CE3302

CONSTRUCTION MATERIALS AND TECHNOLOGY

UNIT I

STONES – BRICKS – CONCRETE – BLOCKS LIME

Stone as building material – Criteria for selection – Tests on stones – Bricks -Classification - Manufacturing of clay bricks – Tests on bricks – Compressive strength – Water Absorption – Efflorescence – Lime – Preparation of lime mortar – Concrete hollow blocks – Lightweight concrete blocks.

Stones, bricks, lime are the conventional materials used in Civil Engineering constructions for many centuries. In this chapter classification, properties, tests and uses of these materials are explained. In addition to these materials concrete blocks are also discussed.

STONE AS BUILDING MATERIAL

Stone is a natural construction material which is used from the prehistoric days. It is obtained from quarries in the form of rocks, which is then cut into required shape and size and used as building stones. Stones that are used for building construction are known as building stones. These are used for constructing different building components like foundations, walls, lintels, floors, roof etc. In India most of the ancient forts and temples were built using stones. Some of the examples of buildings constructed using stones are Red Fort, Parliament House and Rashtrapati Bhawan at Delhi; The Taj and the Victoria Memorial at Calcutta; Vidhan Sabha at Bangalore.

CLASSIFICATION OF STONES

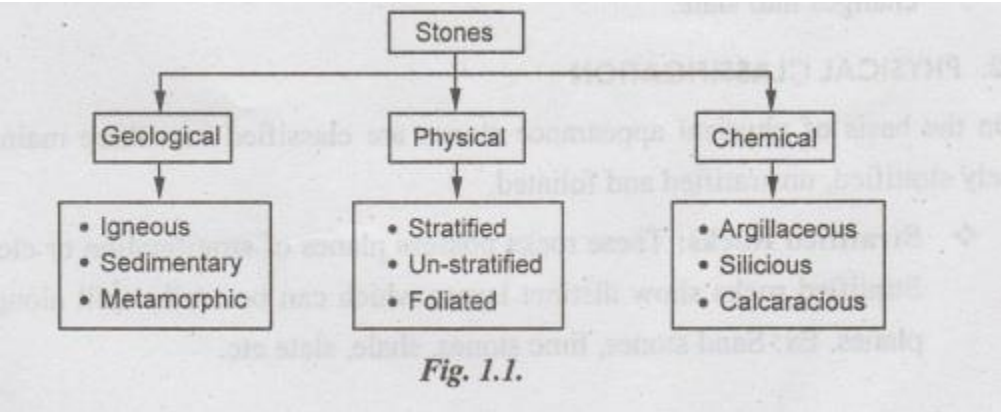


Fig. 1.1.

In general stones used for civil construction works may be classified into the three ways.

1. GEOLOGICAL CLASSIFICATION

Geological classification is based on the mode of formation. On the basis of Geological formation stones are classified into three main forms namely igneous, sedimentary and metamorphic.

❖ Igneous Rocks: Igneous rocks are formed by cooling and solidification of the molten mass lying above or below the surface of the earth. In general igneous rocks are strong and durable. Ex: Granite, trap and basalt. Granites have crystalline surface since they are formed by slow cooling of the molten mass under thick layer on the top surface. Non-crystalline and glassy textures are formed by the cooling of the molten mass at the top surface. Ex: Basalt and trap.

❖ Sedimentary Rocks: Sedimentary rock properties differ considerably based on the nature of sediment and bonding between the sediment and grains. These rocks thus formed are fine grained, more uniform and dense in their nature. In general they represent a bedded or stratified structure. Ex: Sand stones, lime stones, mud stones, chalk etc.

❖ Metamorphic Rocks: Metamorphic Rocks are formed from igneous and sedimentary rocks, since they undergo changes because of metamorphic action of internal heat and pressure. Due to the metamorphic action, granite changes to greisses, trap and basalt becomes schist and laterite, lime stone changes to marble, sand stone becomes quartzite and mud stone changes into slate.

2. PHYSICAL CLASSIFICATION

On the basis of physical appearance stones are classified into three main forms namely stratified, unstratified and foliated.

❖ Stratified Rocks: These rocks possess planes of stratification or cleavage. Stratified rocks show distinct layers which can be easily split along these planes. Ex: Sand stones, lime stones, shale, slate etc.

❖ Unstratified Rocks: These rocks possess compact grains and crystalline. These rocks are not stratified and cannot be split into thin layers. Ex: Granite, marble, basalt, etc.

❖ Foliated Rocks: These rocks have a tendency to split up in a distinct direction. In general most of the metamorphic rocks have a foliated structure, whereas quartzite and marble have granulose structure.

3. CHEMICAL CLASSIFICATION

On the basis of chemical characteristics stones are categorized into Silicious, Argillaceous and calcareous rocks.

❖ Silicious Rocks: These rocks are very hard and durable. The primary- constituent is silica (SiO_2). Ex: Granite, sandstones, trap etc.

❖ Argillaceous Rocks: These rocks are hard, durable and brittle in nature. The primary constituent is silica (Al_2O_3). Ex: Slate, laterite etc.

❖ Calcareous Rocks: These rocks are formed from a variety of chemical and detrital sediments. The primary constituent is calcium carbonate ($CaCO_2$). Ex: Limestone, marble, dolomite etc.

PROPERTIES OF STONES

The criteria for selection of stone as a building material is based upon the following properties:-

(i) Structure:

❖ Structure of a stone layer may be either stratified or unstratified.

❖ Structured stones are easily dressed and are suitable for the superstructures.

❖ Unstratified stones are hard and difficult to dress and are preferred for the foundation works.

(ii) Texture:

❖ Fine grained stones are usually strong and durable.

❖ For carving, attractive fine-grained stones with homogeneous distribution are used.

(iii) Density:

❖ Light weight stones are weak and denser stones are stronger.

❖ Stones with specific gravity less than 2.4 are not suitable for buildings.

(iv) Appearance:

❖ Appearance is a chief requirement for the selection of the stone.

❖ A stone with uniform and attractive colour is durable, if grains are compact.

❖ The colour and ability to receive polish greatly influence the appearance.

❖ Marble and granite get very good appearance, when polished. Hence they are used for face works in buildings.

(v) Colour

❖The colour of stone along with its shape and arrangement of mineral constituents greatly influence its fashion and ornamental value.

❖ A stone with uniform and the attractive colour is durable if its grains are compact.

❖The engineer selecting the stone should be aware of the variation of colour of the stone after long exposure and in polluted atmospheres.

(vi) Strength:

❖ For the selection of stone as a building block, strength is an important property to be looked for.

❖ For any building block, minimum crushing strength should be 3.5 N/mm2 as recommended by Indian Standard Code.

❖ Due to non-uniformity of the material, usually a factor of safety of 10 is used to find the permissible stress in a stone.

(vii) Hardness:

❖ When stone is used for flooring and pavement, this is an important property to be considered

❖ Coefficient of hardness should be less than 14, for building work stones.

❖ Coefficient of hardness should be at least 17, for road works.

❖The stones used in floors and pavements should be able to resist abrasive movement caused due to the movement of men and materials over them.

(viii) Durability:

❖When stone is used as aggregate for road works and railway ballast, this is an important property to be considered.

❖The durability of the stone is significantly determined by its resistance to fire and weathering.

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

❖ A good stone should not show wear of more than 2%.

(ix) Toughness:

❖ Building stones should have more toughness to sustain stresses developed due to vibrations.

❖In general, the resistance to impact is known as toughness, and can be found by impact test.

❖ Stones having toughness index 13 to 19 are medium tough and less than 13 are poor.

❖For road works, the toughness index of the stone should be more than 19.

(x) Porosity and Absorption:

❖ Building stones should not be porous, since rain water might enter the pores and deteriorate it.

❖All stones have pores and hence absorb water. The percentage of water absorbed by the stone when it is immersed underwater for 24 hours should not be more than 5% for a good stone.

(xi) Resistance to Fire and Weathering:

❖ Rain and wind cause loss of good appearance of stones.

❖ Stones with good weather resistance should be used for face works.

❖ Sand stones resist fire better.

❖ Argillaceous materials, though poor in strength, are good in resisting fire.

(xii) Specific Gravity:

❖For the construction of dams, retaining walls, harbours, etc. a heavier variety of stones should be used.

❖ For a good building stone, specific gravity is between 2.4 and 2.8.

(xiii) Ease in Dressing:

❖ Dressing is the process of giving required shape to the stone.

❖ 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.

(xiv) Seasoning:

❖ The process of removing moisture from pores is called seasoning.

❖ Quarry stones contain moisture in the pores. If this moisture is removed before using the stone, the strength of the stone improves.

❖The optimum way of seasoning is to let it exposed in the nature for 6 to 12 months. Seasoning is very much required in the case of laterite stones.

(xv) Cost:

1. Cost is an essential consideration while selecting a building material.
2. Cost of dressing has a great contribution in the total cost of stone masonry.
3. Transportation charges, quarrying and cutting costs, adding ornamental features and the durability of a stone mostly persuades the total cost.

Nevertheless, it is prominent that a single stone cannot satisfy all the criteria's of a good building stone. One property may contradict with another, like strength and durability criteria oppose the ease of dressing requirement. Therefore it is essential that, the engineer has to consider the criteria based on its properties before selecting the stone for particular work.

COMMONLY USED BUILDING STONES IN INDIA

The following are the some of the commonly used building stones widely used in India:

(i) Marble:

Marble is the most familiar variety of metamorphic rock. It's chemically calcareous, and is formed from crystallized limestone by metamorphism. It is chiefly composed of calcium carbonate. Its specific gravity is 2.65 and crushing strength is 70 to75N/mm2. The usual color of marble is white, but it is also available in different shades of colors such as grey, black, red, brown, yellow and combination of any of these. It can take a fine polish due to its crystalline structure. It is less durable and can be easily carved. Hence it is most suitable for sculpture work, flooring, steps, facing and ornamental works in decorative panels.

(ii) Granite:

Granite is the most common variety of igneous rock. The hardest and most durable granites contain a greater proportion of quartz and smaller proportion of feldspar and mica. Its specific gravity is from 2.6 to 2.7 and crushing strength is 100 to 250 N/mm2. It is heavy, hard, strong, durable and crystalline in nature. It is available in wide ranging colours like grey, green, brown and pink and red. Because of its uniform structure, granite can be quarried in large blocks. Medium-grained stone is best fitted for building construction. Fine-grained stone can be carved and polished. They are also used for bridge piers, river walls, and for dams. They are used as kerbs and pedestals. Granite is also used for monumental and and flooring works. Polished granites are used as table tops and wall cladding.

(iii) Sand stone:

Sand stone is the most familiar variety of sedimentary rock. It's physically stratified, chemically siliceous, and is chiefly composed of quartz .Other minerals such as felspar, mica, magnetite etc. are also present. The specific gravity varies from 1.85 to 2.7 and crushing strength ranges from 20 to 170 N/mm2. They are found in a variety of colours like white, grey, red, brown, yellow and light brown. Weathering of rocks makes it unsuitable as a building stone. They are used for masonry work, for dams, bridge piers and river walls. If required, it is suitable to use sand stones with silica cement for heavy structures.

(iv) Basalt:

Basalt is the most common variety of igneous rock, formed by solidification of lava on the earth's surface due to volcanic eruption. The structure is medium to fine grained and compact. Some basalt extend step like appearance and are called as traps. They are chiefly composed of silica, alumina and feldspar. The specific gravity varies from 2.9 to 2.96 and crushing strength ranges from 200 to 350 N/mm2. They are greenish grey to black in color. They are used as road metals, aggregates for concrete and also in rubble masonry works for bridge piers, river walls and dams.

(v) Slate:

Slate is the well known variety of metamorphic rocks, composed of quartz, mica and clay minerals. Having a fine grained structure, they are split along the planes of initial bedding easily. The specific gravity varies from 2.6 to 2.7 and crushing strength ranges from 100 to 200 N/mm2. They are available in

various shades of grey colour such as dark grey, greenish grey, purple grey and black. It offers good abrasive resistance. Generally slates are used for steps, shelves, roof tiles, pavements and black boards..

(vi) Limestone:

Limestones are of sedimentary origin, carbonate of lime being their principal ingredient. They are fine to crystalline and may have fossils. The stone is called as argillaceous limestone if clay is present. If iron is prevalent, then it is known as ferruginous limestone. When silica predominates, then it is siliceous limestone. They are available in white, light grey to light buff colours. They are mostly used as fillers and powdered limestone has industrial uses.

(vii) Quartzite:

Quartzite is a metamorphic rock, having fine to coarse grained structure. The chief component is quartz, where feldspar and mica are available in small quantities. The specific gravity varies from 2.55 to 2.65 and crushing strength ranges from 50 to 300 N/mm2. They are available in different colours like white, gray and yellow. They are used as building stones, slabs and even as aggregates for concrete.

(viii) Gneiss:

Gneiss is a coarse-grained laminated metamorphic rock, having alternate dark and white bands. Due to the presence of deleterious constituents these stones are generally not preferred. The specific gravity varies from 2.5 to 3.0 and crushing strength ranges from 50 to 200 N/mm2. They are available in variety of colours like light grey, pink, purple, greenish grey and dark grey. They are used in minor constructions and as concrete aggregate.

(ix) Laterite:

Laterite is a metamorphic rock, having porous sponges structure and high percentage of iron oxide. Its specific gravity is 1.85 and crushing strength ranges from 1.9 to 2.3 N/mm2. It is available in different colours like brown, red, yellow and grey. Its strength can be increased by seasoning and can be easily quarried in blocks. Plastering is required on the outer surface, when it is used as building stone.

TESTS ON STONES

Following are different tests on conducted on building stones:

- ❖ Water absorption test
- ❖ Crushing strength test.
- ❖ Impact test
- ❖ Abrasion test
- ❖ Acid test

(i) Water absorption test:

Water absorption test is conducted on a test cube specimen and the following steps are carried out:

❖From the sample of stone, a cube weighing about 50gm is prepared. Take actual weight as W_1 gm.

❖ Cube specimen is then immersed in distilled water for a period of 24 hrs.

❖ Specimen is taken out of water and surface water is wiped off and weighed again. Let the weight be W_2 gm.

❖ Suspend the specimen freely in water and weight it. Let its weight be W_3 gm.

❖ Water is boiled and the specimen is kept in boiling water for 5 hours.

❖ Cube is removed and surface water is wiped off and is weighted again. Let it be W_4 gm.

❖ From the above observations, values of the following properties of stones are obtained.

Percentage absorption by weight after 24 hours

$= [(W_2 - W_1 / W_1)] \times 100$

Percentage absorption by volume after 24 hours

$= [(W_2 - W_1 / W_2 - W_3)] \times 100$

Volume of displaced water

$= (W_2 - W_3)$

Percentage porosity by volume

$= [(W_4 - W_1 / W_2 - W_3)] \times 100$

Density

$= W_1 / (W_2 - W_1)$ kg/m^3

Specific Gravity

$= W_1 / (W_2 - W_3)$

Saturation Coefficient = (Water Absorption /Total Porosity) = $= (W_2 - W_1) / (W_4 - W_1)$

(ii) Crushing Strength Test:

The crushing strength of a stone can be determined using crushing test machine as follows:

❖ Stone specimen is cut into 40 x 40 x 40 mm sizes of cubes and are finely dressed and finished.

❖ Such specimen should be placed in water for about 72 hours (3 Days) prior to test and therefore tested in saturated condition.

❖ Load bearing surface is then covered with plaster of paris of about 5mm thick on its top and bottom surfaces to get even surface so that load applied is distributed uniformly.

❖ In certain cases 5 mm thick plywood is also used instead of plaster of paris for getting uniform load distribution.

❖ Load is applied axially on the cube in a crushing test machine at the rate of 14 N/mm2 per minute.

❖Crushing strength of the stone per unit area is the maximum load at which the sample crushes or fails divided by the area of the bearing face of the specimen.

❖ Generally 3 specimens should be tested and average values are considered as crushing strength.

(iii) Impact strength test:

The toughness of a stone can be determined by conducting impact strength test as follows:

❖ Impact testing machine consists of a frame with guides, in which a metal hammer weighing 13.5 to 15 kg can freely fall from a height of 380 mm.

❖ Aggregates of size 10 mm to 12.5 mm are filled in cylinder in 3 equal layers, after being tamped 25 times.

❖ The sample is then transferred to a cup of diameter 102 mm and height 50mm and again tamped 25 times. The original weight is taken as W_1 gm.

❖The hammer is then allowed to fall freely on the specimen 15 times.

❖ Finally the sample is then sieved through 2.36 mm sieve. The weight of the fines is taken as W2 gm.

❖ Impact strength value is obtained by W_2/W_1

❖ The impact value should not be greater than 30% for wearing course, 30% for bituminous macadam and 40% for water bound macadam.

(iv) Abrasion Test:

The suitability of stones which are used as aggregates for road works can be determined by conducting abrasion test as follows:

❖ Abrasion test can be conducted using Los Angeles abrasion test apparatus which consists of a hollow cylinder of 0.7 m inside diameter and 0.5 m long with both ends being closed.

❖ The cylinder is mounted on a frame so that it can be rotated about horizontal axis.

❖ A specified number of cast iron balls of 48 mm diameter are placed in the cylinder, along with specified weight of oven dried specimen (W_1 gm).

❖ Then the cylinder is rotated at a speed of 30 to 33 rpm for specified no number of times (500 to 1000). Then the aggregate is removed and sieved on 1.7 mm. IS sieve.

❖The weight of aggregate passing is found (W_2 gm).

❖ Aggregate abrasion value = $[(W_1,- W_2) / W_1 \text{ x } 100]$The nominal values are found to be 30% for bituminous mixes, 50% for base course and 60% for sub-base course.

(v) Acid Test:

Acid test is carried out on sandstones to understand the presence of calcium carbonate in building stone.

❖ A sample of stone weighing about 50 to 100 gm is taken.

❖ The sample is placed in a solution of 1% hydrochloric acid for seven days at periodical agitation.

❖ A good building stone maintains its sharp edges and keeps its surface free from any powder at the end of 7 days.

❖ If the edges are broken and powder is formed on the surface, it indicates the presence of calcium carbonate and such a stone will have poor weathering quality.

USES OF STONES

General uses of building stones are:

❖ Construction of foundations, walls, columns and arches are done using stone masonry.

❖ Stone slabs are used for flooring, damp proof courses, lintels and even as roofing materials.

❖ Polished granite and marbles are commonly used for facing and flooring works.

❖ Road pavements and footpaths are also made using stones.

❖ Constructions of piers and abutments of bridges, dams and retaining walls. are also done suing stones.

❖ Crushed stones are used as base course for roads, inert material in concrete and as railway ballast.

BRICKS

Bricks are the oldest and most commonly used construction material. Bricks are obtained by moulding clay in rectangular blocks of uniform size and then drying and burning these blocks. In order to get a good quality brick, the brick earth should contain silica, Alumina, Lime, Iron oxide and Magnesia. Initially bricks are manufactured by hand moulding, sun dried and then burned. Nowadays due to technological advancement improved techniques are used for moulding, drying

and burning. The standard Size of Brick is 190 x 90 x 90 mm and with mortar joints, the size of these bricks are taken as 200 mm x 100 mm x100 mm.

CLASSIFICATION OF BRICKS

Bricks can be classified based on the following aspects:

- ❖ Based on their Quality
- ❖ Based on constituent materials
- ❖ Based on usage

(i) Classification of Bricks based on their quality:

Bricks used for construction works are burnt bricks. They are classified into four categories based on their manufacturing process as given below.

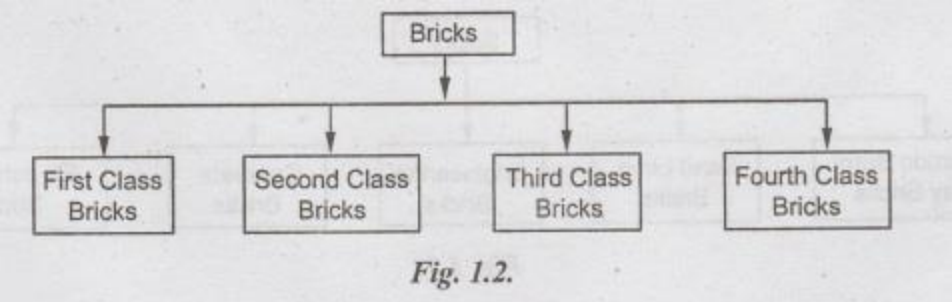


Fig. 1.2.

First Class Bricks:

First class bricks are table moulded and are burnt in kilns. They are of standard shape and size with sharp edges. The colour should be uniform and bright. The bricks should give a clear metallic ringing sound when struck with each other. They fulfill all the qualities of good bricks and are used for superior work of permanent nature.

Second Class Bricks:

Second class bricks are ground moulded and they are burnt in kilns. The surface of these bricks is slightly rough and is somewhat irregular in shape. These bricks may also have hairline cracks and

their edges may not be uniform and sharp. These bricks are generally used at the wall construction which are to be provided with a coat of plaster.

Third Class Bricks:

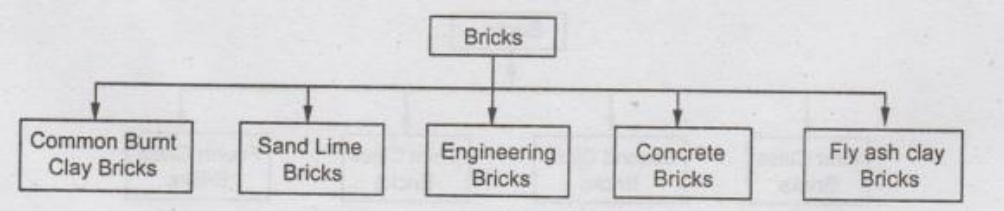
Third class bricks are ground moulded and they are burnt in clamps. These bricks have rough surfaces with irregular and distorted edges and are not hard enough. They cause dull sound when struck together. They are used for insignificant and temporary structures and also at places where rainfall is not heavy.

Fourth Class Bricks:

Fourth class bricks are over burnt bricks having dark colour with irregular shape. They are used as brick jelly for PCC works in foundations, floors, roads etc, since they have a compact structure

(ii) Classification of Bricks based on constituent materials:

There are various types of bricks used in masonry. They are classified into the following categories based on their constituent materials:



Common Burnt Clay Bricks

Common burnt clay bricks are formed by pressing in moulds, dried and burnt in a kiln. These bricks are used for general masonry work which requires plastering or rendering.

Sand Lime Bricks

Sand lime bricks are made by mixing sand, lime and fly ash pursued by a chemical process during wet mixing. The bricks are formed by moulding under pressure. The colour of the sand lime bricks are grey instead of the regular clay bricks which are in reddish colour. Their shape is uniform having smoother finish, hence plastering is not required.

Engineering Bricks

Engineering bricks are bricks manufactured at enormously high temperatures, resulting in a dense and strong brick. Engineering bricks offer outstanding load bearing capacity, damp-proof characteristics and chemical resisting properties.

Concrete Bricks

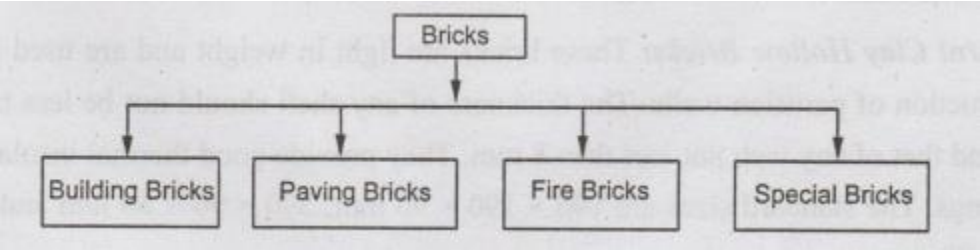
Concrete bricks are bricks made from solid concrete. These bricks can be manufactured in different colours by pigmented during its production. These bricks are usually used in facades, fences to provide beautiful aesthetic appearance.

Fly Ash Clay Bricks

Fly ash clay bricks are manufactured with clay and fly ash, at extremely high temperatures like 1000°C. When these bricks come into contact with moisture and water, they tend to expand.

(iii) Classification of Bricks based on usage:

Based on their utilization, bricks are classified into the following categories:



Building Bricks:

Building bricks are used for the construction of walls. Generally first class bricks are used for building works.

Building Bricks:

These are a porous form of brick formed by mixing small stone hardcore, dyes, cement and sand and other materials in various amounts. Brick Pavers are used in driveways, walkways, pool decks and other general outdoor surfaces.

Fire Bricks:

A fire brick or refractory brick is a block of ceramics used in lining furnaces, kilns, fireboxes, and fireplaces. These bricks are specially made to withstand furnace temperature. Silica bricks belong to this category.

Special Bricks:

Special bricks are different from the conventionally used bricks in their shape and utilization. Some of the special bricks are detailed below.

Specially Shaped Bricks:

To meet the requirements of different situations, sometimes bricks are manufactured in special shapes. Some of these kind are bull nosed brick, coping brick, cant brick, channel brick, cornice brick, plinth brick etc,.

Perforated Building Bricks:

These bricks are manufactured with perforation which is uniformly distributed over the surface. The area of perforation should be 30 to 45% and each perforation should not exceed 500 mm2. The standard sizes are 190 × 190 x 90 mm and 290 x 90 x 90 mm

Facing Bricks:

Facing bricks are manufactured to be used for facing (façade) works at the exterior of the wall. These bricks are different from other structural brickwork and carry a very clean and even appearance. The standard sizes are 190 × 90 × 90 mm and 190 × 90 × 40 mm.

Burnt Clay Hollow Bricks:

These bricks are light in weight and are used for the construction of partition walls. The thickness of any shell should not be less than 11 mm and that of any web not less than 8 mm. They provide good thermal insulation to buildings. The standard sizes are 190 x 190 x 90 mm, 290 x 90 x 90 mm and 290 × 140 x 90 mm.

Acid Resistant Bricks:

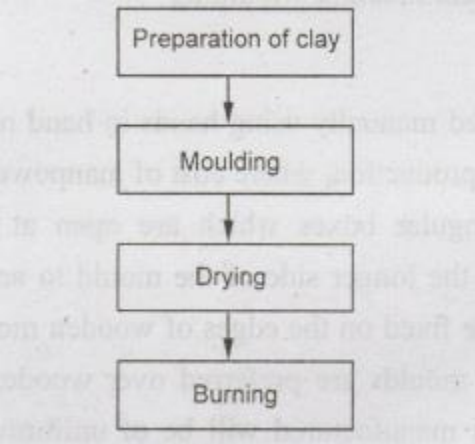
Acid-resistant bricks are made of clay or shale, with low lime and iron content, and are vitrified at high temperatures in ceramic kilns. These bricks are used for floorings probable to be undergoing acid attacks, chamber lining in chemical plants, sewer lining carrying industrial wastes etc.

Sewer Bricks:

Sewer bricks are made from shale or clay, burned to a greenish blue color in a flame of low oxygen in a kiln, and used in drainage structures for the conveyance of sewage, industrial wastes, and storm water. They standard sizes are 190 × 90 × 90 mm and 190 × 90 × 40 mm

MANUFACTURING OF BRICKS

The following operations are involved in the process of manufacturing bricks:



Preparation of Clay

The clay for brick is prepared in the following order:

Unsoiling: The clay in top soil is full of impurities and hence it is to be removed for the purpose of preparing bricks. The top layer of the soil, about 200mm in depth, is to be taken out.

Digging: The clay is then dug out from the ground and is spread on the levelled ground. The height of heaps of clay is about 600mm to 1200mm.

Cleaning: The clay as obtained in the process of digging should be cleaned of stones, pebbles, vegetable matters. If these particles are in excess, the clay is to be washed and screened.

Weathering: *The clay is then exposed to atmosphere for softening and mellowing. The period varies from few weeks to full season.*

Blending: The clay is made loose and blending is carried out by taking a small amount of clay every time and turning it up and down in vertical direction. The blending makes clay fit for the next stage of tempering.

Tempering: In the process of tempering, the clay is brought to a proper degree of hardness and it is made fit for the next operation of moulding. The tempering should be done exhaustively to obtain homogeneous mass of clay of uniform character. For manufacturing good bricks on a large scale, tempering is done in pug mill.

Moulding

Moulding is the next process after preparation of clay. Moulding is of two types namely Hand Moulding and Machine Moulding.

(i) Hand moulding:

The bricks are moulded manually using hands in hand moulding. This process is followed for small scale production, where cost of manpower is low. The moulds are of wood or steel rectangular boxes which are open at top and bottom. Small projections are made on the longer side of the mould to act as handles. Sometimes strips of brass or steel are fixed on the edges of wooden moulds to make them more durable. Generally steel moulds are preferred over wooden moulds since they are more durable and bricks manufactured will be of uniform size. The bricks shrink during drying and burning. Therefore the moulds are made larger than burnt bricks upto 8-12%. The bricks prepared by hand moulding are of two types namely

❖ Ground moulded and

❖Table moulded

Ground moulded bricks: In this process, the ground is first made level and fine sand is sprinkled over the ground. The mould is immersed in water before placing over the ground. A stack of tempered clay is taken and is placed in the mould. Then the clay is pressed in the mould in such a way that it fills all the corners of mould. Using a wooden strike or a frame with wire, the surplus

clay is removed. Wooden strike or a frame with wire thus used is to be dipped in water every time. Finally the mould is then lifted up and raw brick formed is left on the ground for drying. Again the mould is dipped in water and the process is repeated to prepare another brick. The process is replicated till the required number of raw bricks is made. Even though the ground is made level, the lower faces of ground moulded bricks are rough. Hence it is not possible to place frog on such bricks. A frog is a mark of depth about 10mm to 20mm which is placed on raw brick during moulding, since.

❖ It indicates the trade name of the manufacturer

❖ In brick work, the bricks are laid with frog uppermost. Thus it affords a key for mortar when the next brick is placed over it.

The ground moulded bricks of good finishing and with frogs on their levelled surface are prepared by using a pair of pallet boards and a wooden block.

Table Moulded Bricks: In this process, a table is used for moulding of bricks instead of ground. The process remains the same. Raw bricks are moulded on a table of size 2m x 1m and sent for further process of drying. Since bricks are table moulded, the end product will be of better quality with levelled surface and finishing. Challenges faced in table moulding are

❖ The efficiency of the moulder decreases gradually due to standing for a longer duration.

❖ The cost of brick is also more when compared to ground moulding.

(ii) Machine Moulding:

In this process, the bricks are machine moulded and is carried out by two methods namely:

❖ Plastic clay machine moulding

❖ Dry clay machine moulding

Plastic Clay Moulding: This machine consists of a rectangular opening with length and width equal to an ordinary brick. The processed clay is placed in the machine and it comes out through the rectangular opening. Then it will be cut into strips by the wire fixed at the frame. The wire frame is placed in such a way that the strips thickness is equal to standard size of the bricks. The bricks thus manufactures are also called as wire cut bricks.

Dry Clay Machine Moulding: In dry clay machines, the processed clay is dried and converted in to powered form. Then a small quantity of water is added to form a stiff plastic paste. Such paste is placed in mould and pressed by machine to form dry and well-shaped bricks. They do not require the process of drying.

Drying

After moulding the damp bricks are likely to be cracked and distorted while burning. Hence the moulded raw bricks are dried before they are taken for the next process of burning. For the drying process the bricks are laid longitudinally in batches of width equal to two bricks. A batch consists of eight to ten tiers. The bricks are laid along and across the batch in alternate layers and are placed on edges. The bricks are allowed to dry until it becomes leather hard of moisture content about 2%.

Burning

This is the final process in the manufacturing of bricks. Dried bricks are burnt at high temperature to gain the strength, durability and appearance. All the water present is removed at 6500C but they are further burnt till 11000C, since fusing of sand and lime takes place at this temperature. Chemical bonding takes place after the temperature is cooled down resulting in the hard and dense mass. Also bricks are not burnt above this temperature because over burning results in the melting of the bricks leading to distorted shape and a very hard mass when cooled which will not be workable while brickwork. Bricks can be burnt using the following methods:

- ❖ Clamp Burning
- ❖ Kiln Burning

Clamp Burning: Clamp is a temporary structure generally constructed over the ground with a height of about 4 to 6 m. It is employed when the demand of the bricks is less and when it is not a monsoon season. This is generally trapezoidal in plan whose shorter edge among the parallel sides is below the ground and then the surface rising constantly at about 15 degrees to reach the other parallel edge over the ground. First layer of fuel for burning is laid as the bottom most layer with the coal, wood and other locally available materials. Another layer of about 4 to 5 rows of bricks

is laid and then again a second fuel layer is laid over it. The thickness of the fuel layer goes on with the height of the clamp. After these alternate layers of the bricks and fuel, the top surface is covered with the mud so as to preserve the heat. Fire is ignited at the bottom, once fire is started it is kept under fire by itself for one or two months and same time period is needed for the cooling of the bricks.

Kiln Burning: Kiln is a large oven used for the burning of bricks. Generally coal, wood and other locally available materials like cow dung, husk can be used as fuel. They are of two types:

❖ Intermittent Kilns.

❖ Continuous Kilns.

Intermittent Kilns*:* These are like the cyclic kind of kilns, because in these kilns only one process can take place at one time. Various processes which take place in the kilns are loading, burning, cooling and unloading of bricks. There are two kind of intermittent kilns namely

❖ Up-draught Intermittent Kilns

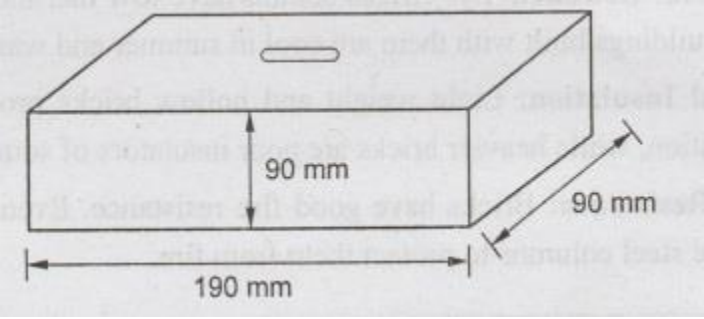
❖ Down draught Intermittent Kilns

Continuous Kilns: These kilns are called continuous because all the processes take place simultaneously. They are used when the bricks demand is more in a short period of time. It is a fast method of burning and bricks burning are completed in one day itself. There are two well-known continuous kilns namely

❖ Bull's Trench Kiln

❖ Hoffman's Kiln

PROPERTIES OF BRICKS



Good quality bricks should consists of the following properties:

❖ Colour: Brick should have a uniform and bright red colour.

❖ Shape: Brick shapes should ideally be rectangular, with well-defined, sharp edges and an even surface.

❖ Size: As prescribed by codes bricks should be of standard sizes.

❖ Texture: They should represent fine, dense and uniform texture and should not possess fissures, cavities, loose grit or any unburnt lime.

❖ Soundness: When struck with another brick or a hammer, metallic sound should be heard

❖ Hardness: Scratching should not cause any impression on the brick's surface.

❖ Strength: Compressive strength of brick should not be less than 3.5 N/mm2. The brick should not break into pieces, when dropped from a height of 0.9 m to 1.0 mm on a hard ground.

❖ Durability: Effectively manufactured bricks are incredibly durable, often lasting many years.

❖ Water Absorption: When immersed in water for 24 hours, water absorption should not be more than 20% by weight of the brick. For Ist class bricks this limit is 15%.

❖ Efflorescence: When immersed in water for 24 hours and then allowed to dry in shade, bricks should not show white patches. Due to the presence of sulphate of calcium, magnesium and potassium, these white patches are formed. Efflorescence keeps the masonry permanently in damp and wet conditions.

❖ Thermal Conductivity: Bricks should have low thermal conductivity, so that buildings built with them are cool in summer and warm in winter.

❖ Sound Insulation: Light weight and hollow bricks provide good sound insulation, while heavier bricks are poor insulators of sound.

❖ Fire Resistance: Bricks have good fire resistance. Even they are used to encase steel columns to protect them from fire.

TESTS ON BRICKS

To know the quality of bricks following tests can be performed. In these tests some are performed in laboratory and the rest are on field.

