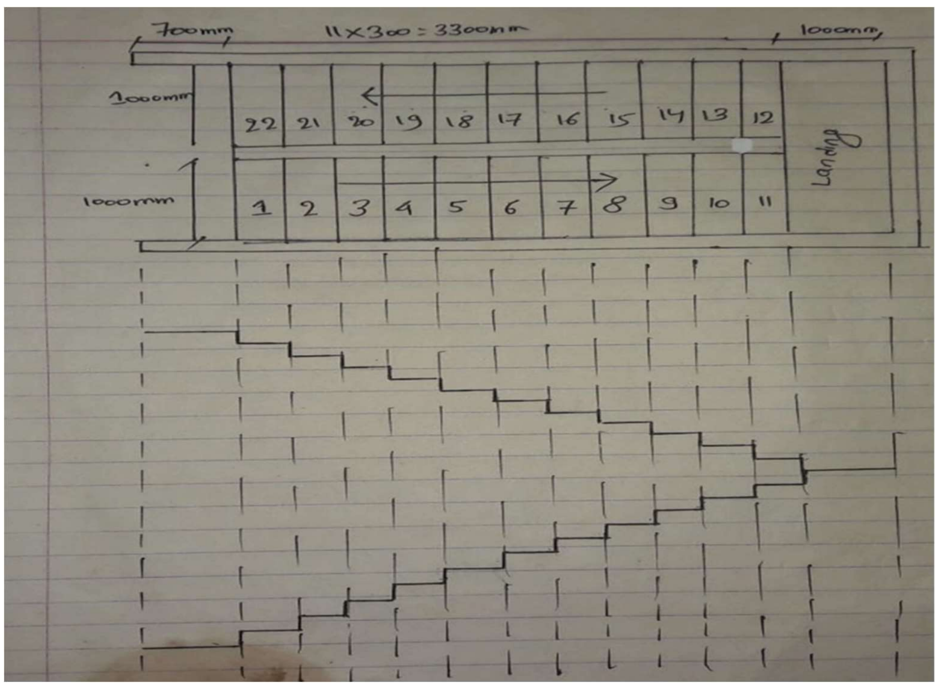
Where, T=Tread and R= Rise Standard values,
For residential building, T=(22-27)cm and R=(15-17) cm
For public building, T=(25-30)cm and R=(10-15)cm

Solved Numerical

1. **Plan a dog-legged stair for a building in which the vertical distance between floors is 3.6m. The stair hall measures 2.5m*5m.**

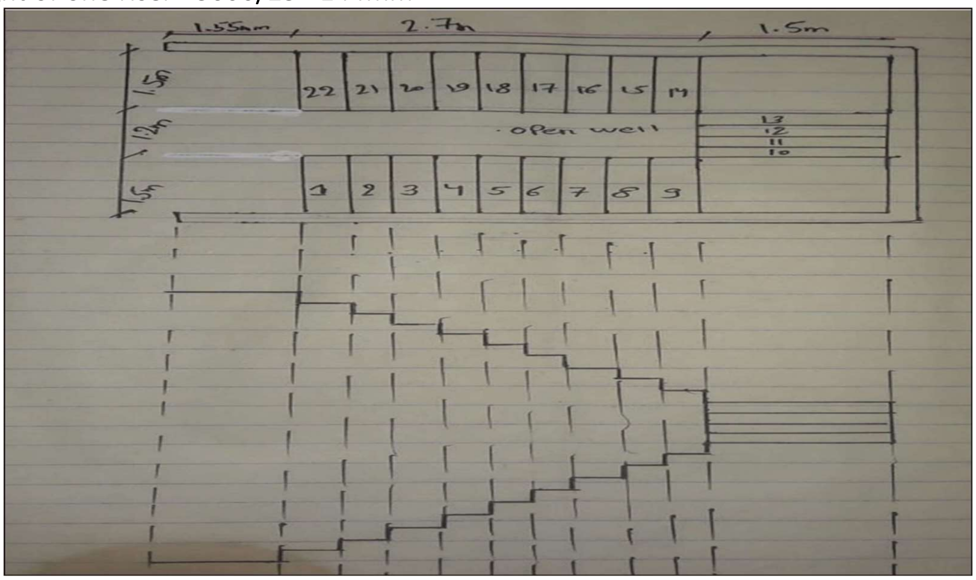
Solution:
Height of stair=floor height=3.6m
Size of staircases hall=2.5m*5m
Types of building= residential
Let us assume

- Riser(R)=150mm
- Assume width of stair=width of landing=1000mm (at least equal to width of staircase)
- Height of each flight= Height of stair/2 =3.6/2 =1800mm
- Number of riser in a flight=1800/150 =12 in each flight
- No of tread in each flight=Number of riser-1 =12-1 =11
- Width of tread, T+2R=600 T=600-2*150=300mm
- Length of stair= Width of tread*number of treads in a flight+ width of landing = 300*11+1000=4300mm
- Space left for passage=5000-4300=700mm
- Total number of risers=12*2=24 and total number of treads=11*2=22



2. **Design a staircase for public building for given space of 4.2m *5.75m with floor height 3.6m.Assume the necessary data and draw a neat sketch to support the design.**
Solution:
Floor height of building=3.6m
Size of staircase=4.2m*5.75m
Types of building=public
Assume type of staircase=Open well
Assume width of staircase=1.5m
Assume width of landing=1.5m (at least equal to width of staircase)
Height of one flight=3600/2= 1800mm
Assume height of riser=150mm
Number of riser in flight a flight=1800/150= 12 number
Number of treads in a flight= number of risers in a flight -1= 12-1= 11 number
Width of tread = 600-2R =600-2*150= 300mm
Here space left between two flights= 4.2-2*1.5= 1.2m=1200mm
Number of tread that can be accommodate in landing portion=1200/300=4 number

Number of tread that we can arrange =22-4=18 number
Length of stair= Width of tread*number of treads + width of landing = 300*9 +1500= 4200mm
Entry space (space available for passage)= 5750-4200=1550mm
Again, number of risers in first flight= number of treads in first flight+1= 9+1= 10
number of risers in second flight= number of treads in second flight+1= 4+1=5
number of risers in second flight= number of treads in second flight+1= 9+1= 10
Total number of risers= 10+5+10= 25
Now, height of one riser= 3600/25= 144mm



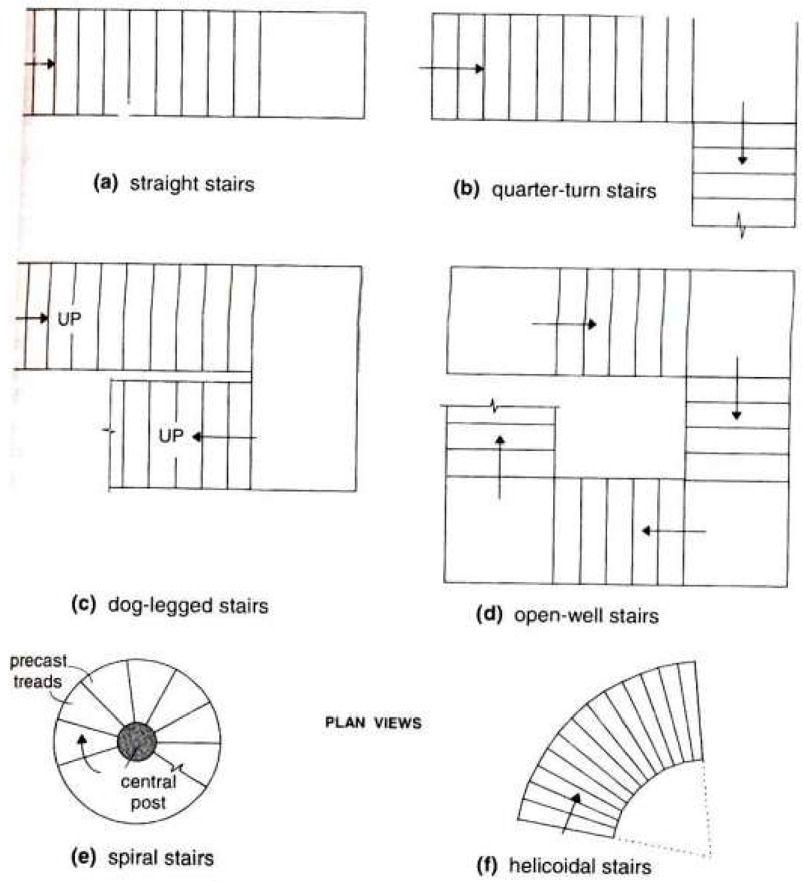
Assignment

a) Design a dog-legged stair for a residential building width floor height 3.2m. The stair room measurement is 2.6m*5.2m. Draw a sketch of plan and section.

b) Draw plan and sectional elevation of stair having a hall size 4890mm*4050mm . It is required to climb the height 3500mm given all major dimension.

c) Design suitable type of stair hall having 4m*2.8m inside dimension and floor height is 3m. Illustrate your design with necessary sketches

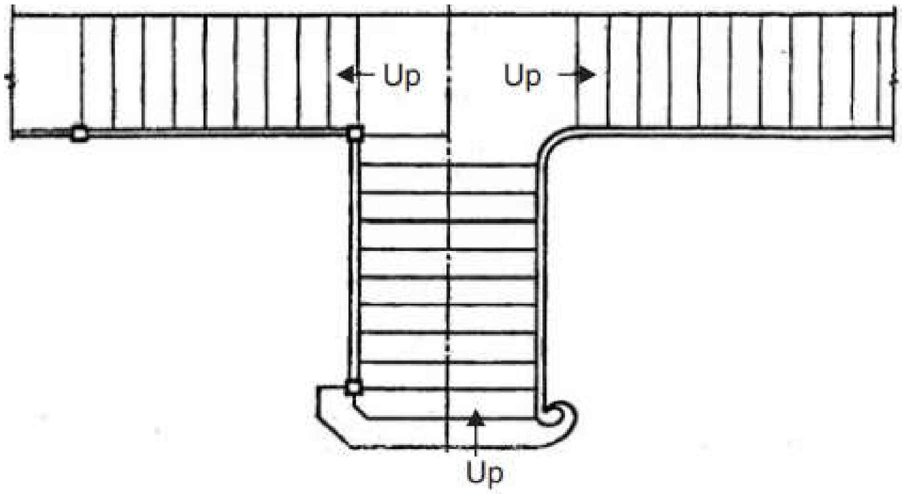
11.4 Types of layout of staircase



Common geometrical configurations of stairs

Types of stairs used in building construction are broadly based on the shape of the stairs. Stairs can be classified in following heads.

1. **Straight stair**
   Generally, for small houses, available width is very retractable. So, this type of straight stairs are used in such conditions which runs straight between two floors. This stair may consist of either one single flight or more than one flight with a landing.
2. **Quarter turn stair**
   A quarter turn stair is the one which changes its direction either to the right or to the left but where the turn being affected either by introducing a quarter space landing or by providing winders. In this type of stairs, the flight of stair turns 90 degrees at landing.
3. **Half turn stairs**
   In case of half turn stairs its direction reversed or changed for 180° . A half turn stair may be of dog legged type or open newel type.
   In case of dog-legged stair, the flight run in opposite direction and there is no space between the flight, and these are useful where total width of space available for the staircase is equal to twice the width of steps. And these are used in most of the building mostly popular residential building in Nepal.
   In case of an open newel stairs, there is a well or hole or opening between the flights. This well may be rectangular or of any geometrical shape and can be used for fixing lift. These stairs are useful where available space for staircase has a width greater than twice the width of steps
4. **Bifurcated stair**



Bifurcated stairs are commonly used in public building at their entrance hall. This has a wider flight at the bottom, which bifurcates into two narrower flights, one turning to the left and other to the right, at landing.it may be either of newel type with a newel post or of geometrical type with continuous stringer and handrails

5. Continuous stair

This type of stairs neither have any landing nor any intermediate newel post. They are geometric in shape.

These may be of following types.

- Spiral stairs
- Helical stairs

I. **Spiral stair**

spiral stairs are usually made either of R.C.C or metal and is placed at a location where there are space limitations. Sometimes these are also used as emergency stairs and are provided at the back side of a building. These are not comfortable because of all the steps are winders and provides discomfort.

II. **Helical stair**

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

11.5 Roof and its types

Roof is the upper most portion of the building which protects the building from rain, wind, and sun. A roof is defined as the uppermost part of a building which is constructed in the form of a framework to given protection to the building against rain, heat, snow, wind etc.
A roof basically consists of structural elements provided at the top of building for the support of roof covering. The structural elements may be trusses, flat slabs, shell, dome or space frame whereas the roof covering materials may be thatch, wooden single, tiles, A.C sheets etc.

Function of roof

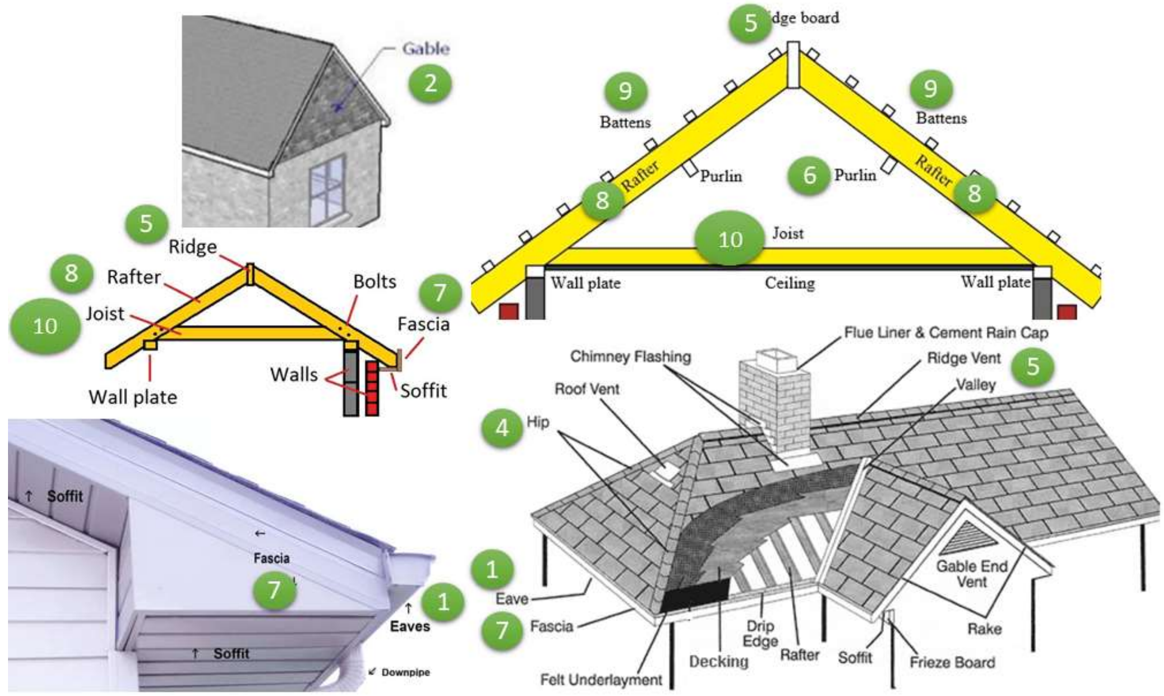
The following are the function of roof

- To keep out rain, wind, snow, and dust
- To prevent excessive heat loss in winter.
- To keep the interior of the building cool in summer.
- Design to accommodate all stresses encountered.
- Design to accept movement due to change in temperature and moisture content.
- For strength, durability, and stability of building.
- Provide resistance to passage of sound.
- Aesthetic beauty.

Requirement of a roof

- Should have adequate strength to carry the superimposed loads.
- Should effectively protect the building against rain, sun, wind etc.
- Should be durable against the adverse effects.
- Should be waterproof and should have effective drainage arrangement.
- Should have adequate thermal insulation.
- Should have fire resistance.

Technical terms used in pitched roof



The various technical terms used in timber pitched roof construction are given below.

a. **Span**: The clear distance between the support of an arch beam or roof truss.
b. **Rise of roof:** It is vertical distance between the wall plate and the top of the ridge.
c. **Pitch of roof:** The inclination of the sides of a roof to the horizontal is termed as the pitch of the roof.
d. **Eaves:** The lower edge of inclined roof surface of a pitched roof is termed as eaves.
e. **Ridge:** It may be defined as the apex of the angle formed by the termination of the inclined at the top of shape.
f. **Ridge piece:** It is a horizontal timber piece provided at the apex of a roof truss.
g. **Valley:** It is the acute angle, or a gutter formed by the intersection of two slopes in a pitched roof.
h. **Hip**: It is a ridge formed by the intersection of two sloped surface having an exterior angle greater than 180 .
i. **Hipped end**: It is sloped triangular surface formed at the end of a roof.
j. **Gable:** It is the triangular portion of the end wall of a sloped roof formed by containing end wall up within end wall of a sloped roof formed by containing end wall up within the roof.
k. **Verge**: Edge of roof covering projecting beyond the gable end of the sloped roof.
l. **Eaves board:** It is wooden plank usually 25mm thick and 150mm wide fixed along the eaves connection the feet of the common rafters.
m. **Common rafter:** These are inclined wooden members laid from the ridge to the eaves. They are usually spaced 30 to 45cm apart.
n. **Purlins:** These are horizontal members of wood used to support common rafter.
o. **Cleats:** These are short sections of wood nailed or screwed to the rafters of the truss for supporting purlins.
p. **Wall plates:** Timber pieces, which are provided over the top of a stone or brick wall for the purposes of fixing the feet of the common rafters.
q. **Template:** This is a block of stone or concrete provided under the end of tie beam to spread the load from the roof over a larger area of bearing.

