# UNIT-I

## 1.0 Introduction
## 2.0 Building Materials

## 1.0Introduction to Civil Engineering

Civil engineering is the oldest branch of engineering which is growing right from the stone age of civilization. American society of civil engineering defines *civil engineering as the profession in which knowledge of the mathematical and physical sciences gained by study, experience and practice is applied with judgment to develop ways to utilize economically the materials and forces of the nature for the progressive well-being of man.*

## 1.1 Roles of Civil Engineering

- Plan new townships and extension of existing towns.
- Providing shelter to people in the form of low cost houses to high rise apartments.
- Laying ordinary village roads to express highways.
- Constructing irrigation tanks, multipurpose dams & canals for supplying water to agricultural fields.
- Supplying safe and potable water for public & industrial uses.
- Protecting our environment by adopting sewage treatment & solid waste disposal techniques.
- Constructing hydro-electric & thermal-power plants for generating electricity.
- Providing other means of transportation such as railways, harbor& airports.
- Constructing bridges across streams, rivers and also across seas.
- Tunneling across mountains & also under water to connect places easily & reduce distance.

**Management Techniques**: Civil engineers must manage men, materials and equipment sufficiently. Since huge funds are to be handled in civil engineering projects, a civil engineer must know the basics in financial management and legal obligations. Knowledge of management techniques is an asset to practicing civil engineer.

**Computer Applications**: Since the magnitude of designing the structures and storing information is increasing very fast nowadays civil engineers go for computer applications in planning and designing of structures. There is good number of civil engineering software commercially available.

## 1.2 Fields of Civil Engineering and their scope

The different fields of civil engineering and the scope of each can be briefly discussed as follows.

**1.2.1 Surveying**: It is a science and art of determining the relative position of points on the earth's surface by measuring distances, directions and vertical heights directly or indirectly. Surveying helps in preparing maps and plans, which help in project implementation. (Setting out the alignment for a road or railway track or canal, deciding the location for a dam or airport or harbor) The cost of the project can also be estimated before implementing the project. Now-a-days, using data from remote sensing satellites is helping to prepare maps & plans & thus cut down the cost of surveying.

## Types of Surveying

PLANE SURVEYING AND GEODETIC SURVEYING

The survey in which the shape or curvature of earth is not taken into account is called plane surveying. The survey in which the shape or curvature of earth is taken into account is called Geodetic surveying

SCOPE OF SUREYING

- To prepare the plan or map
- To determine the dimension and contour of any part of the earth's surface
- To establish boundaries of land
- To measure the area and volume of land
- To select suitable site for an engineering project

**1.2.2. Geo-Technical Engineering (Soil Mechanics)**: Any building, bridge, dam, retaining wall etc. consist of components like foundations. Foundation is laid from a certain depth below the ground surface till hard layer is reached. The soil should be thoroughly checked for its suitability for construction purposes. The study dealing with the properties &behavior of soil under loads & changes in environmental conditions is called geo-technical engineering. The knowledge of the geology of an area is also very much necessary.

SCOPE OF GEOTECHNICAL ENGINEERING

- Foundation design and construction
- Highway pavement design
- Design and construction of tunnels underground structure and drainages structures
- Design of retaining structures
- Design of earthen dams and embankment

**1.2.3. Structural Engineering**: A building or a bridge or a dam consists of various elements like foundations, columns, beams, slabs etc. These components are always subjected to forces. It becomes important to determine the magnitude & direction the nature of the forces and acting all the time. Depending upon the materials available or that can be used for construction, the components or the parts of the building should be safely & economically designed.

A structured engineer is involved in such designing activity. The use of computers in designing the members, is reducing the time and also to maintain accuracy.

SCOPE OF STRUCTURAL ENGINEERING

- Responsible for creation of structural system in accordance with the needs of the client and architect
- Plays an important role to build industrial production and manufacturing unit
- Keys main for total planning and designing of nuclear power plants.
- Take the responsibility about the safety and serviceability of the structure for its lifetime

**1.2.4. Transportation Engineering**: The transport system includes roadways, railways, air & waterways. Here the role of civil engineers is to construct facilities related to each one. Sometimes crucial sections of railways & roads should be improved. Roads to remote places should be developed. Ports &harbors should be designed to accommodate, all sizes of vehicles. For an airport, the runway & other facilities such as taxiways, terminal buildings, control towers etc. should be properly designed.

SCOPE OF TRANSPORTATION ENGINEERING

- Traffic management
- Parking facilities
- Rapid transportation
- Urbanization and industrialization
- Accident study for safe and comfort transport system

**1.2.5. Irrigation & Water resources engineering (Hydraulics Engineering)**: Irrigation is the process of supplying water by artificial means to agricultural fields for raising crops. Since rainfall in an area is insufficient or unpredictable in an area, water flowing in a river can be stored by constructing dams and diverting the water into the canals & conveyed to the agricultural fields. Apart from dams & canals other associated structures like canals regulators, aqua ducts, weirs, barrages etc. are also necessary. Hydroelectric power generation facilities are also included under this aspect.

SCOPE OF WATER RESOURCE ENGINEERING

- Flood mitigation
- Irrigation
- Hydroelectric power
- Domestic and industrial water supply
- Aquatic animal management

SCOPE OF IRRIGATION ENGINEERING

- Diversion of stored water to canal for distribution
- Lifting of water by digging wells and fed to small channels
- Development of hydroelectric power
- Increase in flood production
- Protection from famine
- Ground water storage improvement

**1.2.6. Water Supply and Sanitary Engineering (Environmental Engineering)**:

People in every village, town & city need potable water. The water available (surface water & ground water) may not be fit for direct consumption. In such cases, the water should be purified and then supplied to the public. For water purification, sedimentation tanks, filter beds, etc. should be designed. If the treatment plants are for away from the town or city, suitable pipelines for conveying water & distributing it should also be designed. In a town or city, a part of the water supplied returns as sewage. This sewage should be systematically collected and then disposed into the natural environment after providing suitable treatment.

The solid waste that is generated in a town or locality should be systematically collected and disposed off suitably. Before disposal, segregation of materials should be done so that any material can be recycled & we can conserve our natural resources.

**Scope of Environmental Engineering**

- Protection and conservation of environment
- Good water supply
- Waste water treatment
- Pollution treatment
- Solid waste management

**1.2.7. Building Materials & Construction Technology:** Any engineering structure requires a wide range of materials known as building materials. The choice of the materials is wide & open. It becomes important for any construction engineer to be well versed with the properties & applications of the different materials. Any construction project involves many activities and also required many materials, manpower, machinery & money. The different activities should be planned properly; the manpower, materials & machinery should be optimally utilized, so that the construction is completed in time and in an economical manner. In case of large construction projects management techniques of preparing bar charts & network diagrams, help in completing the project orderly in time.

**Classification of Building Materials**

**Traditional materials**

Stones, timber, bricks, lime, cement, tar, bitumen, mortar ,ferrous and non-ferrous metals, ceramic materials ,etc.

**Alternative Building Materials**

Mud –blocks, concrete-blocks, plastics, glass, aluminum, paints, fly ash, etc.

**Composite Materials**

RCC, fiber reinforcement concrete, ferro-cement, composite laminate doors, plastic laminates, asbestos sheets and fiber reinforced glass, etc.

**Smart Materials Or Intelligent Materials**

Optic fiber, piezoelectric material, electro-strictive and magneto-strictive materials etc.

**1.2.8. Town Planning and Architecture.** With the growth of population and industries new towns are coming up and existing ones are growing. Proper town planning is to be made by civil engineers. Structures should be aesthetically good also. Architecture covers this area. This field of civil engineering has grown up so much that it has become a separate branch of engineering.

## 1.3 Building Materials

### 1.3.1Bricks

Brick is the most commonly used building materials. It is light easily available, uniform shape and size, and relatively cheaper except in hilly areas. Bricks are easily mould from plastic clays, also known as brick clay or brick earth.

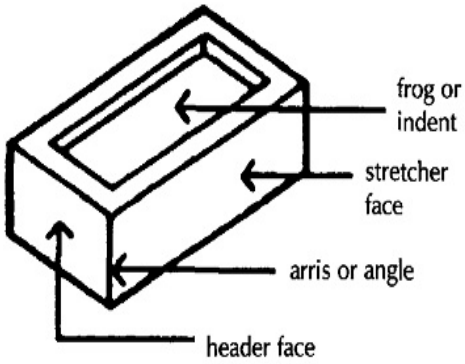



Fig.1.1 Brick

### Qualities of good bricks

The good bricks which are to be used for the construction of important structures should possess the following qualities

- The bricks should be table moulded, well-burnty in kilns, copper- colored, free from cracks and with sharp and square edges. The color should be uniform and bright.
- The bricks should be uniform in shape and it should be of standard size. For India, a brick of standard size *190 mm* x *90 mm* x *90 mm* is recommended by the BIS. With mortar thickness, the size of such a brick becomes *200 mm* x *100 mm* x *100 mm* and it is known as the nominal size of the modular brick.
- The brick should give a clear metallic ringing sound when struck with each other.
- The bricks when broken or fractured should show a bright homogeneous and uniform compact structure free from voids.
- The brick should not absorb water more than 20% by weight for first class bricks and 22% by weight for second class bricks, when soaked in cold water for a period of 24 hours.
- The brick should be sufficiently hard. No impression should be left on brick surface, when it is scratched with finger nail.
- The bricks should not break into pieces when dropped flat on hard ground from a height of about one meter.
- The brick should have low thermal conductivity. They should be sound proof.
- The bricks, when soaked in water for 24 hours should not show deposits of white salts when allowed to dry in shade.
- No brick should have the crushing strength below 5.50N/mm$^2$.