❖ Compressive strength test

❖ Water Absorption test

❖ Size, Shape and Colour test

❖ Hardness test

❖ Soundness test

❖ Structure test

❖ Efflorescence test

Compressive strength test: This test is conducted in laboratory to calculate the compressive strength of brick. It is also called crushing strength test. Generally 5 specimens of bricks are taken and immersed in water for 24 hours. The frog of the brick is filled with 1:3 cement mortar flush and is placed in wet jute bag for 24 hours. Then the specimen is placed in CTM (Compression testing machine) with 6mm plywood on top and bottom for uniform transferring of load on the specimen. Then axial load is applied uniformly at a rate of 14 N/mm^2. The ultimate load at which brick is crushed is noted. All five brick specimens are tested one by one and average result is taken as brick's compressive/crushing strength. Then the crushing strength is calculated as follows:

Compressive strength = Crushing load / Area of brick loaded

Water Absorption test: In this lab test brick specimens are weighed in dry condition and are immersed in fresh water for 24 hours. After 24 hours of immersion, specimens are taken out from water and wipe out with cloth. The weight of each specimen in wet condition is noted. The difference in weights is the water absorbed by brick. The percentage of water absorption is then calculated by the ratio of water absorbed to dry weight multiplied by 100. Average of five specimens is taken as the water absorption. Good quality brick doesn't absorb more than 20% water of its own weight.

Size, shape and colour test: A good quality brick should have bright and uniform colour throughout. Their shapes should ideally be rectangular, with well-defined, sharp edges and an even surface. In this test randomly collected 20 bricks are staked along the length, width and height. Then these bricks are measured to verify for sizes as per standard 190 mm × 90 mm × 90 mm. Bricks are closely viewed to check if its edges are sharp and straight and uniform in shape.

Hardness test: In this field test a scratch is made on brick surface with a nail. If that doesn't left any impression on brick then that is good quality brick.

Soundness test: In this simple field test, two bricks are held by both hands and struck with one another. If the bricks give clear metallic ringing sound and don't break then those are good quality bricks.

Structure test: For this test a few bricks are broken and their cross-section is closely observed. The cross-section should be homogeneous, compact and free from defects. If there are any lumps, cracks or holes present on that broken face then that isn't good quality brick

Efflorescence test: To find out the presence of alkalis in bricks this test is performed. The presence of alkalies in bricks is harmful and they form a grey or white layer on brick surface by absorbing moisture. In this test a brick is immersed in fresh water for 24 hours and then it's taken out from water and allowed to dry in shade. If any white/grey layer is not visible on surface it proofs that absence of alkalis in brick. If the white/grey patch is visible about 10% of brick surface then the presence of alkalis is in the acceptable range. If white/grey layer is about 50% of surface then it is moderate. If the alkalies presence is over 50% then the brick is severely affected by alkalies.

USES OF BRICKS

Bricks are commonly used for the following civil works:

❖ For masonry works and construction of arches, cornices.

❖ As brick jelly aggregates in PCC and waterproofing works.

❖ For pathways as pavers and construction of temporary structures.

❖ For sewer lining, chimney and furnace linings.

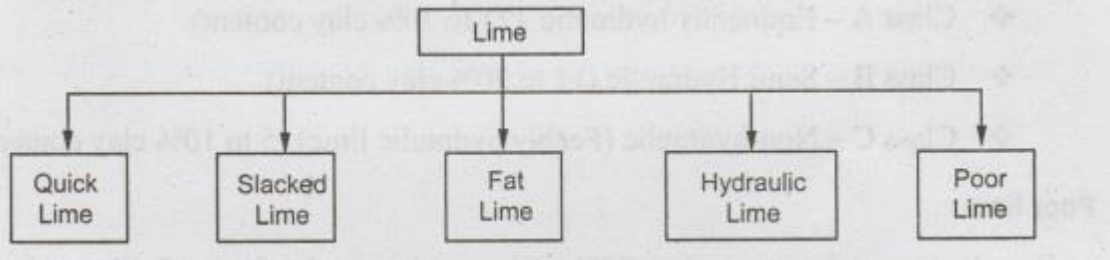
❖ As a fire protective coat for steel columns.

LIME

Lime is a significant binding material used in the construction industry for thousands of years. Since ancient time, lime has been used as a predominant construction material. World wonders like the Egyptian pyramids, the Great Wall of China are constructed using lime mortar only. Lime refers to quicklime, which is made by heating limestone (Calcium Carbonate) at high temperatures in a kiln. When lime is mixed with sand it forms lime mortar. Lime concrete is produced by mixing sand and coarse aggregate, with lime. But, since the arrival of cement, usage of lime in the construction industry has become obsolete.

TYPES OF LIME

When lime is heated, CO_2 is emitted and is reabsorbed when the lime materials slowly dry, set and harden. The re-absorption of CO_2 completes the lime cycle and makes using lime environmentally friendly and sustainable. Following are the different types of lime:



Quick lime:

Quick lime is obtained by calcination (i.e. heating to redness) of comparatively pure lime stone. It is the cheapest form of lime and is also known as caustic lime. It is amorphous in nature, highly caustic and possesses great affinity to moisture. It is ty to moisture. It is the main ingredient in the manufacturing of cement.

Slacked lime:

Slacked lime is also known as hydrated lime. It is obtained by slaking process, which is the chemical combination of quick lime with water. It has got the tendency of absorbing carbonic acid from the atmosphere in presence of water. It is ordinary pure lime, in white powder form, available in market.

Fat lime:

Fat lime is also known as high calcium lime or pure lime. Sometimes it is called as rich lime or white lime as it is white in colour. It is popularly known as fat lime as it slakes vigorously and its volume is increased to about 2 to 2.5 times that of quick lime. It is composed of 95 percentage of calcium oxide. It hardens slowly and has high degree of plasticity. This lime is used for various purposes as white washing, plastering of walls, as lime mortar with sand for pointing in masonry work, as a lime mortar with surkhi for thick masonry walls, foundations, etc.

Hydraulic lime:

Hydraulic lime is also known as water lime since its sets under water. This lime contains some amount of ferrous oxide with clay. Its Colour is not perfectly white and forms a thin paste with water and do not dissolve in water. The binding property can be improved by mixing its fine powder with sand and kept idle for a week before using. Depending upon the percentage of clay content, IS has divided hydraulic lime in three classes namely:

❖ Class A - Eminently hydraulic (21 to 30% clay content)

❖ Class B - Semi Hydraulic (11 to 20% clay content)

❖ Class C-Non-hydraulic (Feebly hydraulic lime) (5 to 10% clay content)

Poor lime:

Poor lime contains more than 30% of impurities, in the form of silica, Alumina and iron oxide. The mortar from this lime is of poor quality, since it contains more than 30% clay. Its colour is muddy and has poor binding property. The mortar made with such lime is used for substandard works.

CLASSIFICATIONS OF LIME

Based on the properties and usage, IS 712-1973 classifies lime as Class A, B, C, D and E.

Class A Lime: It is chiefly hydraulic lime and is usually supplied as hydrated lime. It is generally used for structural works.

Class B Lime: It comprises both hydraulic lime and fat lime and is supplied either as hydrated lime or as quick lime. It is commonly used for making mortar for masonry works.

Class C Lime: It is largely fat lime and is supplied both as quick lime and fat lime. It is frequently used for finishing coat in plastering and for white washing.

Class D Lime: It is similar to fat lime and contains large quantity of magnesium oxide. This is also normally used for white washing and for finishing coat in plastering.

Class E Lime: It is an impure lime stone, known as kankar. It is supplied as hydrated lime, which is available in modular and block form. It is mostly used for masonry mortar.

PREPARATION OF LIME MORTAR

Lime mortar is formed by mixing of lime, sand, and water. The required amount of lime and sand is placed on the ground or tray. The lime and sand are mixed evenly by turning the spades up and down. The water is added till the uniform color and consistency of the mortar area unit is obtained and also the mixture is persistent with spades.

The lime used for mortar could be either fat lime or hydraulic lime. Fat lime includes high burnt lime content. Its hardening depends on the loss of water and also the absorption of carbonic acid gas from the atmosphere and might be recrystallized at the correct time. When mixed with water it forms a putty or mortar that has the property of setting and hardening below water. Slacked fat lime is employed to form mortar for daubing, whereas hydraulic lime is employed for stone construction and is additionally suited to the development of chimneys and also the lightweight structure of buildings.

Also lime mortar mix ratio differs for various types of work. Lime mortar has high physical property and playability, sensible cohesion with alternative surfaces, and low shrinkage. They harden and develop strength, gaining strength endlessly for a protracted time. Fat lime and hydraulic limes are used for making lime mortar. If fat lime is used sand mixed is normally 2 to 3 times its volume. If hydraulic lime is used sand mixed is only 2 times the volume of lime. Lime is prepared by pounding, if quantity required is small or by grinding, if the required quantity is more.

Pounding: For pounding, pits are formed in hard grounds. The size of pit is usually 1.80 m long, 0.4 m wide and 0.5 m deep. It is provided with lining of bricks or stones. Lime and sand dry mixed

with required proportion is placed in the pit. Small quantity of water is added at intervals. In each interval the mix is pounded with wooden pounders and mortar is turned up and down. The process is continued till uniform colour and desired consistency is achieved.

Grinding: The grinding may be carried out in bullock driven grinding mill or in power driven grinding mill. It consists of a circular trench of radius 3 to 4.5 m, 0.3 m wide and 0.4 m deep. A wooden shaft pivoted at centre carries a stone wheel of width just 50 mm to 100 mm less than that of trench. Bullocks drive this wheel in the trench for grinding mortar. The dry mix is placed in the trench. Water is added gradually and bullock driven stone wheels grind the mix. A worker turns the mix up and down regularly. This method of preparing mortar needs 6 hours and can produce about 1.7 m^3 of mortar.

Power driven grinding mill: Two rollers rotate in a pan of diameter 1.8 to 2.4 m. Either pan or roller is rotated with the help of oil engine or electric power. During mixing required quantity of water is added gradually. Lime mortar is also having good grinding property. Fat lime mortar is used for plastering while hydraulic lime mortar is used for masonry construction. This mortar was considered cheap in olden days and was commonly used in small towns. However the combersome process of preparation and ease in availibility of cement in market has almost replaced the use of lime mortar.

USES OF LIME

The following are the uses of limestone in construction works:

❖ For white washing works

❖ For production of lime sand bricks.

❖ For preparing lime mortar for plastering and masonry works.

❖ For manufacturing cement

❖ For lining in open hearth furnaces.

❖ For soil stabilization.

CONCRETE BLOCKS

Concrete block construction has gained importance and has become a valid alternative to fired clay bricks. Concrete blocks are rectangular concrete masonry oldst units either, solid or hollow. The

essential ingredients of concrete blocks are cement, aggregate (sand, gravel) and water. Solid and hollow concrete blocks are manufactured in various sizes to meet the requirements of building blocks in cities and towns. They can be produced manually or with the help of machines.

Concrete solid blocks are made from aggregate, 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 in weight. 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.

CONCRETE HOLLOW BLOCKS

Hollow blocks are the universal type of concrete blocks that have one or more holes which are open at both sides. These blocks are called as artificial blocks, since they replace the bricks in the masonry construction. They are manufactured with lean mixes of cement, sand and aggregate of sizes less than 12 mm. Instead of sharp edged aggregates, round aggregates are used in the manufacture of these blocks. As per the recommendations of the IS 2185 (Part-1) 2005, the total void area shall range from 50% to 75% of the gross cross-sectional area. These holes or cavities reduce the total cross-sectional area of the block and hence the weight of block structure as a whole. For high-density blocks, Portland cement and aggregate, usually sand and fine gravel are used as a raw material. For low density blocks, industrial wastes, such as fly ash or bottom ash are used as the primary raw materials and are often called cinder blocks or breeze blocks.

Hollow concrete blocks are more commonly used in masonry construction. It accelerates the construction process, saves cement and steel and reduces the work expenses at the construction site. These blocks lower the natural weight of masonry constructions and improve the physical properties of walls, such as noise and thermal biley, . 9mad at bus on insulation. They also provide facilities for concealing electrical conduit, water and soil pipes. Standard hollow concrete blocks are available in full size as well as half size. Full-sized blocks are rectangular and have two cores while half-sized blocks are bilo? cubical and contain one core. The nominal dimensions of concrete block are as follows:

❖ Length should be: 400, 500 or 600 mm

❖ Height may be: 200 or 100 mm

❖ Width ranges: 50, 75, 100, 150, 200, 250 or 300 mm

Hollow concrete blocks are available in different types according to their shape, needs and design such as Concrete Stretcher Blocks, Lintel Blocks, Partition Concrete Blocks, Concrete Pillar Blocks, Corner Concrete Blocks, Jamb Concrete Blocks and Bullnose Concrete Block.

Materials used:

❖ **Cement:** Cement complying with any of the following Indian Standards like 33, 43 or 53 grades may be used. When cement conforming to IS 269 or IS 8112 or IS 12269 is used, replacement of cement by fly ash conforming to IS 3812 (Part 1) may be permitted up to a limit of 25%.

❖**Aggregates:** The aggregates used in hollow blocks shall conform to IS 383 for part breplacement of fine aggregate up to a limit of 20%.

❖ **Fly Ash:** Fly ash conforming to IS 3812 (Part 2) may be used for part breplacement of fine aggregate up to a limit of 20%.

❖**Water:** The water used for manufacturing hollow concrete blocks shall conform to the requirements of IS 456. It should be free from any substance harmful to concrete or reinforcement, or substance likely to cause efflorescence in the hollow block units. for part breplacement of fine aggregate up to a limit of 20%.

❖**Additives or Admixtures:** Additives may be added to the cement during manufacture and as admixtures to the concrete mix. Additives or admixtures used in the manufacture of concrete masonry units may be ad no accelerating, water reducing, air-entraining and super plasticizer conforming to IS 9103. Waterproofing agents should conform to IS 2645. For colouring pigments, where no Indian Standards apply; the additives or admixtures shall be shown by test or experience, to be not destructive to bollplan the durability of the concrete.

Physical Properties:

❖ **Blocks Density:** The block density of hollow concrete blocks are of three types as follows: Grade A, has density more than 1500 kg/m3. Grade B, has density less than 1500 kg/m3. Grade C, has density greater than 1000 kg/m3.

❖ **Compressive Strength:** The minimum compressive strength at 28 days of hollow concrete blocks shall vary between 3.5 N/mm^2 to 15 N/mm^2 for Grade A blocks and 3.5 N/mm^2 to 5 N/mm^2 for Grade B blocks.

❖ **Water Absorption:** The water absorption, being the average of three units, shall not be more than 10% by weight.

❖ **Drying Shrinkage:** The dry shrinkage of the hollow block units should not exceed 0.06%.

Advantages of Hollow Concrete Blocks:

Hollow concrete block masonry is the faster construction practice and has the following advantages:

❖ Hollow concrete block masonry reduces the cost of labour and materials, since larger size blocks reduces the number of joints in masonry work.

❖ It is a faster and easier construction practice, when compared to the conventional masonry systems.

❖ The hollow concrete blocks are light in weight, so they reduce the weight of the structure and hence light structural member or minimum percentage of steel is required for R.C.C building.

❖ Hollow concrete block masonry is highly durable as it is compacted by to asvilib high pressure and vibration, which gives substantial strength to the block. Adequate curing increases the compressive strength of the blocks.

❖ Due to the rough texture on hollow concrete blocks, good bonding can be obtained between cement mortar and concrete blocks.

❖ These blocks have good insulating properties against sound, heat and dampness.

❖ These concrete blocks need low maintenance and semi-skilled or unskilled labour can also work in this type of construction.

❖ Hollow blocks are low in water absorption than conventional bricks and have good fire resistance.

❖ Reinforcing the hollow block masonry is possible as there is no additional formwork or any construction machinery required.

❖ In the hollow blocks, the voids or cores can be filled with steel bars and concrete for achieving high seismic resistance.

❖ Hollow concrete blocks are eco-friendly materials as industrial wastes, such as fly ash or bottom ash are used as raw materials.

Use of Hollow Concrete Blocks:

Hollow concrete blocks are used in all type of masonry construction such as,

❖ Exterior and Interior load-bearing walls

❖ Fire-safe walls around stairwells, elevators

❖ Fire walls and curtain walls

❖ Partition wall and panel walls

❖ alans Piers, column and retaining walls

❖ Backing for brick, stone, and other facing works

❖ Boundary fences

LIGHTWEIGHT CONCRETE BLOCKS

A lightweight concrete block is a concrete masonry unit made of expanded aggregate to reduce the density and weight compared to standard concrete block.

These blocks are produced in greater volume but are less strong than other concrete blocks. They can be used in both internal and external walls where loading is slightly limited. They are also used as infill blocks in beam and for block flooring. Also these blocks are made in a standard texture finish providing an excellent surface for mortar works, rendering and plastering works. Light weight concrete blocks weighs less than 20kg and is available in a variety of sizes like 440 x 100 x 215 mm, 300 × 275 × 140mm, and 300 x 250 x 140mm:

Lightweight concrete blocks are manufactured from cement and expanded aggregates such as granulated or foamed blast-furnace slag, expanded clay or shale, furnace bottom ash, pulverized fuel ash or the less common volcanic pumice. The density of the aggregate used is generally proportional to the strength of the light weight concrete block. Super-lightweight aggregates like expanded clay and pumice used for their excellent thermal performance feature a relatively low compressive strength. Average compressive strength of standard high quality lightweight block is 3.6N/mm^2.

Lightweight concrete blocks are perfect for commercial and leisure developments, providing an even surface for paint and other finishes, with excellent resistance to air permeability. These blocks have high-level performance in load-bearing and other structural applications. They can be used in external applications as well as a versatile range of internal applications. The main advantage of lightweight concrete blocks over dense aggregate blocks is a combination of higher insulating properties and a lighter block unit weight. The lightweight block enables time and material cost savings through easier handling than larger units or a different block type with the same dimensions.

Construction Materials And Technology: UNIT I: Stones-Bricks-Concrete Blocks-Lime: Questions And Answers

TWO MARKS QUESTIONS AND ANSWERS

1. Classify the types of stones.

Stones are classified based on the following categories:

❖ **Geological**

* Igneous

* Sedimentary

* Metamorphic

❖ **Physical**

* Stratified

* Un-stratified

* Foliated

❖ **Chemical**

* Argillaceous

* Silicious

* Calcaracious

2. Write the any characteristics of good building stones.

(i) Structure

❖ Structure of a stone layer may be either stratified or unstratified.

❖ Structured stones are easily dressed and are suitable for the superstructures.

❖ Unstratified stones are hard and difficult to dress and are preferred for the foundation works.

(ii) Texture:

❖ Fine grained stones are usually strong and durable.

❖ For carving, attractive fine-grained stones with homogeneous distribution are used.

(iii) Density:

❖ Light weight stones are weak and denser stones are stronger.

❖ Stones with specific gravity less than 2.4 are not suitable for buildings.

(iv) Appearance:

❖ Appearance is a chief requirement for the selection of the stone.

❖A stone with uniform and attractive colour is durable, if grains are compact.

❖The colour and ability to receive polish greatly influence the appearance.

❖Marble and granite get very good appearance, when polished. Hence they are used for face works in buildings.

3. List the tests conducted on stone.

Following are different tests on conducted on building stones:

❖ Water absorption test

❖ Crushing strength test

❖ Impact test

❖ Abrasion test

❖ Acid test

4. What are the uses of stones?

General uses of building stones are:

❖ Construction of foundations, walls, columns and arches are done using stone masonry.

❖ Stone slabs are used for flooring, damp proof courses, lintels and even as roofing materials.

❖ Polished granite and marbles are commonly used for facing and flooring works.

❖ Road pavements and footpaths are also made using stones.

❖ Constructions of piers and abutments of bridges, dams and retaining walls are also done suing stones.

❖ Crushed stones are used as base course for roads, inert material in concrete and as railway ballast.

5. What are the commonly used stones in India?

Commonly used stones in our country are:

❖ Marble

❖ Granite

❖ Sand stone

❖ Basalt

❖ Slate

❖ Limestone

❖ Gneiss

❖ Gneiss

❖ Laterite

6. Classify bricks based on their quality.

Bricks are classified into four categories based on their quality as given below:

❖ First class bricks

❖ Second class bricks

❖ Third class bricks

❖ Fourth class (Over burnt) bricks zonote

7. Classify bricks based on their constituent materials.

Based on the constituent materials used, bricks are classified as follows:

❖ Common Burnt Clay Bricks

❖ Sand Lime Bricks

❖ Engineering Bricks

❖ Concrete Bricks

❖ Fly Ash Clay Bricks

8. Classify bricks based on their utility.

Based on their usage, bricks are classified as follows:

❖ Building Bricks

❖ Paving Brick

❖ Fire Bricks

❖ Special Bricks

9. List the process involved in the manufacturing of bricks.

The following operations are involved in the process of manufacturing bricks:

❖ Preparation of clay

❖ Moulding

❖ Drying

❖ Burning

10. Write about refractory bricks. Where are they commonly used?

Refractory brick is a block of refractory ceramics material used in lining furnaces, kilns & Fireboxes. A refractory brick is built primarily to withstand high temperature, but will also usually have a low thermal conductivity for greater energy efficiency.

11. Define the term Efflorescence.

Efflorescence is defined as the presence of grey or white layer on brick surface by absorbing moisture. It is formed due to the presence of alkalies in bricks. In the efflorescence test, if the presence of alkalies is over 50% then the brick is severely affected by alkalies. Hence more deposits will be visible over the brick surface.

12. How do you calculate water absorption of brick?

In water absorption test brick specimens are weighed in dry condition and are immersed in fresh water for 24 hours. After 24 hours of immersion, specimens are taken out from water and wipe out with cloth. The weight of each specimen in wet condition is noted. The difference in weights is the water absorbed by brick. The percentage of water absorption is then calculated by the ratio of water absorbed to dry weight multiplied by 100. Average of five specimens is taken as the water absorption. Good quality brick doesn't absorb more than 20% water of its own weight.

13. How do you conduct hardness test on brick?

Hardness test is a field test, in which a scratch is made on brick surface with a nail. If that doesn't left any impression on brick then that is good quality brick.

14. Differentiate between first class and second class bricks.

S. No	First class bricks	Second class bricks
1	First class bricks are table moulded and of standard shape.	Second class bricks are ground – moulded and irregular in shape.
2	Its surface is smooth, clean and free from cracks	Its surface is rough and it is not free from lumps and cracks.
3	Minimum crushing strength is 10.5N/mm^2	Minimum crushing strength is 7 N/mm^2

S. No

First class bricks

First class bricks are table moulded and of standard shape.

Its surface is smooth, clean and free from cracks.

Minimum crushing strength is 10.5N/mm^2

Second class bricks

Second class bricks are ground moulded and irregular in shape.

Its surface is rough and it is not free from lumos and cracks

Minimum crushing strength is 7 N/mm^2

15. What are the uses of bricks?

Bricks are commonly used for the following civil works:

❖ For masonry works and construction of arches, cornices.

❖As brick jelly aggregates in PCC and waterproofing works.

❖ For pathways as pavers and construction of temporary structures.

❖For sewer lining, chimney and furnace linings.

❖As a fire protective coat for steel columns.

16. Define "slaking of lime".com

Slaking of lime is the process, which is the chemical combination of quick lime with water. It has got the tendency of absorbing carbonic acid from the atmosphere in presence of water. It is ordinary pure lime, in white powder form, available in market. Slacked lime is also known as hydrated lime.

17. What is Quick lime?

Quick lime is obtained by calcination (i.e. heating to redness) of comparatively pure lime stone. It is the cheapest form of lime and is also known as caustic lime. It is amorphous in nature, highly caustic and possesses great affinity to moisture. It is the main ingredient in the manufacturing of cement.

18. What do you mean by Fat lime?

Fat lime is also known as high calcium lime or pure lime. Sometimes it is called as rich lime or white lime as it is white in colour. It is popularly known as fat lime as it slakes vigorously and its volume is increased to about 2 to 2.5 times that of quick lime. It is composed of 95% of calcium oxide. It hardens slowly and has high degree of plasticity. This lime is used for various purposes as white washing, plastering of walls, as lime mortar with sand for pointing in masonry works.

19. List the tests conducted on lime.

To determine their suitability, the following tests are conducted on lime:

❖ Physical Test

❖Chemical Test

❖ Heat Test

❖ Ball Test

20. What are the uses of lime?

The following are the uses of limestone in construction works:

❖ For white washing works

❖ For production of lime sand bricks.

❖For preparing lime mortar for plastering and masonry works.

❖For manufacturing cement

❖ For lining in open hearth furnaces.

❖ For soil stabilization.

21. Write about hollow concrete blocks.

Hollow concrete blocks are manufactured with lean mixes of cement, sand and aggregates of sizes less than 12 mm. Instead of sharp edged aggregates, round aggregates are used in the manufacture of these blocks. As per the recommendations of the IS 2185 (Part-1) 2005, the total void area shall range from 50% to 75% of the gross cross-sectional area. These holes or cavities reduce the total cross-sectional area of the block and hence the weight of block structure as a whole.

22. What are the advantages of hollow concrete blocks?

Hollow concrete block masonry has the following advantages:

❖ Hollow concrete block masonry reduces the cost of labour and materials, since larger size blocks reduces the number of joints in masonry work.

❖ It is a faster and easier construction practice, when compared to the Em conventional masonry systems.

❖ The hollow concrete blocks are light in weight, so they reduce the weight of the structure and hence light structural member or minimum percentage of steel is required for R.C.C building.

❖ Hollow concrete block masonry is highly durable as it is compacted by high pressure and vibration, which gives substantial strength to the block. Adequate curing increases the compressive strength of the blocks.

23. List the uses of Hollow Concrete Blocks.

Hollow concrete blocks are used in all type of masonry construction such as,

❖ Exterior and Interior load-bearing walls

❖ Fire-safe walls around stairwells, elevators

❖ Fire walls and curtain walls

❖ Partition wall and panel walls

❖ Piers, column and retaining walls

❖ Backing for brick, stone, and other facing works

❖ Boundary fences

24. What is a lime mortar?

Lime mortar is formed by mixing of lime, sand, and water. The required amount of lime and sand is placed on the ground or tray. The lime and sand are mixed evenly by turning the spades up and down. The water is added till the uniform color and consistency of the mortar area unit is obtained and also the mixture is persistent with spades.

25. What is a light weight concrete block?

A lightweight concrete block is a concrete masonry unit made of expanded aggregate to reduce the density and weight compared to standard concrete block. These blocks are produced in greater volume but are less strong than other concrete blocks. They can be used in both internal and external walls where loading is slightly limited

REVIEW QUESTIONS

1. List the different tests on stones. Explain any two tests.

2. Describe the various tests to determine the suitability of a building stone.

3. Explain the various types of common building stones and their uses.

4. Describe various characteristics of good building stones.

5. Explain the various types of stones which are used for building works and give in brief the specifications for a good building stone.

6. Describe any four tests to find the suitability of brick for the construction work.

7. Discuss in detail about different classifications of bricks.

8. Explain the properties of a good brick.

9. Explain in detail about manufacturing process of conventional bricks.

10. Describe various tests to be conducted for testing of conventional bricks.

11. Discuss in detail about different types of lime.

12. Explain in detail about the lime and the preparation of lime mortar.

13. Write in detail about hollow concrete blocks.

14. List down the application of hollow concrete blocks.
15. Discuss in detail about light weight concrete blocks.

UNIT II

OTHER MATERIALS

SYLLABUS

Timber - Market forms - Plywood - Veneer - False ceiling materials - Steel - Mechanical treatment - Aluminum - Uses - Market forms - Glass Ceramics – Refractories Composite Materials - Types and applications - FRP - Fibre textiles - Geomembranes and Geotextiles for earth reinforcement.

❖ Timber as building material

- ❖ Classification of timber
- ❖ Properties of timber
- ❖ Defects in timber
- ❖ Plywood
- ❖ Veneer
- ❖ False ceiling materials
- ❖ Steel
- ❖ Aluminium
- ❖ Glass
- ❖ Ceramics
- ❖ Refractories
- ❖ Composite materials
- ❖ Fibre Textiles
- ❖ Geomembranes and Geotextiles

OTHER MATERIALS

Timber - Market forms - Plywood - Veneer - False ceiling materials - Steel Mechanical treatment - Aluminum - Uses - Market forms - Glass Ceramics Refractories - Composite Materials - Types and applications - FRP - Fibre textiles - Geomembranes and Geotextiles for earth reinforcement.

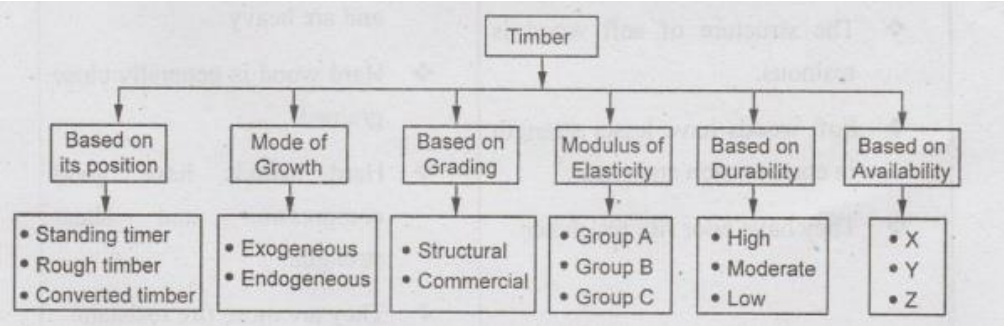
Timber represents wood which is appropriate for carpentry, building and for various engineering purposes. Timber is a fibrous, hard substance which forms a most part of the trunk and branches of a tree. Timber was used as building material even since ancient days. Many prehistoric temples, palaces and bridges which are built with timber exist even now.

TIMBER A BUILDING MATERIAL

Timber as a building material falls in two major classes such as natural and man- made. With the help of science and latest technology, wood in its natural form as timber, lumber, etc. is being rapidly replaced by man-made composite wood materials. Apart from formwork timber has many applications in buildings as doors, windows, frames, temporary partition walls, roof trusses and ceilings. Timber is a good shock absorber and hence it is suitable for constructions in hilly areas which are earthquake prone areas.

1. CLASSIFICATIONS OF TIMBER

Considering various important factors, the timbers are classified as follows:



2. CLASSIFICATION BASED ON ITS POSITION

Trees that produce good timber for construction are called Standing Timber. If the branches of a tree are cut and is approximately converted into pieces of required length, then it is known as rough timber. Through sawing, rough timber is converted into different marketable parts like planks, battens, posts, beams etc. then it is called as converted timber.

3. CLASSIFICATION BASED ON MODE OF GROWTH

Based on the mode of growth, timbers are classified as ***exogeneous*** and ***endogeneous.***

❖**Exogeneous:** These are trees which grow outward by introducing successive rings annually. These rings are called as annual rings. By counting these rings, the age of the timber can also be identified. These types of trees are further classified into coniferous trees which have conical type

leaves, fruits and deciduous trees which have broad leaves. Coniferous trees yield softwood whereas deciduous trees produce strong wood and are mostly used for carpentry and construction works. Some of the difference between soft wood and hard wood are as follows.

Coniferous Trees	Deciduous Trees
❖ Annual rings are seen distinctly ❖ Colour of soft wood is light and are less in weight ❖ The structure of soft wood is resinous. ❖ Soft woods have lesser strength in compression and shear. ❖ They have poor fire resistance.	❖ Annual rings are seen indistinct ❖ Colour of hard wood is dark and are heavy ❖ Hard wood is generally close grained. ❖ Hard woods have good compression and shear strength. ❖ They are more fire resistant.

Coniferous Trees

❖ Annual rings are seen distinctly

❖Colour of soft wood is light and are less in weight

❖ The structure of soft wood is resinous.

❖ Soft woods have lesser strength in compression and shear.

❖ They have poor fire resistance.

Deciduous Trees

❖ Annual rings are seen indistinct

❖ Colour of hard wood is dark and are heavy

❖ Hard wood is generally close grained.

❖Hard woods have good compression and shear strength.

❖ They are more fire resistant.

❖ **Endogeneous:** These are trees which grow inwards, where fresh fibrous mass is in the inner most portion of the tree. Bamboo and sugarcane belongs to this type. These type of trees cannot be used for structural works.

4. CLASSIFICATION BASED ON GRADING

Based on the structure and utility, timbers are classified into structural grading and commercial grading.

❖ **Structural grading:** This type is also known as stress grading, which is based on the visible defects in the timber and the effects on the material strength properties. It follows the standard by which the material is graded by considering the maximum principle stresses to which it can be subjected. They are also further sub divided into grading based on known effects of defects and estimating accumulative value and machine grading.

❖ **Commercial grading:** It is also known as utility grading in which the material is graded by consideration of usage of the material and price. They are further divided in the following types:

Grade A: This type is based on the dimensions and general appearance. Lengths, widths and thicknesses of converted materials are measured and graded.

Grade B: This type is based on the decisive use of the material. Here, each grade is further divided into A, B and C classes to designate the defects. Only two lengths are recognized, long (L) which is 5m and above, and short (S) that is under 5m. Each timber is imprinted as BAL (Beam, A-class, long) and PBS (Plank, B-class, short).

Grade C: This type is based on qualitative evaluation of defects and rough estimate of cost of material usage.

Grade D: This type is based on assessment of units of defects and fixing the permissible number of standard volume of area or the material in each grade.

5. CLASSIFICATION BASED ON MODULUS OF ELASTICITY

Based on the bending test results, value of E is obtained and the timbers are classified as follows:

***Group A*:** If E> 12.5 kN /mm^2

Group B: If E = 9.8 kN/mm^2 to 12.5 kN/mm^2

***Group C**:* If E = 5.6 kN/mm^2 to 9.8 kN/mm^2

6. CLASSIFICATION BASED ON DURABILITY

Durability tests are conducted by half burying the test specimens and observing the conditions periodically for several years. Based on the durability test results, the timbers are classified as follows:

High durability: If average life > 10 years**.**

Moderate durability: If average life = 5 to 10 years.

Low durability: If Average life < 5 years.

7. CLASSIFICATION BASED ON AVAILABILITY

Based on the availability, timbers are classified as follows:

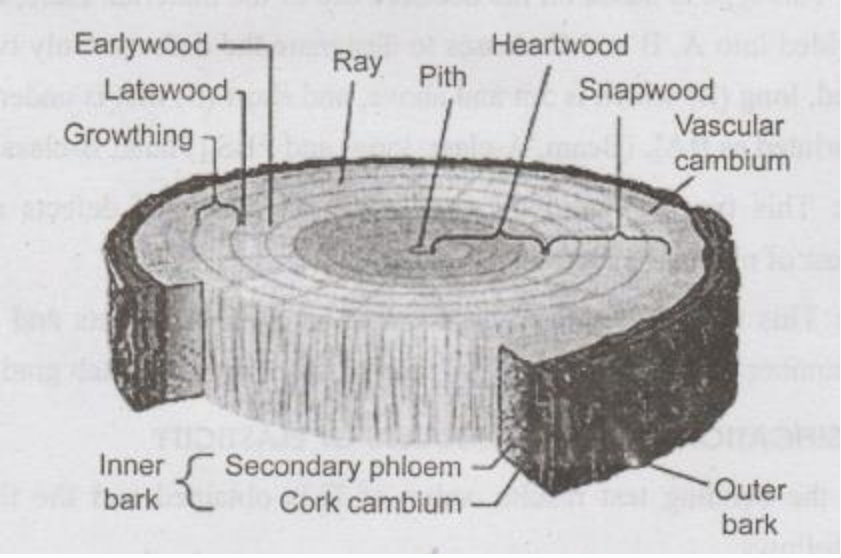
X - Most common, If availability is 1415 m^3 or more per year

Y- Common, If availability is between 355 m_3 to 1415 m^3 per year

Z-Less common, If availability is less than 355 m^3 per year

8. STRUCTURE OF TIMBER

The structure of a timber can be seen from the cross section of a tree as shown in



❖ **Pith:** It is the inner most part of a tree having soft tissues near about the center of log of a timber. When the tree becomes old, the pith will be dark and fibrous.

❖ **Heart Wood:** Inner part of log of a tree surrounding the pith is called Heart. This is the dead part of wood, which is strong and dark in colour. This portion consists of several annular rings.

❖ **Sap Wood:** This layer is present next to heart wood, and is also known as alburnum. Outer part of log of a tree surrounding heard wood & upto the bark which contains living cells is called Sapwood. It denotes recent growth and contains sap. The annual rings of sap wood are light in colour and are less sharply divided.

❖ **Cambium Layer:** Layer of liquid material deposited below the bark & outside the sap wood in the log is called as Cambium Layer. If the bark is removed and cambium layer is exposed to atmosphere, activeness of cells comes to an end and tree dies.

❖**Inner Bark or Bast:** It is the inner skin surrounding the cambium layer. This skin feed & covers the Cambium Layer.

❖ **Outer bark:** It is the covering, outside the log of a tree which consists of wood fibres.

❖ **Annual ring:** The concentric innumerable rings in the log of a timber, indicating its growth are called annual rings.