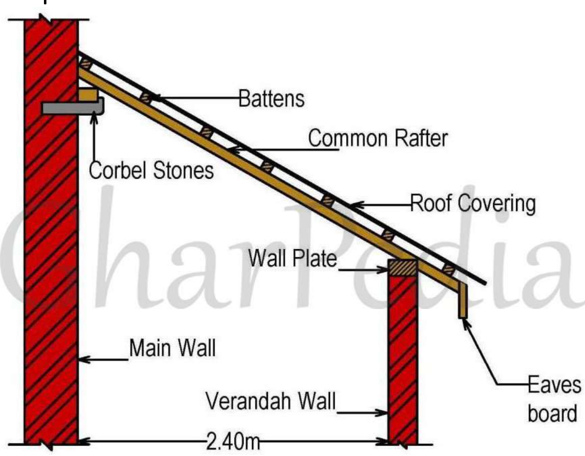
r. **Hip rafters:** These are the rafters which form the hip of a sloped roof. These rafters run from the ridge to the corners of wall to support the covering over the hip. They also received the end of purlins and jack rafters.
s. **Jack rafters**: These are rafters shorter in length which extends from hip or valley to eaves.
t. **Valley rafters**: These are the rafters provided at slope to support the valley gutters.
u. **Post plate:** This is like a wall plate with the only different that it is run continuous parallel to the face of wall over posts and supports the rafters at their feet.
v. **Battens:** Small scantling which are nailed to rafters for laying tiles over sloped roof.
w. **Boarding:** They are like battens and are nailed to common rafters for laying roofing materials like CGI sheet tiles, thatches, and asbestos above.

Types of roofs

1. **Pitched or slope roof**
   - Most common form of roof and is almost always constructed in wood or steel.
   - Consists of a system of rafter and purlin arranged in the form of a triangular shape support known as truss.
   - Slope of the roof varies from 10 to 70 degree according to span, the climatic condition, the nature of covering material and other similar factors.
   - Generally, regarded as the cheapest alternative for covering a structure.
   - Pitched roof are further classified into following types
     a. Single roofs
     b. Double or purlin roofs
     c. Triple membered or framed or trussed roofs

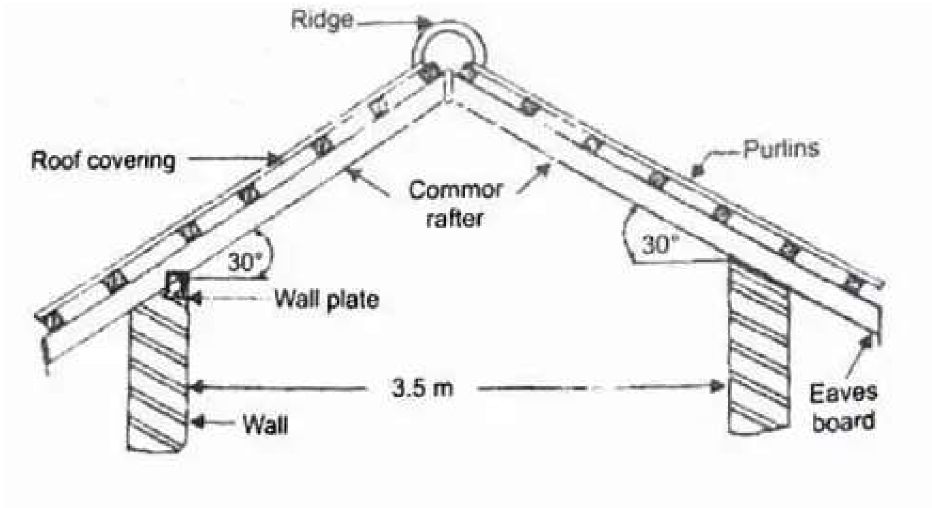
a. **Single roof Single** roofs are those which consists of only the rafters which are supported at the ridge and at the eaves. Such roofs are used only when the span is limited to 5m.
Types of single roofs

i. **Lean to roof**: This is the simplest type of slopping roof, in which rafters' slope to one side only. It is suitable for maximum span of 2.5m .



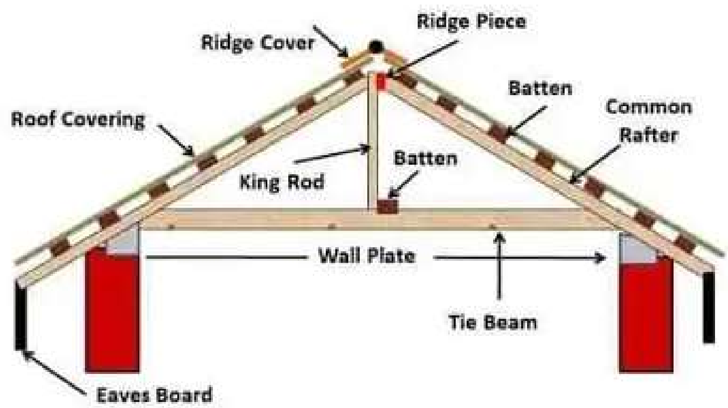
Lean to Roof

ii. **Couple roof**: This type of roof is formed by couple or pair of rafters which slope to both the sides of the ridge of the floor. Upper ends of each pair of rafters are nailed to a common ridge piece and their lower ends are notched and nailed to the wooden wall plates embedded in the masonry on the top of outer wall. The couple roof is used when the span is limited to 3.6m.



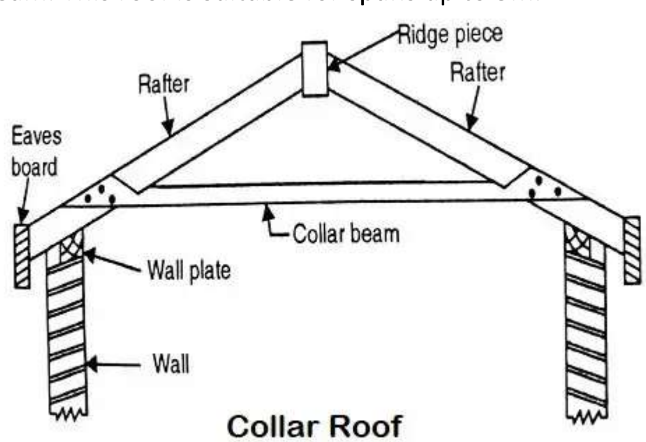
Coupled roof

iii. **Couple closed roof:** A couple closed roof is similar to the couple roof, except that the ends of the couple of common rafters is connected by horizontal member called tie beam to prevent the rafters from spreading and thrusting out of the wall. A couple close roofs is economically suitable for spans up to 4.2m.



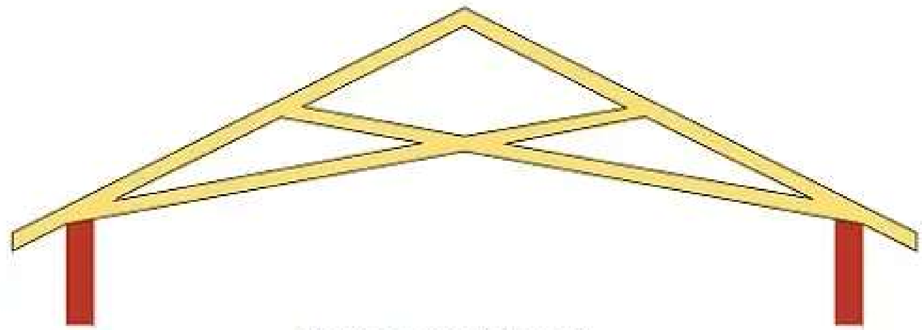
Couple-close Roof

iv. **Collar beam:** Roof when the span increases or when the load is more, the rafters of the couple close roof have the tendency to bend. This is avoided by raising the tie beam and fixing it at one-third to one half of the vertical height from wall plate to the ridge. This raised beam is known as the collar beam. This roof is suitable for spans up to 5m.



Collar Roof

v. **scissors roof:** It is like the collar roof, except that two collar beams, crossing each other to have an appearance of scissors is provided.



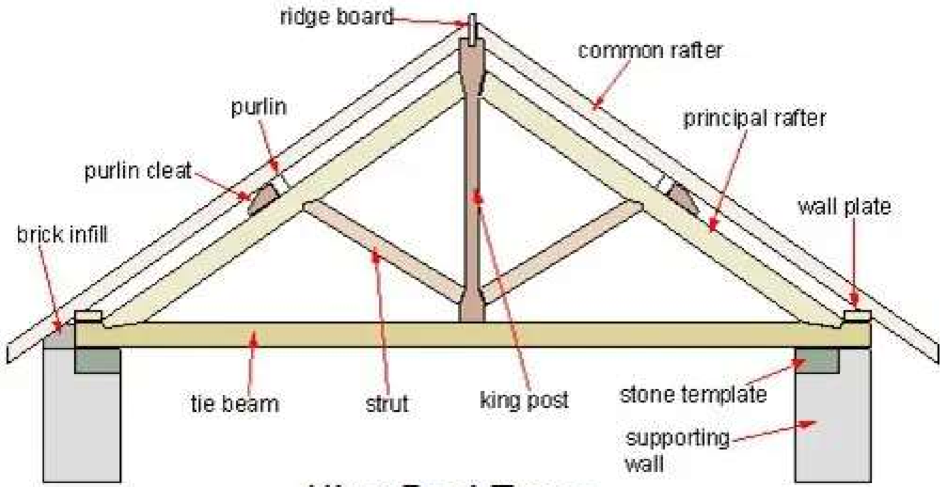
Scissors Roof

b. **Double roof** : These roofs have two basic elements, and they are rafter and purlin. The purlins give intermediate support to the rafters and are supported on end walls. The intermediate supports so provided in the form of purlins, reduce the size of the rafters. Such a roof is also known as rafter and purlin roof. For larger roofs, two or more purlins may be provided to support each rafter.

c. **Tripled or trussed roof** When the span of the roof exceeds 5m and where there are no inside walls to support the purlins trusses are provided at suitable interval along the length of the room. Spacing of truss is generally limited to 3m for wooden trusses.

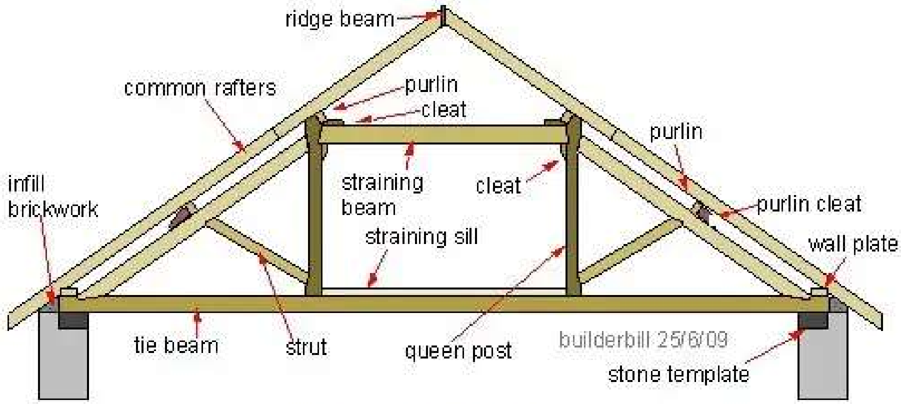
Types of trusses

i. **King post truss** in this type of truss the central post known as king post forms a support for the tie beam. The inclined members known as the struts prevent the principal rafters from bending in the middle. The trusses are spaced at a distance not more than 3m c/c. A king post truss is suitable for roofs of span varying from 5m to 8m.



King Post Truss

ii. **Queen post truss** This truss differs from a king post truss in having two vertical members known as the queen posts. The upper ends of the queen posts are kept in position by means of a horizontal members known as a straining beam. Queen post are tension members. The straining beams recover the thrust from the principal rafters and keep the junction in straight position. The thrust from the two struts tends to force the feet of queen posts inwards which resisted the straining sill fixed between feet of the queen post. A queen post truss is suitable for roof of spans varying from 8 to 12m.

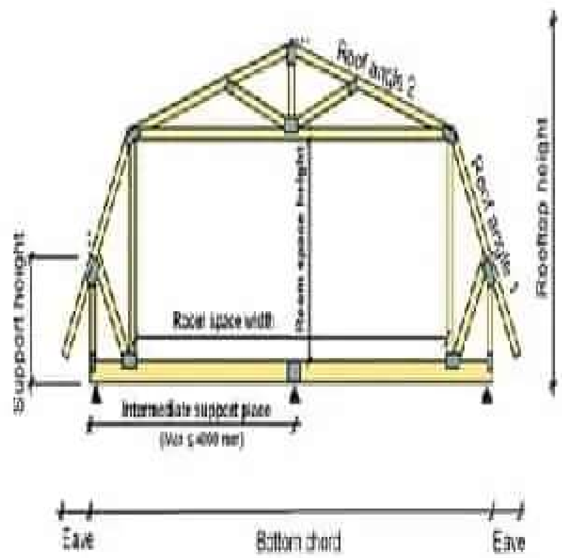


Queen Post Truss

Difference Between King-Post truss and Queen-Post Truss

King-Post Truss	Queen-Post Truss
a. king post has a central vertical post as used in architectural or bridge designs, working in tension to support a beam. below from a truss apex above.	**a.** Queen post truss in define as a pitched roof support using two vertical tie posts connected between the tie beam and the rafters.
b. The king post truss consists of following components: ➢ Tie Beam ➢ Two Inclined Principal rafter ➢ Two Struts ➢ King post ➢ Ridge beam	**b.** The queen post truss consists of following components: ➢ Two queen posts ➢ Two principal rafters ➢ Struts ➢ Tie beam ➢ Straining beams ➢ Straining sills ➢ Purlins
c. King post truss is used when the length of span is in the range of 5 to 8 m.	**c.** Queen post truss used when the length of span is in the range of 8 to 12 m
d. One vertical post is provided at the center of the roof which is called king post.	**d.** Two vertical posts are provided in 2 sides at d distance which is called queen post
e. Straining beam and straining sill are not necessary.	**e.** Straining beam and straining sill are used to k keep the position. queen post in stable Position
f. Kingpost is connected with principal rafter, strut and tie beam	**f.** Queen-post is connected with principal rafter, strut, straining sill, and tie beam.
g. The top ends of two main rafters are connected to ridge pitch	**g.** Top ends of two main rafters are joined with queen post ahead.

iii. **Mansard roof truss:** The mansard truss is a two-storey truss with upper portion consisting of king post truss and the lower portion of queen post truss. Mansard roof truss have two pitches, the lower varying from 60 to 70 degree and upper from 30 to 40 degree.



Mansard Truss

iv. **Composite roof truss** Roof truss made of two materials such as timber and steel are known as composite roof trusses. In a composite truss, the tension members are made of steel while compression members are made of timbers.

v. **Truncated truss** This truss is just like the mansard truss except that the top is finished flat with gentle slope to one side.

2. Flat roof

Roof laid at an angle of less than 10 degree to the horizontal is known as flat roof. Many times, top of these roofs are treated with water proofing materials like mixing water proofing chemicals in concrete. With advent of reliable water proofing techniques such roofs are constructed even in areas with heavy rainfall.

The advantages of flat roofs are

- The roof can be used as a terrace for playing and celebrating functions.
- At any latter stage, the roof can be converted as a floor by adding another storey.
- They can suit to any shape of the building.
- Overhead water tanks and other services can be located easily.
- They can be made fireproof easily compared to pitched roof.

The disadvantages of flat roof are

- Leakage problem may occur at latter date also due to development of cracks. Once leakage problem starts, it needs costly treatments.
- The dead weight of flat roofs is more.
- In places of snow fall flat roofs are to be avoided to reduce snow load.
- The initial cost of construction is more.
- Speed of construction of flat roofs is less.

11.6 False Ceilings Using Gypsum, Plaster Boards, Celotex, Fiber Board

False celling, its advantages, and disadvantages

False calling, also known as drop ceiling or suspended ceiling, is a celling that hangs lower from the roof leaving space between actual roof and ceiling. False ceiling imparts an aesthetic appearance to the place and the interiors of the place. False ceiling is provided below the roof slab on suspended supports. The false celling is usually provided for temperature control (heat insulation for AC), to install lights, or to conceal electrical and other networking cables and ugly or too high ceiling, false ceiling is an example of modern construction and architecture in both residential and commercial applications.

Advantages of false ceiling

- provides a smooth homogeneous surface to the roof.
- provides fire protection as it creates compartmentation.
- False ceiling helps in acoustical treatment.
- It conceals all the non-pleasing elements and hides it from the viewer's eyes.
- It also hides the pipelines and the electrical cables running in the room. All the ducts of air-conditioning can be hidden under it.
- False ceiling materials are easy to install and cheap as compared to traditional roof systems.

Disadvantages of false ceiling

- The most worrying aspect of having a false ceiling would be pests. They can get through into the space between and can start their own breeding which might lead to a lot of trouble.
- Also be careful while putting up decorations or hangings while you have a false ceiling in place. Make sure you know the strength and durability, do and don't regarding your ceiling.
- Lastly, the false ceiling would reduce the height of the ceiling considerably and hence do not install false ceiling unless you have a decent ceiling height.

Materials used for false ceiling

Material used for false ceilings can be understood from classification of false ceilings based on the material used in it. The major classification based on materials used are listed briefly below,

a. Gypsum false ceiling

- Gypsum false ceiling is a hydrated sulfate of calcium. These types of false ceiling are lightweight, sound insulated, fire resistance and soft and thermally insulated.
- Gypsum false ceiling comes in the shape of square boards that are hung with the help of lion framework. The finishing work on these boards like paints, laminates, wallpapers, and texture finish gives good look.

b. Plaster of Paris ceiling

- Plaster of Paris (POP) is the majorly used material in the construction of false ceiling. POP is obtained when gypsum is heated to a certain degree. It gives both aesthetical and functional help.
- Plaster of Paris false ceiling are attractive, almost no maintenance and has a long-life span. They are very excellent insulators of heat and cold. These types of false ceiling don't only hide the ugly members of structure, ventilation ducts and conduits but also give smooth finish to the ceiling.

c. Fiber false ceiling

- Fiber false ceilings are in high in demand for the construction of false ceilings due to their low cost and easy installation.
- The materials used to manufacture fiber celling panels are man-made by synthetic and natural minerals used to manufacture fiber key come in many shapes and sizes.

d. Celotex ceiling

Celotex ceiling provides several benefits, some of which are described below:

1. **Sound absorption**
   - It absorbs noise from machinery and people in the surrounding area, creating a quieter, more acoustically controlled environment.
   - This can be helpful in high-density areas.