**Classification of Bricks Based on their Quality**

The bricks used in construction are classified as:

- First class bricks: These bricks are of standard shape and size. They are burnt in kilns. They fulfill all desirable properties of bricks.
- Second class bricks: These bricks are ground moulded and burnt in kilns. The edges may not be sharp and uniform. The surface may be somewhat rough. Such bricks are commonly used for the construction of walls which are going to be plastered.
- Third class bricks: These bricks are ground moulded and burnt in clamps. Their edges are somewhat distorted. They produce dull sound when struck together. They are used for temporary and unimportant structures.
- Fourth class bricks: These are the over burnt bricks. They are dark in color. The shape is irregular. They are used as aggregates for concrete in foundations, floors and roads.

**Engineering application of bricks**

Bricks are used in the following civil works:

- As structural unit, since the clay bricks or burnt bricks are strong, hard, durable and resistive to abrasion and fire.
- As aesthetic unit/ surface finish: Bricks can be used in different color, sizes and orientation to get different surface design. As an aesthetic material brick can be used in pavements, facing work and architectural purposes.
- For lining of ovens, furnaces and chimneys as it shows good fire resistance.
- For protecting steel columns from fire.
- As aggregates in providing water proofing to R.C.C. roofs.
- For pavers for footpaths and cycle tracks.
- For lining sewer lines.

Based on quality of brick

- First class and second class bricks are widely used for all sorts of sound work especially of permanent nature. These structures include buildings, dams, roads, sewers, bridge piers, tunnels, pitching works etc.
- Use of first class bricks are specified for obtaining the architectural effects on faces of structures where they are to be kept exposed for beauty.
- Masonry with second class bricks is generally plastered to make the smooth surface obtained due to the irregular shape and size of bricks. Mortar required in brick masonry using second class bricks will also be more.
- Third class and sun-dried bricks are used for construction work of temporary nature. These bricks are not used in damp situations or at places subjected to heavy rains.
- Forth class bricks are used as road metal and as aggregates in the foundation concrete.

**Advantages of Bricks**

- Economical (Raw material is easily available)
- Hard and durable
- Compressive strength is good enough for ordinary construction
- Different orientations and sizes give different surface textures
- Very low maintenance cost is required
- Demolishing of brick structures is very easy, less time consuming and hence economic
- Reusable and Recyclable
- Highly fire resistant

**Disadvantages of Bricks**

- Time consuming construction
- Cannot be used in high seismic zones
- Since bricks absorb water easily, it causes fluorescence when not exposed to air
- Very less tensile strength
- Rough surfaces of bricks may cause mold growth if not properly cleaned.
- Cleaning brick surfaces is a hard job.
- Color of low quality brick changes when exposed to sun for a longer period of time

### 1.3.2Stones

Stone is a 'naturally available building material' which has been used from the early age of civilization. It is available in the form of rocks, which is cut to required size and shape and used as building block.

Fig 1.2. Stones

**Properties of Stones**

The following properties of the stones should be looked into before selecting them for engineering works:

**Structure:** The structure of the stone may be stratified (layered) or unstratified. Structured stones should be easily dressed and suitable for super structure. Unstratified stones are hard and difficult to dress. They are preferred for the foundation works.

**Texture:** Fine grained stones with homogeneous distribution look attractive and hence they are used for carving. Such stones are usually strong and durable.

**Density:** Denser stones are stronger. Light weight stones are weak. Hence stones with specific gravity less than 2.4 are considered unsuitable for buildings.

**Appearance:** A stone with uniform and attractive color is durable, if grains are compact. Marble and granite get very good appearance, when polished. Hence they are used for face works in buildings.

**Strength:** Strength is an important property to be looked into before selecting stone as building block. Indian standard code recommends a minimum crushing strength of 3.5 $N/mm^2$for any building block. Table 1.1 shows the crushing strength of various stones.

Table 1.1:Crushing strength of common building stones

| Name of Stone | Crushing Strength in N/mm2 |
|---|---|
| Trap | 300 to 350 |
| Basalt | 153 to 189 |
| Granite | 104 to 140 |
| Slate | 70 to 210 |
| Marble | 72 |
| Sand stone | 65 |
| Lime stone | 55 |
| Laterite | 1.8 to 3.2 |

**Hardness:** It is an important property to be considered when stone is used for flooring and pavement. Coefficient of hardness is to be found by conducting test on standard specimen in Dory's testing machine. For road works coefficient of hardness should be at least 17. For building works stones with coefficient of hardness less than 14 should not be used.

Percentage wear: It is measured by attrition test. It is an important property to be considered in selecting aggregate for road works and railway ballast. A good stone should not show wear of more than 2%.

**Porosity and Absorption:** All stones have pores and hence absorb water. The reaction of water with material of stone causes disintegration. Absorption test is specified as percentage of water absorbed by the stone when it is immersed under water for 24 hours. For a good stone it should be as small as possible and in no case more than 5.

**Weathering:** Rain and wind cause loss of good appearance of stones. Hence stones with good weather resistance should be used for face works.

**Toughness:** The resistance to impact is called toughness. It is determined by impact test. Stones with toughness index more than 19 are preferred for road works. Toughness index 13 to 19 is considered as medium tough and stones with toughness index less than 13 are poor stones.

**Resistance to Fire:** Sand stones resist fire better. Argillaceous materials, though poor in strength, are good in resisting fire.

**Ease in Dressing:** Cost of dressing contributes to cost of stone masonry to a great extent. Dressing is easy in stones with lesser strength. Hence an engineer should look into sufficient strength rather than high strength while selecting stones for building works.

**Seasoning:** The stones obtained from quarry contain moisture in the pores. The strength ofthe stone improves if this moisture is removed before using the stone. The process of removing moisture from pores is called seasoning. The best way of seasoning is to allow it to the action of nature for 6 to12 months. This is very much required in the case of laterite stones.

**Requirements of Good Building Stones**

The following are the requirements of good building stones:

**Strength**: The stone should be able to resist the load coming on it. Ordinarilly this is not of primary concern since all stones are having good strength. However in case of large structure, it may be necessary to check the strength.

**Durability:** Stones selected should be capable of resisting adverse effects of natural forces like wind, rain and heat.

**Hardness:** The stone used in floors and pavements should be able to resist abrasive forces caused by movement of men and materials over them.

Toughness: Building stones should be tough enough to sustain stresses developed due to vibrations. The vibrations may be due to the machinery mounted over them or due to the loads moving over them. The stone aggregates used in the road constructions should be tough.

**Specific Gravity:** Heavier variety of stones should be used for the construction of dams, retaining walls, docks and harbours. The specific gravity of good building stone is between 2.4 and 2.8.

**Porosity and Absorption**: Building stone should not be porous. If it is porous rain water enters into the pour and reacts with stone and crumbles it. In higher altitudes, the freezing of water in pores takes place and it results into the disintegration of the stone.

**Dressing:** Giving required shape to the stone is called dressing. It should be easy to dress so that the cost of dressing is reduced. However the care should be taken so that, this is not be at the cost of the required strength and the durability.

**Appearance:** In case of the stones to be used for face works, where appearance is a primary requirement, its colour and ability to receive polish is an important factor

**Seasoning:** Good stones should be free from the quarry sap. Laterite stones should not be used for 6 to 12 months after quarrying. They are allowed to get rid of quarry sap by the action of nature. This process of removing quarry sap is called seasoning.

**Cost:** Cost is an important consideration in selecting a building material. Proximity of the quarry to building site brings down the cost of transportation and hence the cost of stones comes down.

**Engineering application of Stones**

- Stones are used in the following civil engineering constructions:
- Stone masonry is used for the construction of foundations, walls, columns and arches.
- Stones are used for flooring.
- Stone slabs are used as damp proof courses, lintels and even as roofing materials.
- Stones with good appearance are used for the face works of buildings. Polished marbles and granite are commonly used for face works.
- Stones are used for paving of roads, footpaths and open spaces round the buildings.
- Stones are also used in the constructions of piers and abutments of bridges, dams and retaining walls.
- Crushed stones with graved are used to provide base course for roads. When mixed with tar they form finishing coat.
- Crushed stones are used in the following works also:
    - As a basic inert material in concrete
    - For making artificial stones and building blocks
    - As railway ballast.

### 1.3.3Cement

One material which has completely revolutionized the construction industry is cement. It was in 1824, a mason of England by name Joseph Aspidin developed cement by burning at high temperature a mixture of lime and clay and then grinding it into fine powder. This is known as Ordinary Portland Cement.

Cement is a binder, a substance used in construction that sets and hardens and can bind other materials together. The most important types of cement are used as a component in the production of mortar in masonry, and of concrete, which is a combination of cement and an aggregate to form a strong building material.

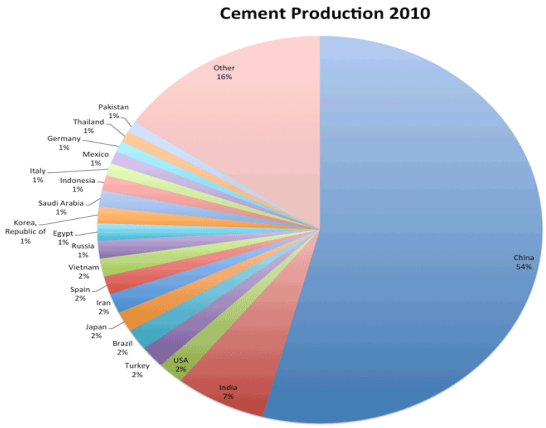



Fig 1.3 Cement Production Pie Chart

**Composition of Ordinary Portland Cement**

Table1.2: Composition of Ordinary Portland Cement

| Ingredient | Average (%) |
|---|---|
| Lime | 62 |
| Silica | 22 |
| Alumina | 5 |
| Calcium Sulphate | 4 |
| Iron oxide | 3 |
| Magnesia | 2 |
| Alkalies | 1 |
| Sulphur | 1 |

**Grades of Cement**

Cement is graded according to its compressive strength. Cement mortar of 1: 3 proportion is made and then cubes of surface area 50 sq cm is made and then tested after 28 days.