❖ **Medullary Rays:** Horizontal thin fibrous tissues which extended radially from the cambium layer towards the core or from the pith towards the bark. They hold annular rings together.

9. PROPERTIES OF TIMBER

The following are the properties of a good timber:

❖ **Colour**: Colour should be uniform.

❖ **Odour:** When freshly cut, odour should be pleasant.

❖ **Texture**: Good timber should have fine and even texture. Grains: Grains are close in good timber.

❖ **Density**: If density is more, timber is said to be stronger.

❖ **Warp:** Even under changing environmental conditions, good timbers do not warp.

❖ **Soundness:** When struck together, clear ringing sound indicates the timber is in good quality.

❖ **Hardness:** If timber is hard, they are strong and durable.

❖ **Toughness:** Timber should be capable enough to resist shock loads.

❖ **Abrasion:** Good timber does not weaken due to wear.

❖ **Strength:** Timber should have good strength in compression, bending and shear.

❖ **Fire resistance**: A good timber should have greater resistance to fire.

❖ **Permeability**: Good timber should have low water permeability.

❖ **Workability:** Timber should be easily workable and should not congest

the saw.

❖ **Durability:** Good timber should have high resistance against fungal and insects attack.

❖ **Defects:** Good timber should be from defects like dead knots, shakes and cracks.

10. CHARACTERISTICS OF GOOD TIMBER

The principal characteristics of timber are strength, durability and finished appearance:

❖ Narrow annual rings, closer the rings greater is the strength.

❖ Heavy weight and compact medullary rays.

❖ Dark colour and uniform texture.

❖ Sweet smell and a shining fresh cut surface.

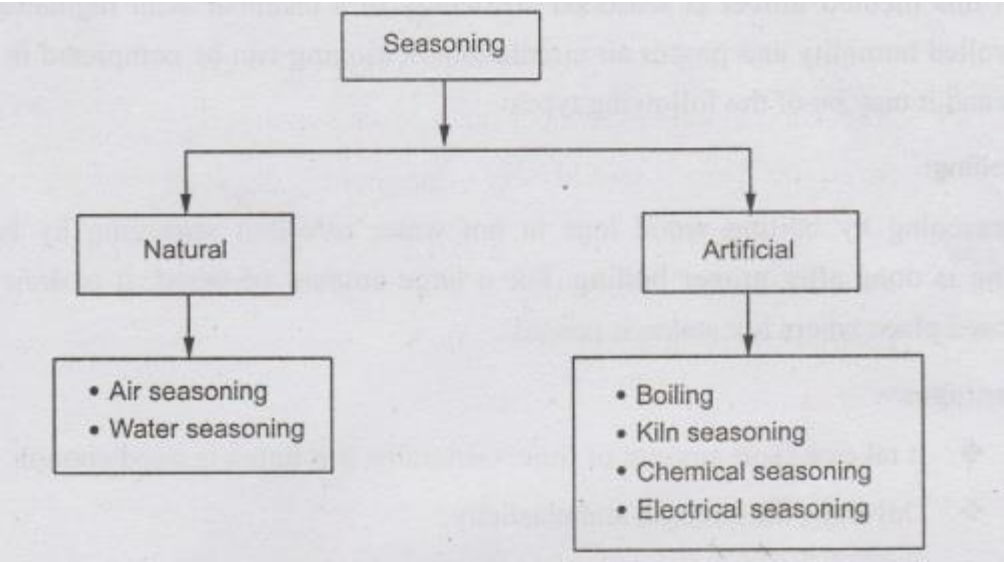
❖When struck sonorous sound is produced.

❖ Free from the defects in timber.

❖ No woolliness at fresh cut surface.

11. SEASONING OF TIMBER

The process of drying out the water from "wet" or "green" timber is termed as "seasoning" of timber. Drying the moisture out of wood enhances its properties to such an extent that the resulting timber is given the special name "seasoned" rather than "dried" although the terms are identical. The process of seasoning of timber may be of the following types:



12. NATURAL SEASONING

Seasoning of woods or timbers using natural elements is called natural seasoning. may be of two types namely water and air seasoning.

(i)Water seasoning: Removal of wood sap by immersing logs into water flow is called water seasoning. It is carried out on the river banks while thicker ends are kept towards upstream. After that, the logs are allowed to dry. This process is time consuming such as 2 to 4 weeks generally.

(ii) Air seasoning: This process involves exposing of woods to air for seasoning. At first, a platform is required that is built on the ground at 300mm height above the ground. Next process is the arrangement of woods in layers. Air circulation is maintained between logs because it helps to reduce the moisture which is important for seasoning. A clean, shady, dry, cool place is preferred for this process. Sometimes coated by the impermeable substance to reduce extreme moisture. To improve the quality oil coating, thick paint coating is maintained. To prevent fungal infection logs are treated with petrol or gasoline. Using this process good quality of seasoned wood can be obtained.

13. ARTIFICIAL SEASONING

In this method timber is seasoned artificially in a chamber with regulated heat, controlled humidity and proper air circulation. Seasoning can be completed in 4 to 5 days and it may be of the following types:

(i) Boiling:

Seasoning by boiling wood logs in hot water is called seasoning by boiling. Drying is done after proper boiling. For a large amount of wood, it is done in an enclosed place where hot steam is passed.

Advantages

- ❖ It takes a short amount of time. Generally, 3-4 hours is good enough.
- ❖ Develops the strength and elasticity.

Disadvantages

❖ It is serviceable basically for a small quantity of wood, not convenient for a large amount.

❖ The cost is high.

(ii) Kiln seasoning:

Seasoning of wood by using a large chamber or kiln where there is a good process for the circulation of hot air. Fully saturated air with a temperature 35°C to 38°C is forced in the kiln. Kiln seasoning can be done by 2 processes such as:-

Progressive kiln Seasoning: Wood log is entered through the kiln and the temperature and humidity differentials are maintained through the length of the kiln to maintain proper drying.

Compartmental Seasoning: It is maintained by enclosed container or buildings. It accelerates the process because external energy is used

Advantages

❖ Most effective and economic seasoning.

(iii) Chemical seasoning

Reduction of moisture using salt solution is called chemical seasoning. After the absorption of water by the chemical solution logs are let to dry.

Advantages

❖ It increases the strength of the timber.

❖ It is less time-consuming.

Disadvantages

❖ Chemical reagents can sometimes reduce strength.

❖ It can cause a problem in gluing or finishing or corrosion while using.

(iv) Electrical seasoning

Dry wood is non-conductor of electricity while green timber is a conductor, so, can pass alternating current. Thus in this method alternating current is used for drying the cells of wood by creating heat. As electricity is used, it's called electrical seasoning.

Advantages

❖ Using this method quick drying is obtained. a French electrical seasoning method is used to season overnight.

Disadvantages

❖ The equipment required is very costly.

❖ It is an uneconomic process as a high rate of electricity is consumed.

❖ During heating the cells of wood or timber they lose their strength and become weak.

14. PRECAUTIONS DURING SEASONING

Following precautions must be taken during seasoning of timber:

❖ During seasoning, the moisture should be removed under an environment maintaining conditions.

❖ Seasoned timber should be protected from exposure to the rain and excessively high humidity during air seasoning

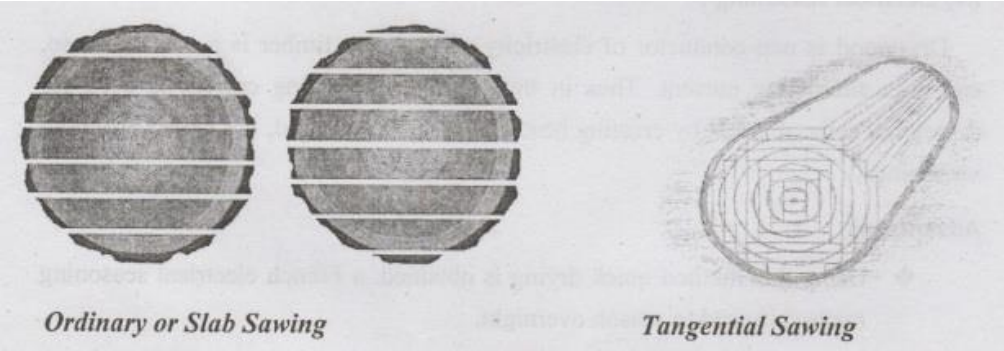
❖ During seasoning, a proper gap between logs should be maintained for easy and uniform air or water or hot air passing.

❖ Moisture should be extracted almost at an equal rate from all logs because differentiated dryness causes irregular shape.

15. SAWING OF TIMBER

Sawing is the cutting of timber from logs into different shapes and sizes. Sawn timber is generally cut into varying rectangular widths and lengths, but may also be wedge-shaped. The following are the two types of sawing of timber:

Ordinary or Slab Sawing: This is the most economical method of sawing, as the wastage of timer & cost of sawing is minimum. Cuts are made into the log of wood according to the required thickness, not necessarily tangential to the annual rings.



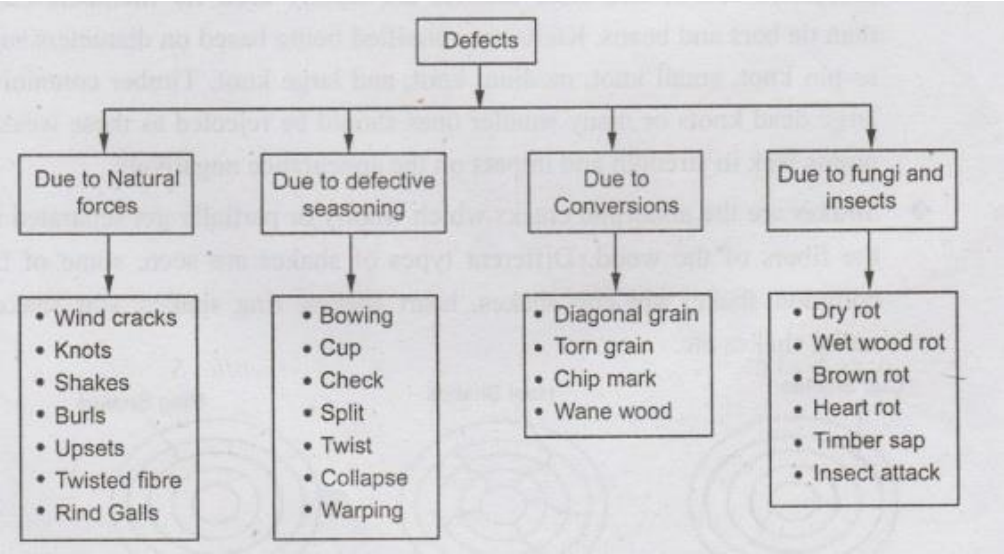
Tangential Sawing: In this method the board & planks are sawn out of wood tangentially to the annual rings. This method is economical due to less wastage &involves less Labor. But this method do not suit for heavy works as for flooring.

Quarter Sawing: Here, logs are cut into four quarters. These quarters have their flat faces essentially radial. Annual rings are cut at angles not less than 45 degrees. This method requires more labour & also involves more wastage.

Radial or Rift Sawing: Logs are cut out of quarter logs, parallel to the medullary rays and perpendicular to the annual rings. It produces tiny end grains which are sometimes known as "Silver Grains", by sawing parallel to the medullary rays. Used for high class decoration and joinery work. This method is not economical.

16. DEFECTS IN TIMBER

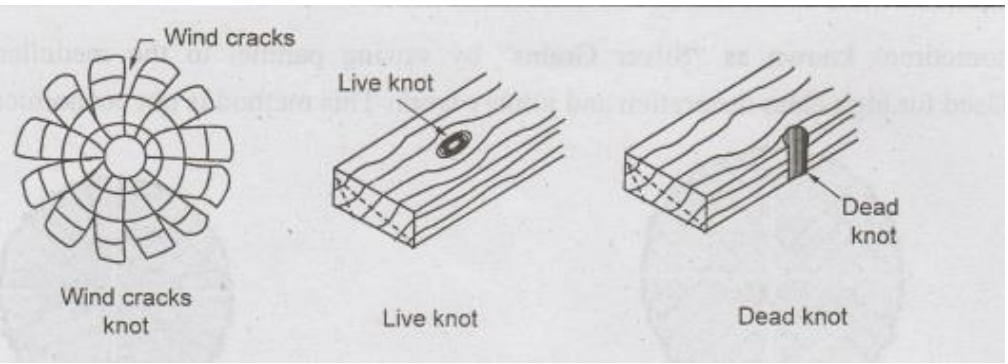
Different defects which are liable to occur in timber can be classified as follows:



(i) Defects due to Natural Forces:

Defects due to natural forces in wood are as follows:

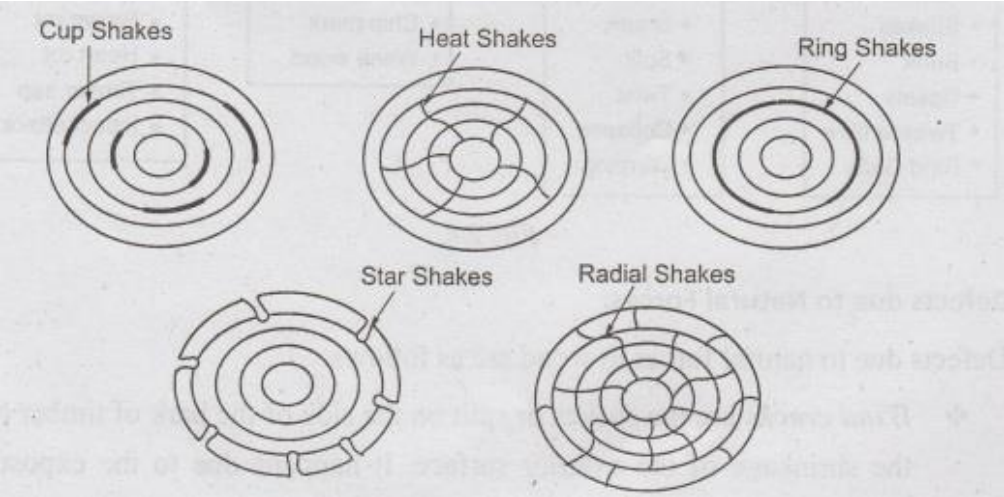
❖ **Wind cracks** are the shakes or split on the side of the bark of timber due to the shrinkage of the exterior surface. It happens due to the exposure to atmospheric agencies like sun. wind etc



❖ **Knots** are the roots or bases of small branches of the tree. These may stay alive or may become a dead part of the tree but they break the continuity of fibers. In the beginning, the base portion gets food from the stem, but finally it results in the formation of the dark and hard ring known as the knots. These knots are not very harmful when these are small in size, feel hard, look round,

and these timbers are mostly used for members other than tie bars and beans. Knots are classified being based on diameters such as pin knot, small knot, medium knot, and large knot. Timber containing large dead knots or many smaller ones should be rejected as these weaker points lack in strength and impact on the appearance negatively.

❖ **Shakes** are the abnormal cracks which wholly or partially get separated by the fibers of the wood. Different types of shakes are seen, some of the common shakes are cup shakes, heart shakes, ring shakes, star shakes, ib boradial shakes etc.



(i) Cup Shakes in Timber: Cup shakes are caused by the rupture of tissue in a circular direction. It is a curved crack, and it separates partly one annual ring from the other developing one due to non-uniform growth or due to excessive bending of a growing tree during a cyclonic weather. It may prove to be harmful if it covers only a portion of the ring.

(ii) Ring Shake in Timber: When cup shake covers the entire ring of timber, they are known as ring shakes. Ring shake in timber is a tangential separation of wood fibers along with the parts of the annual rings. It often looks so fine that is not found visible in greenwood and can be detected in dry wood later.

(iii) Heart Shakes in Timber: Heart shakes occur in the center of a cross- section of timber due to the shrinkage of the interior part of a tree, which is approaching toward its maturity. It divides the tree in cross-sectional way bon into two to four pieces.

(iv) Star Shake in Timber: Star shake cracks start from the bark and extend. toward the sapwood. It is usually confined up to the plane of sapwood. These cracks are more extensive on the extreme

ends and get narrower on the inside ends. Star shake cracks are typically formed during the growth of the tree.

(v) Radial Shake in Timber: Radial shakes are same as star shakes, but as compared to star shakes, radial shakes are quite irregular, fine and numerous in shape. Generally, these cracks occur when timber is exposed to the sun for seasoning after falling. Radial shakes cracks start from a short distance from the bark and gets extended toward the center, then follow the annual ring direction and then run toward the pith

❖ **Burls** are also known as the excrescences. These are mainly formed when a tree has received shock or injury in its young age. Due to such damage, the growth of a tree may get completely upset and irregular projections start appearing on the body of timber.

❖ **Upsets** are ruptures of a fiber of timber caused by some major impacts, injury, pressure, due to incompetent chopping and related potent effect.

❖ **Twisted** fibers are also known as the wandering hearts. The twisting of young trees causes these being impacted by fast blowing wind, and the fibers of timber gets twisted in one direction. The wood with twisted fiber is inapt for sawing.

❖ **Rind Galls:** The meaning of word rind is bark, and gall is a kind of abnormal growth. Therefore, an unusual cured swelling is found on the branch of a tree. This is known as the rind galls. Rind gall develops at the points from where branches are improperly cut off or removed. Rind galls are rarely found in a tree, and the timber in this part of tree becomes very weak and mostly fragile.

(ii) Due to defective seasoning

Due the defective process of seasoning, the following defects might occur in wood:

❖ **Bowing:** The bow is a timber defect indicated by the curvature formed in the direction of the length of timber.

❖ **Cup:** It is a defect of timber which is indicated by the curvature formed in the transverse direction of the wood.

❖ **Check:** It is a crack which forms due to the timber seasoning process and it tends to separate the fiber layer of the wood.

❖ **Split**: When check extends from one end to the other in a wood log, it is known as a split. Splits are lengthwise separation of the wood caused by either mishandling or seasoning.

❖ **Twist:** When a timber piece gets spirally distorted along its length, it is known as a twist.

❖ **Collapse:** Due to uneven shrinkage, wood sometimes get flattened during the drying process. This is known as a collapse.

❖ **Timber Warping**: When a piece of timber has twisted out of its shape, it is called the warp.

(ii) Defects due to Conversion

The following defect occurs in wood, while converting the timber to commercial form:

❖ **Diagonal Grain:** It is a timber defect that is formed because of improper timber sawing indicated by a diagonal mark on the straight-grained surface of the wood.

❖ **Torn Grain:** It is also known as a form grain, and it is usually caused by a small depression formed on the finished surface of the timber by accidental falling of tool.

❖ **Chip Mark:** It is indicated by the marks or signs placed by chips on the finished surface of the timber. The parts of a planning machine may also stand responsible for forming these marks.

❖ **Wane Wood:** It is a timber defect that is denoted by the presence of real rounded surface on the manufactured piece of timber.

(ii) Due to Fungi and Insects

Due the fungal attack, the following defects might occur in wood:

❖ **Dry Rot:** Certain types of fungi feed on wood and during feeding they attack timber and convert it into dry powder form, which is known as the dry rot. It occurs at the places where there is no free circulation of air is experienced. The unseasoned softwoods and sapwood easily get attacked by dry rot. The most favorable conditions for the rapid growth of fungus, which is responsible for dry rot, is the absence of sunlight, sogginess, presence of sap, stagnant air and warmth. If timber is not properly stacked after cutting and shaped, it may get affected by an attack of dry rot.

❖ **Wet Wood Rot:** Some varieties of fungi cause chemical decomposition of timber and convert wood into a grayish brown powder, which is known as wet rot. The main reason for the development of wet rot is alternate dry and wet conditions. If unseasoned timbers are exposed to

rain and wind, they become easily liable for attacks of wet rot. The well-seasoned timber should be used for exterior work to prevent wet rot problem.

❖ **Brown Rot:** It is used to indicate decay and underlying disease of timber. Specific Types of fungi remove cellulose compounds from wood, and hence the wood takes the brown color, which is known as brown rot.

❖ **White Rot:** White rot defect is just the opposite of brown rot defect. In the case of white rot defect, certain types of fungi attack lignin of wood, and the wood assumes the appearance of a white mass consisting of cellulose compounds, hence the name white rot.

❖ **Heart Rot:** Heart rot defect is formed when branches have come out of a tree. Hence, the heartwood is exposed to the attack of atmospheric agents. Ultimately the tree becomes feeble, and it gives out hollow sound when the hammer hits the log.

❖ **Timber Sap Stain:** The particular types of fungi do not cause the complete decay of timber, but they feed on cell contents of sapwood, and the sapwood loses its color and texture gradually This is known as sap strain. It generally occurs when moisture content gets equal to higher than 25%.

The insects usually found responsible for the decay of timber are termites, beetles, and marine borers.

❖ **Termites**: Termites are also known as white ants, and they are found in tropical and sub-tropical countries. These insects live in a colony and are truly fast in eating away the wood from the core of the cross-sections. These insects make tunnels inside the timber in different directions and usually do not disturb the outer shell or cover. Very few woods such as teak, sal etc. can resist the attack of termites.

❖ **Beetles:** Beetles are small insects, and they cause rapid decay of timber. They form holes of size about 2 mm diameter in wood and attack the sapwood of all species of hardwoods. Tunnels are formed in all directions in sapwood by the larvae of beetles and wood gets converted into a fine flour-like powder. They usually do not disturb the outer layer of the timber. Hence the timber piece gets attacked by beetles may look sound externally till it completely gets withered inside.

❖ **Marine Borers:** Marine borers are generally found in salty water. Most of the varieties of marine borers do not feed on wood but they make holes or bore tunnels in wood for taking shelter. The approximate diameter and length of holes or bores are between 25 mm and 60 mm. The timber

attacked by marine borers loses strength and colour. It is noted that no wood is completely protected by the attack of marine borers.

17. COMMON MARKETS FORMS & SIZES OF TIMBER

Some of the commonly available market forms of timber are explained below:

❖ **Log:** Stem or trunk of a tree which is felled is known as a log. It can be converted and used as firewood and lumber ,etc.

❖ **Bolt:** A Short log 1.25m or less in length.

❖ **Cant:** A thick piece of timber with or without squared edges.

❖ **Baulk**: Baulk is a piece of timber obtained by removing the bark and sapwood, which looks roughly square-shaped. The cross-sectional dimensions are usually more than 50 mm on one side and more than 200 mm on the other side.

❖ **Deal:** Deal is a type of softwood, usually sawn with parallel sides of thickness 50 to 100mm, and of width 200 to 250mm.

❖ **Plank:** It is a long timber piece with parallel sides of width more than 50 mm and thickness less than 50 mm.

❖ **Pole:** Pole is also known as Spar, which is a long log of diameter less than or about 200 mm.

❖ **Post:** Timber member used in upright position in Building fencing or structural work is called a post. It is a rectangular wooden piece used as a compression member in buildings, having a diameter less than 300 mm.

❖ **Strip**: Strips are wooden pieces of a thickness not more than 50 mm and width not exceeding 100 mm.

❖ **Batten:** It is a strip of timber, of thickness 50 to 100mm and breadth 150 to 200mm. It is used in roofing, flooring, ceilings, wall and other construction applications.

❖ **Boards:** It is a plank of timber with parallel sides, thickness not exceeding 50 mm and width exceeding 200 mm.

❖ **Scantling:** Scantlings are pieces of timber with different sizes, with thickness and breadth are more than 50 mm but limited to 200 mm. Depending on the type of work they are sawn out of a log and cut into required sizes.

❖ **Quartering:** These are square pieces of timber, of length varying from 50 mm to 150 mm.

❖ **End:** The small pieces of battens, deal, poles or scantlings are referred to as Ends.

❖ **Sleeper:** Transverse supports under rails in a Railway track of size 250mm x 125mm or 200mm x 115mm.

❖ **Slat:** Wood about 185mm x 65mm x 6mm in size.

18. USES OF TIMBER

Timber is used for the following purposes:

❖ It is ready to use material available naturally and easy to transport and handle.

❖ It has more thermal insulation, sound absorption and electrical resistance.

❖ It can be easily worked. Hence repairs and alterations to wood work can also be done easily.

❖ It possesses excellent strength and a good preference for making load bearings like columns, beams, trusses and piles.00

❖ Timber is widely used for doors, windows, flooring and roofing as it is easily convertible into any shape and size.

❖ It is used for temporary works in construction like scaffolding, centering, shoring and strutting, packing.

❖ It is also used for other permanent works like for railway sleepers, fencing poles, electric poles and gates.

❖ Timber is widely used in ornamental works like showcases, furniture, sports goods and musical instruments

❖ It is used in body works of buses, lorries, trains and boats and for industrial uses like paper pulps card boards and wall papers.

PLYWOOD

Plywood is an engineered wood sheet material made up of fine layers or flimsy strands of wood veneers attached together by placing wood grains 90 degrees to one another. It is one type of manufactured board which can be described as a mixture of medium density fibre board (MDF) and Chip Board (Particle Board).

It is a complex material and attaches resin and fibre sheets of wood. The outer most veneer sheets in a plywood panel are called/faces. The interior ply/plies which have their grain directions parallel to that of the faces are termed as core/centre. Other sheets which have grain directions perpendicular to that in the face are termed as cross bands. 29ilieup Inige om

Plywood has become much popular nowadays because of its relatively low moisture content which makes various tasks easy to perform. Mostly for outdoor uses plywood has become very important to use.

1. CLASSIFICATIONS OF PLYWOOD

Based on various aspects, plywood can be classified as follows:

Based on direction of Grains: Plywood may be classified based on the direction of grains in the plies. Normally the alternate plies are oriented at 30° or 60° in star plywood. The faces are arranged with the grain at 45° to that of the centres in diagonal plywood. When the plies are bonded together with water-soluble glues such as casein glue, interior grade plywood is obtained and when bonded with phenol formaldehyde adhesive it is identified as exterior grade plywood which is completely water proof.oile

Based on Grade: Plywood may be classified based on the grades for general purposes. It depends upon the bond strength developed by the adhesive used for bonding the veneers:

* Boiling water resistant or BWR Grade, and

* Moisture resistant or MR Grade.

Based on type of wood: Plywood may be classified based on the type of wood and properties.

❖ **Softwood Plywood** which is also known as spruce-pine-fir or SPF because it's made from spruce, pines, and fir. If made from spruce the prominent grains are coated by a system so that this

kind of plywood becomes more effective as hard as concrete and used for shuttering strands and construction.

❖ **Hardwood Plywood** is made from angiosperms. This type of plywood is identified by its firmness, hardness on surface, inflexibility, resistance quality. This can be used to bear heavy weight.

❖ **Tropical Plywood:** Different types of timbers of tropical area are mixed to make this type of plywood. Though previously it was only collected from the Asian region, now also from Africa and America it is collected. Tropical plywood popular for some special qualities like Strength, wolly Density, Evenness, Inflexibility, Resistance quality and Thickness.

❖ **Aircraft Plywood:** Woods from Mahogany, Spruce, Birch are used to make Aircraft Plywood. The African mahogany gives usable structural aircraft plywood. Among birch trees European birch is good. This type is famous for strength. This type is also made from Mahogany, Spruce, Birch but the special quality is that this is resistant to heat.

❖ **Decorative plywood** is also called overlaid plywood. Usually made from woods of ash, oak, Red oak, birch, Maple, mahogany, Philippine mahogany also called seraya, rosewood.

❖ **Flexible Plywood:** As the name suggests, flexible plywood is used for making flexible furniture or structures. The furniture of eighteenth century was mostly of curved structures. These are made from Baltic Birch.

❖ **Marine Plywood:** The type of plywood which can be used in moisture, humid, wet environment is called marine plywood. Even it can be used in moisture for long period. The layers of marine plywood bear too small core gap to feel that doesn't permit the wood to fix water inside the gaps. It is also fungal resistant.

Based on Appearance: Plywood for general purposes should be classified into three types, namely, AA, AB and BB based on the quality of the two surfaces, namely, A and B in terms of general permissible defects. The type of plywood should, therefore, be designated by the kind of surfaces of the panels. The better quality surface should be called 'face', and the opposite side should be called 'back'. If the face and the back are of the same quality, they are not distinguished. The type of plywood would denote first the quality of face followed by the quality of back. For example, Type AA should have both surfaces of quality A, Type AB should have face of quality A and the back of quality B and Type BB should have both the surfaces of quality B. Structural

plywood panels are available in following sizes. 2400 x 1200 mm, 2100 × 1200 mm, 1800 x 1200 mm, 2400 x 900 mm, 2100 × 900 mm, 1800 × 900 mm.

2. USES OF PLYWOOD

❖ It has good strength both along as well as across the grains and are extensively used for partitions, ceilings, doors, concrete form work, plywood boards, lamin boards etc.

❖ It has better splitting resistance due to the grains in adjacent veneers in cross direction as such nailing can be done very safely even near the edges.

❖ Plywood has cross-grained construction, the tendency to shrink or swell is reduced and hence it can be curved into desired shapes.

VENEER

The primary process in the manufacture of wood based products is veneering which produces thin sheets of wood known as veneers. Timber veneer is a decorative building material comprising thin slices of timber glued onto wooden board, particle board or fibre board. It has been preferred by builders and designers since ancient times as the finest and most efficient use of the valuable timbers. Veneer is produced as a thin layer of timber that is uniform in thickness. The veneer is normally between 0.5 and 0.85mm thick. Timber veneer is from a natural and renewable resource competing with non-renewable commodities like steel, aluminium and plastics. The surface coverage of veneer is approximately 40 times more than 25mm timber, which makes it the most economical way of utilizing precious wood. 1 cubic metre of log produces around 1,000 sqm of real timber in veneer form. No other form of wood working material results in such an efficient use with minimal wastage.

Veneer is produced by slicing or peeling of logs. It is sliced at approximately 0.6mm or can be peeled at various thicknesses. The most suitable wood for this purpose is walnut. However other species like teak, rose wood, etc. are also used.

The logs to be used for this purpose are kept in wet storage to avoid end splitting and are softened by heating with hot water or steam and the bark is removed. The log is then cut to veneers.

TYPES OF VENEER

Several cut methods are used to create various wood grain patterns. The most commonly produced grains are: Crown, Quarter, and Rotary. However, other cuts exist and highlight specific features such as Birdseye, Quiltes, Pommele or Burl/Burr. Different ways of slicing wood to get veneers are as follows:

Rotary cut: The log is cantered on a lathe and turned against a broad cutting knife set into the log at a slight distance.

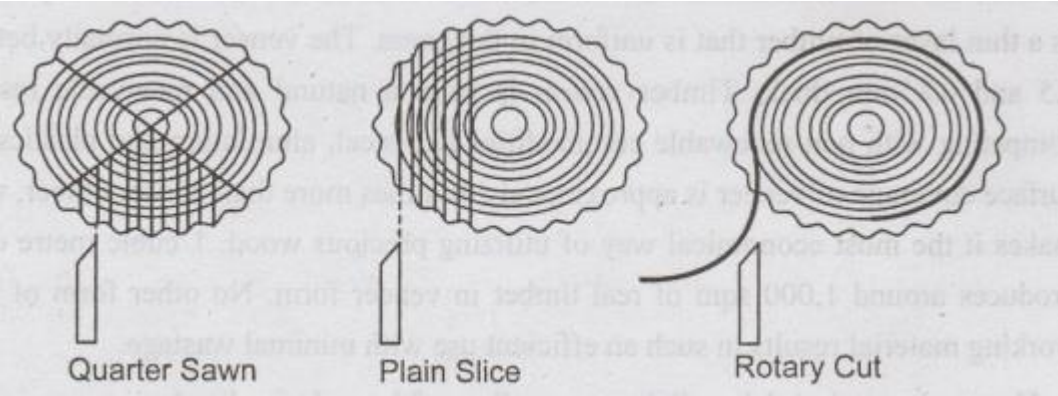
Quarter slicing: The slicing is made perpendicular to the annual growth rings of the tree. This creates a straight grain appearance.

Lengthwise slicing: This is done from a board of flat sawn lumber rather than from a log. A variegated figure is created with this slice.

Plain slicing: By slicing parallel to the centre of the log, a raised "cathedral effect" is formed by the innermost growth rings.

Half round slicing: Sliced on an arc parallel to the centre of the log, this cut achieves a flat-cut veneer appearance.

Rift cut: This straight grain cut is derived by slicing red and white oak at a slight angle to minimize the irregularities in the wood.



FALSE CEILING

A false ceiling is a fitted ceiling that is suspended below the original ceiling of a room or home. It is provided below the roof slab on hanging supports. The false ceiling is usually provided for temperature control like heat insulation for air conditioning, to install lights, or to conceal electrical

and other networking cables. False ceiling is the advancement in modern construction and architecture to implement the interior designs in both residential and commercial applications. It can be differentiated into many types based on their uses, material used and appearance and visibility.

TYPES OF FALSE CEILING

The major classifications based on materials used are listed briefly as follows:

Gypsum False Ceiling: Gypsum false ceiling is a hydrated sulfate of calcium. This type of false ceiling is lightweight, sound insulated, fire resistance, soft and thermally insulated. Gypsum false ceiling comes in the shape of square boards that are hung with the help of iron framework. The finishing work on these boards like paints, laminates, wallpapers and texture finish gives good appearance.

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 serves both the aesthetical and functional purpose. Plaster of Paris false ceiling are attractive, almost no maintenance is required and has a long life span. They are very excellent insulators of heat and cold. These types of false ceiling gives smooth finish to the ceiling.

Fibre false Ceiling: These are in high demand for the construction of false ceiling due to low cost and easy installation. The materials used to manufacture fiber ceiling panels are man made by synthetic and natural minerals. As these are man-made they come in many shapes and sizes.

Wooden False Ceiling: This type of ceiling is commonly used due to its natural textures, pattern and pleasant look. Wooden false ceiling being costly, it is not used in malls and hospitals but can be installed in residential buildings. They can be given various finishes and paintings to get the right look. Wooden false ceiling has many disadvantages like termite attack and warping.

Glass False Ceiling: Glass is a non-crystalline material with the property of brittle and transparent. But this can be altered to make it non brittle and non- transparent using some admixtures. As glass is a good insulator of heat, it can be used for false ceiling. This type of false ceiling improves aesthetical appearance of the building.

Metal Ceiling: As metal is a hard and durable material, it is used extensively in the false ceiling. When the metal surface is polished it gives a shiny surface which is a treat for eyes. The metals used in this are galvanized iron and aluminum. The cost of this ceiling is low as they are easy to install and access. The hidden members of the structure are easily accessed as the panels are easily removable and reattached. The construction cost becomes less as the installation, fixing and maintained is low.

Synthetic Leather or Cloth Ceiling: The materials used in this type of ceilings are either leather or cloth. As both the materials are man-made they can be given any form, shape and design which improve the aesthetic view of interior of the building. As these collects dust and has low light transferring property it's only used in temporary tents or other temporary buildings.

ADVANTAGES OF FALSE CEILING

❖ False ceiling materials are easy to install and cheap as compared to traditional roof systems and also gives aesthetic appearance.

❖ It provides a smooth homogeneous surface to the roof and helps in acoustics.

❖ It conceals all the non-pleasing elements and hides it from the viewer's eyes.

❖ It provides fire protection as it separates the roof.

DISADVANTAGES OF FALSE CEILING

❖ The major disadvantage 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.

❖ False ceiling would reduce the height of the ceiling considerably and hence it is not recommended to install false ceiling unless for a decent ceiling height.

❖ Decorations or hangings in false ceiling can be done only after considering the strength and durability of the false ceiling.

STEEL

Steel is an alloy of iron and carbon containing less than 2% carbon and 1% manganese and small amounts of silicon, phosphorus, sulphur and oxygen. Steel is the world's most important engineering and construction material. It is used in every aspect of our lives; in cars and construction products, refrigerators and washing machines, cargo ships and surgical scalpels. It can be recycled over and over again without loss of property.

PROPERTIES OF STEEL

Steel has a number of properties, including: hardness, toughness, tensile strength, yield strength, elongation, fatigue strength, corrosion, plasticity, malleability and creep.

❖ **Hardness** is the material's ability to withstand friction and abrasion, and it is different from strength and toughness in the context of metal properties.

❖ **Toughness** is the ability to absorb energy without fracturing or rupturing. It is also defined as a material's resistance to fracture when stressed. It is usually measured in Joules per sqcm.

❖ **Yield strength** is a measurement of the force required to start the deformation of the material (bending or warping).

❖ **Tensile strength** is a measurement of the force required to break the material.

❖ **Elongation** is the "degree" to which the material can be stretched or compressed before it breaks. It is expressed as a percent of the length being tested and the value lies between the tensile strength and yield strength.

❖ **Fatigue strength** is the highest stress that a material can withstand for a given number of cycles without breaking.