2. **Thermal insulation**
    - The mineral fiber material in Celotex ceiling tiles helps prevent heat loss in a room or throughout a building, allowing you to cut down on your energy use and lower your bills.
    - Lowering energy bills is great for homeowners and commercial businesses.
3. **Fire protection**
    - Its installation can also help contain flames in the event of a fire, minimizing damage to the building and providing an additional safety measure for people.
4. **Aesthetic appearance**
    - We can customize our ceiling appearance with a selection of smooth, fissured, and textured patterns, as well as the addition of quality crafted crown molding or custom.
5. **Adaptability**
    - They are easy to shape and cut, so no matter the size or shape of your space. We can easily replace individual tiles if the need arises.
6. **Moisture resistance**
    - With their density design, they are moisture resistant, helping your celling had longer by avoiding mold or water damage.
7. **Low maintenance damaged**
    - They are simple to clean, and in the unlikely event that a tile or group of tiles is damaged, replacing them is a considerably simpler option than attempting to remove or replace a ceiling entirely.

CHAPTER 12: Doors and windows

12.1 Glossary of terms with neat sketches of doors and windows

A door is defined as an open barrier secured in an opening left in a wall for the purpose of providing access to the users of the structure. Basically, it consists of two parts:

- Door frame
- Door shutter

Function of doors

i. Facilitate light and ventilation.
ii. Act as a barrier to sound.
iii. Weather control.
iv. Provide facility of visual distinction.
v. Provide physical safety and privacy.

Location of doors

i. From consideration of adequate air circulation within the room, the door should be provided in opposite walls facing each other.
ii. From consideration of proper space utilization and privacy, doors should as far as possible be located near the corner of a room.
iii. The location of the door should meet the functional requirements of the room.
iv. The number of doors in a room should be kept minimum to achieve optimum utilization of space.

Size of doors

The size of door to be adopted for a room depends basically upon the functional requirements of the room. In general, the size of the door adopted should be such that it will permit the movement of the largest object likely to pass through the door opening.

Generally used width height relations are

- Width=0.4 to 0.6 of height
- Height= (Width +1.2m)

Technical terms (parts) of door

1. **Frame:** It is an assembly of horizontal and vertical members forming an enclosure to which the shutter are fixed.
2. **Shutters:** These are openable parts of door or window which is hinged with frame.
3. **Header:** This is the uppermost horizontal part of frame.
4. **Horn:** These are the horizontal projections of the header and sill of frame to facilitate the fixing of the frame on the wall. The length of the horns is kept about 10 to 15cm.
5. **Style (Stile):** Style is the vertical outside members of the shutter of a door or window.
6. **Top rail:** This is the topmost horizontal member of a shutter.
7. **Lock rail:** This is the middle horizontal member of a door shutter, to which locking arrangement is provided.
8. **Bottom rail:** This is the lowermost horizontal member of a shutter.
9. **Intermediate or cross rail:** These are additional horizontal rails fixed between the top and bottom rails of a shutter. A rail fixed between the top rail and lock rail is called frieze rail.
10. **Panel:** This is the area of shutter in closed between the adjacent rails.
11. **Hold fast:** These are mild steel flats, generally placed in Z or Y shape to fix or hold the frame to the opening.
12. **Jamb:** This is the vertical wall faces of an opening which supports the frame.
13. **Reveal:** It is the external jamb of a door or window opening at right angles to the wall faces.
14. **Rebate:** It is depression made inside the door frame, to receive the door shutter.

12.2 Classification of door

a. Classification based on materials used

Based on the material used for manufacturing or fabrication, the doors can be classified as.

i. Wooden doors

Most popular and expensive option for both internal and external doors is wood. They are the preferred option because of their classy appearance, high level of durability, and capacity to combine in with any architectural style. Additionally, they have an appealing look and are widely accessible for an affordable price. Custom-made wooden doors are available for any functional need and style. They are the most traditional material still in use and never lose their brightness.

Advantages of wooden doors

- Wooden door has lots of appeal and benefits given below.
- The Wood is a material that is easy to work.
- Solid wooden panel PVC glass door is eco-friendly, soundproof, waterproof (suitable for coastal areas).
- We can use it as a security door, entry door or a revolving door.
- A wooden door has simple installation, smooth surface, master sculpture, and durability.

Disadvantages of wooden doors

However, the wooden door has some disadvantages too. These are:

- It needs care and maintenance to keep performing at its peak.
- A wooden door should be sealed before installation, otherwise, it might absorb moisture.
- Because of its heavy material, a wooden door may sag over time. Thus, it needs to update its hardware and frame.

ii. Metallic doors

As the name suggests, metal door is made of metal. It has a prolonged functional life with high dimensional accuracy and less corrosion resistance.

Advantages of metal doors

Metal door provides the following benefits

- This door is effortless to handle.
- It can only be placed on a door frame with durability and easy installation.
- Having windstorm resistant component, it can be as superior as a wooden door.
- The metal door comes in various forms.
- Sheet metal door is a hinged door made of metal fragments with a lock and a lock code.
- It is strong with various designs and patterns, also chemical resistant.
- Real wood texture effects are the reason behind the success of a metal door.
- Using paints, we can keep it for a long time.
- As the price is not high, all classes of people can afford it.

Disadvantages of metal doors

The disadvantages of a metal door are

- It has a rusting problem.
- It cannot give an architectural view.
- This might be heavy.

iii. plastic doors (UPVC and PVC)

UPVC door is a replacement for a wooden door. It is made of a fully recyclable material keeping with our green living either like plastic, glass, or bamboo. It has various types e.g., gold, solid or platinum. Double glazed UPVC doors is in high demand now a days. It is mainly used in the interior, bathrooms, and garden.

Advantages of UPVC doors

The UPVC door has many pros and fewer cons.

Pros are-

- It keeps a home safe and secure by multipoint locking.
- Guarantees never to warp, rot or discolor.
- The UPVC door looks good because of its different color and sizes.
- It is durable and water resistant.
- Strong and affordable at the same time.
- You can make it energy efficient by upgrading thermally.
- It is long lasting and maintenance free.
- It is made of lightweight materials.

Disadvantages of UPVC doors

- It is not suitable for front door due to its lightweight.

vi. Aluminum door

The aluminum doors frames are made from extruded aluminum sections. The channels and box sections have flanges and grooves for double glazing and weather- stripping. The glazed doors are commonly advertised as 'patio doors'. Aluminum is a conductive material. Heat transmission can be reduced by separating the ALU profile in 2 parts using an insulating material to reduce the thermal transmission. Conductivity of aluminum is 160 W/mK.

Advantages of aluminum door

However, if you need a customized door, the entire process of making it would take a bit longer. In the case of regular and common designs, a supplier will always have them readily available in different sizes. Regular doors will only require delivery and installation upon ordering.

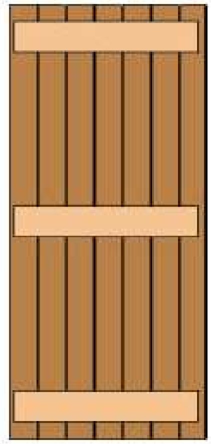
- A great advantage to most properly owners who use these doors is that they will not have to maintain them often. Aluminum resists rust and this is good news since it makes them ideal for use in any weather condition, even in areas near the ocean.
- Salty air around coastal regions damages many metallic products due to rust. You can always find metallic products due to rust. You can always find these doors from most dealers. This is a big advantage. You will not have to struggle looking for them since most door suppliers worldwide stock them in plenty.

Dis-advantages of Aluminum Door

- The marks may increase in size and number over time. Although they don't rust, these/ marks look unsightly. Hence, consider this shortcoming before making your final decision.
- These doors are also relatively more expensive than those made of other materials Aluminum is expensive and metal prices fluctuate often. This makes it challenging to budget much in advance.
- They require expert installers since their quality demands the highest installation standards.

b. Classification on the arrangement of different components

i. Battened and ledged doors

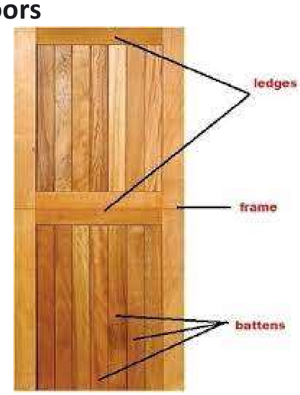


- Simplest type of door, especially suitable for narrow opening.
- Formed of the vertical boards, known as battens, which are secured by horizontal support known as ledge.
- Battens are 100 to 150mm wide and 20 to 30mm thick and ledges are 100 to 200mm wide and 25 to 30mm thick

ii. **Battened, ledged and braced doors.**

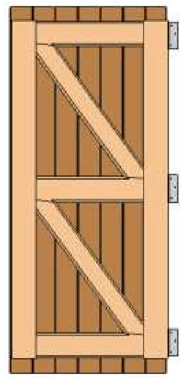
- These doors are improved versions of battened and ledged doors in which additional inclined (diagonal) members called braces are provided to give more rigidity.
- The braces are generally 100mm to 150mm wide and 30mm thick.
- The braces give rigidity to the door and hence the door of this type are useful for wide openings

iii. **Battened, ledged, and framed doors**



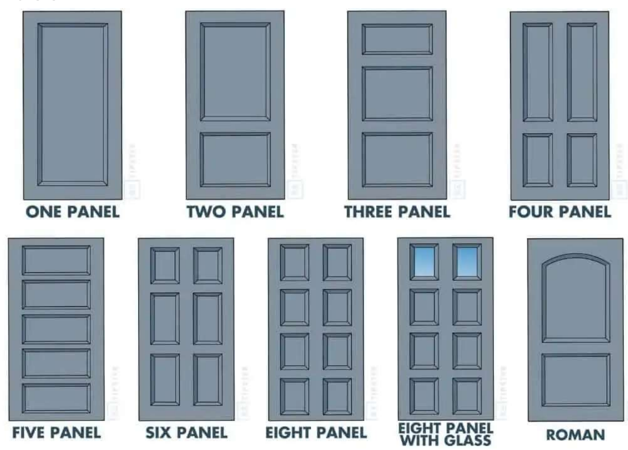
- In this type of door, a framework for shutter is provided to make the door stronger and better in appearance.
- The styles are generally 100mm wide and 40mm thick where battens and ledges are provided as usual

iv. Battened, ledged, braced, and framed doors



c. Classification based on method or manner of construction

i. Framed and paneled door

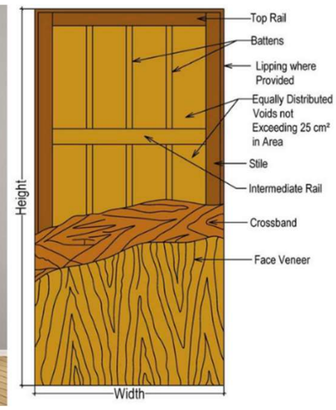


These types of doors are widely used in almost all types of building since they are strong and give better appearance than batten door. It consists of a framework of vertical members (called styles) and horizontal members called rails which are grooved along the inner edges of the frame to receive panels. The panel are made from timber, plywood, block board or even of glasses. And the thickness of panels is about 20mm. The number and size of panels depends upon the architect's design or owner's desire.

ii. Glazed or sash doors

- In order to admit lighter, in addition to that coming from the window, the fully glazed or partly glazed doors is used.
- Usually, the station of glazed portion to paneled portion is 2:1. The glass is received into the rebates provided in the wooden sash bars and secured by nails and putty or by or by wooden beads fixed to the frame.
- The glazed or sash doors are useful for hospitals, offices, libraries, show rooms, banks, shopping units etc.

iii. Flush doors

- Flush doors are becoming increasingly, popular these days because of their pleasing appearance, simplicity of construction, less cost, better strength, and greater durability. They are used both for residential as well as public and commercial buildings.
- These doors consists of solid or semi-solids skeleton or care covered on both sides with plywood; face veneers etc. presenting flush and joint less surface which can be neatly polished Framed flush door.
  i. **framed flush door:** A framed flush door consists of styles, rails, horizontal ribs, and plywood. The holes in horizontal ribs are provided for ventilation. The vertical ribs rest on rails. The hollow space, instead of being kept empty is sometimes filled up with granulated cork or any other light material.
  ii. **laminated flush door**: laminated flush door consists of styles, rails, laminated core, and plywood. The laminas of wood are glued together under pressure. The plywood sheets on either side are also glued to the laminated core under great pressure. Thus, a laminated flush door is heavy and requires more material for construction

iv. Louvered doors

- Louvered doors permits free ventilation through and at the same time maintain privacy of the room. However, these doors ports dust which is very difficult to be cleaned.
- These doors are generally used for latrines and bathrooms of residential and public buildings.

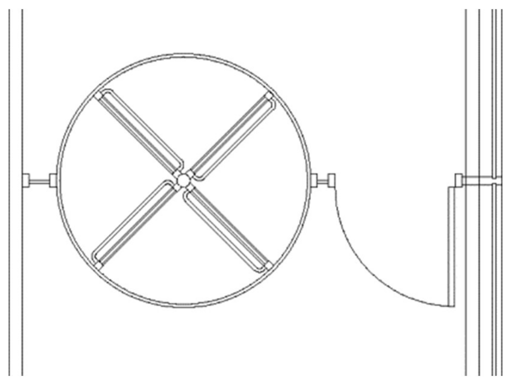
- The doors may either be louvered to its full height or may be partly louvered and partly paneled.

v. Wire-gauged doors

- These types of doors are provided to check the entry of flies, mosquitos, insects etc. and are economical used for refreshment of rooms, hotels, sweet shop etc.
- Wire mesh is provided in the panels, and therefore they permits free passage of air.
- The doors is formed of a wooden framework consisting of vertical styles and horizontal rails and the panel opening are fitted with fine mesh galvanized wire gauge.

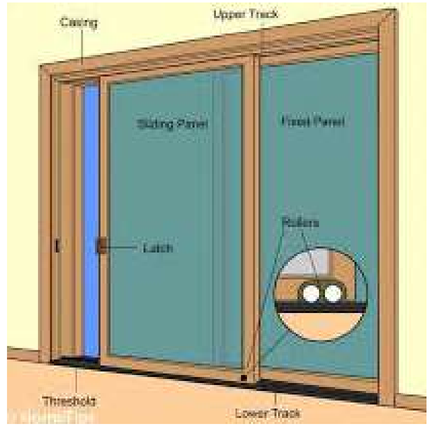
d. Classification based on working operations

i. Revolving doors



- Revolving door provides entrance on one side and exit on the other simultaneously keeping the opening automatically closed when not in use. The door is so assembled as to exclude the wind draught.
- This type of door is advantageously provided in places where there is a regular foot traffic of people entering in and going out of the building especially when it is air conditioned or situated in a place where strong winds blow for most part of the year.
- The door essentially consists of four leaves radially attached to a centrally placed mullion in a circular opening. The mullion or the central member is provided with ball-bearing at the bottom and bus bearing at the top to enable the door to revolve smoothly without producing jerks. The leaves and the mullion are enclosed in an entrance. Their edges the leaves are provided with rubber pieces which fil flexibly against the inside face of the vestibule.
- The attached leaves may be glazed, paneled or partly glazed and partly paneled.
- Such doors are commonly used in hotels, banks, offices, and other such important public buildings.

ii. Sliding doors



- This type of door is considered suitable for shops, sheds, godowns, garage etc. and in places where the use of hinges for fixing the shutter is to be avoided.
- Depending upon the size of the opening, and the space available on either side, the door can have single. double or a greater number of leaves or shutters.
- The door is provided with top and bottom guide rails or runners within which the shutters slide.
- The guide rails run past the opening for a distance equal to the width of the shutter so that when the door is required to be opened, the door shutter occupies a new position parallel to the wall face and clear off the opening.

iii. Swing doors

- This type of door is generally provided in passages of public buildings like offices, banks etc. The door may have single shutter or two shutters.
- The shutters are fixed with special hinges known as double action spring hinges which hold the shutter in closed position when not in use.
- Since these doors are pushed open, they should have glazed shutters to enable the users to see the objects on other side of the door and avoid accidents. As the springs return the door with force, the glazing should preferably be carried out by use of wired glass, or it should be protected by other suitable means.

iv. Collapsible steel doors

- These doors are extensively used for shops, garrages, public buildings, godowns etc. and in situations where width of opening is large, and provision of hinged shutter becomes difficult for want of space.
- These doors are also used from consideration of increased safety and protection of the property. Collapsible steel doors are commonly recommended in situations where light and ventilation are desired even when the opening is closed.
- Depending upon the size of the opening, the door may have single or double shutters.
- The door essentially consists of vertical double channels each 20 x 10 x 2 mm in size and spaced at 10 to 12 cm apart. The channels are joined together with the hollows of channels on the inside and are braced with flat iron diagonal 20 mm wide and 5 mm thick which allow the shutter to open out or get folded.
- The shutters operate between two T-iron rails, one fixed to the floor and the other to the lintel by means of anchor bolts. The door shutter slides over roller mounted at its bottom and is held in position by the rails .The door is provided with locking arrangements, handles, stoppers etc. and it can be opened or closed manually by slight push or pull.

v. Rolling steel shutter doors

- Rolling steel shutter door consists of a frame a drum and a shutter of thin steel plates of iron sheets of thickness about 1 mm as shown in above figure. The width of door very from 2 to 5 m. The grooves of about 25mm thickness are left in the frame.
- The shutter moves on steel guides provided on sides and can easily roll-up for this counter balancing is mode with helical springs on the drum, the diameter of drum is about 200 mm to 300 mm. The shutter usually rolls in turns; `thus a slight pull or push will close or open the shutter.
- They are commonly used as additional doors at shops, offices, banks, factors, showrooms, Godowns, building etc.

12.3 Windows

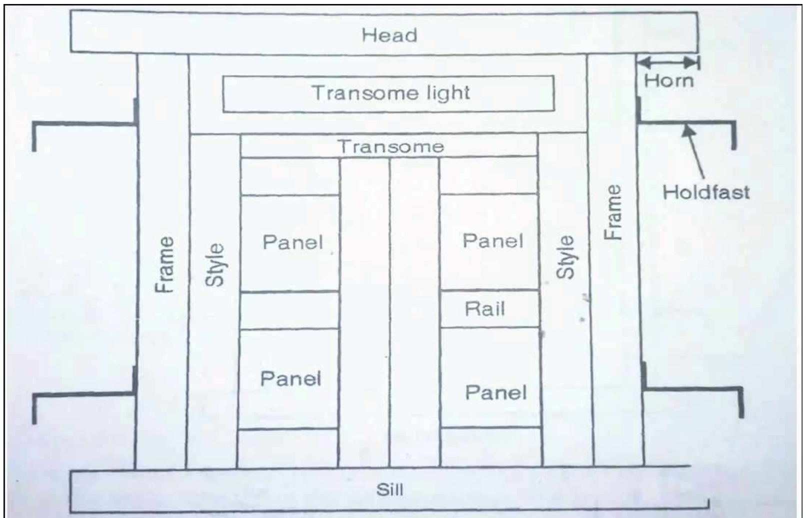


Fig: Window

A window is an opening formed in a wall to admit daylight through some transparent or translucent material fixed in the window opening.