Table 1.3: Grades of Cement

| Cement type | Compressive strength ($N/mm^2$) |
|---|---|
| Grade 33 | 33 |
| Grade 43 | 43 |
| Grade 53 | 53 |

**Properties of Cement**

**Physical Properties**:

- **Fineness:**Finer cement particles impart better quality. It is measured in terms of percentage of weight retained after sieving the cement through 90 micron sieve or by surface area. According to IS code specification weight retained on the sieve should not be more than 10 per cent. In terms of specific surface should not be less than 2250 cm2/gm.
- **Soundness:** Once the concrete has hardened it is necessary to ensure that no volumetric changes takes place. The cement is said to be unsound, if it exhibits volumetric instability after hardening. It is determined by the Le Chatelier test.
- **Setting of cement:** When water is added to cement it forms a thick paste. Gradually as time passes, it transforms into a non-plastic rigid mass. The setting time is influenced by the amount of water added to the cement, the temperature at which the cement paste is allowed to set and the humidity of the atmosphere. The setting of cement is identified in two stages, initial setting and final setting. The setting time is determined in the laboratory by Vicat Needle Apparatus As per Bureau of Indian Standards (BIS), for ordinary cement , the initial setting time shall not be less than 30 minutes and the final setting time should not be more than 10 hours.

**Mechanical Properties:**

- **Compressive strength:** Cement mortar cubes of size 7.06 cm are made out of mortar of 1: 3 composition (1 part of cement to 3 parts of sand) and tested in a Universal compressive testing machine. Normally the tests are done after 3, 7 and 28 days.

- **Tensile strength:** Test pieces (briquettes) are made out of cement sand mortar 1: 3 and tested in a standard tensile testing machine after 3, 7 and 28 days.

Table 1.4:Tensile strength Cement

| Compressive and Tensile strength as per BIS | | | |
|---|---|---|---|
| Ordinary Portland Cement | Period | Strength | |
| | 3 days | Compressive | not less than 115 kg/sq cm |
| | | Tensile | not less than 29 kg/sq cm |
| | 7 days | Compressive | not less than 175 kg/sq cm |
| | | Tensile | not less than 35 kg/sq cm |

**Different Types of Cement and their applications**

**Portland Cement:** The most common use for Portland cement is in the production of concrete. Concrete is a composite material consisting of aggregate (gravel and sand), cement, and water. As a construction material, concrete can be cast in almost any shape desired, and once hardened, can become a structural (load bearing) element. Concrete can be used in the construction of structural elements like panels, beams, street furniture, or may make cast-*in situ* concrete for building superstructures like roads and dams. These may be supplied with concrete mixed on site, or may be provided with "ready-mixed" concrete made at permanent mixing sites. Portland cement is also used in mortars (with sand and water only) for plasters and screeds, and in grouts (cement/water mixes squeezed into gaps to consolidate foundations, road-beds, etc.).

**White Cement:** The cement when made free from colouring oxides of iron, manganese and chlorium results into white cement. In the manufacture of this cement, the oil fuel is used instead of coal for burning. White cement is used for the floor finishes, plastering, ornamental works etc. In swimming pools white cement is used to replace glazed tiles. It is used for fixing marbles and glazed tiles.

**Coloured Cement:** The cements of desired colours are produced by intimately mixing pigments with ordinary cement. The chlorium oxide gives green colour. Cobalt produce blue colour. Iron oxide with different proportion produce brown, red or yellow colour. Addition of manganese dioxide gives black or brown coloured cement. These cements are used for giving finishing touches to floors, walls, window sills, roofs etc.

**Quick Setting Cement:** Quick setting cement is produced by reducing the percentage of gypsum and adding a small amount of aluminium sulphate during the manufacture of cement. Finer grinding also adds to quick setting property. This cement starts setting within 5 minutes after adding water and becomes hard mass within 30 minutes. This cement is used to lay concrete under static or slowly running water.

**Rapid Hardening Cement:** This cement can be produced by increasing lime content and burning at high temperature while manufacturing cement. Grinding to very fine is also necessary. Though the initial and final setting time of this cement is the same as that of portland cement, it gains strength in early days. This property helps in earlier removal of form works and speed in construction activity.

**Low Heat Cement:** In mass concrete works like construction of dams, heat produced due to hydration of cement will not get dispersed easily. This may give rise to cracks. Hence in such constructions it is preferable to use low heat cement.

**Pozzulana Cement:** Pozzulana is a volcanic power found in Italy. It can be processed from shales and certain types of clay also. In this cement pozzulana material is 10 to 30 per cent. It can resistaction of sulphate. It releases less heat during setting. It imparts higher degree of water tightness. Its tensile strength is high but compressive strength is low. It is used for mass concrete works like dam, tall structures etc. It is alsoused in sewage line works.

**Expanding Cement:** This cement expands as it sets. This property is achieved by adding expanding medium like sulpho aluminate and a stabilizing agent to ordinary cement. This is used for filling the cracks in concrete structures.

**High Alumina Cement:** It is manufactured by calcining a mixture of lime and bauxite. It is more resistant to sulphate and acid attack. It develops almost full strength within 24 hours of adding water. It is used for under water works.

**Blast Furnace Cement:** In the manufacture of pig iron, slag comes out as a waste product. By grinding clinkers of cement with about 60 to 65 per cent of slag, this cement is produced. The properties of this cement are more or less same as ordinary cement, but it is cheap, since it utilize waste product. This cement is durable but it gains the strength slowly and hence needs longer period of curing Concrete.

**Acid Resistant Cement:** This cement is produced by adding acid resistant aggregated suchas quartz, quartzite, sodium silicate or soluble glass. This cement has good resistance to action of acid and water. It is commonly used in the construction of chemical factories.

**Sulphate Resistant Cement:** By keeping the percentage of tricalcium aluminate C3A below five per cent in ordinary cement this cement is produced. It is used in the construction of structures which are likely to be damaged by alkaline conditions. Examples of such structures are canals, culverts etc.

### 1.3.4 Plain Concrete

Plain concrete, commonly known as concrete, is an intimate mixture of binding material, fine aggregate, coarse aggregate and water. This can be easily mould to desired shape and size before it loses plasticity and hardens. Plain concrete is strong in compression but very weak in tension. The tensile property is introduced in concrete by inducting different materials and this attempt has given rise to RCC, PSC, FRC, cellular concrete and Ferro cement.

Major ingredients of concrete are:

- Binding material (like cement, lime, polymer)
- Fine aggregate (sand)
- Coarse aggregates (crushed stone, jelly)
- Water.
- A small quantity of admixtures like air entraining agents, water proofing agents, work ability agents etc. may also be added to impart special properties to the plain concrete mixture.


Fig 1.4. Plain Concrete

Depending upon the proportion of ingredient, strength of concrete vearies. It is possible to determine the proportion of the ingredients for a particular strength by mix design procedure. It is represented as x:y:z (say 1:1.5:3) which is the ratio of weights of cement to sand to coarse aggregate.

**Preparation of Concrete**

The following steps are involved in the concreting:

- Batching
- Mixing
- Transporting and placing and
- Compacting.
- Curing

**Batching:** The measurement of materials for making concrete is known as batching. The following two methods of batching is practiced:

- Volume batching
- Weight batching.

**Mixing:** To produce uniform and good concrete, it is necessary to mix cement, sand and coarse aggregate, first in dry condition and then in wet condition after adding water.

**Transporting and Placing of Concrete.** After mixing, concrete should be transported to the final position. In small works it is transported in iron pans from hand to hand of a set of workers. Wheel barrow and hand carts also may be employed. In large scale concreting chutes and belt conveyors or pipes with pumps are employed.

**Compaction of Concrete:** In the process of placing concrete, air is entrapped. The entrapped air reduces the strength of concrete up to 30%. Hence it is necessary to remove this entrapped air. This is achieved by compacting the concrete after placing it in its final position. Compaction can be carried out either by hand or with the help of vibrators.

**Curing of Concrete:** Curing may be defined as the process of maintaining satisfactory moisture and temperature conditions for freshly placed concrete for some specified time for proper hardening of concrete. Curing in the early ages of concrete is more important. Curing is done for 28 days. If curing is not done properly, the strength of concrete reduces. Cracks develop due shrinkage. The durability of concrete structure reduces. The following curing methods are employed:

- Spraying of water
- Covering the surface with wet gunny bags, straw etc.
- Ponding
- Steam curing
-

**Properties of concrete**

***Properties of green/fresh concrete***

**Workability:** This is defined as the ease with which concrete can be compacted fully without segregating and bleeding. It can also be defined as the amount of internal work required to fully compact the concrete to optimum density. The workability depends upon the quantity of water, grading, shape and the percentage of the aggregates present in the concrete.

**Segregation:** Separation of coarse particles from the green concrete is called segregation. This may happen due to lack of sufficient quantity of finer particles in concrete or due to throwing of the concrete from greater heights at the time of placing the concrete. Because of the segregation, the cohesiveness of the concrete is lost and honey combing results. Ultimately it results in the loss of strength of hardened concrete. Hence utmost care is to be taken to avoid segregation.

**Bleeding:** This refers to the appearance of the water along with cement particles on the surface of the freshly laid concrete. This happens when there is excessive quantity of water in the mix or due to excessive compaction. Bleeding causes the formation of pores and renders the concrete weak. Bleeding can be avoided by suitably controlling the quantity of water in the concrete and by using finer grading of aggregates.

**Harshness:** Harshness is the resistance offered by concrete to its surface finish. Harshness is due to presence of lesser quantity of fine aggregates, lesser cement mortar and due to use of poor graded aggregates. It may result due to insufficient quantity of water also. With harsh concrete it is difficult to get a smooth surface finish and concrete becomes porous.