❖ **Corrosion** is the destruction of the steel material and its vital properties due to the electrochemical or chemical reaction of its surface to environmental factors such as acids, moisture and oxygen.

❖ **Plasticity** is the deformation of a material undergoing non-reversible changes of shape in response to applied forces.

❖ **Malleability** describes the property of a metal's ability to be distorted below compression. It is a physical property of metals by which they can be hammered, shaped and rolled into a very thin sheet without rupturing.

❖ **Creep** is a type of metal deformation that occurs at stresses below the yield strength of a metal, generally at elevated temperatures.

TYPES OF STEEL

❖ **Mild steel:** It is also known as low carbon or soft steel. It is ductile, malleable; tougher and more elastic than wrought iron. Mild steel can be forged and welded, difficult to temper and harden. It rusts quickly and can be permanently magnetized. Its specific gravity is 7.3. Ultimate compressive and tensile strengths ranges from 800 to 1200 N/mm2 and 600 to 800 N/mm2 respectively. Mild steel is used in the form of rolled sections, reinforcing bars, roof coverings and sheet piles and in railway tracks.

❖ **High carbon steel**: The carbon content in high carbon steel varies from 0.55 to 1.50%. It is also known as hard steel. It is tougher and more elastic than mild steel. It can be forged and welded with difficulty. Its ultimate compressive and tensile strengths are 1350 N/mm2 and 1400-2000 N/mm2, respectively. Its Specific gravity is 7.9. High carbon steel is used for reinforcing cement concrete and prestressed concrete members. It can take shocks and vibrations and is used for making tools and machine parts.

❖ **High tensile steel:** The carbon content in high tensile steel is 0.6-0.8%, manganese 0.6%, silicon 0.2%, sulphur 0.05% and phosphorus 0.05%. It is also known as high strength steel and is essentially a medium carbon steel. The ultimate tensile strength is of the order of 2000 N/mm^2 and a minimum elongation of 10 %. High Tensile steel is used in prestressed concrete construction.

DEFECTS IN STEEL

The common defects in steel are as follows:

❖ Cavities or blow-holes

❖ Cold shortness

❖ Red shortness

❖ Segregation.

*** Cavities or Blow-Holes**: These are formed when gas is confined or imprisoned in the molten mass of metal. Such confined gas produces bubbles or blow-holes on solidification of metal.

*** Cold Shortness:** The steel, having this defect, cracks when being worked in cold state. This defect is due to the presence of excess amount of phosphorus.

*** Red Shortness:** The steel, having this defect, cracks when being worked in hot state. This defect is due to the presence of excess amount of sulphur.

*** Segregation:** Some constituents of steel solidify at an early stage and they separate out from the main mass. This is known as the segregation and it is prominent on the top surface of the ingots or castings

MECHANICAL TREATMENT OF STEEL

The purpose of giving mechanical treatment to the steel is to give desired shape, so as to make steel available in market forms. The mechanical treatment of steel may be hot working or cold working. The hot working is very common. Following are the operations involved in the mechanical treatment of steel:

* Drawing

* Forging

* Pressing

* Rolling

❖ **Drawing:** This operation is carried out to reduce the cross-section and to increase the length proportionately. In this operation, the metal is drawn through dies or specially shaped tools. The drawing is continued till wire of required diameter or cross-section is obtained. This process is used to prepare wires and rods.

❖ **Forging:** This operation is carried out by repeated blows under a power hammer or a press. The metal is heated above the critical temperature range. It is then placed on anvil and subjected to blows of a hammer. This process increases the density and improves grain size of metal. The riveting belongs to forging operations. The process is used for the manufacture of bolts, cramps, etc. The steel may be either forged free or die-forged. In the former case, the steel is free to spread in all directions as it is hammered. In the latter case, the steel flows under the blows of a hammer to fill the inside of a die and the excess material are forced out through a special groove and then it is cut off. The die- forged parts have very accurate dimensions.

❖ **Pressing:** This is a slow process and it is carried out in equipment known as the press. The main advantage of this process is that it does not involve any shock. A press consists mainly of a die and a punch. The die and punch are suitably shaped to get article of desired shape. The metal is placed on the die and punch is then lowered under a very heavy pressure. The metal is thus pressed between die and punch and article of desired shape is obtained. For preparing articles with wide changes of shape, the pressing is to be carried out in different stages. This process is useful when a large number of similar engineering articles are to be produced.

❖ **Rolling:** This operation is carried out in specially prepared rolling mills. The ingots, while still red hot, are passed in succession through different rollers until articles of desired shape are obtained. The various shapes such as angles, channels, flats, joists, rails, etc. are obtained by the process of rolling. It is possible to prepare joint-less pipe with the help of this process. The solid rod is bored by rollers in stages until the pipe of required diameter and thickness is obtained.

USES OF STEEL

The following are the uses of steel:

❖ Steel is environment-friendly, sustainable and possesses great durability.

❖ It requires a low amount of energy to produce lightweight steel construction.

❖ Steel is the world's most recycled material which can be recycled very easily, due to its unique magnetic properties.

❖ It gives better shape and edge than iron which is used to make weapons.

❖ Steel is highly used in the automobile industry. Different types of steels are used in a car body, doors, engine, suspension, and interior.

❖ Mild steel is used for building construction. It is also a highly favoured building frame material.

❖ Because of its easily welding capability and attractive finishing, steel has become a prominent feature in modern architecture.

❖Stainless steel gives a hygienic environment. That's why it is used for surgical implants.

❖ Renewable energy resources like solar, hydro and wind power use the stainless steel components.

❖ Steel has a wider range of temperature which is used to make large sheets.

❖ Stainless steels are used to produce offshore platforms and pipelines.

ALUMINIUM

Aluminium is a silvery-white metal, which is widely used in building because of its inherent properties of lightness and corrosion resistance. It's the most widespread metal on earth, making up more than 8% of the earth's core mass. It's also the third most common chemical element on our planet after oxygen and silicon.

PROPERTIES OF ALUMINIUM

The different properties of aluminium are discussed below:

❖ **Durability:** Aluminium building products are made from alloys, which are weather-proof, corrosion-resistant and immune to the harmful effects of UV rays, ensuring optimal performance over a very long serviceable lifetime.

❖ **Design flexibility**: The extrusion process offers an almost infinite range of forms and sections, allowing designers to integrate numerous functions into one profile. Rolled products may be manufactured flat, curved, shaped into cassettes, or sandwiched with other materials. In addition, aluminium can be sawn, drilled, riveted, screwed, bent, welded and soldered in the workshop or on the building site.

❖ **Hundreds of surface finishes:** Aluminium can be anodized or painted in any colour, to any optical effect, using any number of surface touches, in order to meet a designer's decorative needs. Such processes also serve to enhance the material's durability and corrosion resistance, as well as providing an easy-to-clean surface.

❖ **High reflectivity:** This characteristic feature makes aluminium a very efficient material for light management. Aluminium solar collectors can be installed to lower energy consumption for artificial lighting and heating in winter, while aluminium shading devices can be used to reduce the need for air conditioning in summer.

❖ **Fire safety:** Aluminium does not burn and is therefore classed as a non- combustible construction material. Aluminium alloys will nevertheless melt at around 650°C, but without releasing harmful gases. Industrial roofs and external walls are increasingly made of thin aluminium cladding panels, intended to melt during a major fire, allowing heat and smoke to escape and thereby minimizing damage.

❖ **Optimal security:** Where high security is required, specially designed, strengthened aluminium frames can be used. While the glass for such applications may well be heavy, the overall weight of the structure remains manageable thanks to the light weight of the aluminium frame.

ALUMINIUM ALLOYS

Aluminum is commonly alloyed with copper silicon, magnesium, or zinc to improve its mechanical properties. Some aluminum alloys also contain one or more of the metals manganese, lead, nickel, chromium, titanium, and beryllium. A large part of the aluminum production is utilized in making light, stiff, corrosion-resistant alloys with these metals. Aluminum alloys may be classed as the cast alloys, which are shaped by casting and wrought alloys, which are worked into different shapes by mechanical operations. Cast alloys are generally binary alloys containing copper or silicon, and sometimes magnesium. Wrought alloys contain copper, magnesium, silicon,

and manganese that form precipitation hardening alloys with aluminum. Following are some of the aluminum alloys.

❖ **Magnesium** is an alloy of aluminum and magnesium (6 per cent). It has got very good mechanical properties and is a little lighter than pure aluminum. It is easy to work, exceptionally strong, and ductile and is widely used as deoxidizers in copper smelting operations.

❖ **Y-alloy:** It contains 4% copper, 20% nickel and 1.5% magnesium. Toughness and hardness are achieved by heating it to 500° C for six hours and then cooling it down in boiled water. Its relative density is 2.80 and resists corrosion better than duralumin. Y-alloy has good thermal conductivity and can sustain high temperature. It is used for making pistons of I.C. engines, cylinder head, connecting rod and propeller blades.

❖ **Aluminium Bronze** contains less than 11% of aluminium and is highly ductile when aluminium is less than 7.3%. As the aluminium increases, ductility decreases and at 12% the alloy is very brittle. Bronzes containing less than 7.3 per cent aluminium are highly resistant to torsional stress, readily rolled, forged, cold drawn, exhibit toughness under impact and resistance to alternate bending stress.

❖ **Light Alloy** contains 3% copper and 12% zinc. It is used for castings such as crank and gear housings.

❖ **Aluminium-Copper Alloy** contains copper up to 4%. Less liable to burning the alloy produces light castings that are stronger and tougher than that made from aluminium. It is mainly used in automobile industry for casting.

❖ **Aluminium-Zince Alloy** contains zinc up to 15% and is used for light casting which can be easily machined or forged into desired form. These are very sensitive to high temperatures in melting and in solid form exhibit low strength and brittleness when heated above 50° C. Alloys containing 15 to 25% zinc are harder, stronger, but less ductile and more difficult to roll or draw.

❖ **Aluminium-Silicon Alloy:** Aluminium alloys containing 5 to 15% silicon are important because of their excellent casting qualities and fluidity. It is free from hot-shortness and permits the pouring of thin intricate sections. They also have high resistance to corrosion and are good conductors of heat having low thermal expansion .

MARKET FORMS OF ALUMINIUM

Common products and applications of aluminium are stated as follows:

1. Fenestration (Windows and Openings) Casing Profiles

The major usage of aluminium can be observed in building fenestration casings like door and window frame profiles. These are easy to extrude sections and executed on-site and are readily available as per requirement. They are light in weight, yet strong. These are rigid in composition but flexible enough to use for design executions. They are available in various finishes like anodised colours, raw mill finishes with different hardness according to the alloy used in the extrusion process.

2. Facade Cladding (Aluminium Composite Panels- ACP)

Exterior facades are prone to weather hazards and building designs are now preferably shifted towards added aesthetics. Aluminium cladding is the most used type of cladding for building exteriors for economical, functional and aesthetical reasons. Aluminium composite Panels (A.C.P.) are widely used because of variety of colours and ease of installation with low maintenance.

3. Structural Glazing and Curtain Walls

These glazings provide a smooth look to the design with extremely low heat-gain coefficient through glazing solutions. Curtain wall systems are typically designed with aluminium framing members. These frames are infilled with glass for pleasing finishes and better daylighting effect.

4. Light Weight Partitions

Aluminium section profiles can create partitions that are easy to alter and are functionally considerable. They are better options for designing partitions at low cost and better aesthetics. They can be customized on-site and are readily available in different section profiles for different infill options like glazing, net or solid panels of acrylic.

5. Architectural Hardware and Shop Fittings

Architectural fittings like handles, knobs, clamps, holding fixtures are easy to produce in aluminium and are light weighted option. It is a cost-effective solution when compared to wood

and steel with similar strength and lesser strength to weight ratio. Thus they can be produced in larger quantities in similar weight productions.

6. Aluminum Shutters for Cladding

Aluminium shutters can be considered as a viable long term investment as they don't require frequent servicing and does not require replacing regularly. These are durable and are fairly resistant to possible impacts. These can be sturdy, strong and rigid structures with variable available colour option to choose with your choice of colour scheme.

7. Aluminium Long Span Roof System

Use of aluminium in large-span structures is useful and effective. These large- span structures are light-weight when constructed in aluminium composition. Generally, Halls and auditoriums that require clear spaces of large spans can opt for aluminium bracing and frames for structural form. Complex structures of large spans can be divided into simpler units in aluminium sections for construction purposes.

8. Aluminium in Electrical Transmission Towers

Electrical transmission Structures that are constructed at inaccessible places where transportation is tough, simpler units of aluminium are transported through air and assembled. Aluminium is used for reduced weight construction in such construction processes.

9. Aluminium Ladders, Scaffoldings and Mezzanine Frames

Aluminium ladders, scaffoldings are stable and secure options when produced in adequate diameters. It is easy to mantle and dismantle. These are light-weight than all other available options. Aluminium is a viable option here than wood or steel because it needs less maintenance.

USES OF ALUMINIUM

❖ Aluminum is used in external facades, roofs and walls, in windows and doors, in staircases, railings, shelves, and other several applications.

❖ Aluminium is widely used in the packaging industry for the production of coils, cans, foils, and other wrapping materials.

❖ Aluminium bronze is used for pump lines, tubes, springs, screws, rivets, ornamental works, marine engineering castings, motor boat shafting, musical instruments, and as a substitute of mild steel to resist corrosion, grill works, etc.

❖ It is also a component of many commonly used items such as utensils and watches.

❖ It is used in the transport industry for the production of cycles, spacecraft, car bodies, aircraft and marine parts.

❖ Aluminium also finds applications in the production of paints, reflective surfaces, and wires.

GLASS

Glass Building Material is a mixture of raw materials like silica, sodium potassium carbonate, lime or lead oxide, manganese oxide which are grounded, sieved, and mixed in specific proportion to make glass. It is one of the oldest & multifaceted materials utilizing in the building industry. Glass has been used to enhance the aesthetic view of structure and is fascinating material ever since it was discovered. It is an open hard substance created by giving heat to sand or quartz, glass forms an inorganic, transparent, or translucent material which can be molded into any shape. It is a transparent glazing material, providing the architect's new designs and possibilities to enhance the look and features of the building. It adds beauty & elegance to the look and feel of the structure, and is one of the most versatile materials to be used in the construction industry.

PROPERTIES OF GLASS

Glass has main engineering properties due to which the utilization has become vast in construction industries;

❖ **U Value:** This represents how much heat is transferred through the glass. Insulated glass units provide a low U value.

❖ **Transparency:** Transparency is the main and primary engineering property of glass that allows us to see through it. Due to this property glass can be transparent from both sides or from one side only and the other side acts like a mirror.

❖ **Work-ability and Recycle Property:** Glass has superior workability as it can be molded into countless shapes or blown during melting. Also, any type of glass can be 100% recyclable and used as a raw material in construction.

❖ **Strength:** Glass's strength is measured by its modulus of rupture value. Glass is generally brittle or tends to break easily but we can make it stronger by adding admixtures and laminates.

❖ **Transmittance:** This property of glass refers the visible fraction of light passing through the glass.

TYPES OF GLASS

The different types of glass used in construction industries are described below:

❖ **Sheet glass** is produced by having molten glass pass through the rollers to manufacture a nearly flat finish. It can be cut using a glass cutter and no special equipment is needed. It's generally available in the market in a range of standard sizes/thicknesses. Due to the comparatively low cost of this glass and its lack of distortion, flat sheet glass is mainly used in glazing greenhouses and where the visual distortion isn't an issue as opposed to domestic windows, etc.

❖ **Float glass:** It is made from sodium silicate and calcium silicate, it is also known as soda-lime glass. The "Float" name suggests the method used to manufacture it, where the molten glass is floated onto a bed of molten tin. This gives us a flat, clear, distortion-free glass. Float glass can be cut with a special thin coating on one side. This glazing allows solar energy to pass through in only one *Construction Materials and Technology*- by utilizing a glass cutter without a need for special equipment. It is available in thickness ranging from 2mm to 20mm, with a weight ranging from 6 to 36 kg/m2. The functions of this type of glass include fixed & opening windows above waist height, shop fronts, as well as in public places.

❖ **Laminated Glass:** As the name refers, this glass comprises layers of ordinary glass bonded by a transparent, flexible material. As it is a sandwich made up of two or more sheets of glass. This type of glass is commonly UV and soundproof, which explains its applications in the construction of bridges and aquariums. It is mostly the best suited for making glass canopies as it can reduce harmful rays. This glass comprising of 2 sheets of toughened glass and a laminate in the middle portion. This is typically 6mm toughened / 2.28mm laminate / 6mm toughened.

❖ **Toughened glass** is used extensively throughout the industry for its ability to resist breaking, also called safety or tempered glass. If it breaks, it does so into much smaller called 'safer' pieces as opposed to large shards. Toughened glass is typically used in home interiors such as the kitchen and shower screens, glass balustrade, and swimming pool fencing. It can also be utilized in laminated panels where extra safety precautions should be taken.

❖ **Shatterproof glass** is a type of glass that is resistant to shattering. In other words, it doesn't break into pieces in the event of destruction. Making up of shatterproof glass includes the addition of a plastic polyvinyl butyral resin to prevent it from forming sharp pieces. It is commonly used in windows, floors, and skylights.

❖ **Energy efficient glass**: This type of glass building material is manufactured by glazing float glass with a special thin coating on one side. This glazing allows solar energy to pass through in only one direction while minimizing the transfer of thermal energy in the other direction.

❖ **Wired glass:** In this type of glass a wire mesh is provided in the middle portion of the structure of glass. The main objective of the wire is to hold the glass together in the event of cracking or breaking, however, it doesn't stop the glass from forming sharp pieces when broken. Wired glass is available as clear or obscured, wired glass is generally used in more industrial areas or structures such as garages.

❖ **Tinted glass:** It is a simply colored glass. A certain type of ion is added to the normal glass mix to produce colored glass. In tinted glass, color doesn't affect the properties of glass. For example, iron oxide gives green and Sulphur gives blue color shades in glass manufacturing.

DISADVANTAGES OF GLASS

Some of the drawbacks of glass are narrated below:

❖ **Cost is High:** The manufacturing of glass is a highly energy-consuming process due to the high temperatures required for processing the raw materials. Using glass in a building increases the total cost of security & privacy because of the transparency that it offers.

❖ **Brittleness:** Glass is a stiff, rigid, and brittle material. When glass is subjected to stress, it fails/breaks without any significant strain. Cracked pieces of glass may be very sharp, and the chances of injury to humans become very high.

❖ **Impact Resistant is Low:** The Glass is less resistant against impact load, so the capability of the glass to withstand an immediately applied load is very poor. It will immediately break under impact.

❖ **Corrosion due to Alkali Solution:** The Glass is affected by alkalis ions. Alkali solution dilutes a glass surface, and if the supply of alkali is more, this type of corrosion takes place at a uniform rate.

❖ **Unsafe for Earthquake-prone Areas:** Structures that are located in earthquake-prone areas require to be specially designed to take horizontal loads and movements. The material of glass is more brittle than other material, hence it tends to break or collapse quickly.

❖ **Maintenance Cost is High:** In more dust-prone regions & humid areas, dust particles will stick to the glass surface and hence it will not only look dirty and shabby but the internal lighting, as well as transparency, will be poor.

CERAMICS

Ceramics are a material often used in construction, made from a mixture of minerals, typically silica sand, with a clay binder and some impurities, and up to 30% water. They are fired at a higher temperature than bricks, so that the silica re- crystallizes to form a glassy material that has greater density, strength, hardness, resistance to chemicals and frost and a greater dimensional stability. During firing, the water is driven off, though this may be reduced from 30% to 2-5% by drying before firing. At this reduced water content products are moulded as powder before being fired at 1,800-2,000 degrees for days, depending on the ceramic and process details. Ceramics may have an as-fired appearance or be glazed. These materials are environmentally stable and will not oxidize further in the atmosphere, Hence, they are economical in terms of maintenance costs. Problems are likely to occur when they are combined with other materials, typically fixings which are highly stressed and subject to corrosion. Unlike metals, ceramics are not capable of ductile behaviour. They fail in a brittle manner, directly after their elastic limit.

TYPES OF CERAMICS

❖ **Fire clays and shales:** These products include ordinary bricks, clay roof bailoge tiles, flooring tiles, flooring quarries and pavers.

❖ **Terracotta:** This is literally 'burnt earth'. It is made from yellow to brownish-red clays with a uniformity and fineness between brick and vitrified wall tiles. Terracotta is often used for unglazed chimney pots, air bricks, copings and planters.

❖ **Faience:** This is a glazed form of terra-cotta or stoneware. The base material may be fired to the 'biscuit' stage before glazing and re-firing, or a 'once-fired' process may be used. The latter improves resistance of the glaze to crazing, but reduces the range of colours available.

❖ **Fireclay**: This contains a high proportion of clay resistant to high temperatures (kaolin). It is used for chimney flue linings and fire backs. Stoneware: This is similar in composition to fireclay, but is fired at a higher temperature than fireclay and contains a higher proportion of glass. As a result it is harder and less absorbent. Modern manufacturing processes mean that stoneware no longer has to be glazed for use in drainage pipes.

❖ **Earthenware**: The raw materials are blended and may contain a considerable proportion of limestone. It is a finer product than stoneware and is used as the body for glazed wall tiles and table 'china'. Water absorption may be up to 15%, however, making it less suitable for sanitary ware than vitreous china.

❖ **Vitreous china:** This has a higher glass content than earthenware, and its water absorption is only about 0.5%, which makes it suitable for sanitary fittings. It is stronger than earthenware.

❖ **Porcelain:** Porcelain is very similar to vitreous china, but is often made from purer materials under more strictly controlled conditions. It is used for special uses, such as electrical insulators.

❖ **New ceramics:** These are also called 'technical' or 'engineering' ceramics. Their purity is far higher than traditional ceramics, not using raw clay mined directly from the ground. Powders are formed which are then cast, pressed, extruded or moulded into shape. The powders may be set in organic binders. The combination of pure materials and exacting production techniques ensures the very high strength of these materials.

USES OF CERAMICS

Some of the uses of ceramics are listed below:

❖ Ceramic products are hard, porous, and brittle. As a result, they are used to make pottery, bricks, tiles, cements, and glass.

❖ They are used in automobiles (sparkplugs and ceramic engine parts found in racecars), and phone lines.

❖ They can also be found on space shuttles, appliances (enamel coatings), and airplanes (nose cones).

❖ Ceramics are also used at many places in gas turbine engines.

❖ Bio-ceramics are used as dental implants and synthetic bones.

one of the most chemically stable oxides known. It is mechanically very strong, insoluble in water, super heated steam, and most inorganic acids and alkalies. Its properties make it suitable for the shaping of crucibles for fusing sodium carbonate, sodium hydroxide and sodium peroxide. It has a high resistance in oxidizing and reducing atmosphere. Alumina is extensively used in heat processing industries. Highly porous alumina is - used for lining furnaces operating up to 1850° C.

USES OF REFRACTORIES

❖ Refractory materials are used in linings for furnaces, kilns, incinerators brand reactors.

❖ They are also used to make crucibles and moulds for casting glass and metals and for surfacing flame deflector systems for rocket launch structures.

❖ Iron- and steel industry uses approximately 70% of all refractories produced. They are widely used in foundries as well.

❖ Manufacturing of cement, glass, paper, metals.

❖ They are mainly used in muffles and it is also an ideal choice for recuperaters.

COMPOSITE MATERIALS

A **composite** is any material made from more than one constituent material with significantly differing properties. The union of these constituent materials often yields a product that is stronger, more versatile, and more durable than any of the input materials alone. The individual components remain separate and distinct within the finished structure. The new material may be preferred for many reasons: common examples include materials which are stronger, lighter or less expensive when compared to traditional materials. Typical engineered composite materials include:

❖ Composite building materials such as cements, concrete

❖ Reinforced plastics such as fiber-reinforced polymer

❖ Metal Composites

❖ Ceramic Composites (composite ceramic and metal matrices)

Composite materials are generally used for buildings, bridges and structures such as boat hulls, swimming pool panels, race car bodies, shower stalls, bathtubs, storage tanks, imitation granite and cultured marble sinks and counter tops.

TYPES OF COMPOSITES

Composite materials are usually classified by the type of reinforcement they use. This reinforcement is embedded into a matrix that holds it together. The reinforcement is use to strengthen the composite. For example, in a mud brick, the matrix is the mud and the reinforcement is the straw. Common composite types include random-fiber or short-fiber reinforcement, continuous-fiber or long-fiber reinforcement, particulate reinforcement, flake reinforcement, and reinforcement. matrix is the mud and the reinforcement is the straw. Common composite types include random-fiber or short-fiber reinforcement, continuous-fiber or long-fiber reinforcement, particulate reinforcement, flake reinforcement, and reinforcement.

❖ **Concrete and Reinforced Concrete:** Concrete is a composite material made of cement, sand, stones and water. A chemical reaction that occurs when these materials were combined makes concrete stronger than any one of its components. When reinforced steel is added to the concrete, another composite with greater strength and flexibility is formed which is called reinforced concrete.

❖ **Fiberglass:** Fiberglass is made of tiny glass shards held together by resin and other components. In the automotive industry, fiberglass is important for making body kits. The body shell for a car is made up of different layers of fiberglass, such as a gel-coat layer, tissue layer, matting and cloth. The outcome is a complete, waterproof, lightweight and strong body kit. Fiberglass can also be a less expensive alternative to other materials.

❖ **Natural Composites:** Composites can be easily found in nature. Wood is an example of a composite because cellulose fibers are held together by a substance called lignin. These fibers can be found in cotton and thread, but it's the bonding power of lignin in wood that makes it much tougher. Certain types of large rocks can also be regarded as natural composites when they are composed of a variety of smaller rocks and minerals.

❖ **Metal Matrix Composites (MMC):** Metal Matrix Composites are composed of a metallic matrix (aluminum, magnesium, iron, cobalt, copper) and a dispersed ceramic (oxides, carbides) or metallic (lead, tungsten, molybdenum) phase.

❖**Ceramic Matrix Composites (CMC):** Ceramic Matrix Composites are composed of a ceramic matrix and embedded fibers of other ceramic material (dispersed phase).

❖**Polymer Matrix Composites (PMC):** Polymer Matrix Composites are composed of a matrix from thermoset (Unsaturated Polyester (UP), Epoxy (EP)) or thermoplastic (Polycarbonate (PC), Polyvinylchloride, Nylon, Polysterene) and embedded glass, carbon, steel or Kevlar fibers (dispersed phase).

❖ **Laminar composites** are found in as many combinations as the number of materials. They can be described as materials comprising of layers of materials bonded together. These may be of several layers of two or more metal materials occurring alternately or in a determined order more than once, and in as many numbers as required for a specific purpose. Clad and sandwich laminates have many areas as it ought to be, although they are known to follow the rule of mixtures from the modulus and strength point of view. Other intrinsic values pertaining to metal-matrix, metal-reinforced composites are also fairly well known.

❖ **Fibrous Composites:** Short-fiber reinforced composites consist of a matrix reinforced by a dispersed phase in form of discontinuous fibers. They may be composites with random orientation of fibers or composites with preferred orientation of fibers. Long-fiber reinforced composites consist of a matrix reinforced by a dispersed phase in form of continuous fibers. They may be unidirectional or bidirectional orientation of fibers (woven).

FIBER-REINFORCED PLASTIC (FRP) COMPOSITES

Fiber-reinforced plastic (FRP) composites have transformed the manufacturing sector. FRP composites offer high-end performance at a fraction of the weight and cost of comparable metal materials. Construction, energy, aerospace, and other critical sectors are realizing the benefits of FRP for producing reliable parts and components. An FRP composite consists of a plastic resin or polymer matrix and a fiber. The fiber may be anything from glass to recycled carpet flooring, depending on target properties of the material. The resin provides superior support and transfer of force between fibers and insulates them from exposure to environmental conditions such as rain, insects, heat, and wind. In turn, the fibers provide stiffness and structural support for the flexible plastic, granting the composite material an incredibly high strength-to-weight ratio. Fiber-reinforced plastic composites also go by other names, such as fiber-reinforced polymer composites, fiber reinforcement composites, and fiber composites-though they all generally refer to the same type of material. Designers and manufacturers across industry sectors turn to FRP for the expansive range of benefits it offers. Here are some of the beneficial features of FRP composites:

- ❖ Lightweight compared to most metals
- ❖ Corrosion-resistant
- ❖ High impact strength
- ❖ Electrical insulation
- ❖ Easy installation
- ❖ Low maintenance
- ❖ Exceptional durability
- ❖Low relative cost compared to competitive materials
- ❖ Waterproof
- ❖ Impervious to moisture, termites, fungus, and bacterial growth

❖ Easily recyclable

❖ Long service life

APPLICATIONS OF FRP COMPOSITES

Some of the **common applications** for FRP materials include:

❖These are widely used in public works like commercial, industrial, and municipal applications

❖ FRP are used in wood replacement like Benches, Boardwalks, Decks, Fences, Ramps

❖ They have also wide application in Military (Navy) and Mining works

❖ FRP are used in Concrete forming (reusable) and Construction works like Flooring, Roofing and Pergolas

FIBRE TEXTILES

Textile fibres are microscopic hair like substances with comparatively high ratio of length to width that helps in spinning them into yarns or bonding them together for creating fabrics directly. Fibre is what the fabrics are made of and textile fibres are distinguished by their suitability for conversion into fabrics. In spinning, fibres are twisted together lengthwise for producing a continuous strand called yarn. Apart from having several hundred times of length in relation to its length, the textile fibres need also to be strong enough to withstand the mechanical actions of spinning, weaving, knitting, etc. Other properties like elasticity, fineness, uniformity, durability, lustre, and crimp are also necessary for improving the quality of yarns, fabrics and garments.

CLASSIFICATIONS OF FIBRE TEXTILES

Textiles can be classified based on its origin, length and also by its thermoplastic properties. Based on their sources, textile fibres are broadly classified into natural and man-made or manufactured fibres. There are also several sub categories under each as explained below:

❖ **Natural Fibres:** Natural fibres are classified, according to their origin as vegetable fibres, animal fibres and Mineral fibres.

Vegetable fibres: These fibres are derived from plant or vegetable sources such as stalk, stem, leaf, or seed pods, and include cotton, linen, jute, flax, ramie, coir, sisal and hemp.

Animal fibres: Fibres sourced from animals are also known as protein- based fibres. They are harvested from animals or removed from cocoons or webs and include silk, hair, fur, wool, feathers, etc.

Mineral fibres: These fibres are mined from the earth. The asbestos fibre for example, found its use in textile because of its acid, fire and rust resistance. However. It is being phased out because of its suspected carcinogenic effect.

❖ **Man Made Fibres:** Man Made Fibres are artificial fibres manufactured using chemical or metallurgical technologies and fall into the following categories:

Regfenerated Fibres: These fibres are prodouced using a natural source as a base and using a chemical process for generating the filament. Examples include viscose rayon, cuprammonium rayon, acetate rayon, rubber fibres, etc . some of the recent additions to this include Lyocell and Tencel.

Based on length fibre textiles are classified as follows:

Sunthetic Fibres: These are manufactured using only chemical processes and use petroleum, natural gas and coal as the raw materials. These raw materials are converted into substances capable of forming fibres. The petrochemical industry is the main source of fibres in this category with coal and natural gas also contributing a bit. Nylons, polyesters, acrylics and polypropylene are examples of synthetic fibres.

Staple Fibres: Any fibre with a limited or finite length is called as staple fibre. It includes fibres like cotton, wool, jute etc. These natural fibres may be a short staple fibre having a maximum length of 60 mm or a long staple fibre having lengths between 60 to 150 mm. Staple fibres must be spun or twisted together to make a long continuous strand of yarn. They may also be used in their staple form to produce non-woven or felted fabrics. Synthetic fibres can be cut into short lengths for the purpose of blending with natural staple fibres or used on their own to produce yarns with a natural feel.

Filaments: All fibres having unlimited or infinite lengths are called filaments. Silk is a natural filament, which is reeled from cocoons. Man-made fibres nylon, polyester etc. are also filaments by forcing liquid raw materials through spinnerets and then hardened to produce continuous filament strands of a determined length. Regular filament yarns are smooth and silk-like as they come out of the spinneret. Filament yarns have no protruding ends and therefore, do not shed lint or pill. Filament fibre is usually stronger than staple.

GEOMEMBRANES AND GEOTEXTILES FOR EARTH REINFORCEMENT

Geomembranes are impermeable membranes used widely as cut-offs and liners. These are used mostly as canal and pond liners; however, one of the largest current applications is to the containment of hazardous or municipal wastes and their leachates. In many of these applications geomembranes are employed with geotextile or mesh underliners, to reinforce or protect the more flexible geomembrane whilst also acting as an escape route for gases and leachates generated in certain wastes. Geofabrics are also called geosynthesis or geotextiles. These are synthetic fabrics which are sufficiently durable to last a good length of time in soil environment used in geotechnical engineering. Some geofabrics are polyester, nylon, polyethylene and geotechnical engineering. The fabric may be woven, knitted or punched. They are used for the following functions:

- ❖ Drainage paths for water for soil consolidation
- ❖ Separation of different types of soil materials
- ❖ Soil reinforcement in reinforced earth construction
- ❖ Filtration of water from soil.

GEOTEXTILES FOR EARTH REINFORCEMENT

Geotextiles are permeable fabrics which, when used in association with soil, have the ability to separate, filter, reinforce, protect or drain. As the use of geotextile fabrics has expanded there has been the introduction of geotextile composites and the development of products such as geogrids and meshes. Overall these materials are referred to as geotextiles and related products. These are ideal for use in soil as they do not deteriorate by corrosion in the presence of chemicals. They last

for a long time when not exposed to direct sunlight and are also not affected by water. They are extensively used for Mechanically Stabilized Earth (MSE) / Reinforced Earth Construction. and eyewlin

CLASSIFICATION

❖ **Geotextiles:** These materials consist of either woven or non-woven fabrics and are generally used for separation, drainage, filtration and reinforcement. The strongest of these are woven fabrics, then the resin bonded, melt bonded and finally the needle punched fabrics.

❖ **Geogrids:** They have large openings and are made of materials with high tensile strength, low elongation and dimensional stability. They are made from plain polymer sheets by punching holes in it followed by two stretching operations so that a grid is formed. They can be designed to have different strength or same strength in two directions. They are mainly used for soil reinforcement or for separation of materials or for improving bearing capacity of soil

❖ **Geomembranes:** These materials are available in wide range of permeability. Continuous geomembrane barriers of sufficiently low permeability can be used to control fluid migration in geotechnical engineering while those of high permeability are used for drainage.

❖ **Linear strips for soil reinforcement:** Polymer fibres are made into strips which can be used for reinforced earth in retaining walls. Glass- reinforced plastics are also considered as suitable for soil reinforcement.

USES OF GEOTEXTILES

❖ As the embankments for flyovers in cities should occupy as little width as possible, the use of geotextiles as soil reinforcement for these embankments comes in very handy.

❖ Much steeper slopes than normally admissible with earth only can be provided by using soil reinforcement in the embankment.

❖As soil reinforcement for retaining walls and stability of slopes. For improving the bearing capacity of foundations.

❖As a filtration medium for drainage. In many situations, when used for drainage and separation, it also acts as a filter.

❖ Many new railway embankments for Indian Railways has been carried out by using plastic geotextile drains instead of old fashioned sand or wick drains. It is used as under railway track, to separate the ballast from sub grade, thus decreasing penetration of ballast into the weak sub grade.

❖ Geotextiles are used as drainage wicks to assist drainage and consolidation of clayey deposits. The modern readymade plastic geotextile drain consists of a plastic drain core and a geotextile jacket covering the plastic core pipe. They are efficient for soil drainage to assist in preloading of foundations.

TWO MARKS QUESTIONS AND ANSWERS

1. What is a timber?

Timber represents wood which is appropriate for carpentry, building and for various engineering purposes. Timber is a fibrous, hard substance which forms a most part of the trunk and branches of a tree.

2. Write about rough timber and converted timber.

If the branches of a tree are cut and is approximately converted into pieces of required length, then it is known as rough timber. Through sawing, rough timber is converted into different marketable parts like planks, battens, posts, beams etc. then it is called as converted timber.

3. Enumerate the various market forms of timber.

The followings are the various types of market forms of timber.

❖ Log

❖ Lumber

❖ Deal

❖ Batten

❖ Bilk

❖ Plank

❖ Board

❖ Scantline

❖ Pole

4. List any four properties of timber.

The following are some of the properties of a good timber:

❖ **Colour**: Colour should be uniform.

❖ **Odour**: When freshly cut, odour should be pleasant.

❖ **Texture:** Good timber should have fine and even texture.

❖ **Grains:** Grains are close in good timber.