Types of Windows

a. Fixed windows

- These windows are provided for the sole purpose of admitting light and/or providing vision on the room.
- The window consists of a window frame to which shutters are fixed. The shutters are made fully glazed.

b. Sliding windows

- Like sliding doors, the shutters move either horizontally or vertical on small roller bearings.
- Suitable openings are provided in the walls to receive the shutters when the window are opened out.
- They are provided in train, buses, bank counters, shops etc.

c. **Double hung windows**

- Double hung windows consist of pair of shutters attached to one frame.
- The shutters are arranged one above the other.
- These two shutters can slide vertically with in the frame.
- So, we can open the windows on top or at bottom to our required level.

d. **Casement windows**

- These are the common types of windows usually provided in buildings. The shutters of the window open like shutters of doors.
- The construction of casement windows is like the door, and it consists of frame, styles, rails, vertical and horizontal sash bars.

e. **Sash or glazed windows**

- They are fully glazed casement windows. The sashes are rebated to receive glass panels.
- The width and depth of rebates are about 15mm and 5mm, respectively.
- The glass is secured in position either by putty or by small fillets, known as glazing beads.

f. **Corner window**

- This is a special type of window which is provided in the corner of room.
- This window has two faces in two perpendicular directions.
- Due to this light and air is admitted from two direction.
- Such a windows very much improves elevation of the building; however, special lintel has to be cast over the window-opening for seismically strong.

g. Bay window

- These windows projects outside the external wall of a room.
- The projection may be triangular, square, circular and polygonal in plan.
- Such window is provided to get an increased area of opening for admitting greater light and air.
- They also provide extra space in the room and improve the appearance of room as well as the building.

h. Ventilators

- The ventilators are windows of small height, and they are generally fixed at the top of door or windows.
- They are placed generally about 30 to 50cm below the roof level.
- It has a frame and shutter, generally glazed, and horizontally pivoted.

i. Pivoted windows

- In these windows the shutters are allowed to swing rounds pivots fixed to the window frame, horizontally or vertically.
- The window frame has no rebates.

12.4 Door and Windows Frames

A door is a solid barrier i.e., fixed in the opening of a wall. It can be opened for access to and from buildings and between the rooms or closed for privacy.

The door has two parts: one part is frame, and second part is shutters.

The classification of door frames according to material is

a. Wooden door frame
b. Aluminum door frame
c. Iron door frame

Window frame

Window is an opening into the wall for providing daylight, ventilation and to view outside look. It has two parts: one is window frame, and the other is shutters. All other specifications of window frame are the same as for door frames.

Fixing of door and window frames

- Frames are fixed in opening abutting masonry or concrete with iron hold fast.
- Hold fasts are embedded in cement concrete block 1:3:6 ratios in the masonry walls.
- While fixing frames it should be in plumb, level and in straight line.
- Door and window frames can be fixed in masonry either at the time when work is in progress or in the opening left in masonry for fixing frames.
- Vertical members of door frames are embedded in the floor for full thickness of floor finish.

Spacing for fixing hold fasts.

The spacing recommended for fixing hold fasts vary for different types of frames:

- **For wooden frame:** Minimum three hold fasts are fixed on each side of door frames; one at the center point and the other two at 30 cm from the top and the bottom of the frame.
- **For M.S. steel frame:** Three lugs /hold fasts are provided on each jamb spacing not more than 75 cm.
- **For aluminum door frame:** In aluminum door frames, the frame is fixed with four numbers of lugs/hold fast.

CHAPTER 13: FINISHING WORKS

13.1 Plastering

Plastering is the process of covering rough surface of walls, columns, ceiling and other components of building with a thin coat of mortar to get smooth and durable surface. Plastering hides defective workmanship.

Objective of plastering

- To give a smooth surface and decorative effect.
- To protect the external surface against penetration of rainwater and other atmospheric action.
- To hide inferior materials and defective workmanship.
- To protect surface against atmospheric agent.

Requirement of good plaster.

- It should adhere to the background and should remain adhered during all variations of the climatic change.
- It should be cheap and economical.
- It should be hard and durable.
- It should be possible to play it during all weather conditions.
- It should effectively check the entry or penetration of moisture from the surface.
- It should possess good workability.

Material used in plaster

There are mainly three types of mortar which can be used for the process of plastering. The selection of type of mortar for plaster depends on various factors such as availability of binding materials, atmospheric conditions, durability required, location of surface etc.

a. Lime plaster: (Lime +sand +water)
b. Cement plaster: (cement+ sand + water)
c. Mud plaster: (earth+ sand+ straw+ water)

Classification of plaster based on Surface Finishes

Different types of plaster finishes with different appearances are available as follows

- Smooth cast finish(Plain Plaster)
- Rough cast finish
- Sand faced finish
- Pebble dash finish
- Scrapped finish
- Depeter finish
- Textured finish

a. Smooth cast plaster finish (plain plaster)

To obtain smooth cast finish, mortar used should be in the ratio 1: 3 [cement: sand]. Fine Sand should be taken to prepare the mortar. For spreading the mortar, skimming float or wood float is best suitable tool. Hence, smooth, and levelled surface is obtained finally.

b. Rough cast plaster finish

Rough cast finish is also called as spatter dash finish. Mortar used to get rough cast finish consist coarse aggregate along with cement and sand. Their ratio is about 1: 1.5: 3. The size of coarse aggregate used is 3mm to 12mm. Large quantity of mortar is taken by trowel, and it is dashed into the surface and levelled using wooden float. Usually, this type of plaster finish is preferred for external renderings.

c. Sand faced plaster finish

To get sand faced finish two coats of plastering is required. For first coat, 12mm thick layer of cement sand mortar in 1: 4 ratio is preferred. The first coat should be provided in zigzag lines.

And then it is allowed for curing for 7days. After that 8mm thick layer of second coat with cement and sand in 1:1 ratio is applied. Level the surface using sponge. Finally take some sand and screened it to obtain uniform grain size. The screened sand is applied on the second coat using skimming float or wooden float. Finally, sand faced finish with uniform grain size of sand is obtained

d. Pebble dash plaster finish

Pebble dash finish requires mortar layer of 12mm thickness with cement and sand in the ratio of 1: 3. After plastering pebbles of size 10mm to 20mm are dashed on to the plastered surface. Then press them into the plastered surface using wooden float slowly. After hardening they provide aesthetic appearance to the structure.

e. Scrapped plaster finish

To obtain scrapped finish, apply final coat of 6 to 12 mm thickness and allowed it to dry. After some time using steel blade or plate scrap the plastered layer up to 3mm depth. Scrapped finish is less liable to cracks.

f. Depeter plaster finish

This is also similar to pebble dash finish. But in this case pieces of gravel or flints are used in place of pebbles.

g. **Textured plaster finish**

Textured finish is obtained from the stucco plastering in which different textures or shapes are made on the final coat using suitable tools. External rendering of buildings Generally, external face of buildings constructed from concrete or clay blocks are not assumed to be pleasing aesthetically and do not provide attractive appearances. That is why the external faces are changed and rendered by two or three coats of lime or cement mixed with natural aggregate and finished textured or smooth. Moreover, rendering improves and increases wall resistant to penetration of rain fall. Furthermore, external rendering is based on strong bond to the background, utilized mixtures, and surface finish.

1. **Preparation of Surface for Plastering and Curing**
   - Keep all the mortar joints of wall rough, to give a good bonding to hold plaster.
   - Roughen the entire wall to be plastered.
   - Clean all the joints and surfaces of the wall with a wire brush, there should be no oil or grease etc. left on wall surface.
   - If there exist any cavities or holes on the surface, then fill it in advance with appropriate material.
   - If the surface is smooth or the wall to be plastered is old one, then rake out the mortar joint to a depth of at least 12 mm to give a better bonding to the plaster.
   - Wash the mortar joints and entire wall to be plastered, and keep it wet for at least 6 hours before applying cement plaster.
   - If the projection on the wall surface is more than 12 mm, then knock it off, so as to obtain a uniform surface of wall. This will reduce the consumption of plaster.
2. **Groundwork for Plaster**

- In order to get uniform thickness of plastering throughout the wall surface, first fix dots on the wall. A dot means patch of plaster of size 15 mm * 15 mm and having thickness of about 10 mm.
- Dots are fixed on the wall first horizontally and then vertically at a distance of about 2 meters covering the entire wall surface.
- Check the verticality of dots, one over the other, by means of plumb-bob.
- After fixing dots, the vertical strips of plaster, known as screeds, are formed in between the dots. These screeds serve as the gauges for maintaining even thickness of plastering being applied.

3. Applying Under Coat or Base Coat

- In case of brick masonry, the thickness of first coat plaster is in general 12 mm and in case of concrete masonry this thickness varies from 9 to 15 mm.
- The ratio of cement and sand for first coat plaster varies from 1:3 to 1:6.
- Apply the first coat of plaster between the spaces formed by the screeds on the wall surface. This is done by means of trowel.
- Level the surface by means of flat wooden floats and wooden straight edges.
- After leveling, left the first coat to set but not to dry and then roughen it with a scratching tool to form a key to the second coat of plaster.

4. Applying Finishing Coat

- The thickness of second coat or finishing coat may vary between 2 to 3 mm.
- The ratio of cement and sand for second coat plaster varies from 1:4 to 1:6.
- Before applying the second coat, damp the first coat evenly.
- Apply the finishing coat with wooden floats to a true even surface and using a steel trowel, give it a finishing touch.
- As far as possible, the finishing coat should be applied starting from top towards bottom and completed in one operation to eliminate joining marks.

5. Curing of Plastering works

- After completion of the plastering work, it is kept wet by sprinkling water for at least 7 days in order to develop strength and hardness.
- Use of gunny bags or other materials is used to keep the plastering works wet in external works.
- Improper curing may lead to cracks formation or efflorescence in plaster work.

Care be taken after Completion of Plaster Work

- Cleaning of doors or frame and floor area is necessary at the completion of work.
- Curing should be started as soon as the plaster has hardened sufficiently and must be cured for at least 7 days.
- Curing shall commence, 24 hours after the plaster is laid.

13.2 Pointing

Pointing is the finishing of mortar joints in brick or stone masonry construction. Pointing is the implementing of joints to a depth of 10 mm to 20 mm and filling it with better quality mortar in desired shape. It is done for cement mortar and lime mortar joints.
In exposed masonry, joints are the weakest and most vulnerable spots from which rainwater or dampness can enter.

Mortar for Pointing Work

- Lime mortar of 1:2 (1 fat lime : 2 sand or surkhi)
- Cement mortar of 1:3 (1 cement : 3 sand)

Preparation of Surface for Pointing

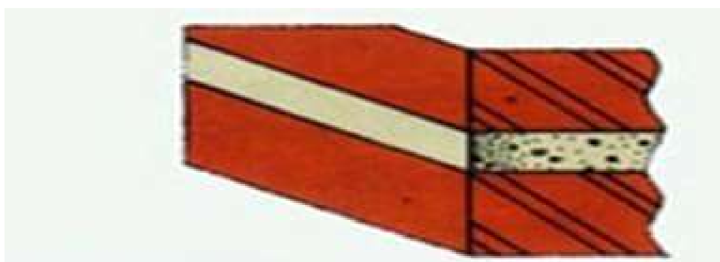
- All the joints in masonry are raked down to a depth of 20mm while the mortar is still soft.
- The joints and surface are cleaned and then thoroughly wetted.

Methods of Pointing

- After preparing the surface as mentioned above, mortar is carefully placed in joints using a small trowel. The placed mortar should be of desired shape.
- Whenever the fresh mortar is placed in the joints it should be pressed hardly to gain strong bond with old interior mortar.
- Care should be taken while using ashlar or 1st class brick work otherwise the mortar does not cover the face edges.
- The pointed surface is kept wet for at least a week or till it sets after application.

Types of Pointing

1. . **Flush Pointing**

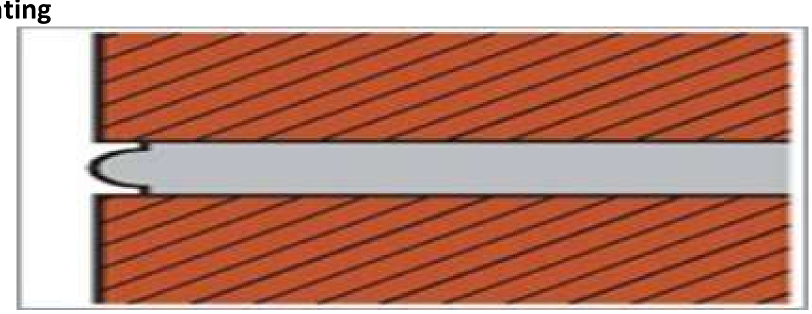


In this type, mortar is pressed hard in the raked joints and by finishing off flush with the edge of masonry units. The edges are neatly trimmed with trowel and straight edge. It does not give good appearance. But flush pointing is more durable because of resisting the provision of space for dust, water etc., due to this reason, this method is extensively used.

2. **Recessed Pointing**

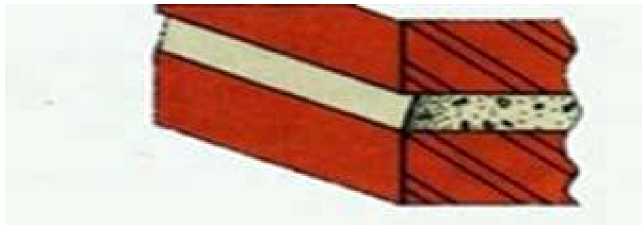
In this case, mortar is pressing back by 5mm or more from the edges. During placing of mortar the face of the pointing is kept vertical, by a suitable tool. This type gives very good appearance.

3. **Beaded Pointing**



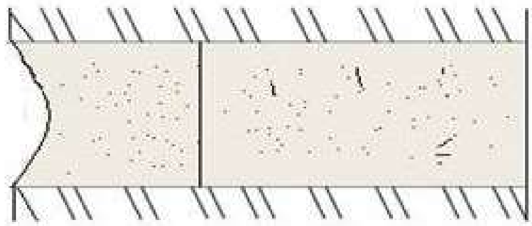
It is formed by a steel or ironed with a concave edge. It gives good appearance, but it will damage easily when compared to other types.

4. **Struck Pointing**



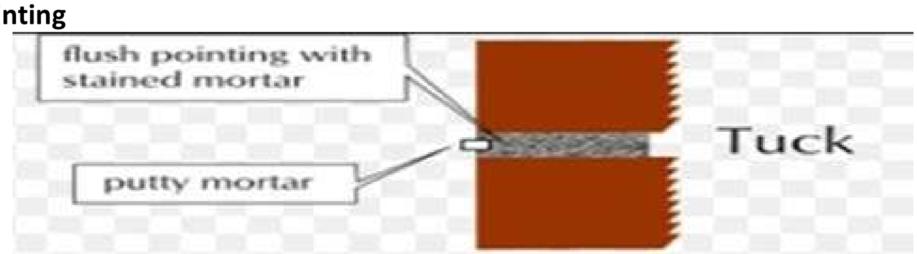
This is a modification of flush pointing in which the face the pointing is kept inclined, with its upper edge pressed inside the face by 10mm which drains water easily.

5. **Rubbed, Keyed or Grooved Pointing**



This is also a modification of flush pointing in which groove is formed at its mid height, by a pointing tool. It gives good appearance.

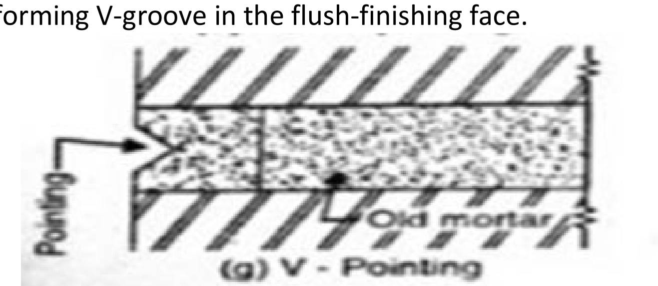
6. **Tuck Pointing**



In this case mortar is pressed in the raked joint first and finishing flush with the face.
While the pressed mortar is green, groove or narrow channel is cut in the center of groove which is having 5mm width and 3mm depth. This groove is then filled with white cement putty, kept projecting beyond the face of the joint by 3 mm. if projection is done in mortar, it is called bastard pointing or half tuck pointing.

7. **V- Pointing**

This is formed by forming V-groove in the flush-finishing face.



8. **Weathered Pointing**

This is made by making a projection in the form of V-shape.

S. No.	Plastering	Pointing
1.	It is applied to entire surface.	It is provided only at exposed joints.
2.	It provides smooth surface.	It does not provide smooth surface.
3.	It conceals defective workmanship in the masonry construction.	It is used to expose beauty of well built masonry work.
4.	It provides a base for applying white/ colour washing.	White washing or colour washing are ruled out.

13.3 Paints and paints procedure

Paint is the liquid material applied on timber, metal, or masonry surfaces to protect and decorate them. It is composed of two main components: pigment and organic binder.

Function of paint

- It protects the surface from weathering effects of the atmosphere and action by other liquid, fumes, and gases.
- It prevents decay of wood and corrosion in metal.
- It give good appearance to the surface.
- It provides smooth surface for easy cleaning.
- It render surface hygienically safe and clean.
- It protects joints from adverse effect of atmosphere.
- It prevents entry of water into wall through joints.

Characteristics of an ideal paint

- It should possess good spreading power.
- It should be cheap and economical.
- It should be such that it can be easily and freely applied on the surface.
- Its color must maintain for a long time.
- The paint should not affect health of workers during its application.
- The paint should possess attractive and pleasing appearance.
- It should not crack on drying.
- It should be good fire and moisture resistance.
- When applied on surface, the paint should form a thin film of uniform nature.

Types of paint

1. **Cement paint**

This paint consists of white cement, pigment, accelerator, and other additives. It is available in dry powder form. It is desirable to provide cement paint on rough surface rather than on smooth surface because its adhesion power is poor on smoothly finished surface.