***Properties of Hardened Concrete***

**Strength:** The characteristic strength of concrete is defined as the compressive strength of 150 mm size cubes after 28 days of curing below which not more than 5 per cent of the test results are expected to fail. The unit of stress used is N/mm2. It is represented as M20 where, M stands for design mix and 20 stands for strength of concrete.

**Dimensional Change:** Concrete shrinks with age. The total shrinkage depends upon the constituents of concrete, size of the member and the environmental conditions. Total shrinkage is approximately 0.0003 of original dimension

**Durability:** Environmental forces such as weathering, chemical attack, heat, freezing and thawing try to destroy concrete. The period of existence of concrete without getting adversely affected by these forces is known as durability. Generally dense and strong concretes have better durability. The cube crushing strength alone is not a reliable guide to the durability. Concrete should have adequate cement content and should have low water cement ratio.

**Impermeability:** This is the resistance of concrete to the flow of water through its pores.

Excess water during concreting leaves a large number of continuous pores leading to the permeability. Since the permeability reduces the durability of concrete, it should be kept very low by using low water cement ratio, dense and well graded aggregates, good compaction and continuous curing at low temperature conditions

**Application of Concrete**

- As bed concrete below column footings, wall footings, on wall at supports to beams
- As sill concrete
- Over the parapet walls as coping concrete
- For flagging the area around buildings
- For pavements
- For making building blocks.

However major use of concrete is as a major ingradient of reinforced and prestressed concrete. Many structural elements like footings, columns, beams, chejjas, lintels, roofs are made with R.C.C. Cement concrete is used for making storage structures like water tanks, bins, silos, bunkers etc. Bridges, dams, retaining walls are R.C.C. structures in which concrete is the major ingradient.

**1.3.5 Reinforced cement concrete**

Concrete is good in resisting compressive stress but it is very weak in resisting tensile stress. Hence reinforcement is provided in the concrete wherever tensile stress is expected. The best reinforcement is steel, since the tensile strength of steel is quite high and the bond between steel and concrete is good. As the elastic modulus of steel is as high as concrete, the force developed in steel is high. However in tensile zone, hair cracks in concrete are unavoidable. Reinforcement are usually in the form of mild steel or ribbed steel bars of diameter 6 to 32 mm diameter. A cage of reinforcements, kept in a form work and then green concrete is poured. After the concrete hardens, the form work is removed. The composite material of steel and concrete, now called R.C.C. acts as structural member and can resist tensile as well as compressive stress efficiently.

**Properties of concrete**

- It should be capable of resisting tensile, compressive, bending or shear stresses.
- It should not show excessive deflections to the serviceability requirement.
- There should be proper cover to reinforcement so that corrosion of steel is prevented
- The hair cracks developed should be with permissible limit.
- R.C.C is a good fire resistant 6. It can be moulded to desired shape and size.
- Durability of R.C.C. is very good. 8. R.C.C. structure can be designed to take any load.

**Uses of R.C.C.**

- R.C.C is used as a structural element, wherever direct tension or bending tension is expected. The common structural elements in a building where R.C.C is used are footing, columns, beams, lintels, chejjas, roof slabs, curved roofs etc, and stairs.
- R.C.C. is used for the construction of storage structures like water tanks, dams, bins, silos and bunkers they are used for the construction of big structures like bridges, retain walls, docks and harbors, and under water structures
- R.C.C. is used for pre-casting rail sleepers, elective poles
- R.C.C is use for tall buildings like multistoried buildings, chimneys and towers
- R.C.C is used for paving highways, city roads and airport

# 2.0 Building Components

The structure of the building is divided into two parts. The sub-structure and thesuper structure.

**Substructure** is defined as the structural work below ground level used to support the structure above. Foundations, basement, subfloor are some components of this area. **Superstructure** is an upward extension of an existing structure above a baseline called Ground Level in general and it usually serves the purpose of the structure's intended use. The various members of super-structure such as columns and beams are designed to provide strength for carrying the dead load and live load expected to come on the various parts of the structure in a safe and well distributed manner

Table2.1: Building Components

| Super Structure | Sub-Structure |
|---|---|
| Plinth<br>Wall and columns<br>Beams<br>Arches<br>Roofs and slabs<br>Lintel and arches<br>Chajjas<br>Parapet<br>Steps and stairs | Foundation<br>Abutment<br>Pier |

## 2.1 Foundation

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

- Distribute the load from the structure to soil evenly and safely.
- To anchor the building to the ground so that under lateral loads building will not move.
- It prevents the building from overturning due to lateral forces.
- It gives level surface for the construction of super structure.

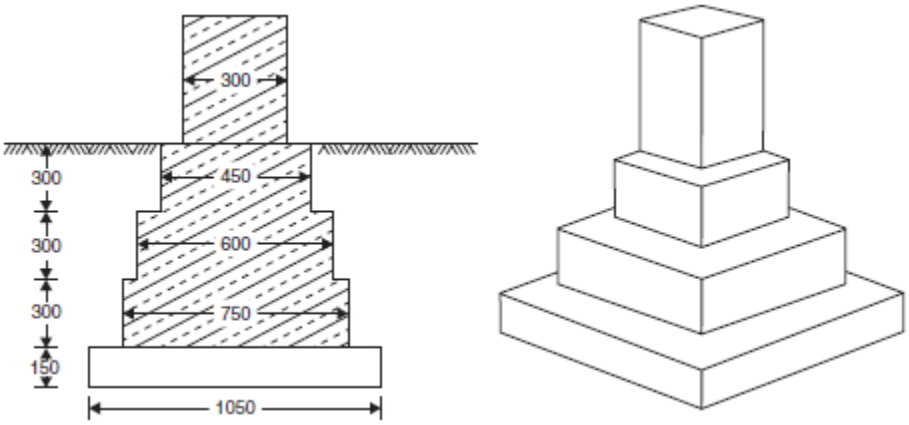
### Types of foundation

Mainly there are two types of foundation: they are shallow and deep foundation.

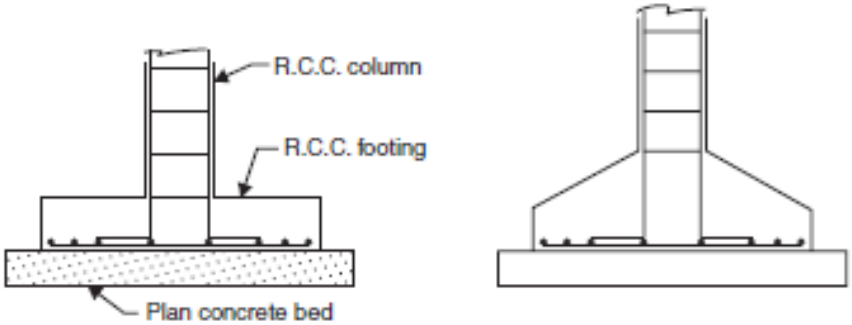
**Shallow Foundation:** If the depth of foundation is less than or equal to width of foundation is called shallow foundation. EX; Masonry footing, Isolated footing, combined footing, strap and RCC footing etc.

**Deep Foundation:** If the depth of foundation is greater than the width of foundation is called Deep foundation. EX. Friction piles, Load bearing piles (End bearing piles), compaction piles, well foundation, caissons.

**Masonry Footing:** Masonry footing is comes under stepped footing category. A step footing is the one which provides a continuous longitudinal bearing. The spread footing for a continuous wall is called strip footing. When the wall carries heavy load or when the SBC of soil is not very high, then one can go for stepped masonry footing. According to National Building Code in Brick and stone masonry slope is 0.5 H: 1V.

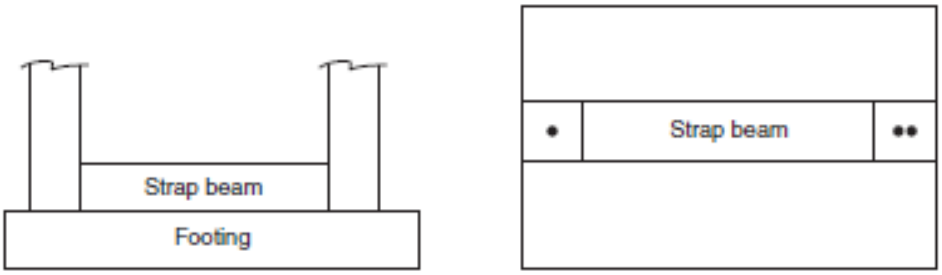



**Isolated Footing:** If separate footings are provided for each column, it is called isolated column footing. The size of footing is based on the area required to distribute the load of the columns safely over the soil. These footings are provided over a 100 to 150 mm bed concrete. Required reinforcements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