❖ **Density**: If density is more, timber is said to be stronger.

5. What is water seasoning?

Removal of wood sap by immersing logs into water flow is called water seasoning. It is carried out on the river banks while thicker ends are kept towards 10 upstream. After that, the logs are allowed to dry. This process is time consuming 00 such as 2 to 4 weeks generally.

6. List any four characteristics of timber.

The Characteristics of timber are,

❖ Hardness.

❖Strength.

❖Toughness.

❖ Elasticity.

❖Durability.

❖ Defects.

❖ Fibres and structure.

❖ Appearance and colours.

7. What is a cup shake in timber?

Cup shakes are caused by the rupture of tissue in a circular direction. It is a curved crack, and it separates partly one annual ring from the other developing one due to non-uniform growth or due to excessive bending of a growing tree during a cyclonic weather. It may prove to be harmful if it covers only a portion of the ring.

8. Give some of the uses of Timber.

Timber is used for the following purposes:

❖ Timber is widely used for doors, windows, flooring and roofing as it is easily convertible into any shape and size.

❖ It can be easily worked. Hence repairs and alterations to wood work can also be done easily.

❖ It possesses excellent strength and a good preference for making load bearings like columns, beams, trusses and piles.

❖ Timber is widely used in ornamental works like showcases, furniture, sports goods and musical instruments

9. Define Plywood.

grime Plywood is an engineered wood sheet material made up of fine layers or flimsy strands of wood veneers attached together by placing wood grains 90 degrees to one another. It is one type of mar ufactured board which can be described as a mixture of medium density fibre board (MDF) and Chip Board (Particle Board).

10. What are the uses of Plywood?

❖ It has good strength both along as well as across the grains and are extensively used for partitions, ceilings, doors, concrete form work, plywood boards, lamin boards etc.

❖ It has better splitting resistance due to the grains in adjacent veneers in cross direction as such nailing can be done very safely even near the edges.

❖ Plywood has cross-grained construction, the tendency to shrink or swell is reduced and hence it can be curved into desired shapes.

11. What are the different ways of slicing of veneer?

Different ways of slicing wood to get veneers are as follows:

Rotary cut: The log is cantered on a lathe and turned against a broad cutting knife set into the log at a slight distance.

Quarter slicing: The slicing is made perpendicular to the annual growth rings of the tree. This creates a straight grain appearance.

Lengthwise slicing: This is done from a board of flat sawn lumber rather than from a log. A variegated figure is created with this slice.

Plain slicing: By slicing parallel to the centre of the log, a raised "cathedral o effect" is formed by the innermost growth rings.

12. List the advantages of false ceiling.

The advantages of false ceiling are:

❖ False ceiling materials are easy to install and cheap as compared to traditional roof systems and also gives aesthetic appearance.

❖ It provides a smooth homogeneous surface to the roof and helps in acoustics.

❖ It conceals all the non-pleasing elements and hides it from the viewer's eyes.

❖ It provides fire protection as it separates the roof.

13. What are the common defects in steel?

The common defects in steel are as follows:

❖ Cavities or blow-holes

❖ Cold shortness

❖ Red shortness

❖ Segregation

14. Name the constituents of glass.

The constituents of glass are,

❖ Silica

❖ **Oxides of lead**

❖ Oxides of Cobalt

❖ Oxides of Manganese

15. Mention the application of fibre glass reinforced plastic.

The most important application of fibre glass reinforced plastics is said to be in the manufacture of corrugated sheeting, mainly for use in roof lights and also for interior paneling and decoration.

16. Define the term Refractories.

A refractory material is a material that retains its strength at high temperatures. Refractory materials are used in for furnaces, kilns, incinerators, and reactors. They are also used to make crucibles and moulds for casting glass and metals and for surfacing flame deflector systems for rocket launch structures.

17. Write the properties of refractories.

Physical properties

(i) Bulk density (ii) Porosity (iii) Cold compressive strength (iv) Flexural strength (v) Wear resistance

Chemical properties

(i) Corrosion resistance

Thermal properties

(i) Melting point (ii) Thermal expansion (iii) Dimensional stability (iv) Thermal shock (v) Thermal conductivity.

18. Name any four merits of aluminum in construction?

❖ High corrosion resistance

❖ Safety against attack from insects

❖ Economy in maintenance

❖ Aesthetic appearance

❖ Ease in fabrication and assembly

19. List the operations involved in the mechanical treatment of steel.

Following are the operations involved in the mechanical treatment of steel:

❖ Drawing

❖ Forging

❖ Pressing

❖ Rolling

20. Give some of the uses of aluminium.

Uses of Aluminium are

❖ Aluminum is used in external facades, roofs and walls, in windows and doors, in staircases, railings, shelves, and other several applications.

❖ Aluminium is widely used in the packaging industry for the production of coils, cans, foils, and other wrapping materials.

❖ Aluminium bronze is used for pump lines, tubes, springs, screws, rivets, ornamental works, marine engineering castings, motor boat shafting, musical instruments, and as a substitute of mild steel to resist corrosion, grill works, etc

21. Define laminates.

Laminates are the products made by bonding together of two or more layers of materials. Special laminates from plastics are also available in the market. These can be glued to wood to make the surface aesthetic as well as heat- resistant.

22. What are geo synthetics?

Geo fabrics are also called geo synthetics or geotextiles. These are synthetic fabrics which are sufficiently durable to last a good length of time in soil environment used in geotechnical engineering.

23. List the uses of ceramics.

Some of the uses of ceramics are listed below:

❖ Ceramic products are hard, porous, and brittle. As a result, they are used to make pottery, bricks, tiles, cements, and glass.

❖ They are used in automobiles for sparkplugs and ceramic engine parts found in racecars and phone lines.

❖ They can also be found on space shuttles, appliances as enamel coatings, and airplanes in nose cones.

24. Define FRP.

Fiber-reinforced plastic (FRP) composites have transformed the manufacturing sector. FRP composites offer high-end performance at a fraction of the weight and cost of comparable metal materials. Construction, energy, aerospace, and other critical sectors are realizing the benefits of FRP for producing reliable parts and components.

25. What are the applications of FRP Composites?

Some of the common applications for FRP materials include:

❖ These are widely used in public works like commercial, industrial, and municipal applications

❖ FRP are used in wood replacement like Benches, Boardwalks, Decks, Fences, Rampsia

❖ They have also wide application in Military (Navy) and Mining works

❖ FRP are used in Concrete forming (reusable) and Construction works like Flooring, Roofing and Pergolas

REVIEW QUESTIONS

1. List the common market forms of timber and explain in detail.

2. Discuss in detail about plywood and its advantages.

3. Write the physical and chemical properties of aluminium in detail.

4. Discuss in detail about false ceiling materials

5. Classify glass and mention its uses in detail.

6. Describe the following wood based products with neat sketch.

(i) Veneers (ii) plywood

7. Recall the properties of fiber glass reinforced plastic.

8. Recall the physical and mechanical properties of (i) Aluminum and (ii) steel.

9. Disucss the various types of heat treatment of steel and their purpose.

10. Discribe the various applications of geo synthetic in civil engineering construction works. And also explain the properties of geotextiles.

11. Discuss in detail about refractories.

12. Write detailed notes on composite materials.

13. Explain the types of ceramics and their applications.

14. Define FRP and explain in detail

15. As a Civil Engineer recommend various building materials involved in the construction of a building with their criteria with respect to quality.

UNIT III

CONSTRUCTION PRACTICES & SERVICE REQUIREMENTS

SYLLABUS

Types of Foundations - Shallow and Deep Foundations - Stone Masonry Brick Masonry - Plastering and Pointing - Cavity Walls - Diaphragm Walls - Formwork - Centering and Shuttering - Shoring - Scaffolding - Underpinning - Roofing Flooring - Joints in concrete - Contraction/Construction/Expansion joints - Fire Protection - Thermal Insulation - Ventilation and Air conditioning - Acoustics and Sound Insulation - Damp Proofing.

- ❖ Types of Foundations
- ❖ Stone Masonry
- ❖ Brick Masonry
- ❖ Plastering and Pointing
- ❖ Cavity walls
- ❖ Diaphragm wall
- ❖ Formwork, Centering and shuttering
- ❖ Shoring and Scaffolding
- ❖ Underpinning
- ❖ Roofing and flooring
- ❖ Joints in concrete
- ❖ Fire protection and thermal insulation

❖ Ventilation and Air conditioning

❖ Acoustics and sound insulation

❖ Damp proofing

CONSTRUCTION PRACTICES AND SERVICE REQUIREMENTS

Types of Foundations - Shallow and Deep Foundations - Stone Masonry - Brick Masonry - Plastering and Pointing - Cavity Walls - Diaphragm Walls - Formwork - Centering and Shuttering - Shoring - Scaffolding – Underpinning - Joints in concrete – Roofing – Fire Protection - Thermal Insulation - Ventilation and Air conditioning - Acoustics and Sound Insulation - Damp Proofing.

Foundation is the most important part of the building as it forms the base of a structure. Construction works starts with the excavation works for foundation and then proceeding towards the super structure. It forms the sub-structure of a building. The main function of a foundation is that it transfers the building load to the ground.

TYPES OF FOUNDATIONS

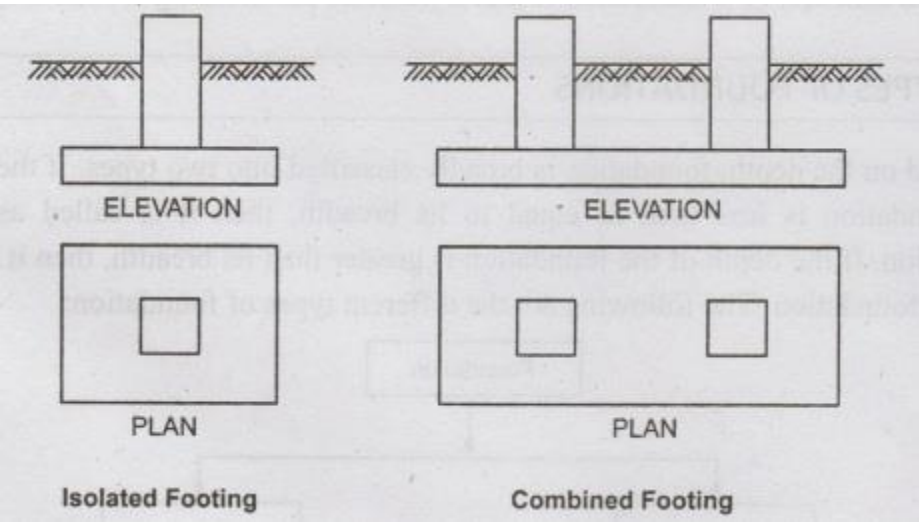
Based on the depth, foundation is broadly classified into two types. If the depth of the foundation is less than or equal to its breadth, then it is called as shallow foundation. If the depth of the foundation is greater than its breadth, then it is known as deep foundation. The following are the different types of foundation:

SHALLOW FOUNDATIONS

The depth of the shallow foundation is less and is economical to build lightweight structures. It depends on the ratio of the depth and width of the foundation of the structure. They are constructed where soil layer at shallow depth (upto 2m) is able to support the structural loads. The depth of shallow foundations is generally less than its width. Various types of shallow foundation are described below:

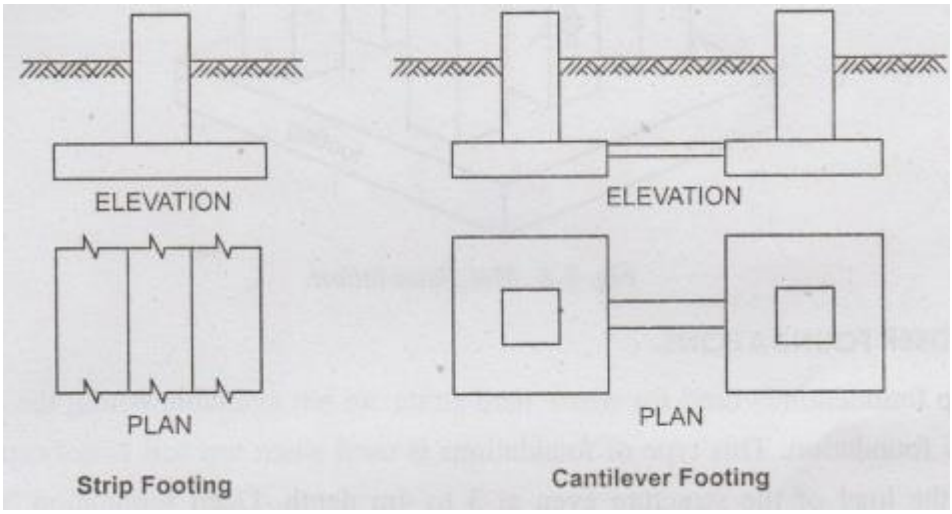
❖ **Isolated Footing:** Isolated footing is also known as spread footing or individual footing. It is the type of footing which supports either one wall or one column spread the superimposed load of wall or column over a brs suas large area. In this footing the bearing capacity of soil is high. If the

shape of footing is in rectangular or square, then it is called as pad footing. Sometimes, it is stepped or haunched to spread the load over a large area and it is termed as stepped footing. If the footing is sloped, then it is called as sloped footing.



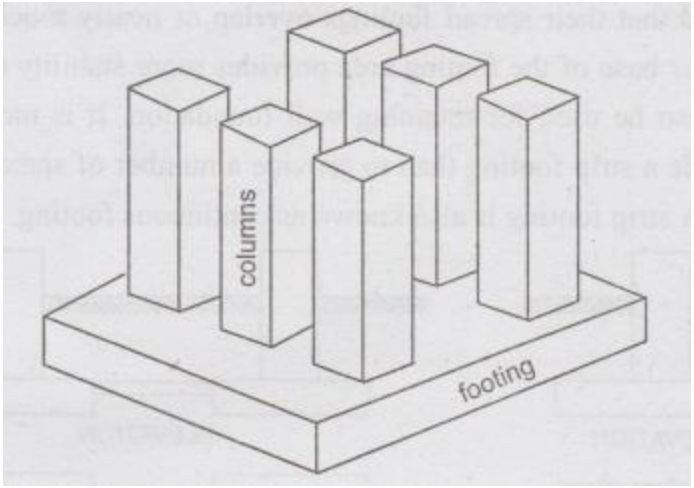
❖ **Combined footings**: If two to three columns connected collectively with one single footing is called combined footing. It is used when the two nouson role columns are so close to each other that their individual footings would overlap. Also this footing is necessary when a column is very close to the boundary of the property and hence there is no scope to project footing much beyond the column face. A combined footing may be rectangular or trapezoidal in plan.

❖ **Strip footing:** A strip footing is provided for a load-bearing wall. The width of the footing is generally two three times the thickness of the wall. A strip footing is also provided for a row of columns which are so closely spaced that their spread footings overlap or nearly touch each other. The broader base of the footing area provides more stability to the structure. It can also be used for retaining wall foundation. It is more economical to provide a strip footing than to provide a number of spread footings in one line. A strip footing is also known as continuous footing.



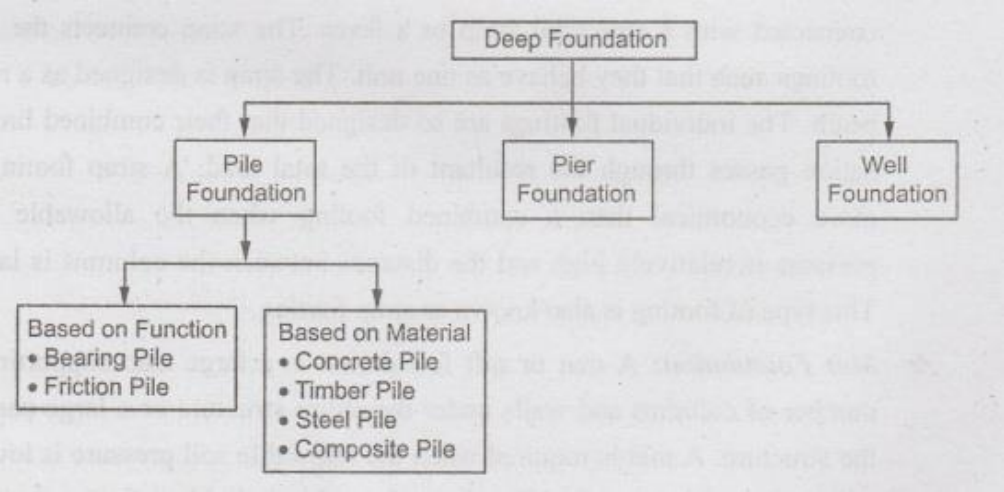
❖ **Cantilever Footing:** This type of footing consists of two isolated footings connected with a structural strap or a lever. The strap connects the two footings such that they behave as one unit. The strap is designed as a rigid beam. The individual footings are so designed that their combined line of action passes through the resultant of the total load. A strap footing is more economical than a combined footing when the allowable soil pressure is relatively high and the distance between the columns is large. This type of footing is also known as strap footing.

❖ **Mat Foundation:** A mat or raft foundation is a large slab supporting a number of columns and walls under the entire structure or a large part of the structure. A mat is required when the allowable soil pressure is low or where the columns and walls are so close that individual footings would overlap or nearly touch each other. Mat foundations are useful in reducing the differential settlements on non-homogeneous soils or where there is a large variation in the loads on individual columns. It is also known as raft or Grid foundation.



DEEP FOUNDATIONS

Deep foundation is used for where hard strata are not available within the mit of shallow foundation. This type of foundations is used when top soil is not capable of taking the load of the structure even at 3 to 4m depth. Deep foundation helps to prevent the structure from the uplift. Various types of deep foundation are described below:



❖ **Pile Foundation:** In this type of foundation, the load is transmitted by a vertical member. This vertical member is known as a pile. These piles are generally made of steel, concrete and wooden. Nowadays precast members are also used. Pile foundation is further classified as follows:

According to Function

Bearing pile: These piles are used if the hard strata are available at reasonable depth. The load is transmitted by columns to the hard layer of soil.

Friction pile: These piles are used where the soil is soft at a considerable depth. Friction piles transfer the load to the soil by the friction between soil and the pile. 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.

According to Material

Concrete pile: The piles which are made with the help of concrete are known as concrete piles. The diameter of these pile varies from 30 to 50 cm. Minimum length of these pile is not taken less than 20 meters and maximum it can be taken till 30 meters. These piles may be either precast or cast-in-situ. Precast piles are manufactured in the factory which is further transported to the construction site where ever it is required. These piles can bare load up to 800 KN. Cast-in-situ piles are made or manufactured on site where it is to be installed. It saves money as the transportation cost is reduced. These files bare load up to 750 KN.

Timber piles: As the name suggests these piles are made up of wooden so they are known as wooden or Timber piles. For these piles, seasonal timber wood is used. The diameter of the timber pile varies in between 20 to 50 cm. The maintenance cost of these piles is more because as it is wood if it comes in contact with water then it can be damaged by fungus or white ants. So care has to be taken.

Steel piles: These Piles are generally in shape of 'I' or hollow section. It can be easily driven in the soil because it has a very small cross-sectional area. These piles can be used as a bearing pile but cannot be used as friction piles because if we use them as a friction pile it can sunk in the soil due to structural load.

Composite pile: When the piles are made from more than one material they are known as composite pile. These piles are made from concrete and wood. These piles are used in those areas where the water table is up. These piles are used in such conditions just because concrete and wood both are good water absorbers.

❖ **Pier Foundation:** A pier foundation is a vertical column of relatively larger cross-section than a pile. If the diameter is greater than 0.6 m or equal to 0.6 meters then it is termed as a pier. The shape of the pier foundation is cylindrical, and it is supported with the help of piles. The load coming from the superstructure is carried to the hard strata through these vertical piles. They are generally cast on site. It is used for a heavy multi-storey structure where the load of the structure is hefty, and it is generally used in bridges and fly-overs to resist the heavy traffic loads. This type of foundation is chosen when the depth of the hard strata is at 5 meters or less than 5 meter. Also, this type of footing is done when not much heavy load is coming from the superstructure. The size of excavation depends upon the level at which hard strata exists. The size and shape of this concrete pier depend upon the level of hard strata is present.

❖ **Well foundations:** It is also called as drilled shaft or caisson foundation. It is generally used for bearing the very heavy loads of the structure. It is a cast-in-situ foundation and also available

as pre-cast material. Construction of this foundation is done with the help of auger and used where the pile foundation is not enough to bear the heavy load of the structure. The depth of the drilled shaft foundation is more than the pile foundation. And it is not preferable to use in water-bearing granular soils, loose and soft clay soils. This foundation generally used in underwater project like river, lake and sea. It is used as pier of bridge, building and construction of the dam. It is constructed with the help of water shoring. This foundation works as a compression member. Drilled Caissons are classified into three categories as:

* **Concrete caissons with enlarged bottom**: In this at top which is at ground level of cap is provided. Above that cap brickwork is carried out. Below this cap a pier is constructed which is further followed by the enlarged bottom which is also known as bell. The angle of this bell at bottom is 60 degree.

* **Caissons of steel pipe with concrete filled:** In this also at the top which is at ground level, a cap is provided. Below this cap, at both extreme ends, a steel shell is created. This steel shell is the outer portion. Inside this steel shell concrete is filled.

* **Caissons of steel pipe with concrete and steel core:** The assembly of this type is also the same as the caissons of steel pipe with concrete-filled. But the only change is that in the central portion of the steel core or a rod is fixed which gives more stability to the structure as the weight taking capacity increased due to the steel core.

FACTORS FOR SELECTION OF SUITABLE FOUNDATION TYPE FOR A BUILDING

The type of foundation is selected based on the following factors:

- ❖ Building height
- ❖ Load condition
- ❖ Soil type
- ❖ Type of building (residential, administrative, warehouse)

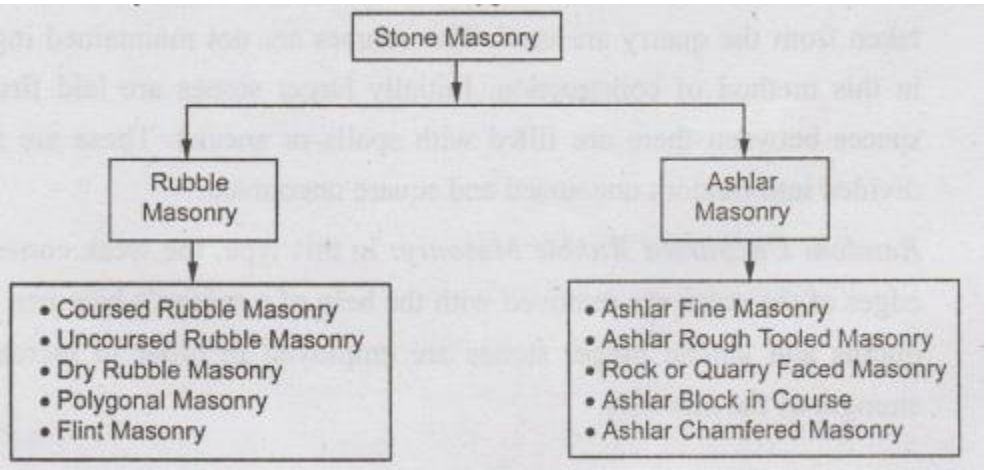
STONE MASONRY

Stone masonry is used for the construction of walls, columns, lintels, arches, beams, etc., of a building. Stones are abundantly available in nature and when cut and dressed to proper shapes,

they provide an economical material for the construction of various parts of building. Stone masonry can be classified according to the thickness of joints, continuity of courses and finish of face.

TYPES OF STONE MASONRY

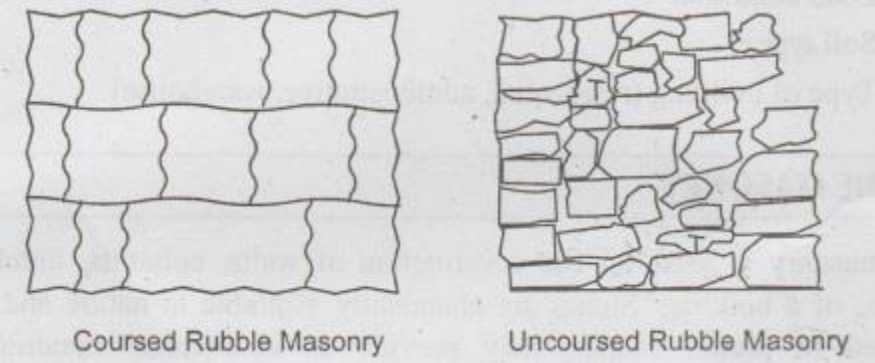
Stone masonry is divided into various types as shown below:



RUBBLE MASONRY

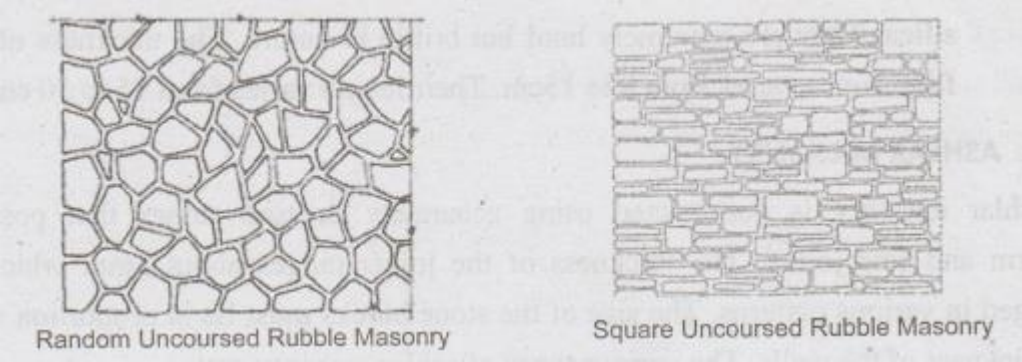
In this type of masonry stones employed are either undressed or roughly dressed. These masonry constructions do not have a uniform thickness. The strength of the rubble masonry is dependent on the quality of mortar used, use of long through stones, and proper filling of mortar between the stone spaces and joints: Rubble masonry can be again classified into the following types:

❖ **Coursed Rubble Masonry**: In this type of masonry, the stones in a particular course are of equal heights. The stones hence used possess different sizes. Also in this type, all the courses do not have same height. This type is commonly employed in the construction of public buildings, abutments, residential buildings and piers of ordinary bridges.



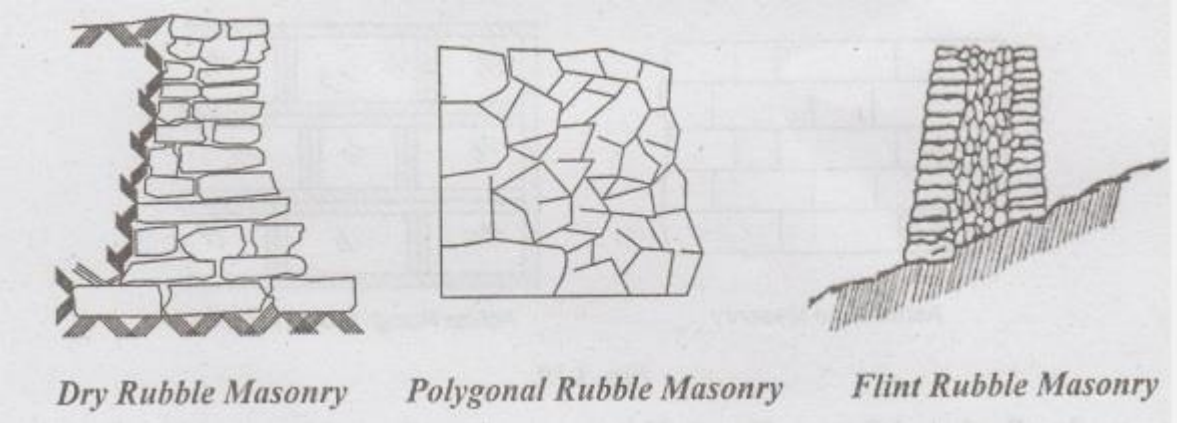
❖ **Uncoursed Rubble Masonry:** This type of rubble masonry is the cheapest and roughest form of stone masonry construction. This masonry use stones of varied shape and size. The undressed stone blocks which are directly taken from the quarry are used. The courses are not maintained regularly in this method of construction. Initially larger stones are laid first. The spaces between them are filled with spalls or sneeks. These are further divided into random uncoursed and square uncoursed.

Random Uncoursed Rubble Masonry*:* In this type, the weak corners and edges of the stone are removed with the help of a mason's hammer. At the quoins and jambs, bigger stones are employed in order to increase the strength of the masonry.



❖ **Square Uncoursed Rubble Masonry:** In this type, the stones are made roughly square shape and used in construction. The facing stones are provided a hammer-dressed finish. Larger stones are used as quoins. Here chips are not used as bedding.

❖ **Dry Rubble Masonry:** These are rubble masonry construction performed without the use of mortar. Small spaces are filled with smaller stone. pieces. It is used in pitching the earthen dams and the canal slopes.



❖ **Polygonal Rubble Masonry:** In this type, the stones used for masonry are roughly shaped into irregular polygons. The stones are then arranged in such a way that it avoids vertical joints in the face work. Also stone chips are used to support the stones.

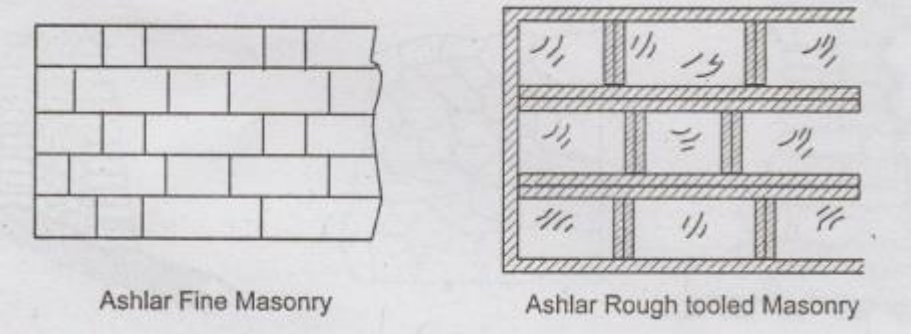
❖ **Flint Rubble Masonry:** In areas where flint is available plenty, a flint rubble masonry is employed. Flints are irregularly shaped nodules of silica. They are extremely hard but brittle in nature. The thickness of the flint stones varies from 8 to 15cm. Their length varies from 15 to 30 cm.

ASHLAR MASONRY

Ashlar masonry is constructed using accurately dressed stones that possess uniform and fine joints. The thickness of the joints ranges about 3mm which is arranged in various patterns. The size of the stone blocks must be in proportion with the thickness of the walls. The various types of ashlar masonry are:

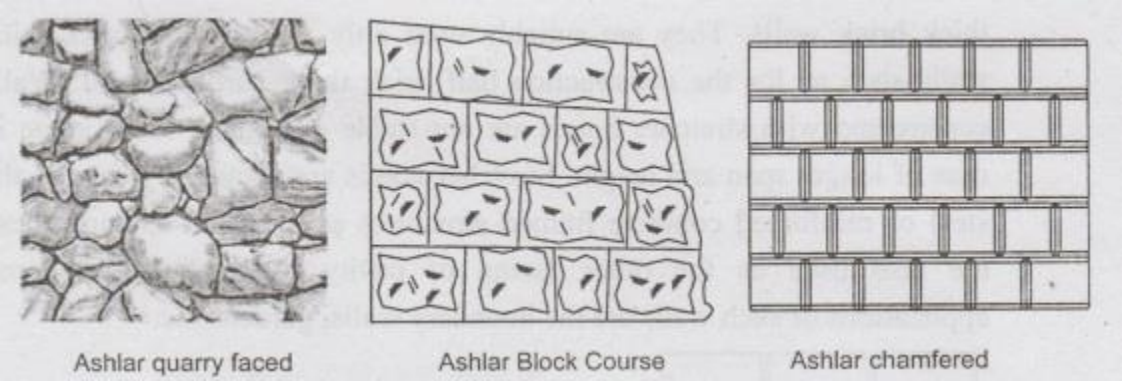
❖ **Ashlar Fine Masonry:** In ashlar fine masonry construction, each stone is cut into uniform size and shape, almost rectangular in shape. This shape hence provides perfect horizontal and vertical joints with the adjacent stones. An ashlar fine masonry construction is very costly.

❖ **Ashlar Rough Masonry:** This type has stones whose sides are finely chisel -dressed. The face of the stones is made rough by means of tools. Around the perimeter of the rough dressed face of each stone, a strip of 25mm width is provided.



❖ **Rock and 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.

❖ **Ashlar Block in Course Masonry:** This type is a combination of ashlar masonry and rubble masonry. The faces work of the masonry stones is either rough tooled or hammer dressed stones. The backing of the wall may be done in rubble masonry.



❖ **Ashlar Chamfered Masonry:** A strip is provided as shown in the figure. Sides of the stones are chamfered or beveled at an angle of 45 degrees by means of a chisel at a depth of 25mm.

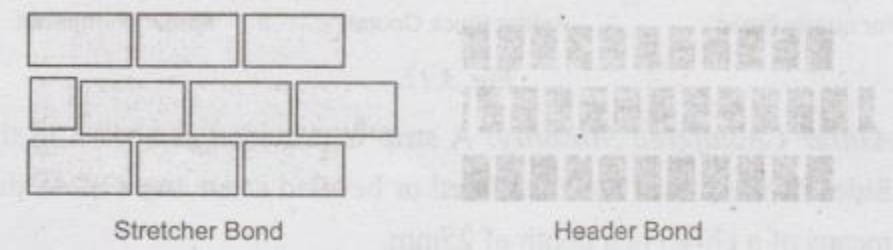
BRICK MASONRY

Brick masonry is built with bricks bonded together with mortar. For all permanent buildings lime or cement mortars are used. But for temporary sheds mud mortar may be used. Brick masonry strength depends on the type of bond and materials used for construction. They play an important role in providing strength, stability, and durability to the brick masonry.

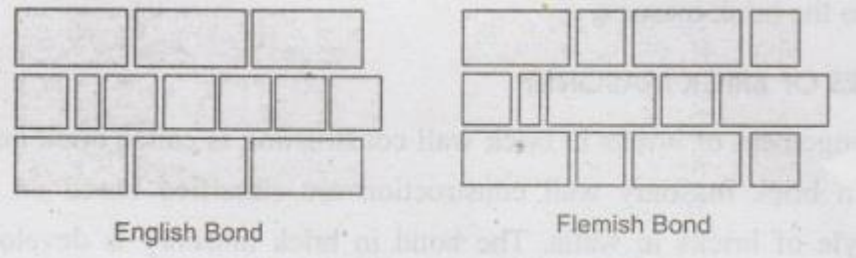
TYPES OF BRICK MASONRY

The arrangement of bricks in brick wall construction is called brick bonds. Types of bonds in brick masonry wall construction are classified based on laying and bonding style of bricks in walls. The bond in brick masonry is developed by the mortar filling between layers of bricks and in grooves when bricks are laid adjacent to each other and in layers in walls. The various types of bonds generally used in brick masonry are:

❖ **Stretcher Bond:** A stretcher is the longer narrow face of the brick. Stretcher bond is also called as running bond. This type of 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. But the limitation of stretcher bond is that it cannot make effective bonding with adjacent bricks in full width thick brick walls. 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. Stretcher bonds are commonly used in the steel or reinforced concrete framed structures as the outer facing. These are also used as the outer facing of cavity walls. Other common applications of such walls are the boundary walls, gardens etc.



❖ **Header Bond:** A header is the shorter square face of the brick. Header bond is also known as heading bond. In header bond brick masonry all the bricks are arranged in the header courses. This type of bond is useful for the construction of full brick thick walls. In header bonds, the overlap is kept equal to half width of the brick. To achieve this, three quarter brick bats are used in alternate courses as quoins.