Advantage of cement paint are

- It requires less skill and time for applying cement water paints and the applying implements can be cleaned with water only.
- The preparation of surfaces is easier in a cement paint system as it is not necessary to remove the previous coats of cement paints.
- They are suitable for painting fresh plasters having high alkalinity because cement paints are not likely to be attacked by the alkalinity of masonry surfaces.
- They become an integral part of the substrata and add to its strength.

- They can be applied over new and damp walls which cannot be painted over with oil paints until they are sufficiently dried.
- They prove to be economical as compared to the oil paints and they dry more rapidly than the oil paints.

2. **Enamel paint**

   This paint is available in different colors. It contains white lead, oil, petroleum spirit and resinous matter. It dries slowly and forms a hard and durable surface. The surface provided with this paint is not affected by acid, alkalis, fumes of gas, hot and cold water, stream etc. It can be used for both internal and external walls. To improve the appearance, it is desirable to apply a coat of titanium white in pale linseed oil before the coat of enamel paint.

3. **Emulsion paint**

   A variety of emulsion paints is available. It contains binding materials such as polyvinyl acetate, synthetic resin etc. This paint is easy to apply, and it dries quickly in about 1.5 hours to 2 hours. The color of the paint is retained for a long period and the surface of paint is tough and it can be cleaned by washing with water. There is absence of odour and the paint possesses excellent alkali resistance.

   The application of emulsion paint can be carried out either by brush or spray gun. For long service life it is recommended to apply two coats of emulsion paint. For rough cement plastered surface, a thin coat of cement paint may first be applied to smoothen the surface. It is necessary to have a sound surface to receive the emulsion paint.

4. **Distemper**

   Distemper may be defined as water paints, consisting of whiting, glue or caseins as a binder and suitable proportion of fast coloring pigments. Distemper may give either a washable or nor washable surface according to the medium used. They are cheaper than paints and varnishes and are easier to work. They act as sealers over porous surfaces and are generally used over plastered surfaces to which a priming coat of whiting has been applied.

   Procedure application

   i. **Preparation of surface**
      - Rubbed down the rough surface with a sandpaper and then cleaned.
      - Keep the surface to dry perfectly before the application of distemper.

   vi. **Priming coat**
      - After preparing the surface, a priming coat is applied and then left to dry.

   vii. **Coats of distemper**
      - Uniform coats of distemper are applied over the priming coat.
      - One coat over other is applied only after the former coats gets completely dried and becomes hard.
      - On newly plastered surface distempers should be applied in 2 to 3 coats over one coat of primer.
      - In applying distemper, the brush should first applied horizontally and then immediately.

   viii. **Painting on different surfaces**
      - The process of painting depends on the nature of the surface to be painted.
      - A brief description of painting on each of the various surfaces is given below.

1. **Painting on new woodwork**

   Normally four coats of paint are required for new woodwork. The process of painting is carried out as follows.

   - The surface of woodwork is prepared to receive the paint.

- For satisfactory working, it is necessary that the woodwork is sufficiently seasoned, and it does not contain more than 15% moisture at the time of painting.
- The surface of woodwork is thoroughly cleaned, and the heads of nails are punched to a depth of 3mm below the surface.
- The surface of the woodwork is then knotted.
- The priming coat is then applied on the surface of new woodwork. Generally, the priming coat is applied before the woodwork is placed on position.
- The subsequent coats of paint and finishing coat are then applied on the surface. The extreme care should be taken to see that the finishing coat presents smooth, and no brush marks are seen on the finished work.

2. **Repainting old woodwork.**
    - If the paint on the old woodwork has cracked or has developed blisters, it is to be removed. It the surface has become greasy; it should be cleaned by rubbing down sandpaper or fine pumice stone.
    - The old paint can also be removed by applying any one of the following three paint solvents.
    - A solution containing 2N of caustic soda to a liter of water is prepared and used to wash surface. The paint dissolves and the surface becomes clean.
    - A mixture consisting of one part of soft soap and two part of potash is prepared and one part of quicklime is then added afterwards.
    - This mixture is applied on the surface in a hot state and allowed to stay for about 24 hours. The surface is then washed with hot water.
    - A mixture consisting of equal parts of washing soda and quicklime is brought to a paste form by adding required quantity of water. It is applied on the surface and kept for about an hour .The surface is then washed with water.
    - After removing old paint from the surface, the woodwork is painted as in case of painting on new woodwork.
3. **Painting on plaster surface (Masonry)**
    1. **Preparation of surface**
        - Allow newly plastered surface to mature. Rectify if there is any water seepage problem. All external and internal drainage and water supply pipes must be checked for rusting or leakage.
        - Remove loose particles and rub the surface with sandpaper to ensure that the surface is dry free from dust, dirt or grease etc.
        - Any holes on the surface are repaired by plaster of Paris or by wall putty or cement and again rubbed.
        - Fill up cracks with a 1:3 cement/sand mortar.
        - In old surface previous coating of lime wash power distemper or cement paint must be through scrapped off by through sanding. Cracked or flaked paint must also be completely removed.
        - Fungus affected areas need to be given a separate treatment.
        - Make a 5-10% solution of bleach power in water and apply on affected areas with brush.
        - Wash the walls with clean water after an interval of 8-10 hours.
        - Allow the surface to dry sufficiently.
    2. **Priming coat**
        - Priming coat is applied on the surface.
        - The primer should be allowed to dry for 10-12 hours.
    3. **First coating**

- After primer coats are completely dry first coat of desired paint is allowed on the surface.

iv. **Final coat**

After first coat is completely dry and becomes hard final coat is applied on the first coated surface.

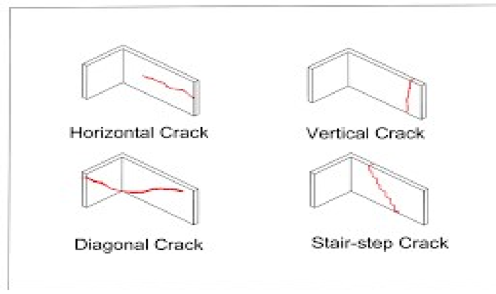
Defects in painting

Following are the usual defects which are found in the painting work.

i. Blistering
ii. Bloom
iii. Fading
iv. Flaking

CHAPTER 14: Miscellaneous Construction works

14.1 Causes and prevention of cracks in building



Majority of cracks occur when the building or the material of which the building is made subjected to forces which are greater than those which it can with stand.
Cracks can be divided in two categories

a) **Structural crack :** Structural crack may arise due to

- Overloading of structural component.
- Overloading of the soil in which the building is constructed.
- Incorrect design and defective load assumption and perception of behavior of the structure.
- Incorrect assessment of bearing capacity of foundation soil and soil property.
- Defective structural detailing of steel reinforcement.
- Poor construction practices.

To overcome this problem following precaution are required to be considered.

- Proper specification for concrete materials and concrete.
- Proper specification to take care of environmental as well as subsoil condition.
- Proper and adequate structural design.
- Proper quality and thickness of concrete cover around the reinforcement steel.
- Proper selection of construction material.

b) **Nonstructural crack**: Nonstructural cracks are generally due to internal forces developed in the building on account of changes in the size of building components due to

- Moisture variation
- Temperature variation
- Elastic deformation
- Chemical reaction
- Corrosion of reinforcement
- Foundation movement and settlement of soil
- Vegetation

The various causes of formation of cracks and remedial measures are described below.

1. **Cracks due to moisture changes**

Most of the building material like bricks, concrete, mortar, stone, timber etc. have pores. Hence these materials increase in size or expand on absorbing moisture and decrease in size or shrink on drying.
Cracks due to moisture changes can be prevented by adopting the following measures.

- Minimum use of rich cement mortar
- Use lean cement mortar or composite cement lime mortar in masonry work.

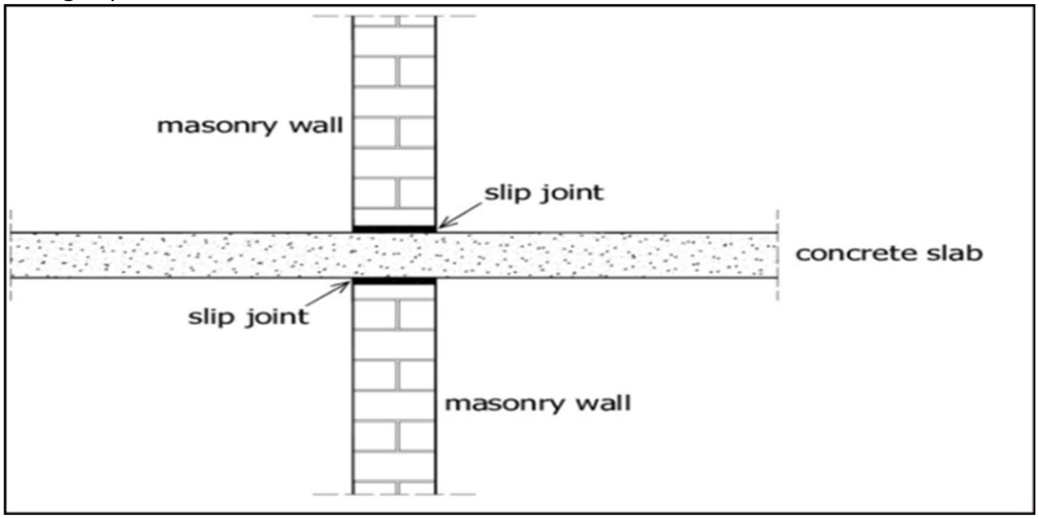
- Use stiffer and leaner mortar allows adequate time for curing and drying.

2. **Cracks due to temperature variation**

All material expand on heat and contract on cool. Thermal movement in components of structure creates cracks due to tensile of shear stresses. It is one of the most potent causes of cracking in building and need attention.

Prevention of cracks due to temperature variation

- Construct joints such as construction joints, expansion joints, control joints and slip joints. The joints should be planned at the time of design and be constructed carefully.
- Adequate insulation or terracing treatment over the roof slab and by introducing slip joint between the slab and the supporting wall.
- Painting top of roof with reflective finish can also serve to minimize cracks.



3. **Cracks due to elastic deformation and creep**

When the walls are unevenly loaded due to variation in stresses in different parts of wall the cracks are formed in walls. When two materials having wide different elastic properties are built together under the effect of load, different shear stresses in this material create cracks at the junction. Dead and live loads causes elastic deformation in structural components of a building.

The situation where cracking due to elastic deformation and creep arises and the preventive measures to avoid such cracks are summarized below.

i. **Cracks in masonry when a wall is unevenly loaded**

If the building has large opening in the external walls. Portion of wall immediately below the sill is subjected to much lesser loads as compared to the portion of the wall on either side of the window opening. This results in uneven loading of the wall which may cause vertical cracks.

Prevention

- To avoid unequal loading condition in the same wall.

ii. **Cracks in masonry due to deflection of RCC beam or slab**

It is observed that when a beam or slab having large spans undergoes collection and there is insufficient downward loads above the supporting wall, horizontal cracks appear in the masonry at support.

Prevention

- Cracks of this type can be prevented by designing the slab or beam in such a way that the depth provided is adequate to restrict the deflection within permissible limits.

iii. **Cracks at junction of brick masonry with RCC columns in load bearing walls.**

With the passage of time, RCC columns undergo some shortening due to elastic deformation and creep resulting in vertical cracks appearing at the junction of column with masonry.

Prevention

- Adequate curing of the RCC columns and providing air gap between the masonry and the column.

iv. **Cracking in brick panel wall in frame structure**

Vertical cracks are formed when the length of panel is more and the tightly constructed wall between columns. The horizontal cracks are formed due to shortening of columns.

Prevention

- The panel wall should not construct tightly between the RCC frames.
- Movement joints should be provided between the top of panel wall and soffit of beam.
- Joints may be filled up with some compressible jointing material.

v. **Crack due to chemical reaction**

Chemical reactions in building material increases their volume and internal stress causes crack. The components of structure also weaken due to chemical reactions.

Some of common instances of chemical reactions are following.

- Sulphate attack on cement products.
- Carbonation in cement-based material.
- Corrosion of reinforcement in concrete.
- Alkali aggregate reaction.

Prevention

- Use dense and good quality concrete i.e., richer mix of cement concrete 1:1.5:3 to prevent cracks.
- Repair corrosive cement surface by Guniting/injecting technique after removing all loose and damaged concrete and cleaning reinforcement from all rust also.
- For preventing sulphate attack avoid use of brick containing high percentage of soluble salts.

vi. **Cracks due to foundation movement and settlement of soil**

Shear cracks occur in buildings when there is large differential settlement of foundation due to any of following causes.

- Unequal bearing pressure under different parts of the structure.
- Bearing pressure being more than safe bearing strength of the soil.
- Low factor of safety in the design of foundation.
- Local variation in supporting soil.

Preventions

- In case of shrinkable soil, adopt under reamed pile foundation.
- The structural design of the foundation should be carried out in such a manner as to achieve uniform distribution of pressure on the ground to avoid differential settlement.
- The foundation should be so proportioned that the safe bearing capacity or soil is not exceeded.

vii. **Corrosion of reinforcement**

Reinforcement corrosion will produce iron oxide and hydroxide on steel bar surface, consequently its volume increases. This increase in volume causes high radial bursting stresses around reinforcing bars and result in local radial cracks. These splitting cracks results in the formation of longitudinal cracks parallel to the bar.

Prevention

- Use low permeable concrete
- Provide adequate cover thickness
- Make sure concrete-steel bond is as good as possible. Otherwise, concrete may crack and allow harmful substance materials to attack steel bars.

viii. Crack due to vegetation

Tree growing close to the building on shrinkable soil may cause cracks in the wall. **Prevention**

- Such crack can be prevented by not planting fast growing trees near the building. Prevention of crack in building
- Drainage arrangement should be made around the building to minimize water entry in the foundation.
- Avoid construction of wall on filled up soil.
- Avoid tree grow to close to building and compounds wall.
- Selection of proper material.
- Specification for concrete and mortar.
- Good construction practices.
- Consideration of weather effect.

14.2 Methods to prevent termite action

The type of insects known as termites cause maximum damage to the building.
Termites are divided mainly into following two types.

a) Dry wood termites

- They are known as non-subterranean or wood nesting termites.
- They live in wood and do not maintain contact with the ground.
- Dry wood termites normally build nests within the dry timber members like door, window frames, wooden furniture etc. and destroy them gradually.

b) Subterranean termites

- They cannot survive or live without maintaining connection with the soil.
- They build underground nests or colonies and form mud-wall tunnels or runways (tubes) which serve as protected shelter for their movements.

Anti-termite treatment

Anti-termite treatment is a chemical procedure carried out for soil, masonry, wood and electrical fixtures to provide the building with a chemical barrier against the subterranean termites before and after construction.

Advantages of anti-termite treatment

- It provides immediate protection to any structure from termites, rodents and pests.
- It lasts for several years.

- It eliminates the problem of gap forming in the protection barrier, allowing termites to enter the home.
- Liquid termiticides are relatively inexpensive when compared to other forms of termite control.

Principle of termite proofing

Some of the termite principle proofings are

a. **Drainage**
   - Provide adequate drainage, as termites are attacked to the moisture.
   - If possible, construct masonry or concrete apron around the periphery of the building. It prevents seepage of water to the underside of the building.
   - Where it is not possible to construct apron, stone slabs should be provided below the rain pipes to help drain away the rainwater.

b. **Bridging**
   - Do not form the bridge between building and untreated soil.

c. **Floor joints**
   - Suitable joint fillers or metal strips may be used to make floor joint termite proof.

d. **Filling material**
   - Care should be taken while inspecting the filling materials or debris used for reclamation of soil.

e. **Foundation**
   - Termites cannot enter through the dense cement concrete foundation or through solid foundation, therefore, it is not necessary to do treatment from the bottom of excavation.
   - In such case, treatment the soil up to 500mm below the ground level up to bottom of the plinth beam.
   - For termite prevention the construction of foundation should therefore be carried out with superior quality materials and better workmanship.

f. **Site clearance**
   - Dead wood, old tree stumps etc. should be cleaned from the site of the building.

g. **Superstructures**
   - Materials of superstructure which are easily susceptible to the termite attack should be treated with suitable preservative.
   - Wooden members such as door frame, staircase, roof etc. should be set on flooring.

d. **Cost**
   - Once the termite have established building, it becomes difficult and costly to remove them completely.
   - Therefore, suitable termite proofing during the construction is crucial.

Method of termite proofing

Termite proofing method adopted in a building should be decided by considering the local conditions and materials to be used in building construction.

i. **Chemical treatment of soil**
   - To provide an effective control of termite the soil insecticides are thoroughly mixed and evenly spread on the soil.
   - Insecticides like DDT(Dichlorodiphenyltrichloroethane), BHC(benzene hexachloride) PCP(Pentachlorophenol) etc. are used.
   - Additions of chemicals like Aldrin 0.5%, chloride 1%, dieldrin 0.5% and heptachlor 0.5% by weight in soil solutions and emulsion in water are effective way or termite treatment.
   - They are used in damage portions of masonry and woodwork by injecting them under pressure in drilled holes. ii. Physical structural barrier

- Physical structural barrier in the form of concrete layer about 50 to 75mm thick or metal layer of non-corrodible metal sheets of copper of galvanized iron having thickness of 0.8mm may be provided at plinth level.

14.3 Maintenance of Existing Building

The following tasks associated with various tasks listed in the building units can be done maintenance on an existing structure. Good maintenance enhances not only the beauty and performance but also the useful life of building.

A. Cleaning of paintwork

a. Washing Paintwork

Washable paints can be cleaned by washing with clean water. Soda, soft soap, and other alkaline substances are injurious to most paints. If at all they are used to remove difficult stains, they should be highly diluted and rinsed off the paint with clean water as soon as the dirt is removed.

b. Repainting

It is advisable to repaint surfaces before the old paint disintegrates and while a compact and continuous film still exists. The life of paint depends on its quality. For example, today's exterior paints have been developed so that frequent repainting of external surfaces of high-rise buildings can be avoided. They are costly but they remain intact and retain their brightness for a long time. We should also choose the correct paint suitable for the exposure condition. Thus, it is better to paint the underside of a wet area such as bathroom and walls where dampness can penetrate with paints which can breathe (such as cement paint).

c. Paints on Steelwork

Careful observation should be made on painted grills, rolling shutters, etc. They should be regularly cleaned with clean water. If any parts get rusted, it should be removed and the surface repainted. Steel windows, if used in buildings, require special attention.