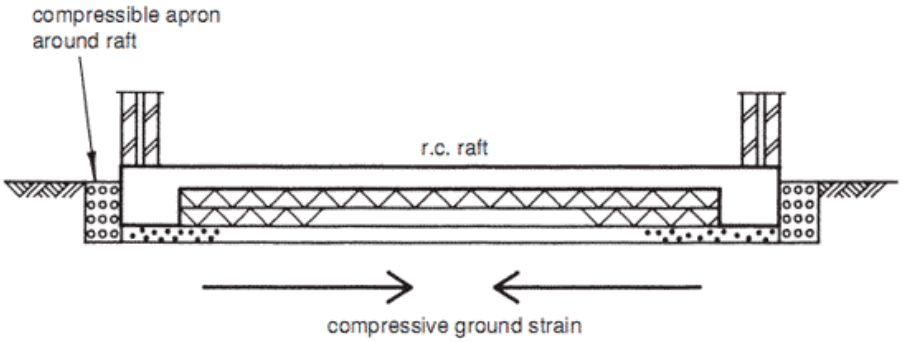


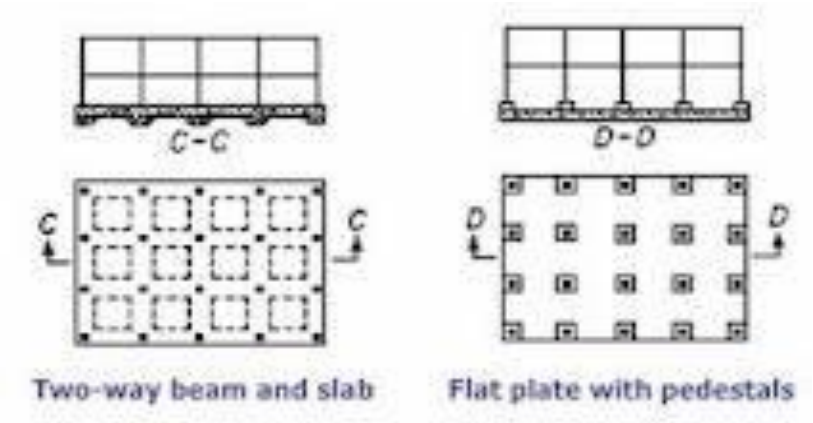

(a) Footing with uniform thickness (b) Sloping footing

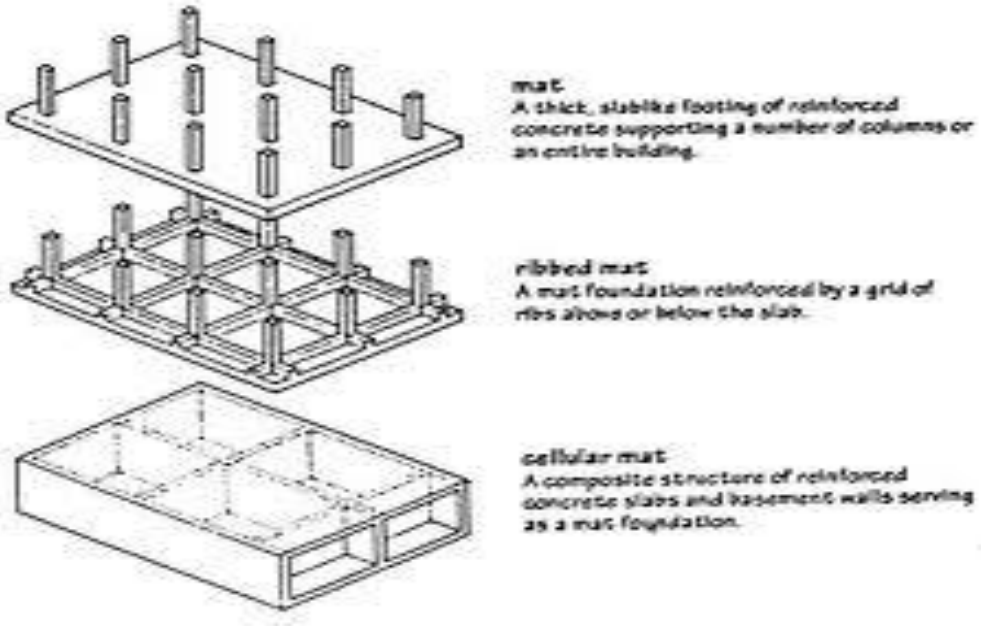
**Combined Footing:** If more than one column is placed on the bottom of the footing is called combined footing. The shape is generally rectangular, trapezoidal in section. A Combined footing is so proportioned that the center of gravity of the supporting are is in line with the center of gravity of the two column loads.



**Raft Footing:** A raft /matt is a thick reinforced concrete slab, which supports all the loads bearing wall and columns loads of a structure or a large portion of structure. If the sum of the base areas of the footings required to support a structure exceeds about half the total buildings area then it is preferable to combine the footings into a single raft. In raft foundation uniform settlement is allowed up to 5 cm, but the differential settlement should not greater then 2 cm. Raft is used when the loads are heavy and soil is very weak or highly compressible and to avoid differential settlement in erratic soil. Raft is very useful in resisting large hydraulic uplift.



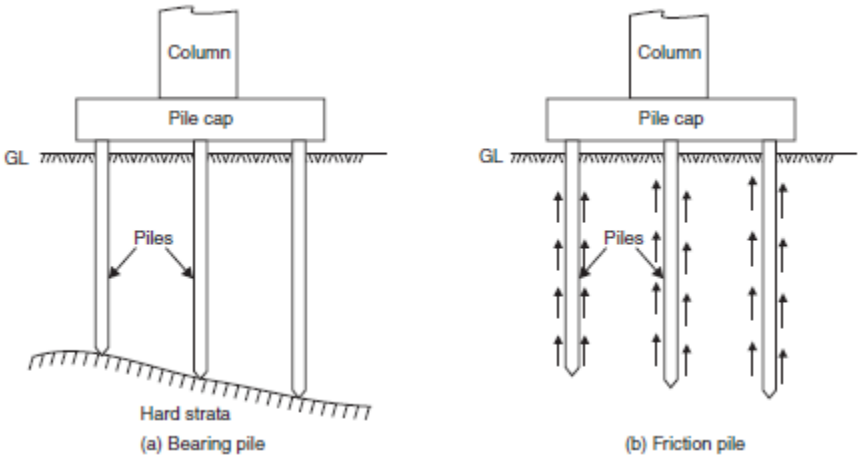



**Pile Foundation:** If the depth of foundation is greater, than the width/diameter of the foundation is called Deep foundation. Following situations Pile foundation is preferred.

- The load of the super structure is heavy and its distribution is uneven.
- The top soil has poor bearing capacity.
- The subsoil water level is high so that pumping out of water from the open trenches for the shallow foundation is difficult and uneconomical.
- The structure is situated on sea shore or river bed.
- The top subsoil is expansive in nature.

**Friction Piles:** Friction piles are used to transfer loads by means of skin friction along the surface area of the piles. For friction pile, $D_f$>B where $D_f$= Depth of the pile B= Diameter of the pile. Such piles are used if hard strata are not available to a considerable depth. The friction developed is to be properly assessed before deciding the length of the pile. The surface of such piles is made rough to increase the skin friction so that required length of pile is reduced.

**End Bearing Piles:** End Bearing Piles are used to transfer load through the pile tip to a suitable hard bearing stratum passing soft soil or transforming load through water. *Df*>B where *Df*= Depth of the pile, B= Diameter of the pile




## 2.2 Walls

Walls are built to partition living area into different parts. They impart privacy and protection against temperature, rain and theft. Walls may be classified as

- Load bearing walls
- Partition walls.

**Load Bearing Walls:** If beams and columns are not used, load from roof and floors are transferred to foundation by walls. Such walls are called load bearing walls. They are to be designed to transfer the load safely. The critical portion of the walls is near the openings of doors and windows and the positions where concrete beams rest. Minimum wall thickness used is 200 mm. It is also recommended that the slenderness ratio of wall defined as ratio of effective length or effective height to thickness should not be more than 27.

**Partition Walls:** In framed structures partition walls are built to divide floor area for different utilities. They rest on floors. They do not carry loads from floor and roof. They have to carry only self-weight. Hence normally partition walls are thin. Depending upon the requirement these walls may be brick partition, clay block partition, glass partition, wood partition, and aluminum and glass partition.

| **Load Bearing Walls** | **Partition Walls** |
|---|---|
| They carry loads from roof, floor, self-weight etc. | They carry self-weight only. |
| They are thick and hence occupy more floor area. | These walls are thin and hence occupy less floor area. |
| As the material required is more the construction cost is more | As the material required is less, the construction cost is less. |
| Stones or bricks are used for the construction. | Stones are not used for the construction of partition walls. |

**2.3Roof**

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

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

**Flat Roofs**

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

The *advantages* of flat roofs are:

- 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.
- Over-head water tanks and other services can be located easily.
- They can be made fire proof easily compared to pitched roof.

The *disadvantages* of flat roofs are:

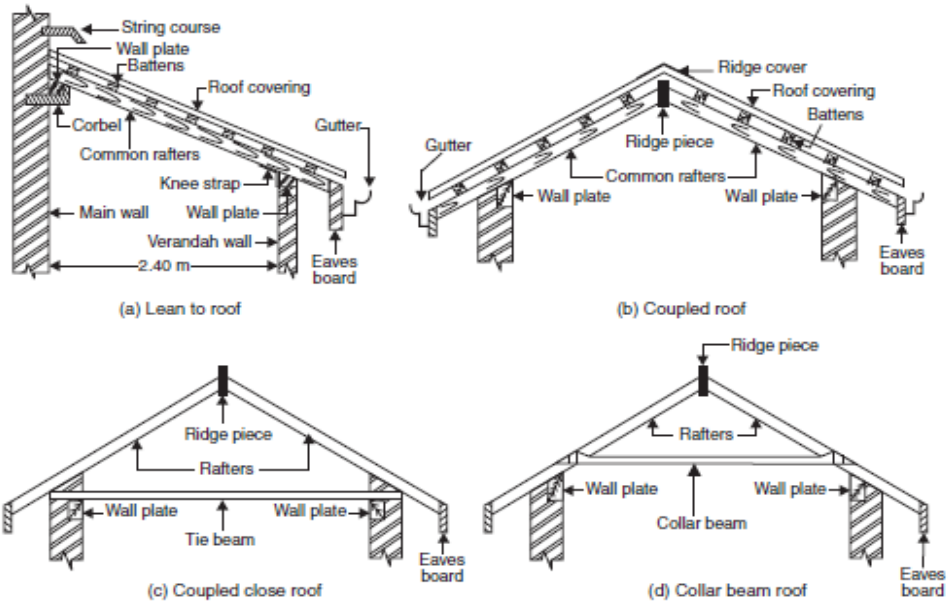
- They cannot cover large column free areas.
- Leakage problem may occur at latter date also due to development of cracks. Once leakage problem starts, it needs costly treatments.
- The dead weight of flat roofs is more.
- In places of snow fall flat roofs are to be avoided to reduce snow load.
- The initial cost of construction is more.
- Speed of construction of flat roofs is less.