❖ **English Bond:** English bond in brick masonry has alternate courses consisting of headers and stretchers. Headers are laid centered on the stretchers in course below and each alternate row is

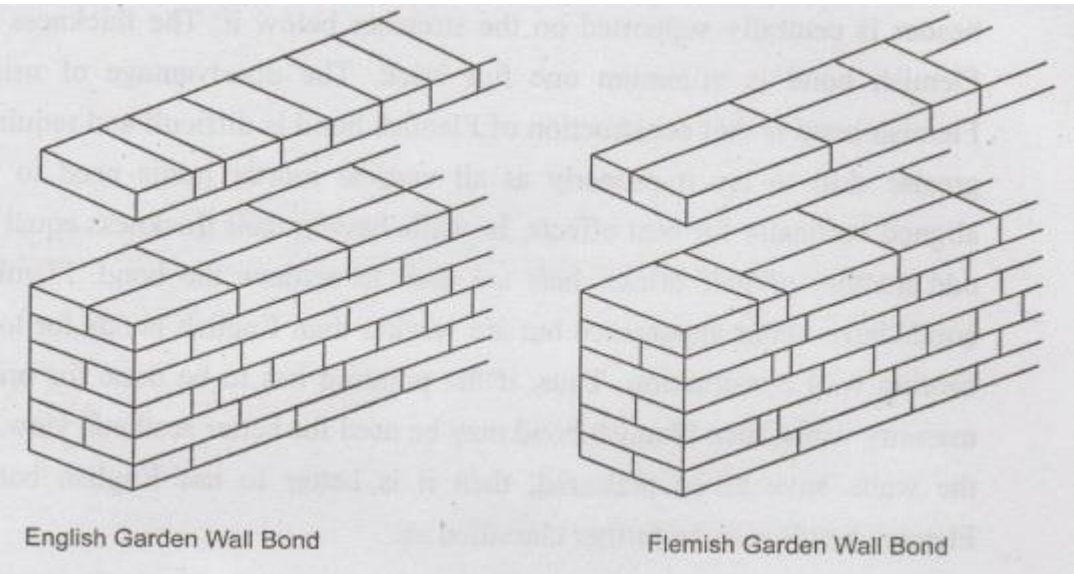
vertically aligned. This is considered to be the strongest bond. Hence it is commonly used bond for the walls of all thicknesses. To break the continuity of vertical joints, quoin closer is used in the beginning and end of a wall after first header. A quoin close is a brick cut lengthwise into two halves and used at corners in brick walls.

❖ **Flemish Bond:** In this type of bond each course comprises of alternate header and stretcher. Alternate courses start with stretcher and followed by header. Flemish bond is also known as Dutch bond. To break the vertical joints queen closers are required, if a course starts with header. Every header is centrally supported on the stretcher below it. The thickness of Flemish bond is minimum one full brick. The disadvantage of using Flemish bond is that construction of Flemish bond is difficult and requires greater skill to lay it properly as all vertical mortar joints need to be aligned vertically for best effects. In walls having their thickness equal to odd number of half bricks, bats are used to achieve the bond. Flemish bonds have better appearance but are weaker than English bonds for load bearing wall construction. Thus, if the pointing has to be done for brick masonry walls, then Flemish bond may be used for better aesthetic view. If the walls have to be plastered, then it is better to use English bond. Flemish bonds may be further classified as:

Single Flemish Bond: It is a combination of English bond and Flemish bond. In this type of construction, the front exposed surface of wall consists of Flemish bond and the back surface of the wall consists of English bond in each course. Minimum thickness required for single Flemish bond is one and a half brick thickness. 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.

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

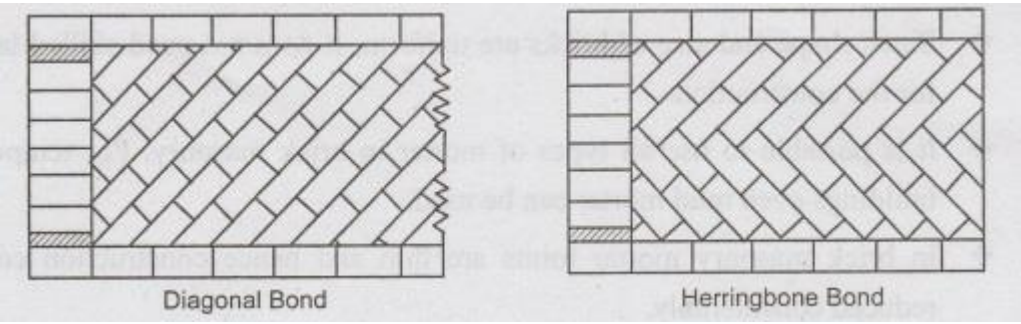
❖ **Garden wall bond:** The arrangement of bricks in the English Garden Wall is similar to that of the English bond except that the heading courses are only inserted at every course whereas stretchers are used in bodi consequent courses. In short, the arrangement consists of one course of headers and three courses of stretchers. The queen closer is placed next to the queen header of the heading course for giving the necessary lap. The Flemish garden wall bond has Stretcher, Header & Stretcher Model. It is also known as Sussex Bond. It is also known as balanced bonding. In the Flemish garden wall bond, it is two types of variation of Flemish bond one is 3 stretchers in 1 header ratio other is 2 stretchers in 1 header ratio.



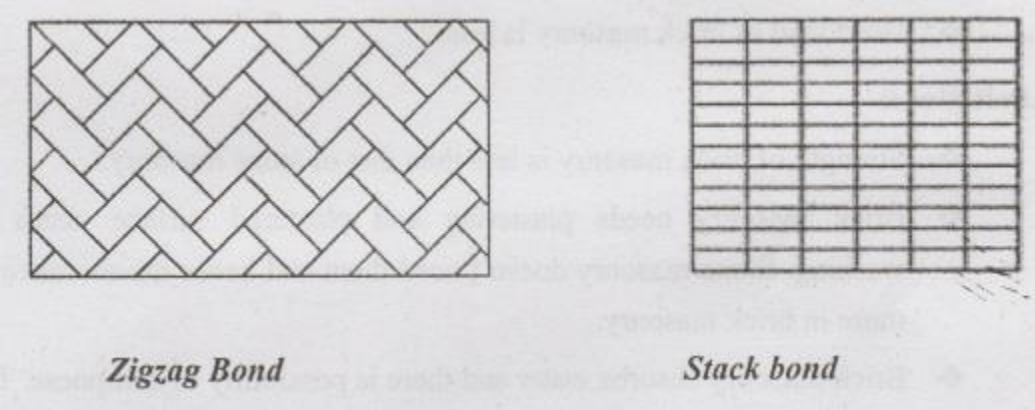
❖ **Raking Bond:** In this bond type, the bonding bricks are laid at any angle except zero or ninety degrees. This type of arrangement helps to increase the longitudinal stability of thick walls' built-in English bonds. In this pattern of bonding, the space between the all external stretchers of a wall is filled using bricks inclined to the face of the wall. Raking bond is introduced at certain intervals along with the height of any wall. It is of two types:

Diagonal Bond: It is best suited for walls of two to four brick thicknesses. A diagonal bond is normally introduced at every fifth or seven-course along with the height of the wall. Bricks in this type of bond are placed end to end in such a way that extreme corners of the sequence remain in contact with stretchers.

Herringbone bond: This type of bond is suited for very thick walls usually not less than four bricks thick. In this pattern of brickwork, bricks are laid in course inclined at 45° in 2 directions from the center. This type of bond is also commonly used for brick paving.



❖ **Zigzag bond:** Zig Zag Bond is very similar to herring-bone bond. The only difference is that in this case the bricks are laid in a zig-zag pattern. It is mostly adopted in brick-paved flooring.



❖ **Stack bond:** In a stack bond, all the bricks are plainly loaded on top of each other and held with mortar where all bonds are perfectly aligned. Because of its weak masonry structure and less strength, Stack bonds are perfect for decorative purposes. This bond is a non-structural bond, hence not suitable for walls which require transferring loads.

BENEFITS AND LIMITATIONS OF BRICK MASONRY OVER STONE MASONRY

Benefits:

❖ Bricks are light in weight and hence handling them is easy.

❖ Bricks are easily available around cities and their transportation cost is less because their weight is less. Stones are to be brought from quarries which are located only at few places.

❖ Since shape and size of bricks are uniform, it does not need skilled labour for the construction.

❖ It is possible to use all types of mortar in brick masonry. For temporary buildings even mud mortar can be used.

❖ In brick masonry mortar joints are thin and hence construction cost is reduced considerably.

❖ Brick masonry has better fire and weather resistance compared to stone no s masonry.

❖ Thinner walls can be constructed with bricks but it is not so with stones.

❖ It is easy to form openings for doors and windows.

❖ Dead load of brick masonry is less.

Limitations:

❖ ❖Strength of brick masonry is less than that of stone masonry.

❖ Brick masonry needs plastering and plastered surface needs colour washing. Stone masonry doesn't need them and hence maintenance cost is more in brick masonry.

❖ Brick masonry absorbs water and there is possibility of dampness. There is no such problem in stone masonry.

❖ Stone masonry gives massive appearance and hence for monumental buildings stone masonry is preferred over brick masonry.

❖ More architectural effects can be given in stone masonry compared to that in brick masonry.

❖ Durability of brick masonry is less when compared to stone masonry.

PLASTERING

Plastering in buildings refers to the process of applying mortar coats on the surfaces of walls, columns, ceiling to get smooth finish. Plastering covers defective workmanship in the construction of a given piece of masonry; and, also it conceals cheap/unsound quality of material used in building up the m onry. It is only after plastering that an appropriate base is ready to further decorate the surface by white- washing, colour-washing, distempering, or painting. Plastering is done to both the surfaces of a wall including the external face and on the internal face. Plaster is a sort of mortar obtained by mixing together materials like cement, lime, clay with fine aggregate and water. Mortar used for plastering may be lime mortar, cement mortar or lime-cement mortar.

OBJECTIVES AND REQUIREMENTS OF PLASTERING

The main objectives of plastering are:

❖To give smooth finish to the wall and RCC surface.

❖To protect the wall from rain water and other atmospheric agencies.

❖To conceal defective workmanship if any.

❖To protect surfaces against vermin.

❖The requirements of good plaster are:

❖It should adhere to the surface easily.

❖It should prevent infiltration by moisture.

❖It should be hard and durable.

❖It should be cheap.

GENERAL SPECIFICATIONS OF PLASTERING

Lime and cement are the two major constituents of plastering and hence the specifications for these two types of plastering are given below:

Lime Plastering:

Lime that is to be used in combination with cement for the purpose of making mortar, shall be ground dry. Stone lime is measured by weight and unslaked lime is measured when freshly burnt. Sand used in the mix should be clean, coarse and free from any admixture of clay, loam, salts, organic matter etc. Before plastering, the surface to be plastered should be prepared by cleaning out any loose materials resent on the surface. The joints shall be raked out thoroughly. Raking shall be done with a hook to a depth of 1.25 cm. It is easier to rake out the joints before the masonry mortar has set. After raking is done, and loose material washed off by water, the surface to be plastered shall be watered for 24 hours before the plaster is applied. If any chemical retarder has already been applied to the formwork, the surface should be roughened by wire brush, leaving no retarders behind on the surface. All putlog holes shall be filled up in advance of the plastering work as the scaffolding is being taken down. Pure fat lime shall be slaked and then immersed in water for at least 48 hours. Lime shall then be thoroughly stirred with water and strained through muslin. On settling, the surplus water shall be removed, and further water is allowed to evaporate, until the paste is thick enough for use. Lime mortar used for plastering shall have fat lime to sand ratio of 1: 3 or 1: 4. If hydraulic lime is used mix proportion (lime: sand) is 1:2.

Cement Plastering

Specifications of cement plaster shall be the same as for lime plastering. The thickness of cement plastering shall be such as 12 mm, 13 mm, 15 mm, or 20 mm. It shall be finished with a floating

coat of neat cement. Smooth finishing shall be done with trowel. In two-coat plastering, when the first coat is set, the surface shall be scratched with a sharp tool to form a key for the next coat. This coat shall be floated and finished, in the same manner as the first coat. Where it is not required subsequently to paint, distemper, or colour wash the plaster, it shall be finished to the final colour required and polished, plasterer's putty being used for the finishing coat. Cement mortar of 1: 4 or 1 : 6 mix is very commonly used for plastering, richer mix being used for outer walls. To combine the cost effectiveness of lime mortar and good quality of cement mortar many use lime-cement mortar of proportion (cement :lime sand) of 1: 1:6 or 1: 1: 8 or 1: 2: 8. Lime mortar is usually applied in 3 coats while cement mortar is applied in two or three coats for the stone and brick masonry. For concrete surfaces cement mortar may be applied in two or three coats. For concrete building blocks only one coat of cement mortar is applied. The first coat provides means of getting level surface. The final coat provides smooth surface. If three coats are used second coat is known as floating coat. If single coat is used its thickness is kept between 6 to 12 mm. Such coats are used on concrete surfaces not exposed to rain.

POINTING

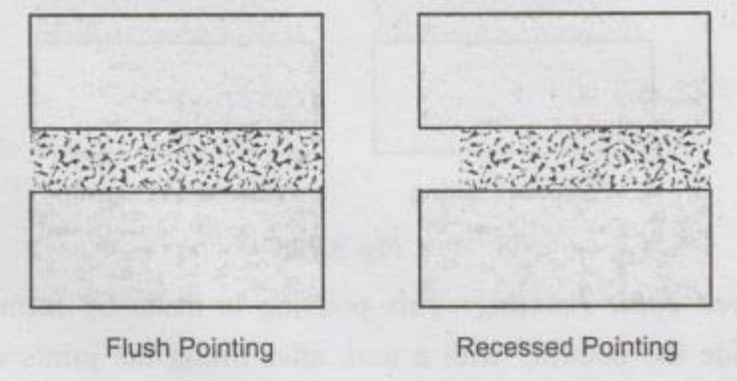
Pointing is the process of finishing the exposed joints in the masonry, instead of plastering the entire surface of the masonry. It consists of raking the joints to a depth of 10 mm to 20 mm and filling it with richer mortar mixes. In case of lime mortar pointing, mix used is 1 : 2 and in case of cement mortar pointing, mix used is 1 : 3. Pointing is preferably suited for stone masonry because stones are strong enough and show good resistance to penetration by water. Pointing gives perfection to joints, which is the weaker part of masonry. It also gives aesthetic view of the masonry.

TYPES OF POINTING

During the process of pointing, 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. Different types of pointing are discussed below:

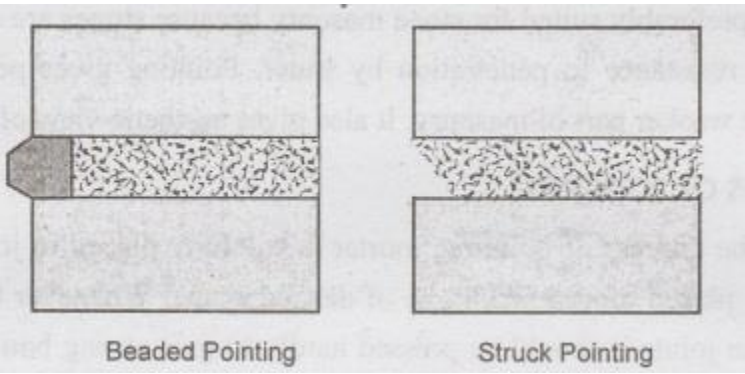
❖**Flush Pointing:** In this type, mortar is pressed hard in the raked joints and by finishing off flush with the edge of masonry units. The edges are neatly trimmed with trowel and straight edge. It does not give good appearance. But, flush pointing is more durable because of resisting the provision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

❖**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.



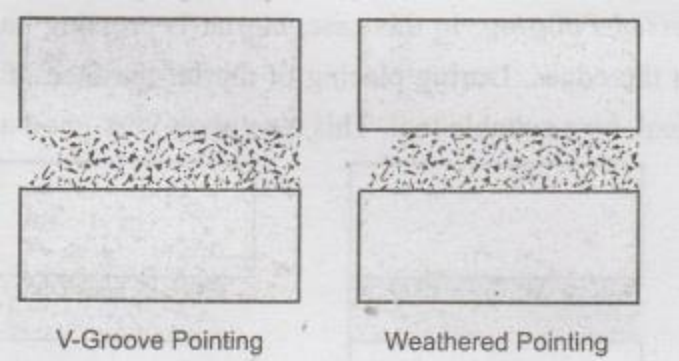
❖**Beaded Pointing:** It is formed by steel or ironed with a concave edge. It gives good appearance, but it will damage easily when compared to other types.

❖ **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.



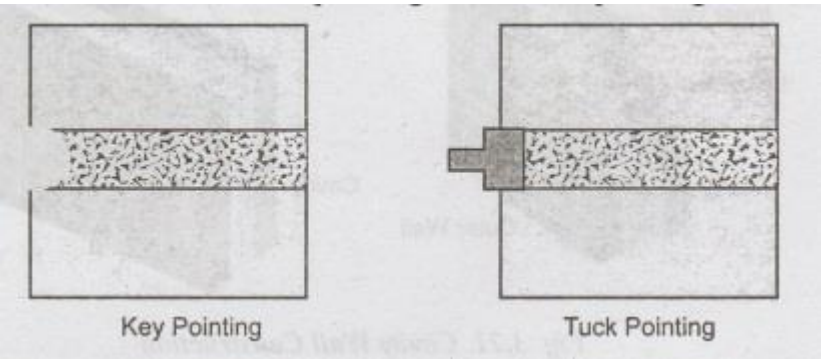
❖ **V-Groove Pointing:** This is also a modification of flush pointing in which groove is formed at its mid height, by a pointing tool. V-groove is formed in the flush-finishing face which gives good appearance.

❖ **Weathered Joint Pointing:** As the name suggests, this type of joint gives adequate protection against weathering. However, it requires a comparatively large quantity of water.



❖ **Keyed Joint Pointing**: This pointing is made by forming a semicircle inside the pointing with a tool, after filling the joints with mortar. The pointing gives an elegant appearance.

❖ **Tuck Pointing:** In this case mortar is pressed in the raked joint first and is 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.



COMPARISON BETWEEN PLASTERING AND POINTING

The following are some of the differences between plastering and pointing

S.No	Plastering	Pointing
1	It is applied on the entire wall surface	It is done only at the exposed joints
2	It gives smooth surface finish	It does not provide smooth surface
3	Defective workmanship in masonry can be covered up by plastering	Well built masonry work can be shown by doing pointing work at the joints
4	It acts as a base for white washing works	Further finishing works like white washing cannot be done

S.No

Plastering

It is applied on the entire wall surface mod, tot been ad

It gives smooth surface finish

Defective workmanship in masonry can be covered up by plastering

Further finishing works like works

Pointing

It is done only at the exposed joints

It does not provide smooth surface

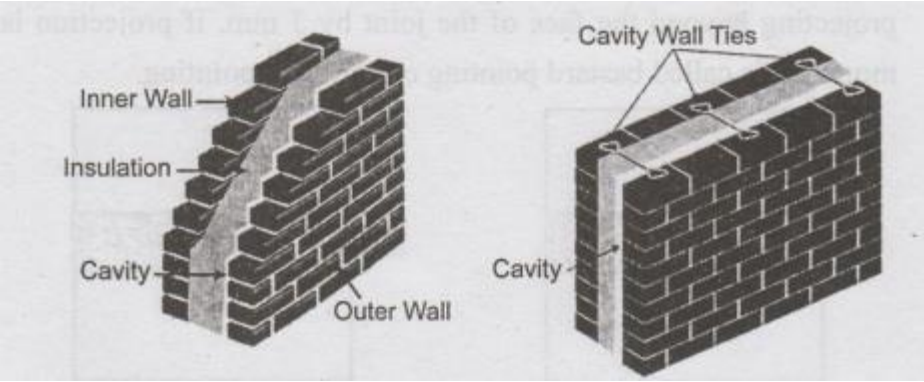
Well built masonry work can be shown by doing pointing work at the joints

It acts as a base for white washing white washing cannot be done

CAVITY WALLS

Cavity walls are those which are constructed in such a way that an empty space or cavity is left between the single wall. They are also known as hollow wall. Cavity walls are two walls constructed as a single wall. A little space is lifted between these two walls for insulation purposes.

These two walls having little space between them for insulation purpose are known as leaves of the cavity wall. The outer wall is called an external leaf, and the inner wall is called an internal leaf. These two leaves of cavity wall are interconnected by links or metal ties for a strong bond.



The inner leaf is found to take a greater portion of the imposed load transmitted by floor and roof. Hence, the two leaves of the wall are bonded together with ties (wall ties) usually placed 900 mm apart vertically and 450 mm horizontally in every 6th course staggered. This gives more than two ties per square meter. These wall ties are made from mild steel wires of 3 to 4 mm diameter or MS bars. In very important works, copper may be used. The bond to be used for both the leaves, when the thickness is half brick, is the stretcher bond. The inner leaves are made thicker for carrying heavy loads, hence English bond can be used for that part. Particular care is required at the top and bottom of the walls and around openings in the cavity wall construction.

PURPOSE OF CAVITY WALLS

The use of cavity walls is common in cold countries. However, when used in tropical countries, sufficient precautions must be taken to see that they do not become breeding places for lizards and insects. The major purposes of cavity walls are as follows:

❖ **Damp Prevention:** Cavity wall reduces the chance of moisture intrusion from outer leaf to the inner leaf and thus helps in keeping inside of the building free from dampness.

❖ **Thermal Insulation:** The air in the cavity wall acts as a non-conductor of heat and hence minimizes the transmission of heat from the outer leaf to the internal face of the interior leaf. Thus, cavity walls help in maintaining the thermal insulation of a premise.

❖ **Sound Insulation:** The air in the cavity acts as a cushion for absorbing sound. By building cavity walls, a premise may work as a sound proof zone as a large quantity of external noise gets absorbed within the cavity.

❖ **Efflorescence Prevention**: As dampness is not allowed to penetrate the cavity, the inner leaf of the cavity, which is always a load bearing wall, is kept free from efflorescence effects.

POINTS TO BE CONSIDERED IN CAVITY WALL CONSTRUCTION

The following are the Points to be considered during cavity wall construction:

❖ The cavity should extend to 15 cm below the damp-proof course level. Damp proof course should be laid to both leaves of the wall.

❖ The upper part of the wall where it ends should also be built solid for two or three courses below the wall plate or roof line, to stiffen the head of the wall and distribute the load over both leaves.

❖ The wall ties must be kept free from mortar droppings by means of a timber batten suspended in the cavity and raised as the work proceeds during its construction.

❖ In exposed positions, a few vertical joints in the outer leaf are left the bottom of the cavity to permit water to drain away.

❖ A certain amount of ventilation to the cavity is desirable to prevent stagnation of air and excessive humidity.

❖The cavity walls should not be built solid at the jambs [the sides of door and window openings] unless a vertical "damp-proof course" is inserted to prevent water driving to the inner face.

❖ A lead, galvanized iron or other suitable material made to form a trough or gutter, may be placed in the cavity above all openings for exposed doors and window to collect water which may drive through the outer leaf.

❖ The cavity wall should not be built solid below window sills also, and a damp-proof course is desirable at this point also.

ADVANTAGES AND DISADVANTAGES OF CAVITY WALLS

Advantages

❖ Cavity walls are best for damp prevention than solid building walls.

❖ They work best as heat insulators; it can decrease heat transmission from the outside environment.

❖ Sound waves travel faster in solid walls as compared to hollow walls. Hence, the cavity walls are also best for sound insulation.

❖ The construction cost of the cavity wall is about 20% less than the construction of solid walls. Hence, they are also economical.

Disadvantages

❖ Highly skilled labor and masons are required for cavity wall construction.

❖ Require standard supervision during its construction.

❖ A vertical damp proof course is also necessary for it.

DIAPHRAGM WALL

Diaphragm wall is method of creating cast in-situ reinforced concrete retaining wall using slurry supported trench method. They are also known as slurry walls. These walls provide rigid, cost effective solution for permanent retaining wall and shafts with less construction joints. Diaphragm wall construction methods are relatively quiet and cause little or no vibration. Diaphragm wall panels are also used in deep, load-bearing soil layers as foundation elements to carry concentrated structural load in the same way as large drilled piles do. These foundation elements are known as "Barrettes".

TYPES OF CONSTRUCTION METHOD

The construction of diaphragm wall may be of the following two types:

❖ **Diaphragm Wall (grabbed):** In this method, two different grab systems, suitable for wall thicknesses of 600 mm to 1,500 mm, are available for trench excavation. The grab is lowered into

the trench and the soil is discontinuously transported. Larger blocks or sections of rock are punched through, excavated or displaced using modified grabs or heavy-duty chisels. Measuring systems can be installed to verify verticality. On mechanical grabs, a roller system operates the jaws. To increase the closure force, the closing cable is reeved five to six times. Hydraulic grabs work with a hydraulic cylinder. They have very high closure forces and work with lower noise and fewer vibrations than mechanical grabs.

❖ **Diaphragm Wall (cut):** Trench cutters are used to produce diaphragm walls in thicknesses of 500 mm to 3,200 mm. As they transport the spoil continuously, they are particularly suitable for depths of more than 40 m. Trench cutters operate with two opposite-running cutter wheels which, depending on configuration, are suitable for a wide variety of strata, including even ultra-hard rock. The soil material is cut by the rotation of the wheels, crushed, mixed with slurry and transported to the surface by a suction pump. Hydraulic steering flaps control the cutter in both horizontal directions. The penetration depth and speed are regulated by controlled activation of the cutter weight.

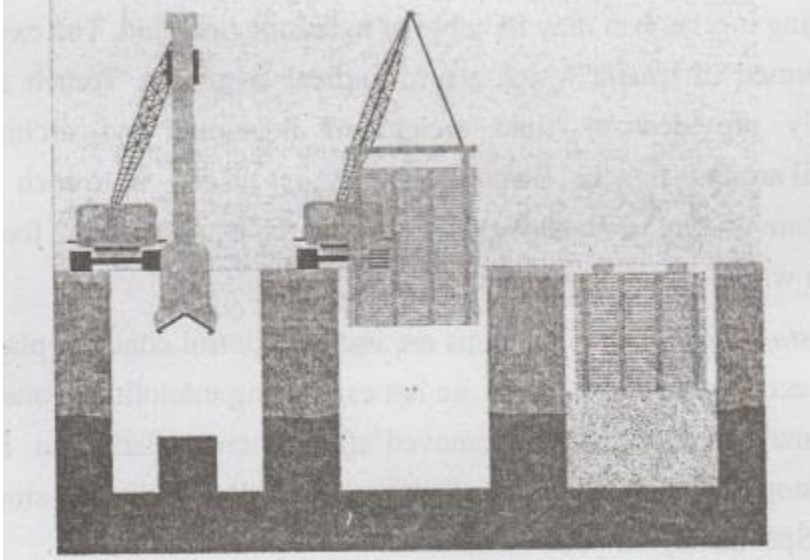


Fig. 3.22. Diaphragm Wall Construction

PROCEDURE FOR CONSTRUCTING DIAPHRAGM WALL:

❖ **Site Logistic and Slurry Plant Setup:** Diaphragm wall installation requires sufficient work area to setup slurry plant and to assemble reinforcing cages prior to placement in wall. This work may be difficult in congested sites. To reduce area requirement of site cage, prefabrication is possible. Slurry plant includes slurry mixer, storage tanks and descending units. Sufficient storage tanks must be used for bentonite slurry hydration.

❖ **Pre-trenching:** It is performed to remove shallow obstructions and provide stable support for guide walls. This is performed as open excavation backfilled with flowfill / excavated under self hardening slurry.

❖**Guide Wall Construction:** Guide walls provide template for wall excavation panel layout, support top of trench, restrain end slopes, serves as platform to hang reinforcement provide reference elevation for inserts, support tremie pipes, hold down cage during concreting and provide reaction for jacking out some types of end slopes. Guide walls are reinforced concrete whose top should be atleast 4 feet above ground water table to allow construction in dry condition.

❖ **Panel Excavation:** Special clamshell also known as grabs/buckets are rectangular shaped and used to excavate vertical slots are known as panels. Digging mechanism may be cable or hydraulic operated. The excavation is performed in panels which are in vertical segments. Trench stability is mostly provided by fluid weight of bentonite and arching action of soil around trench. Bentonite slurry is placed in trench added to maintain atleast 3 feet above ground water table and within 2 feet of top of guide wall.

❖ **End-stop Placement:** End-stops are used to control concrete placement so that secondly adjacent panels are not excavating monolithic concrete. End- stop may be permanent or removed after concrete placement. Permanent End-stops are typically wide flange shaped. Removal End-stops can be pipe/Special keyway End-stops.

❖ **Panel Descending:** Panel may be descended to remove excess sand in slurry and bottom panel. Removal of sand from slurry decreases density of slurry so that tremie concrete doesn't mix with slurry or trap pockets of sand.

❖ **Reinforcing Cage Placement:** Reinforcing cage is inserted into panel excavation concrete is placed around reinforcing cage using tremie methods to form concrete panel.

❖ **Tremie Concrete:** Tremie pipes are placed in panel at bottom concrete with 200-250 mm slump is then allowed into the panel. Concrete mix with high slump and fairly high cement content often other pozzolona, plasticizers and chemicals are used.

APPLICATIONS OF DIAPHRAGM WALLS

Diaphragm wall has many applications to facilitate certain construction activities, as follows:

❖ As a retaining wall and cut-off provision to support deep excavation in areas with dense and historic urban infrastructure.

❖ Used as a final wall for basement or other underground structure like tunnel and shaft.

❖ For a separating structure between major underground facilities and sheet piles in hydraulic structures.

❖ It is intended to take up high vertical loads from above ground structures during construction

❖ It is preferred, where geology and ground water precludes use of conventional earth retention system

ADVANTAGES AND DISADVANTAGES OF DIAPHRAGM WALLS

Advantages:

❖ Facilitate excavations below groundwater while eliminating dewatering.

❖ Provides underpinning and minimizes settlement of adjacent buildings.

❖ Provide fairly watertight walls.

❖ It can be installed before excavation commences.

❖ Accommodate connections to structures.

❖ Easily adapted to both anchors and internal structural bracing systems.

❖ Top-down basement construction gives significant advantages.

Disadvantages:

❖ High Cost

❖ Requires special equipment

❖ Technical skilled labour required

FORMWORK

Formwork is the temporary mold in which concrete is poured to cast the required shape of concrete. For concrete formwork mostly timber and steel are the materials most commonly used for formwork, a range of other materials are used, mainly for specialist applications. The formwork and its associated false work must have sufficient strength to support the weight of the wet concrete without significant distortion. In general, once the concrete has gained sufficient strength, the formwork is removed although in some circumstances it may be left in place (permanent formwork).

TYPES OF FORMWORK

Various types of formwork used in construction are Timber Formwork, Steel Formwork, Aluminum Formwork, Plywood Formwork, Fabric Formwork and Plastic Formwork.

❖**Timber Formwork**: Timber formwork is the most common type of formwork among all others. Timber forms are extensively used in construction from the ancient period. It is the oldest type of form used in construction. Timber offers onsite fabrication of the required shape and size. It is easily used in any construction but it may prove time consuming for large projects. It is low-cost and easily workable formwork. It can be cut and joined in any shape and size.

Advantages

❖ Timber Shuttering is easy to form any shape, size, and height.

❖ It is proven economical for small projects.

❖ It can make using locally available timber.

❖ Timber is light weighted compared to steel or aluminum forms.

❖ **Steel formwork:** This type of formwork is more popular due to its strength, durability, and repetitive reuse for a long period. Steel formwork is costly for small work but can be used for a large number of projects. Steel shuttering offers a smooth surface finish to concrete compared to

timber formwork. It can be used for circular or curved structures such as tanks, columns, chimneys, sewers, tunnels, and retaining walls.

Advantages

❖ Steel is strong, durable & has a longer life.

❖ It offers a smooth finish to the surface of the member.

❖ It is completely waterproof or moisture-proof and minimizes the honeycombing effect.

❖ It can be reused for more than 100 times.

❖ Steel formwork can be fixed and removed with greater ease.

❖ **Aluminum Formwork:** Aluminum formwork is almost the same as the formwork made from steel. Formwork done with aluminum is proven economical if large numbers of repetitions are made in construction. Its major drawback is that no alteration is possible once the formwork is constructed. As we know the density of aluminum is less than compare to steel and that makes it light weighted than steel. This is the main advantage when compared to steel.

❖ **Plywood Formwork:** In this type of formwork, re-molded timber resin- bonded plywood sheets are attached to timber frames to make up panels of the required sizes. It is strong, flexible, and easy to handle. Its lifespan is too short compared to other materials.

❖ **Fabric Formwork:** With the advancement and new technology trends in building planning and designing, the construction of complex shaped structural members is increased. To satisfy this need the fabric formwork is introduced. The flexibility of fabric formwork makes it possible to produce concrete members of any shape.

❖ **Plastic Formwork:** Plastic formworks are light weighted, have interlocking systems and can be re-used many times. It can be used for normal concrete construction. This type of formwork is now becoming popular for typical shapes and large housing schemes.

Advantages

❖ Plastic forms are light in weight hence requires less handling cost.

❖ It can be utilized in the large concrete section.

❖ With careful installation and use, multiple reuses are possible making it highly economical.

SAFETY CONSIDERATIONS IN FORMWORK

Formwork is made from different materials, and requires great skill and experience in its execution. To produce concrete forms that meet all job requirements, engineer must understand the characteristics, properties, and behaviors of the materials used. The following are the safety considerations in formwork:

❖ **Strong:** To ensure the safety of the structure and the protection of the workers, it is essential that formwork be designed to carry the full load and side pressures from freshly placed concrete, together with construction traffic and any necessary equipment.

❖ **Sound:** The materials used to construct the forms must be of the correct size and quantity, of good quality, and sufficiently durable for the job.

❖ **Avoid Deflection:** Deflection is the most important consideration for design of formwork, the limit for deflection varies according to class of the work. For simply supported spans, this limit is not more than span/360.

CENTERING AND SHUTTERING

Centering is used to support horizontal members. Hence, formwork for floor beams and slabs is known as centering. **Shuttering** is used to support vertical members. Hence, formwork for columns, footings, or retaining walls is known as shuttering. In general these are temporary formworks in which the concrete is placed and allowed to hardened

REQUIREMENTS OF CENTERING AND SHUTTERING

The general requirements of shuttering and centering are as follows:

❖ The surface of the form should be smooth

❖ It should be able to withstand all the loads coming on it

❖ It should be able to retain its shape (horizontal and vertical bracing is done for this)

❖ It should have minimum deflection under load

❖ It should be re-usable and should not be costly

❖ It should be water-proof so that it does not absorb water from the fresh concrete

❖ It should facilitate easy stripping during the time of removal

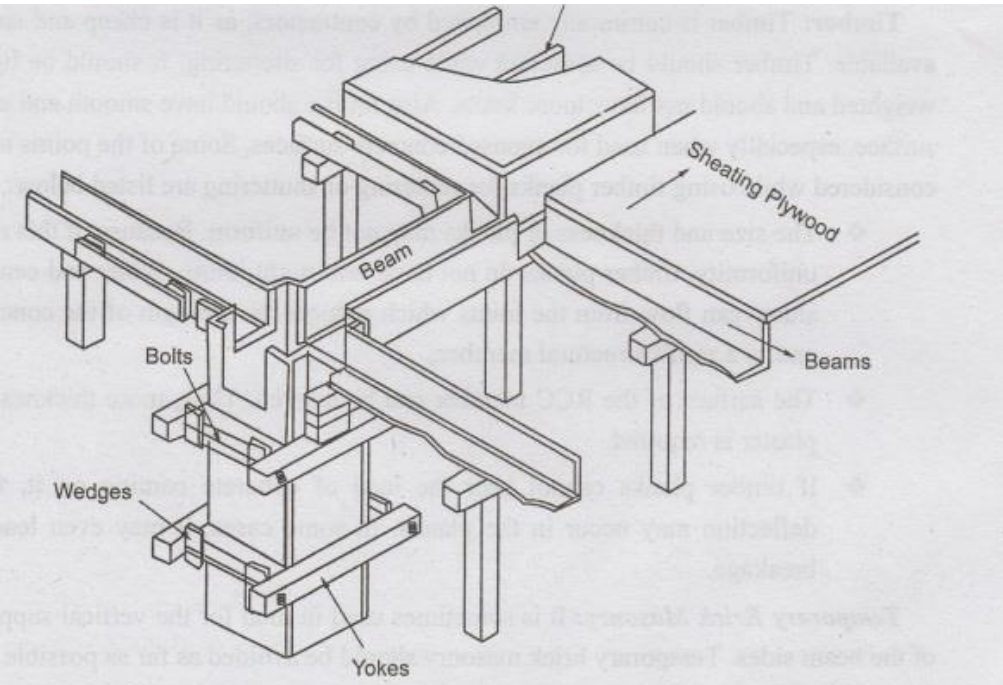


Fig. 3.23. Centering and Shuttering

MATERIALS USED FOR CENTERING AND SHUTTERING

Steel and timber are commonly used as shuttering and centering material, former for its efficiency and later for its cost-effectiveness.