B. Maintenance of floorings

There are many types of floors, and each has its own methods of maintenance. These are discussed further

a. Marble floors

Daily maintenance is to be made by mopping with mild detergent in water Marble can easily get stained and scarred. The lighter the color the more easily the stains can be detected. If there is a spill, it should be wiped out immediately. If these are stubborn stains proceed as follows:

- If the stain is from grease, make a paste of chalk dust or whiting with acetone. This mixture is applied to the stain and allowed to stand overnight. Sponge off the mixture and buff the treated area.
- If the stain is from an organic source such as tea, fruit juice, carbonated beverages mix, use the chalk powder with hydrogen peroxide instead of acetone. Rust stains can also be removed by this paste. If the above process dulls the surface, sprinkle marble polishing powder (tin oxide) and rub it down with thick cloth or an electric buffer. Stubborn dirt can be removed by dry borax and damp cloth followed by rinsing with warm water.

b. Granite and other stone floors

Mopping with mild detergent and water at regular intervals will keep the floor in good shape.

c. Terrazzo floors

- For a period of at least three months after the terrazzo floor has been laid, should be swabbed daily using clean water and a clean, rough swab (floor cloth) which should be rinsed frequently in water to avoid dirt being carried back on to the floor. The Floor is then allowed to dry. If the floor is dirty, water and a mild soap may be used to clean it. The soap should be completely removed by mopping as otherwise it will be deposited on the floor making it slippery and dull looking. After this initial cleaning, ordinary swabbing will keep the floor shining. It is seldom possible to remove oil and grease, if spilled on the floor, and if they are allowed to penetrate below the surface. However, applying a paste made by a powder such as hydrated lime and marble dust, or whiting with benzol or clear gasoline over the stain, and then washing after 12 hours can be.

- Acid polishing of terrazzo floors (using oxalic acid) is usually carried out after machine polishing during the first laying of the floor. This can be repeated, if needed. For this purpose, oxalic acid is dusted over the surface at the rate of 35 g per sq m of the surface sprinkled with water and rubbed hard with a pad of woolen rag. The following day the floor is wiped with a moist rag and washed clean with water. Acids such as dilute hydrochloric acid should not be used for cleaning mosaic floors.

d. PVC floors

PVC flooring subject to normal usage may be kept clean by mopping with soap solution using a clean damp cloth. The traces of soap should be removed by mopping, Water should not be poured over the PVC flooring for cleaning as it may seep through the joints and cause the adhesive to fail. The floor may be periodically polished to keep up its appearance. It should not be over waxed and if it develops this condition, it should be cleared with white spirit or paraffin.

e. Linoleum floors

Mopping with white kerosene oil can pick up all the dirt from linoleum floors. After removing all the dirt, the floor can be wiped with water and mopped well to get a polished surface. As in the case of PVC floors, excess water and alkaline soaps should not be used for cleaning linoleum floors. Block-wood floors: All wood floors should be kept clean, and the blocks should not become loose. The floor is cleaned and kept bright by polishing with beeswax or ready-made wax polish.

f. Ceramic (glazed and vitrified) tile floors

Ceramic tiles are easy to maintain. Soap and water can be used to clean them. Special care should be taken to clean the joints (unless joint less tiles are used for the flooring). Any stains can be removed by any of the methods used for other floors or even by the household methods of using a cut lemon.

C. Maintenance of doors and window

Both the woodwork and glazing must be regularly maintained.

a. Care of woodwork

- Most woods, except teakwood, get deteriorated with time unless they are regularly painted and kept free from water and direct exposure to sun. Door frames adjacent to wet areas such as bathroom get affected by rot. Both dry and wet rots grow with moist condition. They can be prevented by proper ventilation and painting. Similarly, doors and windows which are directly exposed to the sun split up due to heating. Hence, these should be shaded and regularly painted.
- Usually, paneled wood shutters or plastic shutters are provided as bathroom doors. The underside of these wood shutters including the bottom edge is usually protected by U-

shaped Aluminum sheets and painted with waterproof paint so that water does not affect the bottom edge. This precaution is especially applicable to flush doors for bathrooms. Stains and dirt on painted doors can be removed as in painted walls.

b. Care of glazing

- While putty glazing is used for ordinary wood, glazing with beads is usually carried in teakwood. Both do not get damaged quickly, but they should be inspected at regular intervals. Putty glazing can get cracked with time.

c. Cleaning glass in doors and windows

- Glass fitted to doors and windows should be cleaned regularly with clean tepid water. Glass cleaning liquids are available in the market to remove dirt and stains. Less expensive version can be made by mixing 2 tablespoons household ammonia or white vinegar with 1.25 liters of water. This solution is put into a spray bottle and applied with a sponge or rag, wring them out thoroughly to avoid drips. Start from top and work downwards.
- A cotton swab or toothbrush can be used to take dirt from corners. Dry the window with crumbled newspaper or paper towels or chamois. Wipe one side horizontally and other vertically so that if streaks are left, we know which side it is and can remove them.
- The streaks are to be removed by a soft, dry cloth. Ordinary printed newspaper (with printer's ink dipped in water is considered as a good material for cleaning of window and automobile glass.

D. Maintenance of sanitary appliances

Discoloration of fittings and growth of fungus and algae are the main problems. Sanitary appliances (ceramic wares) need frequent cleaning to maintain them in good condition and to presence their appearance. A solution of chloride of lime (bleaching powder) in hot water will remove surface stains from a ceramic ware. To restore the luster of porcelain and glazed surfaces, a cloth moistened with hot water and a little paraffin will be found very effective. Abrasive powders or acid solutions are harmful to these surfaces. There are also several ready-to-use chlorinated cleaning materials available in the market for cleaning sanitary appliances. However, they are usually very costly. If the sewage is to be treated by a septic tank, we should not use chemicals and detergents that can kill the bacteria in the septic tank.

E. Maintenance of water supply taps and fixtures

Taps and other fixtures should be repaired as soon as they become defective. Taps, chrome fittings tubs, basins, wall tiles, etc. can be easily cleaned with liquid ammonia in water (one tablespoon of ammonia to one liter of water). Materials for polishing metals are also available in the market. The sumps and overhead water tanks should be cleaned regularly. The overhead tank should be kept well covered with no holes. Malarial mosquitoes breed in fresh water. If the tank is exposed to sunlight algae-which is harmful to human skin-can grow in unchlorinated water.

F. Maintenance of drainage system

To avoid nuisance and unhealthy conditions, soil and waste-disposal systems must be kept clean as well as in good working order. The main items to be looked after regarding the maintenance of drainage system are discussed further.

i. Fittings inside the building

Water taps, waste pipes (pipes from washbasin or sink to the floor trap), traps in fittings, floor traps. Gratings above floor trap, etc. should be examined periodically by-passing water through them and examining their performance. Otherwise, they are liable to get jammed especially when the water supply is not too good. Gratings in bathrooms require frequent inspection as they are liable to be clogged with hair, oil, etc.

If drains are not working properly, drain cleaning compounds, which are availed in the market. should be used to remove the block. Sometimes, physical methods with to clean them.

ii. **Waste and soil pipes**

These pipes and their fixity to walls should be examined during painting of external walls. If fixings are damaged, they should be repaired. (Many of the pipes in old buildings are AC pipes which are brittle but cheap. Nowadays, PVC pipes are more often used in Class I and Class II buildings.) Wire balloons on the top should be checked and replaced, if necessary.

iii. **Gulleys, manholes, manhole covers and drainpipes**

These should be examined regularly and before the onset of the monsoon. The outlet to the sewer should be checked so that backflow from the street sewer to the house drain does not happen in rainy season. Cockroaches that breed in dark sewers and manholes should be destroyed by chemical sprays. There should be no stagnant water in the drains to breed mosquitoes.

iv. **Roof drainage system**

The roof drainage system should be inspected before the rainy season. Gutters especially (horizontally placed ones) must be cleaned, and leakages repaired before the onset of the rains. Any leak from roof drainage system should be identified and repaired during the first pre-monsoon rains.

G. Maintenance of septic tanks

For efficient working of a septic tank, grease, and slow decomposing matter, etc. should not be put down the drains (a grease trap in the line is desirable). Avoid drain-cleaning chemicals which can kill the bacteria in the septic tanks . The digested sludge should be removed when the depth of the sludge and scum exceed half the depth of the tank. A portion of the sludge should be left in the tank to act as seed to the fresh sewage. Adding 1/4 kg of brewer's yeast to the tank will hasten the septic tank action if such action is dull. Warning signs of a defective system include foul odors from the drains or the tank and the growth of lush vegetation over the tank. If water backs up in the drain, it indicates clogging by sludge and scum.

H. Maintenance of water supply system

It is very important that the water supply system should be maintained in good and sanitary condition. If the supply is from a municipal water supply line to a sump, from the sump to an overhead water tank and from the water tank to the various distribution points, then periodic draining, cleaning, drying, and whitewashing of the sumps at least once in 4 months should be carried out in all public buildings (January, May, and September may be chosen for this purpose).

CHAPTER 15: EARTHQUAKE

15.1 Concept of earthquake

A. Introduction

An earthquake is the sudden and violent motion of the earth caused by volcanic eruption, plate tectonic or by manmade explosions which last for a short period of time and within limited region.

It is a sudden, rapid shaking of the earth surface caused by the breaking and shifting of rock beneath. During earthquake, ground motion occurs in a random fashion in all directions radiating from a point within earth crust, called **epicenter.** It causes vibrations of structures and induces inertia force in them. As a results, structure may collapse resulting into loss of property and lives. Earthquakes do not kill people, vulnerable building do so. Hence there is need of designing earthquake resistance building, especially in the earthquake prone areas.

B. Terminologies

Basic earthquake engineering terms are presented in the following sections.

1. **Magnitude:**
   It is the quantity to measure the size of an earthquake in terms of its energy and is independent of the place of the observation and expressed by Richter scale.
2. **Intensity**
   It is the rating of the effects of an earthquake at a particular place based on the observations of the affected areas, using a descriptive scale like Modified Mercalli Scale.

3. **Epicenter:**
   It is the point on the surface of the earth vertically above the place of origin of an earthquake. This point is expressed by its geographical latitude and longitude.
   Example: Epicenter of Nepal earthquake of April 2015 (Baisakh 12) is 28.230N, 84.731E i.e., Barpak, Gorkha.
4. **Focus (hypocenter)**
   It is the point within the earth from where seismic waves originates. Focal depth is the vertical distance between the hypocenter and epicenter.
5. **Magnitude**
   It is the quantity to measure the size of an earthquake in terms of its energy and is independent of the place of the observation.
6. **Richter scale**
   Magnitude is measured based on ground motion recorded by an instrument and applying standard correction for the epicentral distance from recording station. It is linearly related to the logarithm of amount of energy released by an earthquake and expressed in Richter scale.

C. Causes of earthquake

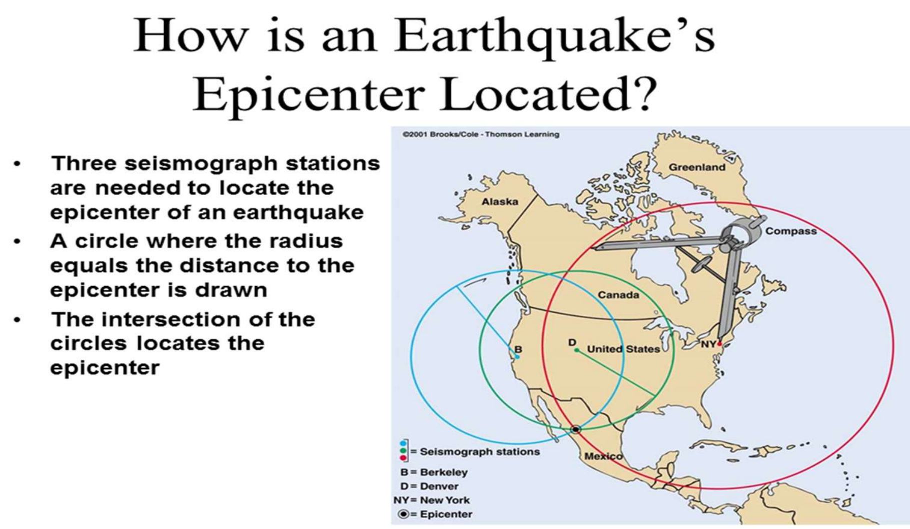
- Earthquake occurs when energy stored in elastically strained rock is suddenly released.
- This release of energy causes intense ground shaking in the area near the source of the earthquake (focus) and sends waves of elastic energy called seismic waves in all directions throughout the earth.
- Earthquake can be generated by bomb blast, volcanic eruption, and sudden slippage along faults.
- Earthquakes occurs due to the circulation of earth mass.
- Earthquake occurs due to the movement tectonic plates.
- Earthquake occurs due to the fractures in earth crusts or lithosphere.

- Earthquake occurs due to the release of accumulated strain energy along the fault.

D. Earthquake location

For location of earthquake , we need a seismic network of as many as possible. A seismic network is defined as a group of stations working together jointly for data collection and analysis minimum number of stations needed to locate the position of an earthquake epicenter is three.

To locate and earthquake, we need precise reading of time when P and S waves arrives at several seismic stations. Accuracy in timing must be with a precision of 0.01 sec that is essential in seismology. Knowing the difference in arrival times of the two waves (P and S wave) and knowing their velocity, we may calculate the distance of epicenter. This is done by travel-time curve which show how long does it take for P and S waves to reach some epicentral distance. The time distance graph shows the average travel time for P and S waves.



E. Measurement of Earthquake

Earthquake measures are used to quantify the size and effect of earthquake. The size of earthquake at the source by the amount of energy released at the source, the magnitude, whereas the effect of earthquakes at different locations is measured by its intensity at a specific site.

i. Earthquake Magnitude

- The magnitude of an earthquake is a measure of the amount of energy released.
- Magnitude of an earthquake is a quantitative measure of its size.
- Thus, the magnitude of an earthquake is a single number which does not vary from place to place.
- It is estimated from instrumental observation.
- The oldest and most popular measurement of an earthquake is the Richter Scale, defined in 1936.
- Since this scale is logarithmic, an increase in one magnitude signifies a 10-fold increase in ground motion or roughly an increase in 30 times the energy release.
- Thus, an earthquake with a magnitude of 7.5 release 30 times more energy than one with a 6.5 magnitude and an approximately 900 times that of a 5.5 magnitude earthquake.
- An earthquake of magnitude 3 is the smallest normally felt by humans.
- Largest earthquake that have been recorded under this system is from 8.8 to 8.9 in magnitude.

ii. Earthquake intensity

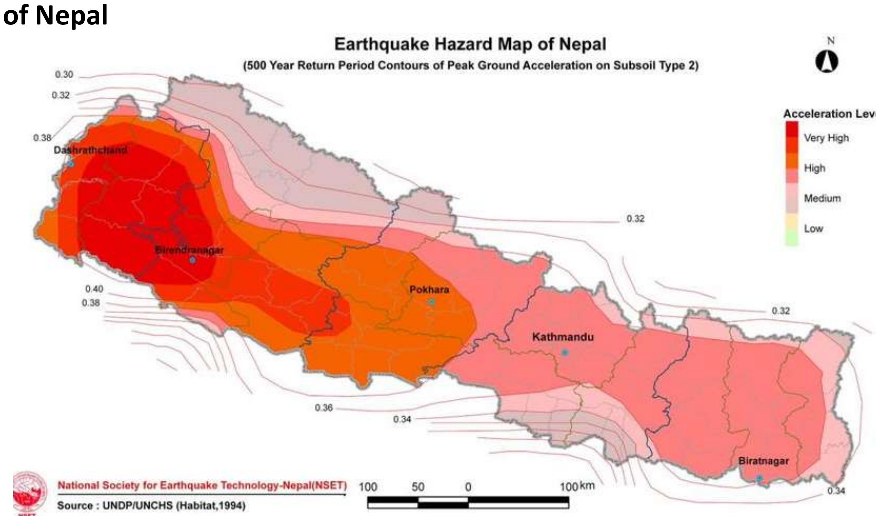
- The intensity is measured as per the effect of an earthquake.

- It is measured based on how severe the earthquake shaking was at any location. So, it could differ from site to site.
- For any earthquake, the intensity is strongest close to the epicenter.
- A single event can have many intensities differing in the severity of ground shaking at different location.
- These two terms, earthquake magnitude and earthquake intensity are frequently confused in describing earthquake and their effects. While magnitude, expressed generally on a Richter scale, is a term applied to the amount of energy released of an earthquake.
- Intensity is a term applied to the effect of an earthquake at the affected site that determines the severity of the effect on a structure.
- The most widely used scale for measuring earthquake intensity has been the **Modified Mercalli Intensity (MMI)** scale that was first developed by Mercalli in 1902, later the modified by Wood and Neuman in 1931.
- It expresses the intensity of earthquake effects on people, structure, and earth's surface in step from I to XII.
- The furthermore detailed and explicit scale, the **Medvedev-Sponheuer-Karnik (MSK) scale (1964)** is now also commonly used.
- Both scales are very close to each other.

F. Seismicity of Nepal

- Nepal is in boundary between the Indian and the Tibetan plate along which a relative shear strain of about 2cm has been estimated.
- The Indian plate is also subducting at a rate of about 2cm per year as a result Nepal is very active seismically.
- West Nepal seems more active than the east.
- The major causes of seismicity in the Himalaya is continuous collision between Indian and Eurasian plate.
- The seismicity in Nepal Himalaya is connected E-W along the narrow belt between main boundary thrust (MBT) and main central thrust (MCT).
- The depth of most of the earthquake lies between 10-29km.
- In last 100 years, 4 major earthquakes accommodate the slip of Indian plate towards Tibet, but in the area between 1905 and 1934 earthquake there is no large earthquake since 1255 earthquake. So, this area of seismic gap seems to be the most vulnerable area for the large future earthquake.