**Pitched Roofs**

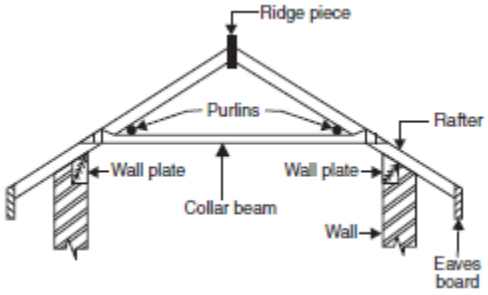
In the areas of heavy rain falls and snow fall sloping roof are used. The slope of roof shall be more than 10°. They may have slopes as much as 45° to 60° also. The sloped roofs are known as pitched roofs. The sloping roofs are preferred in large spanned structures like workshops, factory buildings and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

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

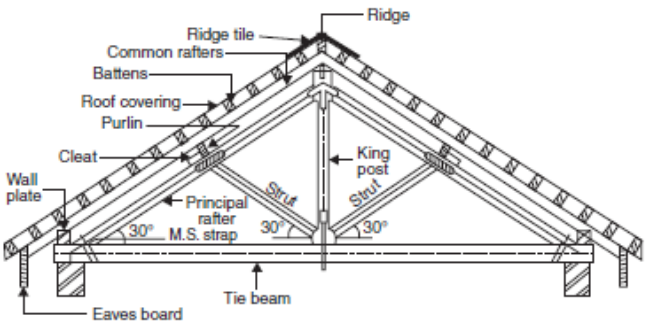
- Lean to roofs
- Coupled roofs
- Coupled-close roof
- Collar beam roof

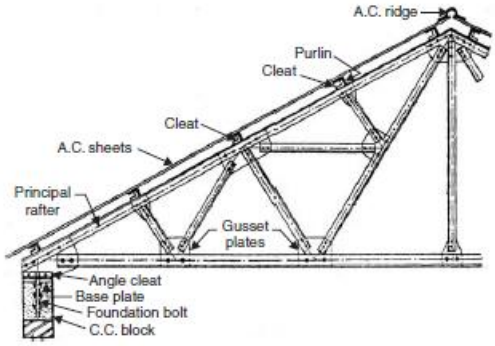



**Double or Purlin Roofs:** If span exceeds the cost of rafters increase and single roof becomes uneconomical. For spans more than 5 m double purlin roofs are preferred. The intermediate support is given to rafters by purlins supported over collar beams. Figure 8.14shows a typical double or purlin roof.



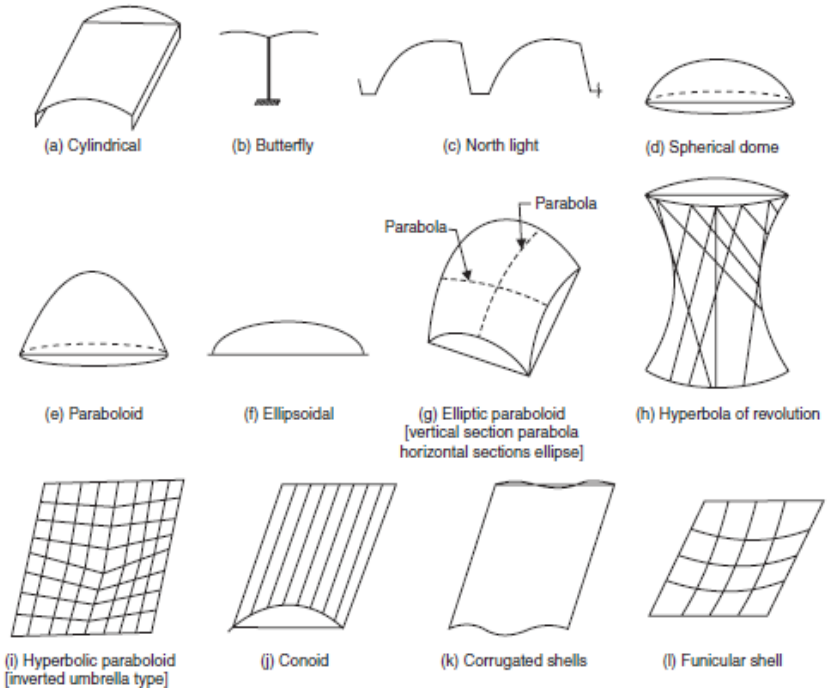

**Trussed Roof:** If span is more, frame works of slender members are used to support sloping roofs. These frames are known as trusses. A number of trusses may be placed lengthwise to get wall free longer halls. Purlins are provided over the trusses which in turn support roof sheets. For spans up to 9 m wooden trusses may be used but for larger spans steel trusses are a must. Depending upon the span, trusses of different shapes are used. End of trusses are supported on walls or on column.




**Shells and Folded Plate Roofs**

*Shell roof* may be defined as a curved surface, the thickness of which is small compared to the other dimensions. In these roofs lot of load is transferred by membrane compression instead of by bending as in the case of conventional slab and beam constructions.

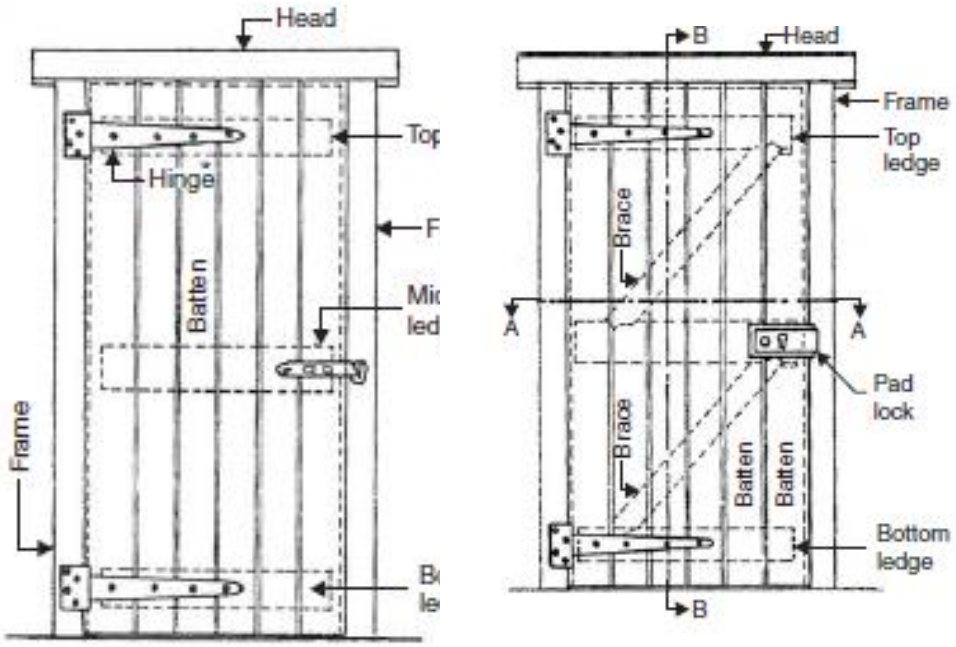



**2.4 Doors**

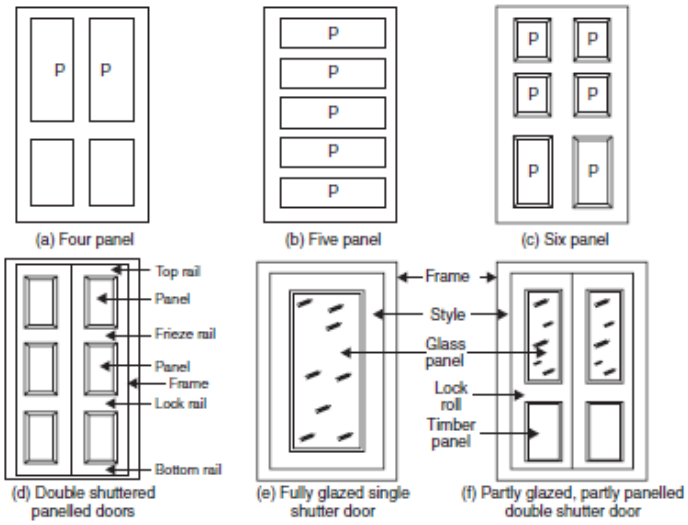
The function of a door is to give access to building and to different parts of the building and to deny the access whenever necessary. Number of doors should be minimum possible. The size of the door should be of such dimension as will facilitate the movement of the largest object likely to use the doors. In case of the resident buildings, the size of the door should not be less than 0.9 m × 2.0 m. larger doors may be provided at main entrance to the building to enhance the aesthetic view. Minimum sized doors are used for bath rooms and water closets. The size recommended is 0.75 m × 1.9 m. As a thumb rule height of door should be 1 m more than its width.