Steel: Panels are fabricated from thin steel plates and small steel angles are used along the edges to stiffen these plates. Clamps, nuts, or bolts are used to hold the steel panels together. Steel is considered the best material for centering and shuttering. The reasons are explained below:

❖ Steel provides a watertight formwork so that strength of the cement pnis concrete is preserved

❖ It can bear the load coming on it easily

❖ It can be used for vertical, horizontal, or any type of formwork

❖ It provides a levelled surface of concrete. Desired appearance based on architectural recommendations is easy to achieve with the help of steel formwork

❖ As the bottom surface of the structural member is levelled, less thickness of plaster is required

Timber: Timber is commonly employed by contractors, as it is cheap and easily available. Timber should be seasoned while using for shuttering. It should be light- weighted and should not have loose knots. Also timber should have smooth and even surface, especially when used for exposed concrete surfaces. Some of the points to be considered while using timber planks for centering or shuttering are listed below:

❖ The size and thickness of planks may not be uniform. Because of this non- uniformity, timber planks do not have watertight joints. Water and cement slurry can flow from the joints which reduces the strength of the concrete and as a result structural member.

❖ The surface of the RCC member can be uneven. Thus, more thickness of plaster is required.

❖ If timber planks cannot bear the load of concrete coming on it, then deflection may occur in the planks. In some cases, it may even lead to breakage.

Temporary Brick Masonry: It is sometimes used in mud for the vertical supports of the beam sides. Temporary brick masonry should be avoided as far as possible due to the following reasons:

❖ The brick masonry soaks the cement slurry from the member. Thus, the strength of the member is greatly affected.

❖ Moreover, the brick masonry formwork cannot bear the weight of vibrator, so proper compaction of the structural member is not possible. This again reduces the strength. here

❖ An uneven surface of RCC member is obtained requiring more thickness of plaster.

SHORING

Shoring is a temporary structure used to prevent the collapse of the main under- construction structure. The most commonly shoring support is required during the early stage of construction which is excavation. It is a momentary support, which is used during the repair or original construction of buildings and in excavations. It can be utilized when walls bulge out or cracks due to unequal settlement of foundation and repairs must be carried out to the cracked wall, when an

adjacent structure needs pulling down when openings must be newly enlarged or made into a wall. Its support requirement depends on the types of soil and when an excavation depth is at least 1.20-meter difference in levels from ground level.

TYPES OF SHORING

Each shoring system has its own function to perform and is based upon the principles of a perfectly symmetrical situation. The types of shoring as discussed below:

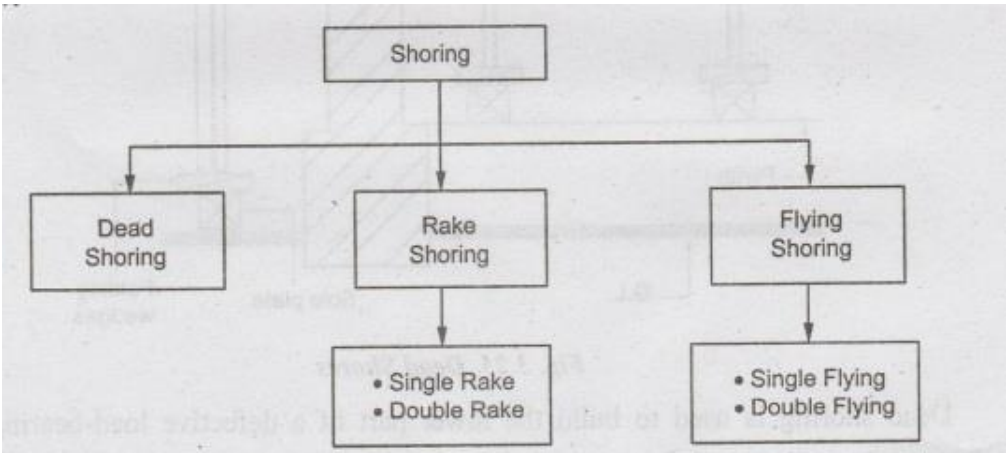
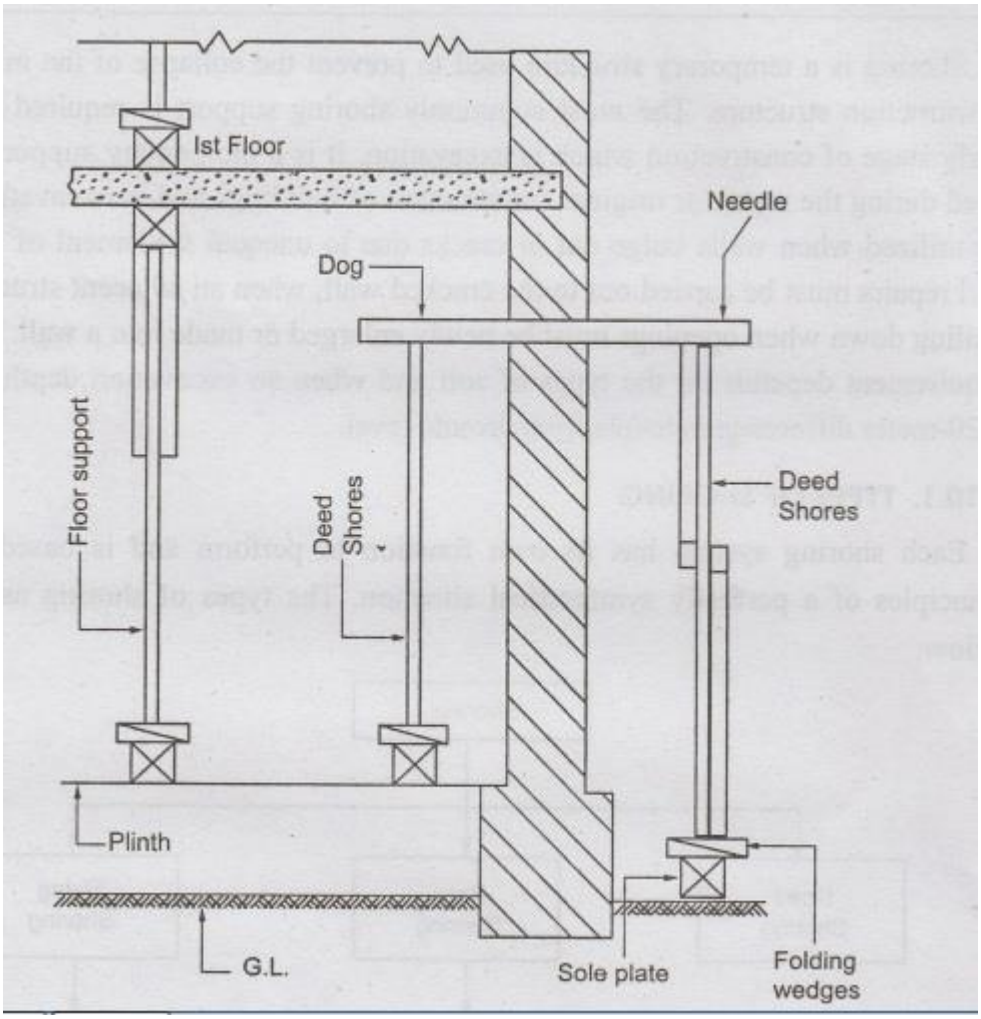


Fig. 3.24.

Dead Shoring:

Dead shoring is also known as vertical shoring. This type of shoring is used to support dead loads that act vertically downwards. It is used to temporarily support the walls, roofs, floors, etc., by providing horizontal members known as needles. It consists of a vertical prop or shore leg with a head plate, sole plate, and some means of adjustment for tightening and easing the shore. The usual arrangement is to use two sore legs connected over their heads by a horizontal beam or needle. The loads are transferred by the needle to the shore legs and hence down to a solid bearing surface.



Dead shoring is used to build the lower part of a defective load-bearing wall, deepen the existing foundations, which have either become unsafe or require strengthening and large openings in the existing walls for doors and windows. This type of shoring system is kept away from the wall for easy repair work. Dead shores are supported and anchored on plates and folding wedges.

Factors to consider for dead shoring are as follows:

- ❖ The needles are spaced at 1 to 2 meters
- ❖ Needles should be suitably braced
- ❖ Folding wedges should be inserted between the two
- ❖ The floors should be suitably supported from inside

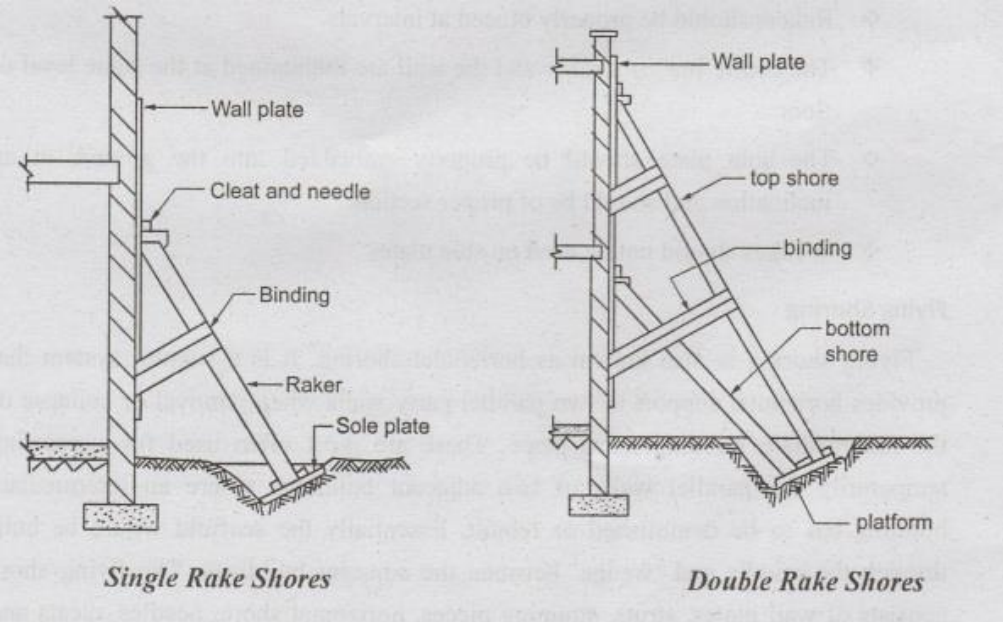
❖ Fix ceiling struts between the suitable head and sole plates to relieve the wall of floor and roof loads

❖ Strut all window openings within the vicinity of the shores

❖ Cut holes through ceilings and floors for the shore legs

❖ Leave the shoring in position for at least seven days before starting new work

Rake Shoring



It is also called as inclined shoring. Rake shoring is used to support any walls that aren't structurally sound within a building. Using cleats, needles, sole plates, inclined members, bracing and wall plates, they help to keep walls intact to minimize any damage to the existing building or structure. It is used to transfer the floor and wall loads to the ground utilizing sloping struts or rakers. The rakers must be positioned correctly so that they are capable of receiving maximum wall and floor loads.

Rakers are positioned against the needles in such a way that the centerline of the raker and the wall meet at the floor level. Thus, there will be one raker corresponding to each floor. These rakers are inter-connected by struts, to prevent their buckling. An inclined soleplate is embedded into the ground on which the feet of rakers are connected. The feet of rakers are further stiffened near the soleplate using hoop iron. The wall plate distributes the pressure to the wall uniformly. Based on

the requirement of the rakes, it may be classified as single rake shore and double rake shore. The factors to consider for rake shoring are:

❖ Rakers should be inclined to the ground by 45° to 75°,

❖ Length of raker can be reduced by introducing rider raker.

❖ Rakers should be properly braced at intervals.

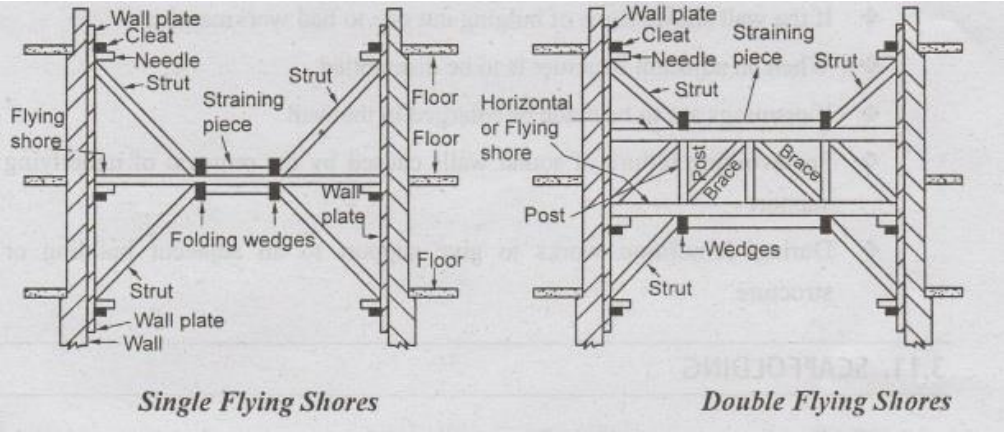
❖ The centre line of a raker and the wall are maintained at the same level of floor.

❖ The sole plate should be properly embedded into the ground, at an inclination and should be of proper section.

❖ Wedges should not be used on sole plates

Flying Shoring

Flying shoring is also known as horizontal shoring. It is a support system that provides horizontal support to two parallel party walls when removal or collapse of the intermediate building takes place. These are most often used for supporting temporarily the parallel walls of two adjacent buildings where an intermediate building has to be demolished or rebuilt. Essentially the scaffold would be built through the middle and 'wedge' between the adjacent buildings. The flying shore consists of wall plates, struts, straining pieces, horizontal shore, needles, cleats and wedges, as shown in the above image. Like inclined shores, in this system also, the wall plates are secured against the walls using needles and cleats.



In this type of shoring also the wall plates are placed against the wall and secured to it. A horizontal strut is placed between the wall plates and is supported by a system of needles and cleats. The

inclined struts are supported by the needle at their top and by straining pieces at their feet. They may be single or double flying shores as shown in the figure. Points to be considered for flying shoring are as follows:

❖ The center lines of flying shore and struts and those of the walls should meet at floor levels of the two buildings.

❖ The struts should preferably be inclined at 45°.

❖ Single shores should be used only up to 9 m distance between walls.

❖ Should be spaced at 3 to 4.5 m centers, along the two walls; and horizontal braces

REQUIREMENTS OF SHORING

Shoring in construction is essentially required to support a deep excavation to prevent the retained soil from overturns and eventually cause a project mishap. The following are some of the requirements of shoring:

❖ To repair a crack on the wall due to unequal settlement of the foundation.

❖To give support to walls that are dangerous or are likely to become unstable because of subsidence, bulging, or leaning.

❖ If the wall shows signs of bulging out due to bad workmanship.

❖ When an adjacent structure is to be dismantled.

❖ If openings are to be made or enlarged in the wall.

❖ For avoiding failure of sound walls caused by the removal of underlying support

❖ During demolition works to give support to an adjacent building or structure.

SCAFFOLDING

Scaffolding is a temporary platform used to lift, support, and supply materials during a construction process of a building. It is installed before construction or maintenance work begins. Scaffolding is done to ensure the safety of workers while the building is being maintained or

constructed. In addition, it also provides some degree of support for a standing structure during the construction phase. These temporary structures are constructed very close to the wall in the form of timber or steel frame work.

COMPONENTS OF A SCAFFOLDING

The components of scaffoldings are standards, ledgers, braces, put logs, transoms, bridle, boarding, guard rail and toe board.

Standards: These are the vertical members of the framework, supported on the ground or drums, or embedded into the ground.

Ledgers: The horizontal supporting members running parallel to the wall.

Braces: Braces are diagonally fixed on standards.

Putlogs: Putlogs are placed one end on ledgers and other ends right angles on the wall. This is a transverse member.

Transoms: Transoms are a type of putlogs supported on ledgers on both sides.

Bridle: This is a member used to bridge a wall opening; supports one end of the putlog at the opening.

Boarding: Boarding is a horizontal platform supported on putlogs and is used for the support of workmen and materials at the time working.

Guard rail: This is a rail, provided like a ledger, at the working level.

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

Scaffolding shall be classified into the following types:

❖ Single scaffolding or brick layer scaffolding

❖ Double scaffoldings or masons scaffoldings

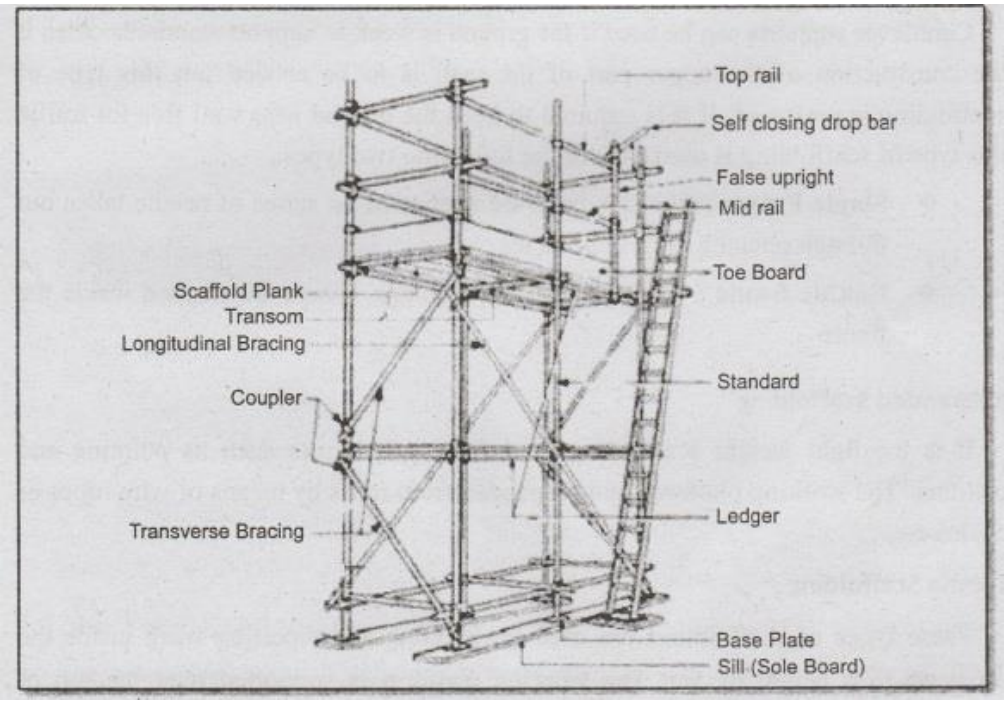
❖ Cantilever or needle scaffoldings

❖ Suspended scaffoldings

❖ Trestle scaffolding

❖ Steel scaffolding

❖ Patented scaffoldings



Single Scaffolding

This type of scaffolding consists of a single frame work of standards, legers and put logs. It is constructed parallel to the wall at a distance of about 1.2 meters. The standards are placed at a distance of 2 to 2.5m interval. Ledger connected with the standards are provided at a vertical distance of 1.2 to 1.5 m. Put logs or connected with one end on the ledgers and other end at the holes of the wall at an interval of1.2 to 1.5 m interval.

Double or masons scaffolding

It is very difficult to put holes in walls to support putlogs in stone masonry. In that case, strong scaffolding is used consisting of two rows of scaffolding. The first row is placed 20 to 30 cm away from the wall the other frame is placed at 1m distance from the first one. Put logs are supported on both the supports, with rakers and cross braces are provided to make the scaffolding more strong. It also called as independent scaffoldings

Cantilever or needle scaffolding

Cantilever supports can be used if the ground is week to support standards. Also if the construction of the upper part of the wall is to be carried out this type of scaffolding is preferred. If it is required to keep the ground near wall free for traffic this type of scaffolding is used. It is of the following two types:

Single Frame: The standards are supported on series of needle taken out through opening or through holes

Double frame: The needles are projecting beams are strutted inside the floors

Suspended Scaffolding

It is the light weight scaffolding used for repair works such as pointing and painting. The working platforms are suspended from roofs by means of wire ropes or chains etc,.

Trestle Scaffolding

These types of scaffoldings are used for painting and repairing work inside the room up to a height of 5m. The working platform is supported over the top of movable contrivances such as tripods ladders etc

Steel Scaffolding

Steel scaffolding is practically similar to the timber scaffolding, here wooden members are replaced by steel couplets are fittings. This type of scaffolding can be erected and dismantled rapidly. It has a greater strength and greater durability.

Patented Scaffolding

Many patented scaffolding made of steel are available in the market. These scaffoldings are equipped with special couplings frames for better durability.

SCAFFOLDING

Scaffolding is a temporary platform used to lift, support, and supply materials during a construction process of a building. It is installed before construction or maintenance work begins. Scaffolding is done to ensure the safety of workers while the building is being maintained or constructed. In addition, it also provides some degree of support for a standing structure during the construction phase. These temporary structures are constructed very close to the wall in the form of timber or steel frame work.

COMPONENTS OF A SCAFFOLDING

The components of scaffoldings are standards, ledgers, braces, put logs, transoms, bridle, boarding, guard rail and toe board.

Standards: These are the vertical members of the framework, supported on the ground or drums, or embedded into the ground.

Ledgers: The horizontal supporting members running parallel to the wall.

Braces: Braces are diagonally fixed on standards.

Putlogs: Putlogs are placed one end on ledgers and other ends right angles on the wall. This is a transverse member.

Transoms: Transoms are a type of putlogs supported on ledgers on both sides.

Bridle: This is a member used to bridge a wall opening; supports one end of the putlog at the opening.

Boarding: Boarding is a horizontal platform supported on putlogs and is used for the support of workmen and materials at the time working.

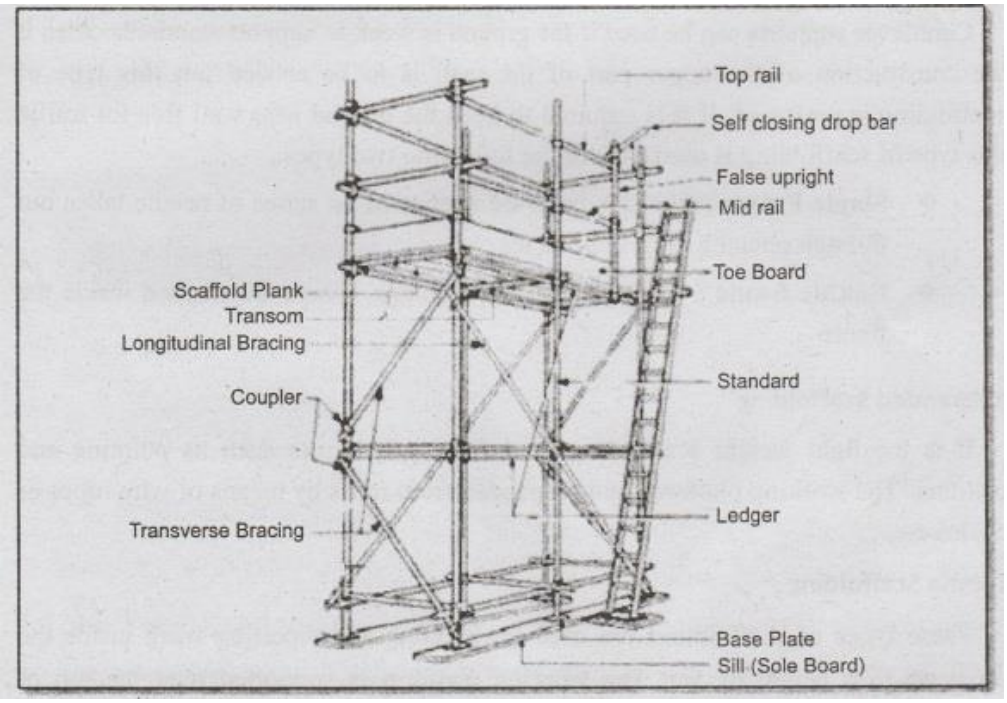
Guard rail: This is a rail, provided like a ledger, at the working level.

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

Scaffolding shall be classified into the following types:

- ❖ Single scaffolding or brick layer scaffolding
- ❖ Double scaffoldings or masons scaffoldings
- ❖ Cantilever or needle scaffoldings
- ❖ Suspended scaffoldings
- ❖ Trestle scaffolding
- ❖ Steel scaffolding
- ❖ Patented scaffoldings



Single Scaffolding

This type of scaffolding consists of a single frame work of standards, legers and put logs. It is constructed parallel to the wall at a distance of about 1.2 meters. The standards are placed at a distance of 2 to 2.5m interval. Ledger connected with the standards are provided at a vertical distance of 1.2 to 1.5 m. Put logs or connected with one end on the ledgers and other end at the holes of the wall at an interval of1.2 to 1.5 m interval.

Double or masons scaffolding

It is very difficult to put holes in walls to support putlogs in stone masonry. In that case, strong scaffolding is used consisting of two rows of scaffolding. The first row is placed 20 to 30 cm away from the wall the other frame is placed at 1m distance from the first one. Put logs are supported on both the supports, with rakers and cross braces are provided to make the scaffolding more strong. It also called as independent scaffoldings

Cantilever or needle scaffolding

Cantilever supports can be used if the ground is week to support standards. Also if the construction of the upper part of the wall is to be carried out this type of scaffolding is preferred. If it is required to keep the ground near wall free for traffic this type of scaffolding is used. It is of the following two types:

Single Frame: The standards are supported on series of needle taken out through opening or through holes

Double frame: The needles are projecting beams are strutted inside the floors

Suspended Scaffolding

It is the light weight scaffolding used for repair works such as pointing and painting. The working platforms are suspended from roofs by means of wire ropes or chains etc,.

Trestle Scaffolding

These types of scaffoldings are used for painting and repairing work inside the room up to a height of 5m. The working platform is supported over the top of movable contrivances such as tripods ladders etc

Steel Scaffolding

Steel scaffolding is practically similar to the timber scaffolding, here wooden members are replaced by steel couplets are fittings. This type of scaffolding can be erected and dismantled rapidly. It has a greater strength and greater durability.

Patented Scaffolding

Many patented scaffolding made of steel are available in the market. These scaffoldings are equipped with special couplings frames for better durability.

UNDERPINNING

Underpinning is a method for repair and strengthening of building foundations. There are situations where a failure in foundation or footing happens unexpectedly after the completion of whole structure. Under such a situation, a remedial method has to be suggested to regain the structural stability. The method of underpinning helps to strengthen the foundation of an existing building or any other infrastructure. These involve installation of permanent or temporary support to an already held foundation so that additional depth and bearing capacity is achieved.

TYPES OF WORKS FOR SELECTION OF UNDERPINNING METHODS

Conversion Works: The structure has to be converted to another function, which requires stronger foundation compared to existing

Protection Works: The following problems of a building have to undergo protection works:

❖ The existing foundation is not strong or stable

❖ Nearby excavation would affect the soil that supports existing footing.

❖ Stabilization of the foundation soil to resist against natural calamities

❖ Requirement of basement below an already existing structure

Remedial Works: The following remedial works requires underpinning:

❖ Mistakes in initial foundation design caused subsidence of the structure

❖ Construction on existing structure than building a new one

STRUCTURAL NECESSITY FOR UNDERPINNING

The following are the reasons to suggest underpinning method for stabilization of the substructure:

❖ The degradation of timber piles used as a foundation for normal buildings would cause settlement. This degradation of structures is due to water table fluctuations.

❖ Rise and lowering of the water table can cause a decrease of bearing capacity of soil making the structure to settle.

❖ Structures that are built over soil with a bearing capacity not suitable for the structure would cause settlement.

METHODS OF UNDERPINNING

The choice of method depends on the ground conditions and the required foundation depth. Following are the different methods of underpinning used for foundation strengthening:

❖ Mass concrete underpinning method (pit method)

❖ Underpinning by cantilever needle beam method

❖ Pier and beam underpinning method

❖ Mini piled underpinning

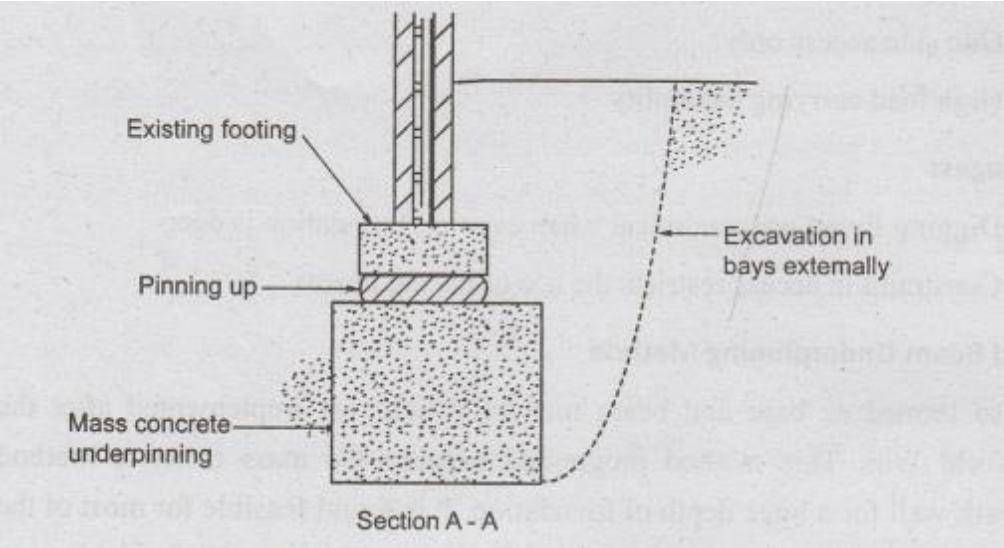
❖ Pile method of underpinning

❖ Pre-test method of underpinning

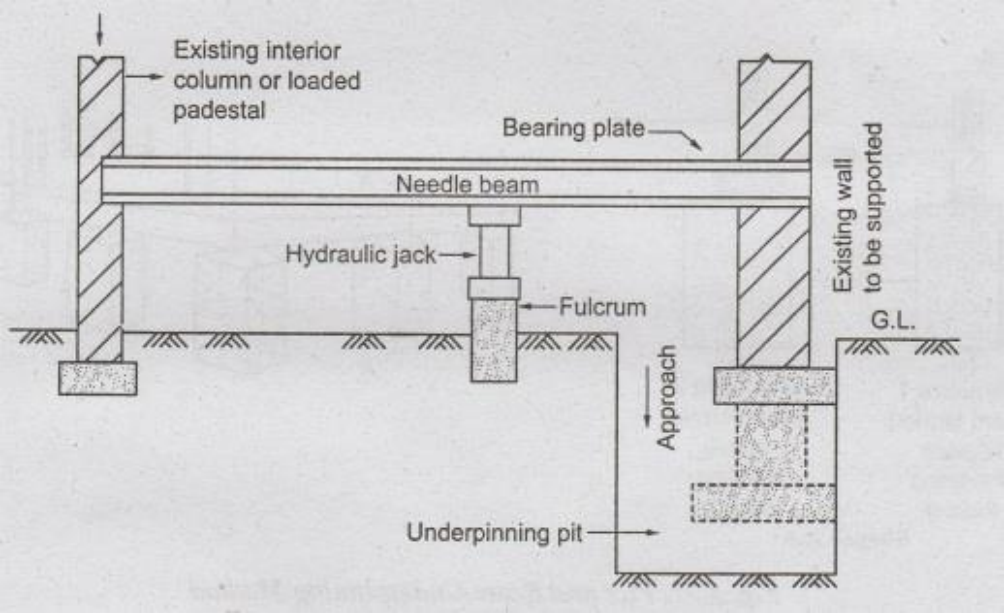
1. Mass Concrete Underpinning Method (Pit Method)

Mass concrete underpinning method is the traditional method of underpinning, as it has been followed by centuries. The method involves extending the old foundation till it reaches a stable

stratum. The soil below the existing foundation is excavated in a controlled manner through stages or pins. When a suitable stratum is reached, the excavation is filled with concrete and kept for curing, before next excavation starts. In order to transfer the load from old foundation to new one, a new pin is provided by means of placing dry sand-cement pack. This is a low-cost method suitable for the shallow foundation.



2. Underpinning by Cantilever Needle Beam Method



If the foundation has to be extended only to one side and the plan possesses a stronger interior column, this method can be used for underpinning. The advantages and disadvantages of cantilever needle beam method are:

Advantages:

❖ Faster than traditional method

❖ One side access only

❖ High load carrying capability

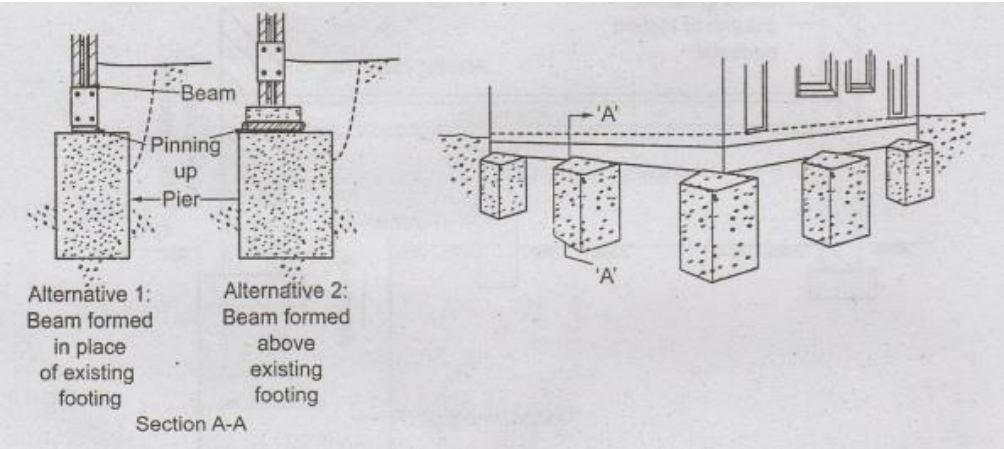
Disadvantages:

❖ Digging found uneconomical when existing foundation is deep

❖ Constraint in access restricts the use of needle beams

3. Pier and Beam Underpinning Method

It is also termed as base and beam method which was implemented after the Second World War. This method progressed because the mass concrete method couldn't work well for a huge depth of foundation. It is found feasible for most of the ground conditions. Here reinforced concrete beams are placed to transfer the load to mass concrete bases or piers. The size and depth of the beams are based on the ground conditions and applied loads. It is found economical for depth shallower than 6m.

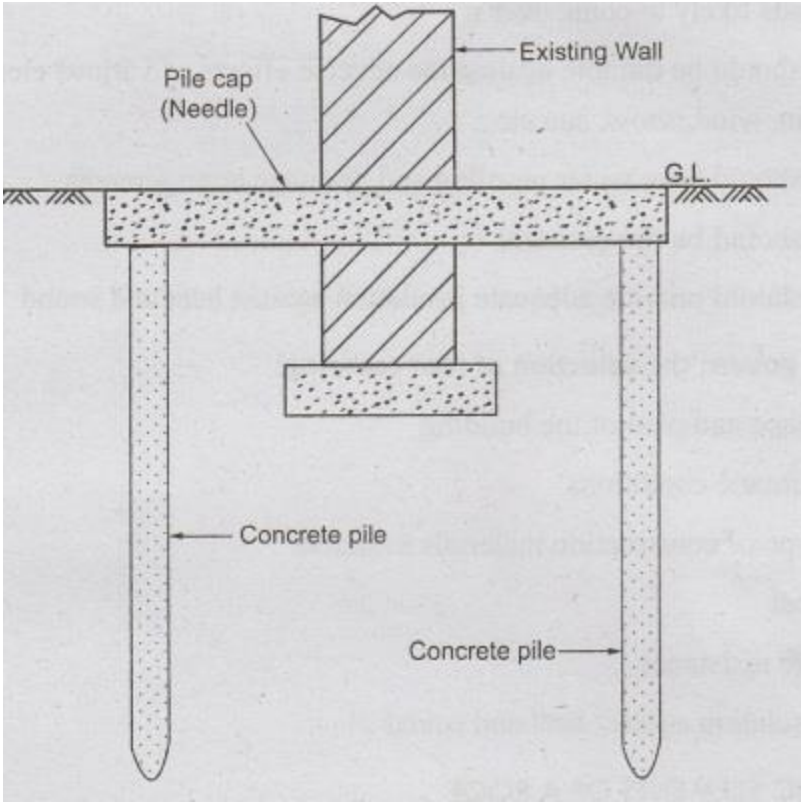


4. Mini Piled Underpinning

This method can be implemented where the loads from the foundation have to be transferred to strata located at a distance greater than 5m. This method is adaptable for soil that has variable nature, access is restrictive and causes environmental pollution problems. Piles of diameter between 150 to 300mm in diameter is driven which may be either augured or driven steel cased ones.