G. Seismic hazard of Nepal



- Nepal lies in seismically vulnerable zone. It is in the boundary of the two colliding tectonic plates- the Indian plate (Indo-Australian Plate) and the Tibetan plate (Eurasian Plate) which is known as "Subduction Zone". Records of earthquakes are available in Nepal since 1255 A.D. Those records reveal that Nepal was hit by 18 major earthquakes since then, resulting in huge loss of life and property. Out of these earthquakes, the 1833, 1934, 2015 earthquakes were the most destructive ones.
- Most of houses are not earthquake resistive.
- A seismic zoning map of Nepal has been prepared to help in design of buildings.
- The seismic zones are based on geologic, tectonic, lithologic features and the observed as well as potential earthquake occurrences and elaborate analysis of their mutual relationship.

15.2 Earthquake Effects

1. Ground effect

The characteristics parameter like intensity, duration etc. of seismic ground vibrations depends upon the magnitude of earthquake, its depth of focus, distance from the epicenter, properties of soil or medium through which the seismic waves travel and the soil strata where the structure stands.

Earthquake induced ground effects has been observed in the form of ground rupture along the fault zone, landslide, settlement, and soil liquefaction as briefly described below.

a) Surface faulting

- Surface faulting along the fault zone may be of very small extent or may extent over hundreds of kilometers.
- Ground displacement along the fault may be horizontal, vertical or both and may be a few centimeters or meter.
- Obviously, a building directly traversed by such a rupture will be severely damaged or collapsed.

b) Liquefaction settlements

- Liquefaction is a type of ground failure which occurs when saturated soil loses its strength and collapses or becomes liquefied.
- It is more prominent if the foundation soil consists of uniform loose sands within a depth of about 8m below the ground surface and is either fully saturated by or submerged under water.
- The building resting on such ground may tilt or sink and may collapse.
- Seismic shaking may cause sinking or tilting or cracking or collapse of building when soil is compacted or consolidated.
- Certain types of soils, such as alluvial or sandy soils are more likely to fail during an earthquake due to liquefaction.

c) Landslides

- Earthquakes causes landslides where the hill slopes are unstable due to badly fractured rocks or consists of loose material.
- The effect is more pronounced in rainy season when the soil is wet than in dry season.

d) Rock fall

- In fractured rock areas, the earthquake can also cause rock fall when riskily supported rock pieces or boulders are shaken loose and roll down the hill slopes and damage buildings or infrastructure.

2. Effects of earthquake on buildings

- The primary effect of an earthquake is shaking of a building or infrastructure.
- During an earthquake, a building is shaken in all possible directions.
- The shaking loosens the joints of different components of building that leads to subsequent damage or collapse.

3. Causes of failure

a. Failure mechanism of building.

- Building as a whole and all their components and contents are badly shaken during severe earthquakes.
- Since earthquakes are earth movements which causes the ground to move under a building, the forces which occur in a building come from the inertia of its own mass. Therefore, the force is proportional to the mass. Hence, heavier the building, the more will be the inertia force i.e., the earthquake load on the building.
- Inertia force caused on any mass (m) can be described by the formula F= ma where a= acceleration effectively acting on mass m.

b. Failure mechanism of masonry building.

- The seismic behavior of masonry building during an earthquake generated vibration strongly depends upon how the walls are interconnected and anchored at the floor and roof level.
  - In the case of masonry buildings where the walls are not interconnected with the help of timber or any other means at junctions, the individual walls tend to separate along the joints or intersections.
  - Vertical cracks occur near the corner either in the side wall or in the adjacent end wall. Under these conditions the vibration of the walls become uncoupled, and walls might collapse.
  - If ties are placed or reinforced and concrete tie beams are cast at the floor levels, the vibration of the walls becomes synchronized.
  - However, in this case, the out of plane bending of the walls takes place again, reducing the resistance of the building.
  - Behavior of the masonry building is improved when walls are connected by means of rigid RCC slabs.
  - In this case, vibrations of the walls are synchronized, and the out of plane bending of wall is less significant. The building behaves like a box and the walls contribute to resistance of the building.

c. Failure mechanism of RCC framed building

RCC framed building fails during large earthquakes due to the following reasons.

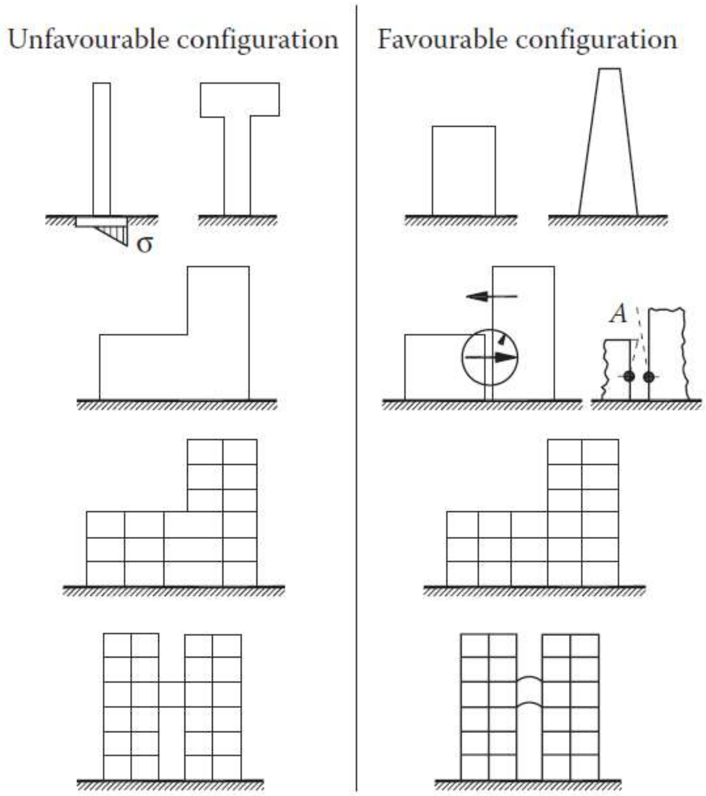
- Columns are overstressed and burst if there is not enough strength.
- Failure of RCC elements at the place of poor ductile detailing.
- Collapse of cladding, partition walls and infill walls.

Cause of damage of building

- Inadequate resistance to horizontal ground shaking.
- Soil amplification.
- Permanent displacement (Surface faulting and ground failure)
- Irregularities in elevation and plain.
- Lack of detailing and construction material.

15.3 Building forms for earthquake resistance

A. Building configuration



The behavior of a building during earthquake depends critically on its overall shape, size and geometry. The choices of shapes and structural system have significant behaving on the performance of the building during strong earthquake.

- The building should be planned to be as symmetrical as possible.
- Simple rectangular shaped building behaves better in earthquake than irregular building with projections.
- Length of block shall not be greater than three times its width to avoid torsional effects which are pronounced in long narrow rectangular blocks.
- Separation of a large building into several blocks may be required to obtain symmetry and regularity of each block.
- The separation can be behaved as an expansion joint which may be filled with a weak material which would easily crush or damage itself without damaging building during earthquake shaking.
- Ornamentation involving large cornices, vertical or horizontal cantilever projections, facia stones etc. must be reinforced properly which shall embedded into the main structure of the building.
- The distribution of stiffness both in plan and over the building height should be as uniform as possible.
- Mixed structural systems, combining masonry load bearing system with RCC load bearing system both in plan and over the height of the building should be avoided.
- The location of load bearing walls or RCC columns shall not be shifted in upper storey. These should be truly vertical and align in a line.

B. Height and number of storeys

The floor height and number of storeys should be limited according to the structural system and construction material.

The floor height of the building is determined as the vertical distance between two consecutive floors.

C. Distribution of load bearing elements

- To have a satisfactory performance of a masonry building, its wall must be uniformly distributed in both the orthogonal directions, sufficient in number and strength to resist earthquake load.
- Walls must be firmly connected together to the floor's roofs, which must be able to act as rigid diaphragms.
- Similarly, columns of a RCC framed building should be oriented in both the direction unless these are square.
- The walls of the masonry building can be defined as follows
    - i. **Structural wall** carrying their own weight together with the vertical and horizontal loads acting on the building.
    - ii. **Nonstructural** walls having exclusively the function of partitioning the building space. Their own weight is transferred by means of floors to the structural walls.
- To obtain satisfactory performances for different masonry system, the distances between the structural walls should be limited within the limiting value.
- Using the above recommended values, the resulting structural layout, however, should be verified by calculation.
- Limiting factors may be the vertical load- bearing capacity and the out-of-plane bending capacity of these walls. If the distance is more than the recommended distance the walls should be laterally supported as shown in figure above.
- Subdividing internal space to reduce length of walls enhances seismic behavior of building.
- But if the functional requirement do not permit the use of cross walls, longer walls must be supported by introduction of RCC columns or external buttresses at spacing not more than 4m in adobe or stone in mud, 5m in case of brick in mud and 6m in case of brick in cement mortar.

Location and size of door and window opening

Openings in walls are a source of weakness and tend to change the behavior of the wall and consequently the building itself. Unsymmetrical position of opening in symmetrical building may introduce structural unsymmetrical which is not desirable under seismic conditions. Size and position of opening have strong effect on the earthquake resistance of the masonry as well as RCC framed structure buildings.

To improve behavior of building, the following recommendations should be observed.

- Openings should be located symmetrically with respect to building configuration in plan in both directions of the building.
- Openings in opposite walls should be balanced as far as possible.
- Openings should be located outside the zones of direct influence of concentrated loads at beam support.
- Openings should be located at the same position in each storey.
- Top of the openings should be at the same horizontal level.
- Opening should not interrupt floor tie beam.
- Opening should be located away from room corners.
- Arches that span over openings should be avoided unless steel ties are provided.

D. Mass and stiffness distribution in buildings

During an earthquake, failure of structure starts at points of weakness. Generally, weakness is the result of the non-regular geometry, mass discontinuity, and stiffness of the structure. The structures having these parameters are termed irregular structures. Past earthquakes have revealed that the major reason for the failure of structures is irregular configuration.

Mass and stiffness are two basic parameters to evaluate the dynamic response of a structural system under vibratory motion. High-rise multistoried buildings are behaved differently depending upon the various parameters like mass stiffness distribution, foundation types, and soil conditions. The dynamic behavior of a building, when an earthquake is shaking, depends on the variation of the parameters of the building structure which are its mass, stiffness, and damping value.

The following conclusions were obtained from earthquake analysis on mass and stiffness distribution in the RCC buildings:

- **a.** Axial forces and base shear rise as column stiffness increases.
- **b.** More mass in the top level will result in more lateral displacements there, which will raise the building's lateral force.
- **c.** While adding mass to the lower stories would reduce the buildings' lateral displacement, it will also increase the need for rebar and base shear.
- **d.** Inconsistencies should be avoided, but if they must exist, they should be incorporated close to the building's base rather than at the top.

CHAPTER 16: Building planning and Building Services

16.1 Site Selection

Factors to be considered for selection of site for residential, public, Commercial, and Industrial Building.

A. Site selection for residential buildings

There are many factors that must be considered while selecting a site for residential buildings. Some of these factors are given below.

i. Shape of the plot

The geometry of the plot for any kind of construction is very important which can largely affect the appearance of your structure. The shape of the plot should be such that the construction can be easily made with the cost low as possible. And in the future, you can further expand it. A plot with more routes will be considered a good one.

ii. Location of the plot

The surrounding area of the residential plot is very important. It affects the price and the beauty of the plot. The plot should be taken in the area provided with a lot of services. And in a suitable environment free from all kinds of pollution. Efforts should be made to buy it near to the main road. Because such plots are more valuable as compared to the plots situated away from the main road.

iii. Availability of amenities

Plot for a residential building should be taken in the area provided with many numbers of amenities. Such as electricity, Telephone, Fax, Internet, Gas, schools, Colleges, universities, etc. and the most important is the good and fast transport system. So that communication becomes faster and quicker.

iv. Water table

The water table at the site of the residential building should not be very high. Otherwise, it will affect the quality of water which are used for drinking and domestic purposes. A plot with a normal water table will be preferred as compared to other plots having a high-water table.

v. Sewerage system

There should be a proper sewerage system at the site of residential plots. So that the extra water from houses can easily be drawn out, especially in rains and floods. If in case, there is no sewerage system the dirty water affects the building and as well the occupants as well.

B. Site selection for public buildings

The site selection of public buildings depends upon the nature of buildings (i.e., schools, hospitals, offices, police stations, etc.).

I. School building

- The school site is the first and foremost educational tool in providing quiet, healthy, and pleasant environment.
- The surround must be calm, quiet, peaceful, and cheerful with adequate natural breeze and sunlight.
- Easily accessible from existing and newly settled area.
- It should be away from busy traffic.
- No public road or railway passes through it.
- It should not be in proximity of pond, river or deep It located in sloping and well drained area.
- No high-tension line should pass through the area

II. **Hospital buildings**

- A general hospital should be located centrally in a quiet place which is well connected by effective means of transport.
- Substantially extra land should be available for future expansion.
- Site should be located away from busy city area.
- Health environment without pollution.

C. Site selection for commercial buildings

The following are the few factors that must be taken into account while selecting a site for commercial buildings:

i. **Location**

The value of a commercial building depends upon its location, whether it is in the center of the region or at the borders or on the main road, or away from the main road. For a good commercial building, it should be on the main road and in the center of the region.

ii. **Climate of Region**

The strength and stability of a building mainly depend upon the climate of the region in which it is going to be constructed. As commercial buildings are very important and expensive from economic points of so they must be constructed according to the terms and conditions of the region. So that it can remain safe from floods, rains, snowfalls, etc.

iii. **Availability of Raw materials**

Usually, commercial buildings require more construction materials as compared to a normal residential house. So, before the construction of the commercial building, it must be sure that raw materials are available nearby. Otherwise, it will become uneconomical.

iv. **Cost and time frame**

Before the construction of the commercial, a thorough investigation should be made of the cost and time frame for the commercial building. Cost and time frame mainly depends upon the location and the availability of Raw materials.

v. **Populations of the region**

Commercials building are constructed to meet the need of the local population. So for this purpose, it must be constructed in a region having a sufficient population in which the commercial building can restore its cost.

D. Site selection for industrial buildings

i. Site should be located on an arterial road.
ii. Local availability of raw material.
iii. Facilities like water supply electricity.
iv. Topography of an area
v. Soil conditions with respect to foundation design.
vi. Waste disposal facilities
vii. Transportation facilities
viii. Sufficient space for storage of raw materials.

16.2 Basic Principle of Building Plannin of Planning and Arrangement of Doors and Windows for Residential Building

A. Basic principle of building planning

The basic objective of planning buildings is to arrange all the units of the bobbing all the level according to their functional requirements making the best use of the space available for a building.

The shape of such a plan is governed by several factors such as climatic conditions, site location, accommodation requirements, byelaw, surrounding environments, etc.

Factors considered in planning

a) Aspect

Aspect means peculiarly of the arrangement of doors and windows in the external walls of a building which allows the occupants to enjoy the natural gifts such as sunshine, breeze, scenery, etc. likely to make its own person who looks it

b) Prospect

Prospect is the impression that a house is from the outside.

c) Privacy

Privacy is one of the important principles in the planning of buildings of all types in general and residential buildings.

d) Grouping

Grouping means the disposition of various rooms in the layout in a typical fashion so that the rooms are placed in the proper correlation of their functions and in proximity with each other.

e) Sanitation

Sanitation consists of providing ample light, and ventilation facilities for cleaning and sanitation conveniences.

f) Circulation

It means the movement space provided on the same floor (horizontal and between the different floors. (Vertical circulation)

g) Economy

Building should have a minimum floor area with maximum utility. It should not achieve at the cost of strength. Only with proper planning and utility of space being maximized.

h) Practical consideration

Strength and stability of structure with convenience and comfort.

i) Flexibility

As the need of owners and occupants change, the building must be flexible.

j) Elegance

Related to architectural effect.

B. Arrangement of doors, and windows for residential building

Openings in walls are a source of weakness and tend to change the behavior of the wall and consequently the building itself. Past earthquakes have revealed a strong effect of the size and the unsymmetrical which is not desirable under seismic conditions. Hence, to improve behavior of buildings, the following recommendations should be observed:

- Openings should be located symmetrically with respect to building configuration directions of the building
- Openings in opposite walls should be balanced as far as feasible.
- Openings should be located outside the zones of direct influence of concentrated loads at beam support.
- Openings should be located at the same position in each story.
- Top of the openings should be at the same horizontal level.
- Openings should not interrupt floor tie beams.
- Openings should be located away from room corners.

- Arches that span over openings should be avoided unless steel ties are provided.

16.3 Orientation of Building in Relation to Sun and Wind, Direction, Rains, Internal Circulation, and Placement of Rooms Within the Available Area

Orientation of building is the term to define the setting or fixing the direction of the layout plan of a building with respect to the north. In the case of a building non-square in the plane, the orientation is indicated by the direction of the normal long axis of the building. Thus, if a building plane is sited in such a manner that its length is parallel or along the east-west axis, such a building is termed to have a north south orientation.

a) **Slope and solid consideration**
Consider both long term storm water and short-term erosion impacts during construction. A void very steep slope.
b) **Site plan**
Bioclimatic design, slopes to the south allow for plenty of solar access while north- facing scopes will provide good shading.
c) **Solar energy**
d) **Proximity of trees to building**
Growth rate, life span of nearby trees should be considered.
e) **Account prevailing winds**
f) **Driving and parking**
Located on east or north side of the building in summer and south and west in winter.