## Types of Doors

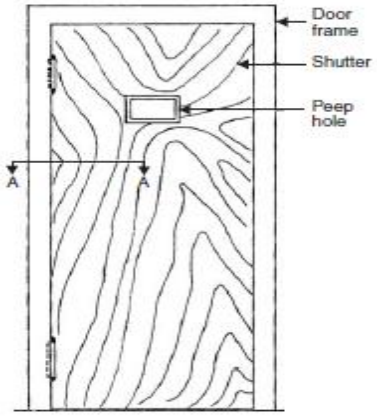
**Battened and Ledged Doors:** Battens are 100 mm to 150 mm wide and 20 mm thick wooden boards. Their length is that of door opening. The battens are connected by horizontal planks, known as ledges of size 100 to 200 mm wide and 30 mm thick. Usually three ledges are used one at top, one at bottom and the third one at mid-height. This is the simplest form of door and the cheapest also. Batten sare secured by tongued and grooved joint. If doors are wide apart from using battens and ledges diagonal members, known as braces, are provided to strengthen the door



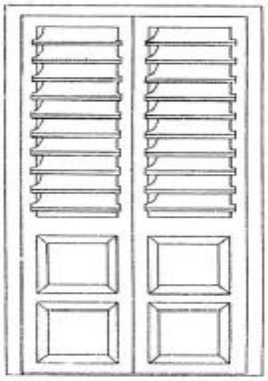

**Framed and Panelled Doors:** This type of door consists of vertical members, called styles and horizontal members called rails. The styles and rails are suitably grooved to receive panels. The panels may be of wood, A.C. sheet, glasses etc. The panels may be flat or of raised type to get good appearance. These are very commonly used doors. They may be of single shutter or of double shutter.



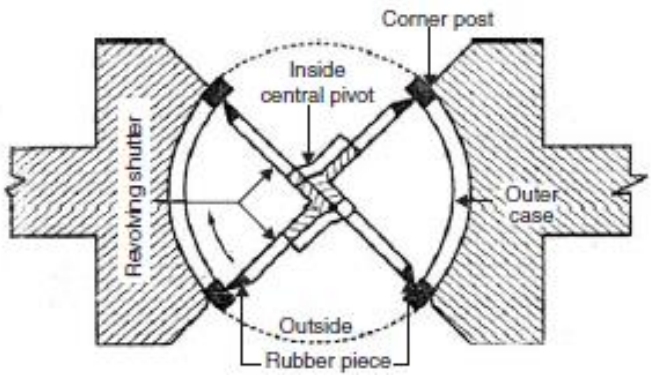
**Flush Doors:** The shutters of these doors are made of plywood or block boards. They are of uniform thickness. These shutters are available with different attractive vineer finishes. The time consumed in making such doors at site is quite less. These doors are suitable for interior portion of a building.



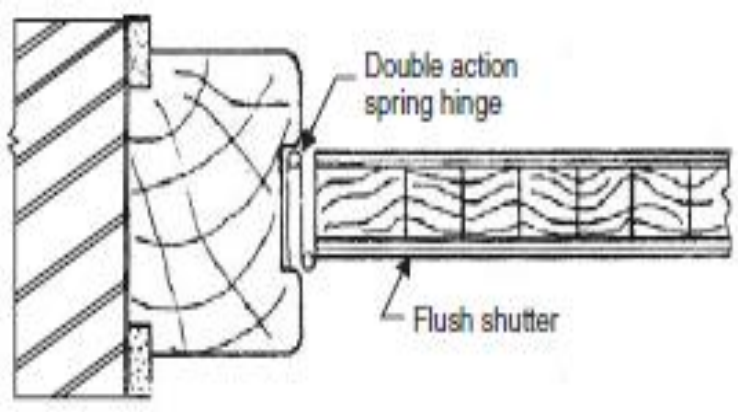

**Louvered Doors:** Whenever privacy as well as ventilation is required such doors can be used. Louvers are the glass, wooden or A.C. sheet strips fixed in the frame of shutter such that they prevent vision but permit free passage of air. The doors may be fully or partially louvered. Such doors are commonly used for public bathrooms and latrines.



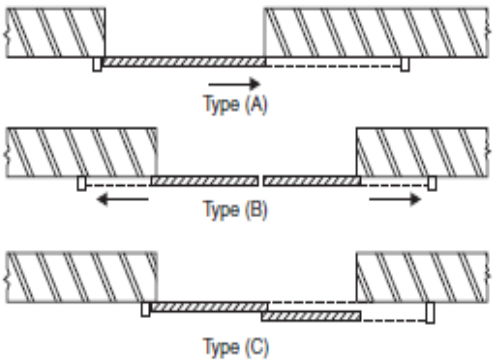
**Revolving Doors:** It consists of a centrally placed pivot to which four radiating shutters are attached. The central pivot is supported on ball bearing at the bottom and has a bush bearing at the top. The shutters may be partly or fully made up of glass.



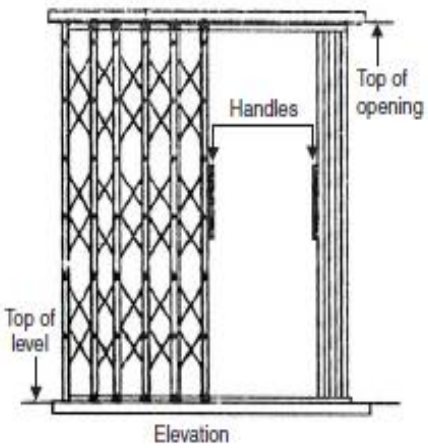
**Swing Doors:** Swing door has its shutter attached to the frame by means of double action springs. Hence shutter can move both inward and outward. They may be single shuttered or double shuttered. Such doors are preferred in offices and banks.



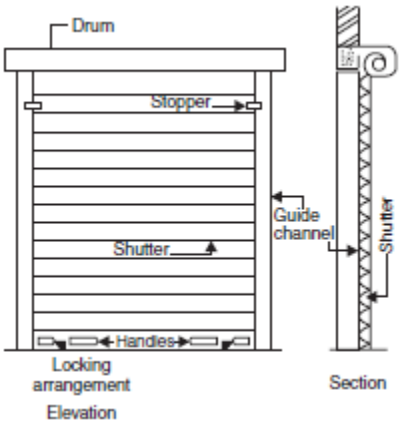

**Sliding Doors:** In this type of doors, shutter slides on the sides. For this purpose runners and guide rails are provided. Sliding shutters may be one, two or even three.




**Collapsible Doors:** Steel channels 16 to 20 mm wide are used as verticals. They are placed with 12 to 20 mm gap. Steel flats 16 mm to 20 mm wide and 5 mm thick are hinged to them. The rollers are provided at their top as well as at bottom so that shutter can be pulled or pushed sideways with slight force.



**Rolling Shutters:** Figure 8.30 show a typical rolling shutter door. It consists of a frame, a drum and a shutter made of thin steel plates. The width of the door may vary from 2 to 3 m. The shutter moves on steel guides provided on sides and can easily roll up. These types of doors are commonly used as additional doors to shops, offices, banks, factory, buildings from the point of safety.




**2.5 Windows**

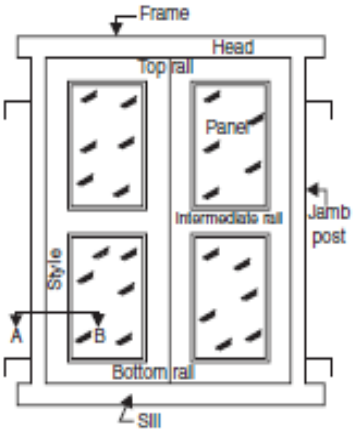
Windows are provided to give light and ventilation. They are located at a height of 0.75 m to0.90 m from the floor level. In hot and humid regions, the window area should be 15 to 20 per cent of the floor area. It is preferable to have at least two openings in two different walls. Another thumb rule used to determine the size of the window opening is for every 30 m3 inside volume there should be atleast 1 m2 window opening.

Various windows used may be classified on the basis of materials used, types of shutters, types of openings of shutters and the position of windows. Timber, steel and aluminum are commonly used to make window frames. Shutters of windows may be panelled, glazed or louvered. Window shutters may be fixed, centrally pivoted, sliding type or double hung

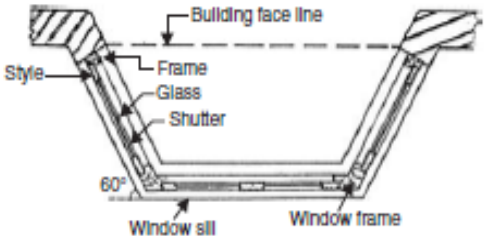
Depending upon the position of windows, they may be classified as:

- **Casement windows** are common type of windows, provided in the outer walls. They are provide dover 50 to 75 mm sill concrete at a height of 750 to 900 mm from floor level.
- **Bay windows** are provided on the projected portion of walls.
- **Corner windows** are provided in the corner of a room. They need heavy lintels. Corner post of window should be strong enough to take load due to deflection of lintel and impact load from thes hutters.
- **Clear storey windows** are provided when the height of the room is much more than adjacent room/varandah. It is provided between the gap of low height room and the top of room with greater height.
- **Gable windows** are provided in the gable portion of the building. They are required in the staircases or in the halls with gable walls.
- **Sky light windows** are provided on a sloping roof. It projects above the top sloping surface. The common rafters are to be trimmed suitably.

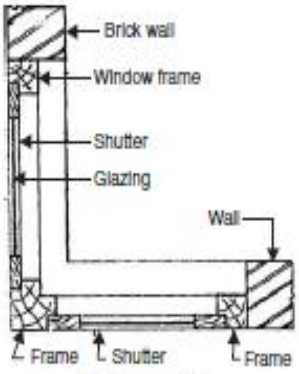
- **Dormer windows** are vertical windows on the sloping roof.
- **Ventilators** are provided close to roof level or over the door frames. They help in pushing out exhaust air. They may be provided with two split and separated glasses or with hung shutters.