Factors affecting orientation

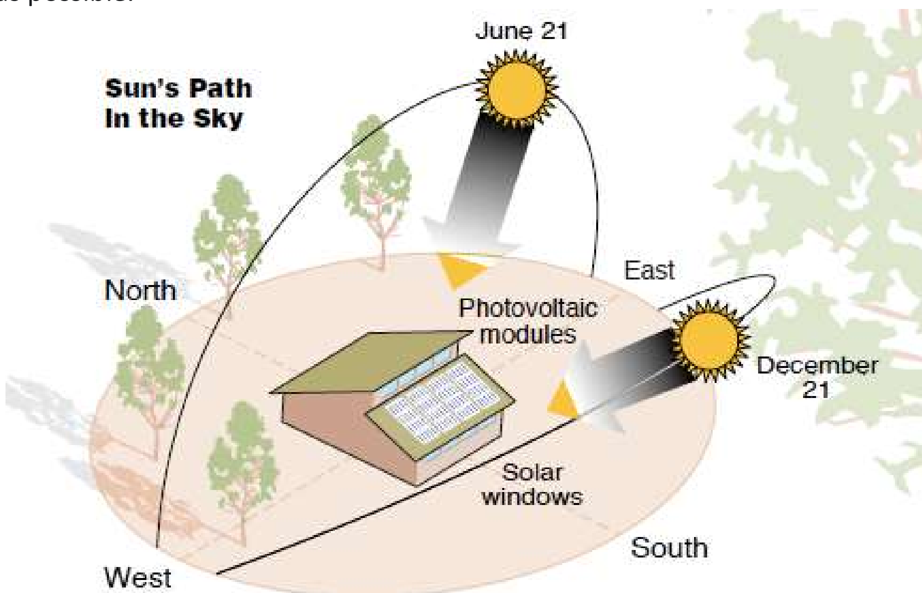
a) **Sensory**
Thermal, visual, acoustical, and environmental west in winter.
b) **Psychological**
Views, privacy, street activity.
c) **Land development patterns**
Street direction, spatial organization, land use, urban design.
d) **Accessibility requirement**
Main/secondary entrances, parking.
e) **Other consideration**
Aesthetic, direction of storms, site condition, site vegetation, view corridors, etc.

Following are the main factors to be considered for best orientation of building.

a) **Sun path**
The orientation of building should be fixed in such a way that the sunlight should enter all parts of the building through doors, windows, and ventilators. Various germs take birth in those rooms where sunlight does not enter. These germs become the cause of various diseases.
b) **The direction of roads street**
Orientation is also much affected by the direction of the road or street. If some plot is situated between two paths, then the front view of the building should be to the side of the major path.
c) **Surroundings**
Surroundings should also be considered in the orientation of building. It also includes the method of their construction, ways of living of the neighbors.

- **d) Wind direction**
  The direction of wind blowing throughout the year should also be kept in mind, favorable and unfavorable winds should also be considered.
- **e) Nature of rainfall**
  Humidity affects a building very much. Therefore, the direction of rainfall should be examined.

So, in the building orientation, it should be kept in mind that the smaller part of the building should be affected as far as possible.



16.4 Planning of Building Services

Planning is the process of providing a safe, healthy, economic, and hygienic atmosphere in and around of building for human habitation. Planning a building is the assembling or grouping and arranging of its component parts in a systematic manner and proper order to form a meaningful wholesome and homogeneous body with a comprehensive lookout to meet its day-to- day functional purpose.

Points to be kept in mind while planning

- **a)** Planning should be according to the functional objects and requirements.
- **b)** General scope and purpose of the building.
- **c)** Legality of ownership right, local rules, and financial status, etc. considered.
- **d)** A double-storied building providing the same floor area as that of the singles story is cheaper by about 15% to 20%.
- **e)** Local byelaws and rules should be considered.
- **f)** Climatic conditions of the area should be considered.
- **g)** A square and circular plan are cheaper and more compact.
- **h)** Plan should be according to the shape of the plot.
- **i)** Relationship between different rooms and their sizes should be considered.
- **j)** Availability of materials and methods.
- **k)** Topography of the plot.
- **l)** A square plan is cheaper than an oblong plan. The area occupied by walls of a square building maybe 15% to 25% less than a rectangular plan.
- **m)** A square plan makes a house compact. It makes the house cooler in the summer season and warmer in the winter season. Since fewer walls are exposed. Hence a sequence plan is always preferred.

According to the planning acts the main objects of planning may be summarized in three words.

a) **Health**
   To create and promote healthy conditions and the environment for all people.
b) **Convenience**
   The object of convenience is meant in the form of various needs of the community such as social, economic, cultural, and recreational amenities, etc.
c) **Beauty**
   To preserve the aesthetics in the design of all elements of the town and city planners which included the preservation of trees, ancient architectural buildings of cultural and historical importance, and building of worship.

Factor governing planning

The factors or principles which govern the theory of planning are detailed as shown below.

a) Aspect
b) Prospect
c) Privacy
d) Furniture requirement
e) Roominess
f) Grouping
g) Circulation
h) Sanitation
i) Flexibility
j) Elegance
k) Economy
l) Practical Consideration

16.5 Introduction to National Building Code

National building code

This National Building Code provides both regulations and guidelines for the construction of buildings in all areas of Nepal. NBC was formulated in 1994. It has 23 parts. The four different levels of sophistication of design and construction that are being addressed in this National Building code are:

- International state-of-art
- Professionally engineered structures
- Buildings of restricted size designed to simple rules-of-thumb
- Remote rural buildings where control is impractical

Hierarchy of building codes

- NBC 000: Requirements for State-of-the-Art Design: An introduction
- NBC 101: Material Specifications
- NBC 102 Unit Weight of Materials
- NBC 103: Occupancy Load (Imposed Load)
- NBC 104: Wind Load
- NBC 105: Seismic Design of Building in Nepal
- NBC 106: Snow Load
- NBC 107: Provisional Recommendation on Fire Safety
- NBC 108: Site Consideration for Seismic Hazards
- NBC 109: Masonry: Unreinforced
- NBC 110: Plain and reinforced Concrete
- NBC 111: Steel NBC 112: Timber
- NBC 113: Aluminum
- NBC 114: Construction Safety
- NBC 201 :: Mandatory Rules of Thumb: Reinforced Concrete Building with Masonry Infill
- NBC 202: Mandatory Rules of Thumb: Load Bearing Masonry
- NBC 203: Guidelines for Earthquake Resistant Building Construction: Low Strength Masonry

- NBC 204: Guidelines for Earthquake Resistant Building Construction: Earthen Building
- NBC 205: Mandatory Rules of Thumb: RC Buildings Without Masonry Infill
- NBC 206: Architectural Design Requirements
- NBC 207: Electrical Design Requirements for Public Buildings
- NBC 208: Sanitary and Plumbing Design Requirements

Procedures for implementation of building code in Nepal

- Any person, body, or government body shall build the buildings in consonance with the standards set in the NBC.
- The building shall be built under the supervision of a designer or his/her representative, engineer, or architect whose rank is at least the same as that of the designer, engineer, or architect who has certified the map and design of that building.
- A person, body, or government body who desires to build a building of category A, B, or C shall take approval from the municipality.

Classification of Buildings:

For the formulation and implementation of the building code, the buildings shall be classified into the following four categories:

a) **Category A**
Modern building to be built, based on the international state-of-the-art, also in pursuance of the building codes to be followed in developed countries.

b) **Category B**
Buildings with a plinth area of more than one thousand square feet, with more than three floors including the ground floor, or with a structural span of more than 4.5 meters.

c) **Category C**
Buildings with a plinth area of up to one thousand square feet, with up to three floors including the ground floor, or with a structural span of up to 4.5 meters. 9 Amended by the First Amendment.

d) **Category D**
Small houses, sheds made of baked or unbaked brick, stone, clay, bamboo, grass, etc., except those set forth in clauses (a), (b) and (c).

16.6 Introduction to Firefighting Systems, Ducting for Air-Conditioning, Service Lines for Cable Telephone, and Electrical Wiring, Garbage Disposal Systems

A. Introduction to firefighting systems

- A building may be made more fire resistant by minimizing use of combustible materials, protecting steel by fire resistant paints, and providing stairs at suitable positions and protecting them from fire.
- Fire protection requirements for multistoried buildings.

Various members of buildings can be made fire resistant as follows:

Walls: A Brick wall with cement plaster gives better fire resistance

Roof: RCC flat roofs have good fire resistance. Hence, they should be preferred.

Ceiling: Ceilings should be made up of cement plaster, asbestos cement board or fibber boards.

Floors: RCC floor is very good fire resisting floor.

Doors and Window Openings: All these openings should be protected against fire by taking the following precautions.

i. The thickness of shutters should not be less than 40 mm.
ii. Instead of wooden, aluminum or steel shutters should be preferred.
iii. They should be provided with fireproof paints.

Stairs: Wood should be avoided in the staircases. To minimize fire hazard, stairs should be centrally placed in the buildings so that people can approach them quickly. More than one staircase is always preferable. Emergency ladder should be provided in the building.

Structural design: It should be such that under worst situation, even if part of the structure collapses, it should be localized, and alternate routes are available for escape.

Fire alarm system and fire extinguishers

- All-important building should be provided with fire alarm system. Alarm may be manual or automatic. Automatic alarm senses the smoke and activates bells.
- Fire extinguishers should be provided at all strategic points in the buildings. The common fire extinguishers are as follows.

i. **Manual**
Carbon dioxide type portable fire extinguishers are commonly used. Sometimes buckets of water, sand and asbestos blankets are kept ready at all possible places where fire is likely to catch.

ii. **Internal hydrant**
The hydrant should be in and around the buildings so that water is available easily for firefighting.

iii. **Automatic water sprinkler**
In the buildings vulnerable for fire like textile mills, paper mills automatic water sprinklers are installed. As the fire takes place the sprinkling of water is automatically activated from the piping system containing water under pressure.

Fire escapes

Every building more than five storied high shall have a separate fire escape having a minimum width of 75 cm. The fire escape shall have a minimum tread width of 20 cm and each riser shall be not more than 19 cm high. The number of risers per flight shall not be more than 15. Such a fire escape shall carry users towards an open space.

Exit doors

- Exit doors shall open to a passageway or to a corridor.
- They should open outwards, but without restricting the movement of people passing outside the door.
- The maximum distance of such an exit doorway from any point in a passage shall be 20 m.
- The exit doorway shall neither be smaller than 90 cm in width, nor 180 cm in height.

The following factors are adopted to limit fire spread in homes:

a) **Firefighting equipment**
The suitable equipment for detecting, extinguishing, and warning of fire should be placed in the buildings. This equipment should be located at such places that they are easily accessible.

b) **Materials of construction**
The structural and non-structural elements of the buildings such as floors, partitions, roofs, walls, doors, windows, etc. Should be constructed of fire resisting materials.

c) **Means of escape**
Suitable means of escape should be provided when fire occurs in the buildings. The means of escape are mainly considered in the designs of cinemas, theatres, town halls, factories, etc.

d) **Protection of openings**
The opening should be sufficiently protected by using fire resistant Inlet fresh doors and windows to limit the fire. The area of the openings should not be excessive.

e) **Subdivision**

It is desirable to subdivide large buildings into small compartments to reduce the chances of spreading the fire into the whole building. In case of industrial buildings, high risk areas should be isolated from others.

B. Ducting for Air-conditioning

Air-conditioning system: Air conditioning refers to the process of controlling and maintaining the air with respect to humidity, temperature, odour, bacteria, dust content etc. So as to make the air suitable for human needs or industrial requirements.

The basic principle of air conditioning involves removing the stale hot air and filling is with fresh, chilled, dry air. The hot air is expelled normally to the outside atmosphere. Air conditioning of buildings results in comfortable, active, and efficient environment.

Elements of air conditioning: In general, air conditioning consists of following basic elements process.

a) **Filters**

Filters are required to remove dust, bacteria etc. from the incoming air. The filters should be cleaned regularly for efficient working of air conditioners. Various types of filters such as dry filters, viscous filters, water sprays etc. are used in air conditioning.

b) **Cooling**

In summer or hot climate, the air is to be cooled appropriately before its entry in the room, the cooling is generally done by mechanical refrigeration, cold water or water spray systems.

c) **Heating**

In winter or very cold climates, it is essential to heat the air before its entry into the room to make the atmosphere comfortable. Heating of air is generally done with the help of passing hot water or steam around the coils or some other heating arrangements like warm air, furnaces, etc.

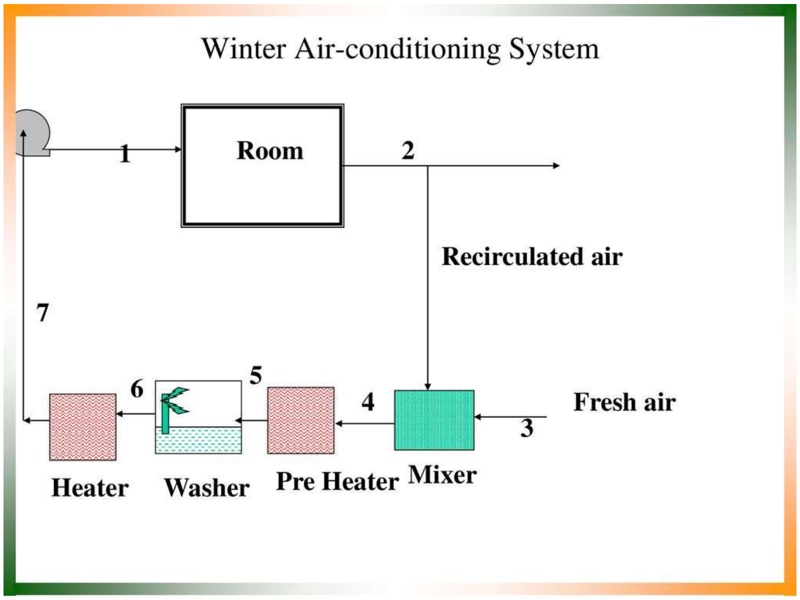
d) **Humidification**

Humidification is the process of adding the required amount of moisture to the air by passing it through wet cloth or containers of water. The humidification of air is required in winter when the air becomes too dry.

e) Dehumidification

Dehumidification is the process of removing the required amount of moisture from the air when the humidity is high.

The figure below explains the various steps of air conditioning.



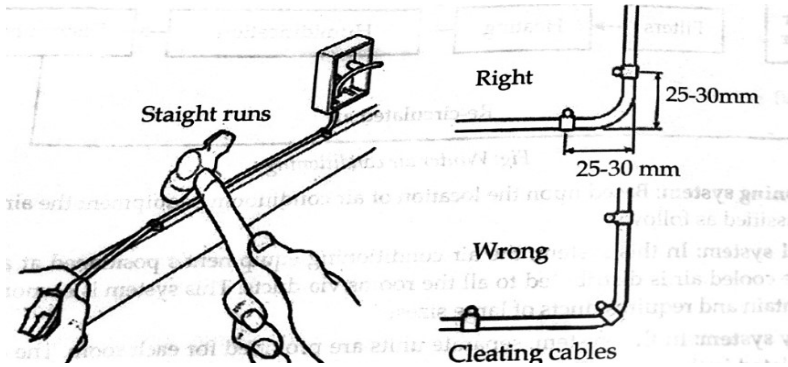
Air conditioning system:

Based upon the location of air conditioning equipment the air conditioning system is classified as follows:

a. **Central system**
   In this system, the air conditioning equipment's positioned at a central place and the cooled air is distributed to all the rooms via ducts. This system is economical and easy to maintain and requires ducts of large sizes.
b. **Unitary system**
   In this system, separate units are provided for each room. The conditioned air is circulated in the room. This system does not require any duct.
c. **Unitary central system**
   It is a combination of the two systems mentioned above. In this system, a heating or cooling unit is provided in each room which gets conditioned air supplied from a central unit. In another arrangement, each room is provided with an air conditioning unit that gets its supply from a central system.
   Note: *This system results in a reduction in the sizes of ducts.*

C. Service lines for cable telephone

- House cable wiring uses cable containing 6x05mm diameter solid conductors.
- It is important that this size of wire is used, or a good electrical connection cannot be guaranteed and there could be problems in the future with the system.
- Never use stranded wire, mains cable, or bell wire.
- Run the cables to due Extension socket positions in accordance with your plan.
- Cable through each socket box entry hole and leave about 200mm (8") of cable spare at the socket.
- When fixing the cable, take care not to puncture or damage it in any way. The damaged cable may cause faulty operation or damage to the system and must be replaced, not taped up.
- On straight run it is easier to fix the cable at one end of the cable run, pull the cable tight, and fix the other end and then insert intermediary cleats at approximately 300mm (12") intervals.



D. Service lines for electrical wiring

Basically, Electrical is a module of designing for rooting or connecting the electrical and electronic systems throughout your Building Industry. Plants and Factory.

Introduction

a. Design of a large building is an extremely complex task. It may take months, even years, and may include several engineers, supervisors, Foremen, and technicians.

b. The designing of a residential building is much simpler and may involve as few as one or two engineers.

c. The design of an electrical system for large projects is the responsibility of the electrical consultant company. Consultant people may also carry out other duties such as cost estimation bills of quantity, Bill of material and field supervision of installation.

d. Each of the tasks will be performed in coordination with the Architects or senior MEP Engineer who will carry out overall building planning and designing.

e. Coordination of work between the architects and other departments is an important and difficult task.

f. An error in coordination will give you bad results.

Designing of Electrical system involves

a. Survey of area and type of structure.
b. Total connected load (TCL)
c. Single-line diagram (SLD) or one-line diagram (OLD)
d. Number of lighting fixtures required.
e. Number of sockets required
f. Transformer sizing
g. Diesel Generator sizing
h. UPS sizing
i. Battery sizing
j. Cable sizing
k. Voltage drop
l. Short circuit
m. Circuit breaker sizing
n. Tripping time of C.B
o. Load Balancing sheet D.B schedule for Lighting Load and Raw Power Load
p. Capacitor Bank Sizing
q. Earthing Calculation
r. Lightning arrestor
s. Bus bar sizing
t. Cable tray

Note: Basically, voltage drop calculation and short circuit calculation are usually done if required otherwise then this value will always be within the range.

Requirements to perform the electrical designing

- Architectural drawing
- Civil drawing or structural drawing
- Reflected ceiling plan (or false ceiling)

- Furniture drawing
- Design brief report

E. Service line for garbage disposal systems

All types of buildings shall be provided with a garbage collection point within the plot limits (property line) of a building or a garbage room at the ground floor level of the building for the garbage collection purposes.

The following are the requirements for the garbage room:

- **a.** It shall be located close to the adjacent road or alleyway, if there is no service route removing the containers and transporting them to the garbage collection vehicles. to facilitate.
- **b.** It shall have a door with a minimum width of 1.8-meter, rust proof with louvers or any other mechanical ventilation that opens outwards leading to the garbage loading area.
- **c.** The minimum height of the garbage room shall be 2.4 meters.
- **d.** It shall have a water supply directly connected to the network or from the distribution (pumping) tank.
- **e.** It shall be connected to the building's drainage network.
- **f.** It shall be provided with adequate lighting and ventilation system.
- **g.** All windows shall be airtight and protected by a metal mesh wire screen to prevent insects and rodents from getting into the room.
- **h.** Floors and walls shall be ceramic tiles, for easy cleaning.