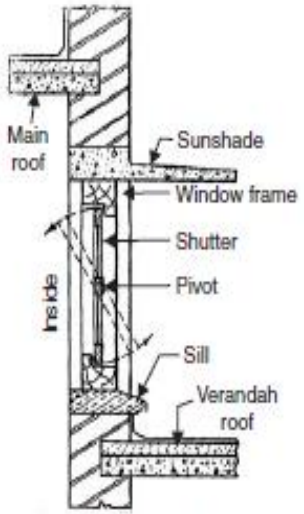

(a) Casement window



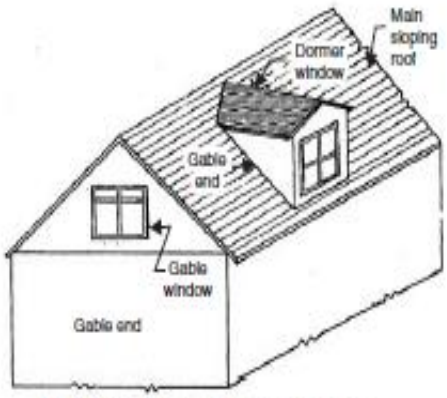

(b) Bay window



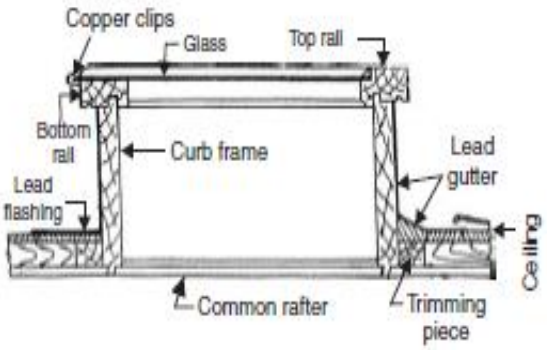

(c) Corner window




(d) Clear storey window




(e) Dormer window and gable window




(f) Sky light

**2.6 Flooring**

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

**Types of floorings**

***Ground Floor***

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

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

**3. Flag Stone Flooring:** Laminated sand stones or slates of 20 mm to 40 mm thick in the form

of slabs of 300 mm × 300 mm or 450 mm × 450 mm or in the form of rectangles of size 450 mm × 600 mm are used as floor finishes. The stone slabs are laid on 20 to 25 mm thick mortar spread over concrete bed. The joints are to be finished with rich mortar.

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

**5. Terrazo Flooring:** Terrazo finishing coat is applied over concrete flooring to get pleasing appearance. Terrazo finish consists of 75 to 80% of surface marble chips embedded in cement mortar. Marble chips are mixed in cement in the proportion 1:1.25 to 1:2 and about 6 mm terrazzo topping is laid. The top is tamped and rolled. Additional marble chips are spread during tamping to get proper distribution of marble chips on the surface. After drying it for 12 to 20hours, it is cured for 2–3 days. Then grinding is made. After each grinding cement grout of cream-like consistency is applied and cured for 6–7 days. After final grinding and curing the floor is washed with plenty of water and then with dilute oxalic acid solution. Then floor is finished with polishing using machines and wax polish.

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

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

**8. Tiled Flooring:** This is an alternative to terrazo flooring, used commonly used in residential, office and commercial buildings. On the concrete base, 25 mm to30 mm thick mortar is laid and these tiles are placed and pressed with trowel or wooden mallet. Next day joints are cleaned of loose mortar and raked up to 5 mm depth. Then that is filled with coloured cement slurry to get uniform colour on the top surface. After curing for 7 days grinding and polishing is made as in the case ofterrazo flooring.

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

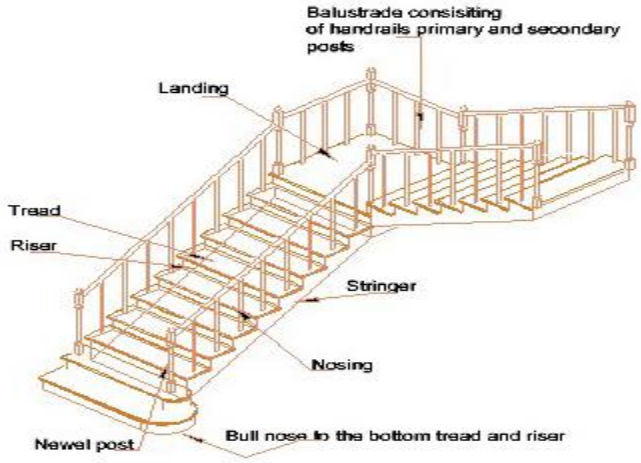
**10. Rubber Flooring:** Tiles or sheets of rubber with fillers such as cotton fibres, asbestos fibreor granulated cork are manufactured in variety of patterns and colours. These sheets or tiles may be fixed to concrete or timber floors. These floors are attractive and noise proof. However they are costly.

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

However it is slippery and costly.

## 2.7 Stairs

Stairs give access from floor to floor. The space/room housing stairs is called staircase. Stairs consists of a number of steps arranged in a single flight or more number of flights.



**Requirements of good stairs**

- **Width:** 0.9 m in residential buildings and 1.5 m to 2.5 m in public buildings.
- **Number of Steps in a Flight:** Maximum number of steps in a flight should be limited to 12to 14, while minimum is 3.
- **Rise:** Rise provided should be uniform. It is normally 150 mm to 175 mm in residential buildings while it is kept between 120 mm to 150 mm in public buildings. However in commercial buildings more rise is provided from the consideration of economic floor area.
- **Tread:** Horizontal projection of a step in a stair case is called tread. It is also known as going. In residential buildings tread provided is 250 mm while in public buildings it is 270 mm to300 mm.
- **Head Room:** Head room available in the stair case should not be less than 2.1 m.
- **Hand Rails:** Hand rails should be provided at a convenient height of a normal person which is from 850 mm to 900 mm.

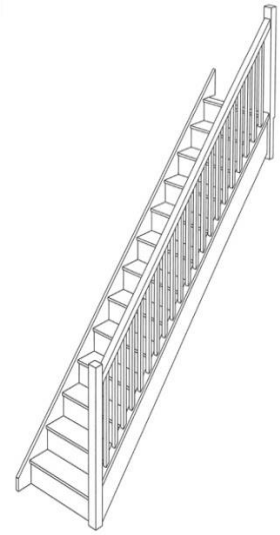
**Salient points to be considered in locating stairs**

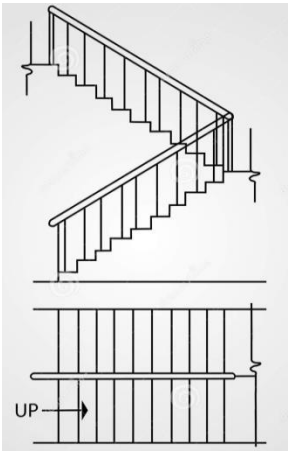
The following points should be considered in locating stairs in a building:

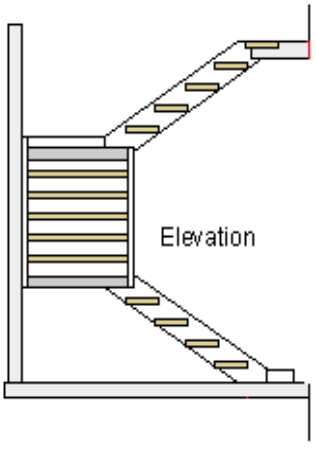
- They should be located near the main entrance to the building.
- There should be easy access from all the rooms without disturbing the privacy of the rooms.
- There should be spacious approach.
- Good light and ventilation should be available.

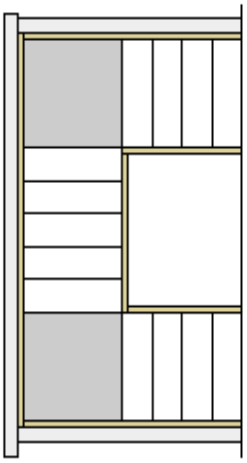
**Types of staircase**

**Straight Stairs:** If the space available for stair case is narrow and long, straight stairs may be provided. Such stairs are commonly used to give access to porch or as emergency exits to cinema halls. In this type all steps are in one direction. They may be provided in single flightor in two flights with landing between the two flights





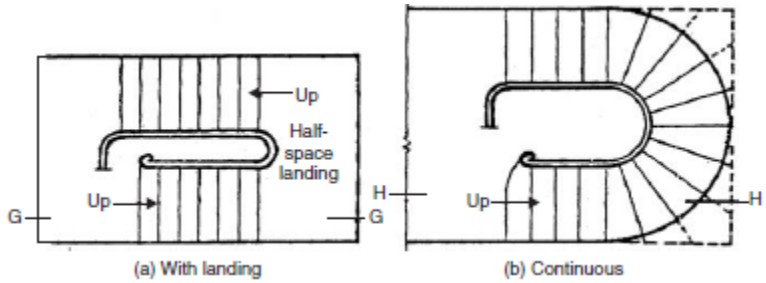



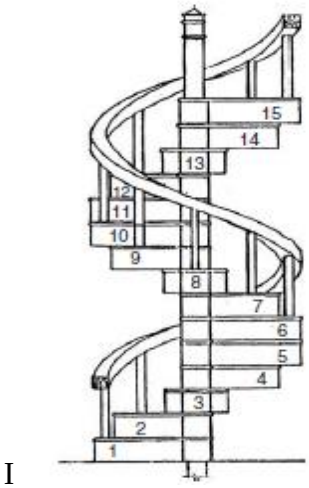
**Dog Legged Stairs:** It consists of two straight flights with 180° turn between the two. They are very commonly used to give access from floor to floor.

**Well or Open-newel Stairs:** It differs from dog legged stairs such that in this case there is0.15 m to 1.0 m gap between the two adjacent flights.

**Geometrical Stair:** This type of stair is similar to the open newel stair except that well formed between the two adjacent flights is curved. The hand rail provided is continuous.




**Spiral Stairs:** These stairs are commonly used as emergency exits. It consists of a central post supporting a series of steps arranged in the form of a spiral. At the end of steps continuous hand rail is provided. Such stairs are provided where space available for stairs is very much limited. Cast iron, steel or R.C.C. is used for building these stairs.

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**Turning Stairs:** Apart from dog legged and open newel type turns, stairs may turn in various forms. They depend upon the available space for stairs. Quarter turned, half turned with few steps in between and bifurcated stairs are some of such turned stairs.