5. Pile Method of Underpinning

In this method, piles are driven on adjacent sides of the wall that supports the weak foundation. A needle or pin penetrates through the wall that is in turn connected to the piles. These needles behave like pile caps. Settlement in soil due to water clogging or clayey nature can be treated by this method



6. Pre-test Method of Underpinning

It is employed for strip foundation. It can be used for building with 5 to 10 storeys. Here the subsoil is made compact and compressed, in the new excavation level that gives predetermined loads to the soil. This is done before underpinning is performed. Hence reduced noise and disruption are expected. This method cannot be implemented for raft foundation.

ROOFING

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

Requirements of a roof

1. It should be structurally stable and sound it should be capable of taking loads likely to come over it

2. It should be durable against the adverse effects of various elements such as rain, wind, snow, sun etc...

3. It should have water proofing and drainage arrangements

4. It should be fire resistant

5. It should provide adequate insulation against heat and sound

Factors that govern the selection of roof covering:

1. Shape and plan of the building

2. Climatic conditions

3. Type of construction materials available

4. Cost

5. Fire resistance

6. Insulation against heat and sound

BASIC ELEMENTS OF A ROOF

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

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

Pitch: It is the inclination of the sides of a roof to the horizontal plane. It is expressed in degrees or as a ratio of rise to span.

Ridge: It is defined as the apex line of the sloping roof.

Eaves: The lower edges of a roof which are resting upon or projecting beyond the supporting walls are known as eave.

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

Valley: When two roof surfaces meet together and form an internal angle, a valley is formed. Verge: The edge of a gable, running between the eaves and ge is known as a verge

Common rafter: These are the intermediate rafters, which give support to the roof coverings.

Principal rafter: These are the inclined members of a truss.

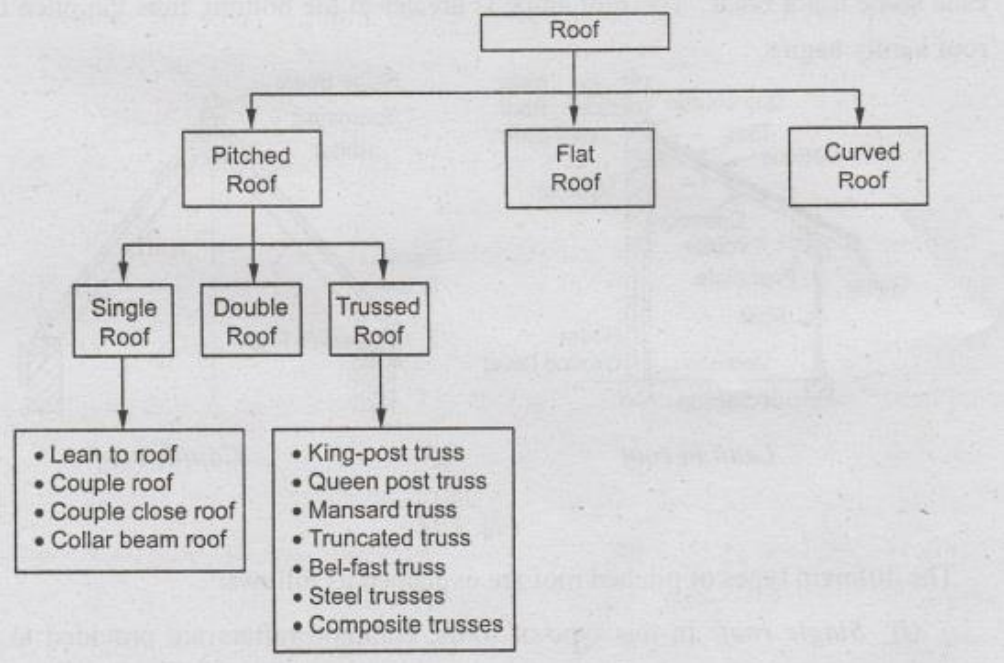
Hip rafter: These are provided at the junction of two roof slopes.

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

Battens: Thin strips of wood which are fixed on rafters or ceiling to support the roof ceiling. Cleats: Small blocks of wood which are fixed on truss to prevent the sliding of purlins.

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

TYPES OF ROOF



1) Pitched roof: A sloping roof is known as pitched roof. These are suitable in those areas where rainfall/ snowfall are very heavy. The pitched roofs are available in various forms:

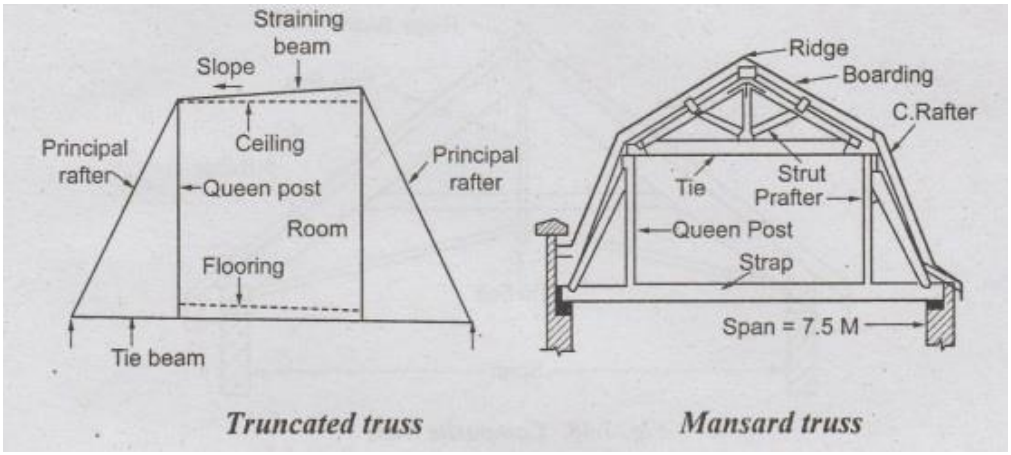
Gable Roof: The triangle produced when the two pitched portions of the roof meet are referred to as a gable. This is the common type of sloping roof which slopes in two directions. The two slopes meet at the ridge.

Hip Roof: A conventional hip roof is made up of four slopes of equal length that meet at the ridge to make a simple ridge.

Gambrel Roof: This roof is like gable roof, which slopes in two directions but there is break in each slope. A gambrel roof is a symmetrical two-sided roof with a shallow upper portion and steeper lower slope on either side, most typically found in barns.

Deck Roof: A deck roof, like a hip roof, has slopes in all four directions, but the top is covered with a deck or plane surface.

Mansard or club roof: This roof like a hip roof, slopes in four directions but each slope has a break. The roof slope is greater at the bottom, thus the pitch of the roof hardly begins.



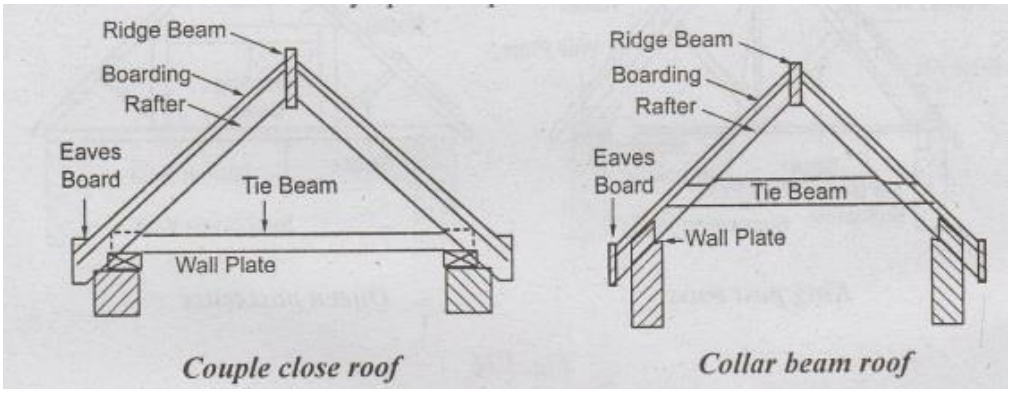
The different types of pitched roof are explained as follows:

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

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

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

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

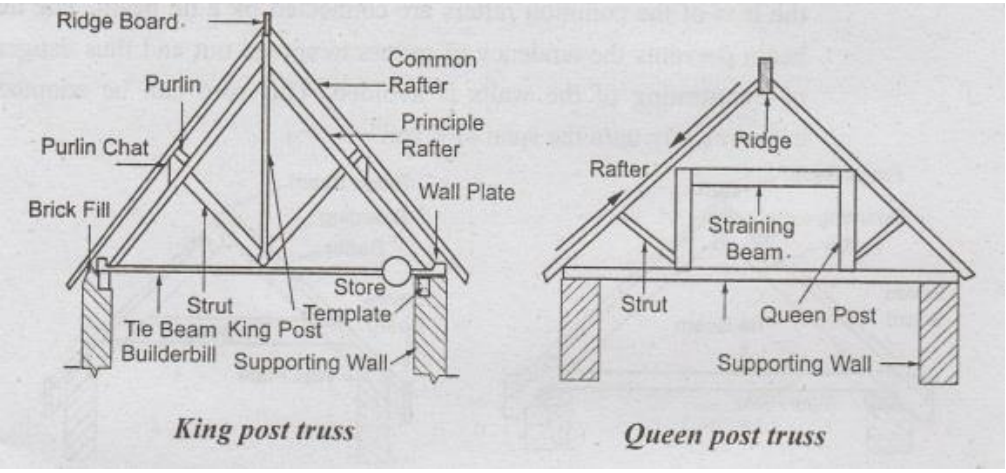


(d) Collar beam roof: The tie beam is raised and placed at a higher level which is known as collar or collar beam. This beam roof is adopted to economize the space and to increase the height of a room. This roof can be adopted upto a maximum span of 4.8m.

(ii) Double roofs: This type is also known as purlin roofs. When the span exceeds 2.4m, the necessary size for the rafters becomes uneconomical. Hence in order to reduce the size of rafters, intermediate supports called purlins are introduced under the rafters. This roof can be adopted economically upto 4.8m.

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

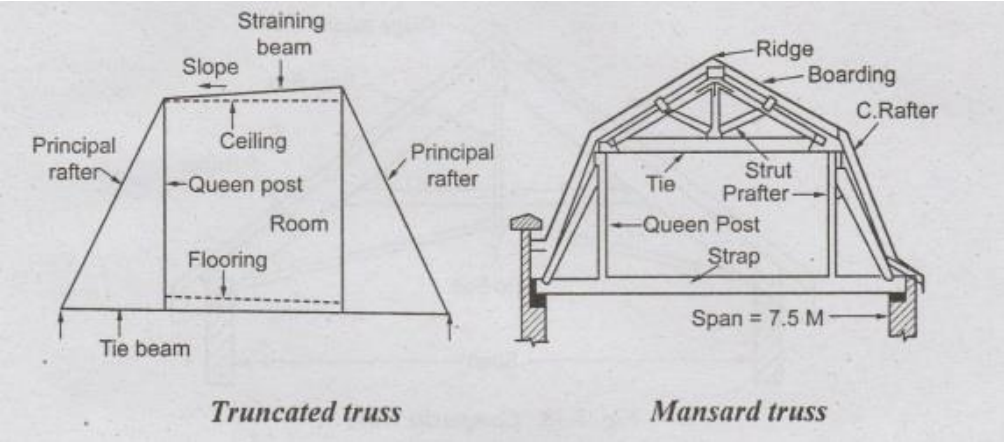
(a) King post truss: In this type of truss, the central post known as king- post forms support for the tie beam. The inclined members known as struts, prevents the principal rafters from bending in the middle. A king-post truss suitable for roofs should be of span varying from 5 to 8 m.



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

(c) Mansard truss: Mansard truss is a type of truss which is the combination of the king post and queen post truss. It is designed with two story truss with upper portion consisting of the king post truss and the Lowe portion of Queen post truss. Mansard truss effectively used in pitched roof with

consisting of two pitches, upper pitch in King post truss which is varies from 30° to 40° and the lower pitch in queen post varies from 60° to 70°.

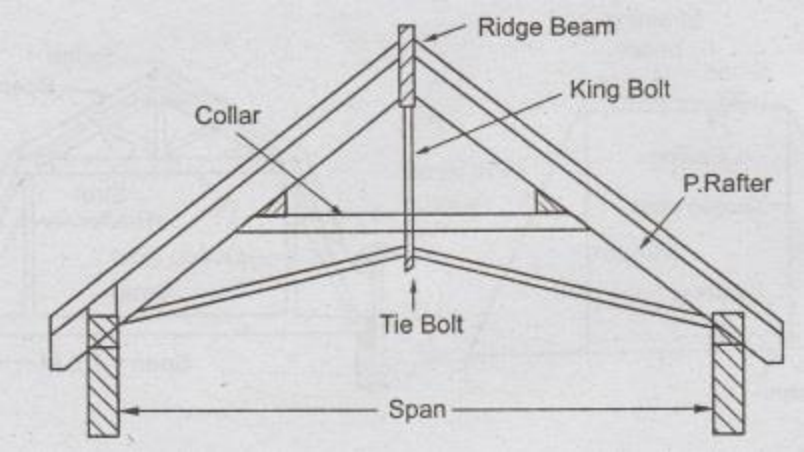


(d) Truncated truss: Truncated truss is the type of pitch roof truss which is similar to the mansard truss except that the top is effectively finished flat with a gentle slope to one side that is effluently used when a room is necessary in the roof.

(e) Bel fast truss: Bel fast truss is a thin section of timber, associated with its top chord curved as a form of a bow which is suitably adopted for long span of 30 metres, this type of truss is effectively carry for light roof covering, this truss is also called as latticed roof truss. The bell fast roof truss is consist form of a bow which is made with a thin section of member, this truss roof is also called bow string or latticed roof truss.

(f) Steel trusses: Steel trusses is designed with the angles riveted or welded together through the plates for the provide facilities the roof construction. This type is economically suitable for spans greater than 12 metres.

(g) Composite trusses: Composite trusses are the type of pitch roof truss which are composed of steel or wrought iron and wooden members that is light in weight and economical, in this type of truss the steel is used for resist the tensile stresses. In the composite trusses, fitting are necessary at the junction of steel and timber.



2. Flat Roofs: These roofs are nearly flat. The construction of flat roof is same as that of floors except that the top surface is made slightly sloping in case of flat roofs 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. With advent of reliable water proofing techniques such roofs are constructed even in areas with heavy rain fall. Flat roofs are used in plains where rainfall is less and climate is moderate.

The advantages of flat roofs are:

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

(b) The roof can be used as a terrace for playing and other utilities.

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

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

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

The disadvantages of flat roofs are:

(a) They cannot cover large column free areas.

(b) Leakage problem may occur at latter date also due to development of cracks.

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

(d) In places of snow fall flat roofs are to be avoided to reduce snow load. (e) The initial cost of construction is more.

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

Advantages of Curved Roof

(a) It can be constructed in short time.

(b) It does not require skilled supervision.

(c) Cheap in construction.

(d) Requires less frame work.

(e) Low maintenance roof.

Disadvantages of Curved Roof

(a) As the complexity of the design of curved roof increases, the cost of the roof also increases.

(b) Height, curve and materials used for covering the roof are generally considered while estimating, while increases the cost.

ROOF COVERING MATERIALS

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

(a) Thatch Covering: These coverings are provided for small spans, mainly for residential buildings in villages. Thatch is a roof covering of straw, reeds or similar materials. The thatch is

well-soaked in water or fire resisting solution and packed bundles are laid with their butt ends pointing towards eves. Thickness varies from 150 mm to 300 mm. They are tied with ropes or twines to supporting structures. The supporting structure consists of round bamboo rafters spaced at 200 mm to 300 mm over which split bamboos laid at right angles at close spacing. The advantage of thatch roof is they are cheap and do not need skilled workers to build them. The disadvantages are they are very poor fire resistant.

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

(c) Tiles: Various clay tiles are manufactured in different localities. They serve as good covering materials. Tiles are supported over battens which are in turn supported by rafters/trusses etc. They give good appearance also. They may be of different types such as Plain tiles, Curved tiles and Interlocking tiles.

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

(e) A.C. Sheets: Asbestos cement is a material which consists of 15% of asbestos fibres evenly distributed and pressed with cement. They are manufactured in sufficiently large size. The width of a A.C. sheet varies from 1.0 to 1.2 m and length from 1.75 to 3.0 m. To get sufficient strength with thin sections they are manufactured with corrugation or with traffords. They are fixed to the steel purlins using J-bolts. The roofing is quite economical and waterproof. They are commonly used as covering materials in ware houses, godowns or for larger halls. In auditorium if these sheets are used, false ceilings are provided to get good thermal resistance.

(f) G.I. Sheets: Galvanised iron corrugated sheets are manufactured in the sizes 1.0 to 1.2 m wide and 1.65 m length. Galvanization of iron makes them rust proof. They are fixed to steel purlins using J-bolts and washers. They are durable, fire proof, light in weight and need no maintenance. They are commonly used as covering materials for ware houses, godown and sheds.

FLOORING

Flooring is the permanent covering of a floor using any finishing material applied over the floor structure to provide a walking surface. The purpose of floor is to provide a level surface capable of supporting the occupants of the building, furniture, equipment and some time interior wall. The floor must satisfy the following requirements:

- ❖ Adequate strength and stability
- ❖ Adequate fire resistance.
- ❖ Sound proof
- ❖ Damp resistance
- ❖ Thermal insulations

TYPES OF FLOORING

Based on the materials used flooring shall be classified as follows:

(a) Mud flooring and muram flooring

These floorings are used in low cost housing, especially in villages. Over the hard layer of earth filling, mud or murum layer is provided. Muram is a form of integrated rock with binding material. To construct such a floor a 15 cm thick layer mud or muram is laid over prepared sub grade over it 2.5 cm thick powder layer of muram is spread and rammed. The floor needs a thin wash of cow dung at least once a week. In order to prevent cracks small quantity of chopped straw is mixed. This type of flooring is cheap, hard highly impervious.

(b) Brick flooring

This is also a cheap floor construction. It is commonly used in godowns and factories. Bricks are laid flat or on edges. The sub grade is compacted properly, to the desired level and 7.5 cm thick layer is spread. Over this a course of brick is laid flat in mortar is built. 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.

(c) 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. This type of works also called paving.

(d) Cement concrete flooring

Cement concrete flooring is commonly used for residential, commercial even industrial building. This flooring is moderately cheap, quite durable and easy to construct. The floor consists of two components like base concrete and topping or wearing surface. The base course may be 7.5 to 10 cm thick and the topping is of 1:2:4 cement concrete. It needs curing for 7 to 14 days. To get good appearance many times red-oxide finishing coat is provided.

(e) 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. Terrazzo is a specially prepare concrete surface containing cement and marble chips in the proportion to 1:1 1/4 to 1:2. When the surface has set the chips are exposed by grinding operation. Plenty of water is used during grinding. After each grinding, cement grout of cream-like consistency is applied and cured for 6-7 days. After final grinding and curing the floor is washed with plenty of water and then with dilute oxalic acid solution. Then floor is finished with polishing using machines and wax polish.

(f) Mosaic flooring

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

(g) Tiled flooring

This is an alternative to terrazo flooring, used commonly used in residential, office and commercial buildings. Tiles of clay, cement or terrazo of standard sizes are manufactured in factories under controlled conditions. On the concrete base, 25 mm to 30 mm thick mortar is laid and these tiles are placed and pressed with trowel or wooden mallet. Before placing tiles cement slurry is applied to bottom side and sides of tiles to get good bond. Next day joints are cleaned of loose mortar and raked up to 5 mm depth. Then that is filled with coloured cement slurry to get uniform colour on the top surface. After curing for 7 days grinding and polishing is made.

(h) Marble flooring

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

(i) Timber flooring

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

(j) Rubber Flooring:

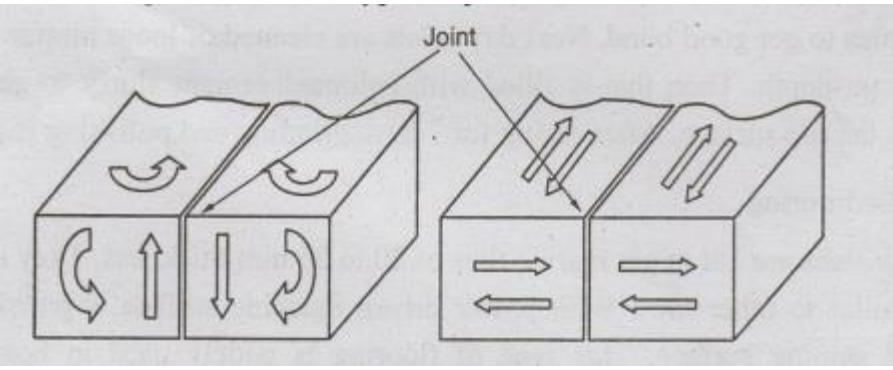
Tiles or sheets of rubber with fillers such as cotton fibers, asbestos fiber or granulated cork are manufactured in variety of patterns and colours. These sheets or tiles may be fixed to concrete or timber floors. These floors are attractive and noise proof. However they are costly.

(k) 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. But it is slippery and costly.

JOINTS IN CONCRETE

Joints in concrete are normally used to prevent cracks when the concrete shrinks by creating forming, tooling, sawing, and placing joint formers. Concrete joints are used to compensate when concrete expands or shrinks with changes in temperature. They prevent cracking of concrete. Types of joints in concrete are described below:



TYPES OF JOINTS

Contraction Joints

A contraction joint is a sawed, formed, or tooled groove in a concrete slab that creates a weakened vertical plane. It regulates the location of the cracking caused by dimensional changes in the slab. Unregulated cracks can grow and result in an unacceptably rough surface as well as water infiltration into the base, subbase and subgrade, which can enable other types of pavement distress. Contraction joints are the most common type of joint in concrete pavements, thus the generic term "joint" generally refers to a contraction joint. Contraction joints are chiefly defined by their spacing and their method of load transfer. They are generally between 1/4 - 1/3 the depth of the slab and typically spaced every 3.1- 15 m. Contraction joints are provided to allow for shrinkage movement in the structure. The contraction joint may be

- ❖ Complete Contraction Joint
- ❖ Partial Contraction Joint
- ❖ Dummy Contraction Joint

Construction Joints

Construction joints key the two edges of the slab together either to provide transfer of loads or to help prevent curling or warping of the two adjacent edges. These are needed to accommodate the construction sequence for placing the concrete. The amount of concrete that can be placed at one time is governed by batching and mixing capacity, crew size, and the amount of time available. Correctly located and properly executed construction joints provide limits for successive concrete placements, without adversely affecting the structure. They must be designed in order to allow displacements between both sides of the slab but, at the same time, they have to transfer flexural stresses produced in the slab by external loads. Construction joints must allow horizontal

displacement right-angled to the joint surface that is normally caused by thermal and shrinkage movement. At the same time they must not allow vertical or rotational displacements.

Expansion Joint

The expansion joint depends upon the context of the change of temperature. These joints are provided when the length of the building is greater than 30m and temperature changes by 50°C then a 10 mm expansion joint is provided. The extent of the structure depends on the coefficient of linear expansion of the material. An expansion joint should be provided at the point where the structure changes its direction. The materials used in expansion joints are:

❖ **Joint Filler:** Bitumen containing cellular material, rubber, and thermocouple expanded plastic, mineral fiber, glass wool. The joint Filler should be compressible material tightly fitted in the gap. It should regain 75% of its original thickness when external pressure is removed from it.

❖ **Sealing Compound:** Its function is to seal, the joint against the passage of moisture and to prevent the ingress of dust grit, or other matter to the joint. Mastic or hot bitumen and silicon are mostly used as sealing compounds.

❖ **Water Bar:** The function of the water bar is to seal the joint against the passage of water. The water bar may be made up of rubber, GI sheet, Copper, and aluminum.

FIRE PROTECTION

In general no building is perfectly fire-proof. Because every building contains some materials which can catch fire easily. The perspective of the builder should be to plan, design, and construct the building such that it ensures the safety of occupants from the outbreak of fie due to any reason. 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. The fire resistance of a building is expressed in terms of hours when it is subjected to fire of known intensity. Fire protection word is used to cover the following aspects:

❖ To prevent fire and reduce the number of outbreaks of fire.

❖ To reduce the fire both externally and internally.

❖ Use of fire extinguishing apparatus.

Most of the outbreaks of fire are caused by carelessness. In case of an outbreak of fire, the danger is from fire, smoke, and panic. The prevention methods should be in relation to these dangers and the number of persons affected. There are three aspects that are considered in the fire safety of buildings and accordingly, protection should be provided against these hazards.

Personal hazards: It is the possibility of loss or damage to life. Personal hazards are naturally considered as of permanent importance and it requires the provision of liberally designed and safe exit escapes in all buildings, especially in multi-storeyed buildings.

Internal hazards: It is the possibility of a fire occurring and spreading inside the building itself. An internal hazard directly influences personal hazards and it concerns damage or destruction of buildings. It is directly related to fire load, which enables the building to be graded when considered along with the duration of the fire.

Exposure hazards: It is the possibility of fire spreading from an adjoining building. Exposure hazards deal with the risk of fire spreading into a building through the open air from fire in other buildings like, from the stocks of combustible material or from a division or apartment of a building through the open air from a fire in another division or apartment of the same building.

GENERAL FIRE SAFETY REQUIREMENTS FOR BUILDINGS

All buildings having more than one storey shall be provided with generously designed and safe fire proof existence. The general fire safety requirements for buildings are as follows:

❖ All exits should be placed in such a way that they provide immediate access and should be capable of taking all the persons on that floor as alternative escape routes may be hindered due to fire.

❖ Electrical or mechanical lifts which are used under normal conditions may not be always relied on during a fire outbreak as the electrical supply to the door may be cut off or interrupted.

❖ Fire-proof doors shall conform rigidly to the fire safety requirements and escape routes should be well-ventilated.

❖ False ceilings of the buildings shall be so constructed as to prevent either total or early collapse in the fire so that persons underneath are not fatally trapped before they have the time to reach the exits.

❖ The floors are required to withstand the effect of fire. The design of floors should be such that it shall obviate any replacement.

❖ Roofs for the various fire grades of buildings shall be designed and constructed to withstand the effect of fire for the maximum period.

❖ Fire resistance of basement shall conform to the highest order and all columns for supporting the upper structure shall have a grading not less than laid down types 1 to 3.

FIRE ALARMS AND FIRE EXTINGUISHING EQUIPMENTS

Fire alarms are installed in buildings to give an alarm and to call for assistance in event of fire. It gives enough time to the occupants to reach a safe place. Two types of fire alarms are there: manual alarms and automatic alarms. Every building should have the suitable fire extinguishing equipments depending upon the importance of the building.

(a) Manual fire extinguishing elements: 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. Foam extinguishing systems are effective for rapidly controlling and extinguishing flammable liquid fires.

(b) Fire Hydrant: The hydrant should be located in and around the buildings so that water is available easily for fire fighting. Fire hydrant protection system is designed to fight fire of huge proportions, in all classes of risks. It is designed to be in operation even if a part of the affected structure collapses.

(c) 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.

THERMAL INSULATION

In general, people living in cold regions, wants warmer atmosphere inside. The heat transfer takes place from hotter to colder areas. As a result, heat loss happens. To overcome this loss in buildings thermal insulation is provided to maintain required temperature inside the building. The aim of thermal insulation is to minimize the heat transfer between outside and inside of building.

METHODS OF THERMAL INSULATION OF BUILDINGS

There are many forms of thermal insulation materials are available in the market as follows:

❖ **Slab or Block Insulation:** The blocks are made of mineral wool, cork board, cellular glass, and cellular rubber or saw dust etc. These materials are fixed to the walls and roofs to prevent heat loss and the required temperature is maintained. These boards are available in 60cm x 120cm with 2.5cm thickness.

❖ **Blanket Insulation:** Blanket insulation materials are available in blanket shape or like paper rolls which are directly spread over the wall or ceilings. They are flexible and having a thickness about 12 to 80mm. these blankets are made of animal hair or cotton or wood fibers etc

❖ **Loose Fill Insulation:** Stud space is provided in wall where windows and doors are to be provided. In that studding space of wall loose fill of some insulating materials is provided. The materials are rock wool, wood fiber wool, cellulose etc.

❖ **Bat Insulating Materials:** These are also available as blanket rolls but bat insulating rolls are having more thickness than blanket type materials. These are also spreader over the walls or ceilings.

❖ **Insulating Boards**: Insulating boards are made from pulp of wood, cane or other materials. This pulp is pressed hard with some stress at suitable temperature to make it as a solid board. They are available in many sizes in the market. And these are generally provided for interior lining of walls as well as for partition walls.

❖ **Reflective Sheet Materials:** Reflective sheet materials like aluminum sheets, gypsum boards, steel sheet Materials will have more reflectivity and low emissivity. So, these materials are having high heat resistance. The heat gets reduced when solar energy strike and gets reflected. These are fixed outside of the structure to stop the heat entrance into the building.

❖ **Lightweight Materials:** By using light weight aggregates while preparing concrete mixture will also results good results in heat loss preventions. Concrete will have more heat resistance if it is made of light weight aggregates like blast furnace slag, vermiculite, burnt clay aggregates etc.

ALTERNATE METHODS OF BUILDING THERMAL INSULATION

Without using any thermal insulating materials as said above we can achieve the thermal insulation from the following methods:

❖ **By Providing Roof Shading:** By providing roof shading for the building at the place where sun directly strikes the building during peak hours, we can reduce the heat by shading of roof. Accurate angle should be provided for shading to prevent from sun light.

❖ **By Proper Height of Ceiling:** The heat gets absorbed by the ceiling and emitted downwards that is into the building. But, the point should be noted is, the vertical gradient of radiation intensity is not significant beyond 1 to 1.3 m. it means it can travel up to 1 to 1.3 m downward from the ceiling. So, provision of ceiling at 1 to 1.3m height from the height of occupant will reduce some heat loss.

❖ **Orientation of Building:** The building orientation with respect to sun is an important thing. So, the building should be constructed in an orientation in such a way that it shouldn't subject to more heat losses.

VENTILATION

Heating, Ventilation and Air Conditioning (HVAC) systems play an important role in buildings and homes. They can effectively be used in industrial areas as well as residential complexes. A good HVAC system provides proper ventilation inside a building and maintains a comfortable temperature. Ventilation acts like the lungs of the building. Ventilation is a process that has to be done to maintain adequate indoor environment quality. Ventilation circulates air from the outside into the building while removing contaminants from the air already present inside. This keeps the air quality at a steady pace. The primary purpose of ventilation is to prepare healthy air for the breathing of people in that place. The different types of ventilation are as follows:

❖ **Natural Ventilation** is a process where the difference in pressure between air inside and outside a building creates an envelope of circulation. The air filters itself through the windows and doors

of the structure. Natural or traditional ventilation systems depend on natural forces such as wind and thermal buoyancy to drive outdoor air throughout the building's openings. Well-designed natural ventilation could be used to access higher levels of daylight.

❖ **Mechanical Ventilation** is used in most buildings as it is easier to control the quality of the indoor air environment. However, it should be done carefully as to not compromise on the overall quality of the indoor environment. Mechanical fans conduct mechanical ventilation. Fans can be installed in windows or walis directly or in air ducts to supply air to or from the room.

❖ **Hybrid Ventilation** (mixed mode) depends on natural driving forces to prepare the desired flow rate. When natural ventilation has a very low flowrate, the role of mechanical ventilation is prominent. When natural ventilation is not acceptable alone, exhaust fans can be installed to increase the ventilation rate. These have enough pre-testing and planning in order to work properly.

❖ **Spot Ventilation** is another kind of ventilation. In order to improve the effectiveness of both natural and mechanical ventilation systems, spot ventilation came into existence. In other words, it is better to say that it is an auxiliary system. This involves deploying local exhaust fans, the same as those used in the bathrooms or kitchens. It removes the moisture and inside air pollution at its source, and as a result, it improves the usefulness of the ventilation system.

AIR CONDITIONING

Air conditioning is the process of giving comfort to the occupant in a particular space irrespective of any external climatic conditions. It can be defined as the treatment of indoor air in order to control certain conditions required for human comfort. The desirable conditions may be temperature, humidity, dust particle level, odor level, and air motion. It is known that the physical properties of air can be controlled by cooling, heating, humidification, and dehumidification. These processes may be employed to maintain specific conditions desirable for comfort. Thus, simultaneous control of temperature, humidity, air motion, and cleanliness is known as air conditioning. Air conditioning systems are broadly classified as follows:

❖ **Comfort Air Conditioning-** The objective of this is to provide thermal comfort to the occupants. Thermal comfort may be defined as the state of mind that expresses satisfaction with its surroundings.

❖ **Industrial Air conditioning** - It is the process of providing air at required temperature and humidity to perform a specific industrial process successfully.

Following are the important equipments used for air conditioning:

❖ Air circulation fan.

❖ Air-conditioned

❖ Supply duct

❖ Supply outlet (grill)

❖ Return outlet duct

❖ Filter

FACTORS AFFECTING AIR CONDITIONING

The four important factors for comfort conditioning are to be observed and maintained:

❖ **Temperature:** The control of temperature is necessary in air conditioning. Even though the outdoor temperature is varying, the indoor temperature is maintained to be constant which is the desired condition. The heat may be either removed or added to the conditioned space depending upon the surrounding conditions. The person may feel comfortable when the temperature is 20°C.

❖ **Humidity:** Humidity control means an increase or a decrease in moisture content inside the space to be air-conditioned. It is necessary not only for human comfort but also to increase the working capability. In summer, the relative humidity should be 60% and in winter it should it should be 40%. Purity/Cleanliness: It is one of the most important factors which affect the air conditioning. In addition to the control of temperature and humidity for human comfort, it is necessary to clean air, i.e., to make the indoor air free from dust, dirt, and odor. It is necessary that proper filtration and purification of air should be done and the supply of air free from dust and dirt should be made in air-conditioned space.

❖ **Air Motion:** Air motion or proper circulation of air is also a factor affecting the human comfort. In order to maintain constant temperature throughout the conditioned space, it is necessary that

there should be equal distribution of conditioned air in the space. The air movement is maintained at the desirable velocity of about 8 m/min using appropriate distribution system, grills, etc.

TYPE OF AIR-CONDITIONING

Based on the working conditions and position air conditioning can be broadly classified as follows:

- ❖ Window air-conditioning system
- ❖ Split air-conditioning system
- ❖ Package air-conditioning system
- ❖ Centralized air-conditioning system

Window air conditioner is the most commonly used air conditioner for single rooms. In this air conditioner all the components, namely the compressor, condenser, expansion valve or coil, evaporator and cooling coil are enclosed in a single box. This unit is fitted in a slot made in the wall of the room, or more commonly a window sill.

Split type air conditioners are named because they split the components of a traditional air conditioning system into two individual units - one indoor and one outdoor. The outdoor unit houses the compressor and condenser components, while the indoor unit contains the distribution and filter components.

Packaged Air Conditioner: This type of air conditioner is preferred if more than two rooms or a larger space at your home or office needs to be cooled. There are two possible arrangements with the package unit. In the first one, all the components, namely the compressor, condenser (which can be air cooled or water cooled), expansion valve and evaporator are housed in a single box. The cooled air is thrown by the high capacity blower, and it flows through the ducts laid through various rooms. In the second arrangement, the compressor and condenser are housed in one casing. The compressed gas passes through individual units, comprised of the expansion valve and cooling coil, located in various rooms.

Central air conditioning is used for cooling big buildings, houses, offices, entire hotels, gyms, movie theaters, factories etc. If the whole building is to be air conditioned, then putting individual

units in each of the rooms is very expensive making this a better option. A central air conditioning system is comprised of a huge compressor that has the capacity to produce hundreds of tons of air conditioning. Cooling big halls, malls, huge spaces, galleries etc is usually only feasible with central conditioning units.

ADVANTAGES AND DISADVANTAGES OF AIR-CONDITIONING

Advantages

❖ Filters the air, improving air quality.

❖ Dehumidifies the ambient air, providing greater comfort.

❖ Easily control the temperature using a simple wall control unit.

Disadvantages

❖ Spending too much time in an air-conditioned room may have a bad effect on your skin as air conditioning may have a drying effect on it and the mucous membranes.

❖ Almost every kind of air-conditioning creates some ambient noise.

❖ The central air-conditioning can transmit infectious respiratory diseases and airborne fungi and dust can cause allergic reactions.

❖ A more comfortable environment makes people lazy and they may start avoiding going out in the sun.

❖ Increase in electricity bills.

VENTILATION

Heating, Ventilation and Air Conditioning (HVAC) systems play an important role in buildings and homes. They can effectively be used in industrial areas as well as residential complexes. A good HVAC system provides proper ventilation inside a building and maintains a comfortable temperature. Ventilation acts like the lungs of the building. Ventilation is a process that has to be done to maintain adequate indoor environment quality. Ventilation circulates air from the outside

into the building while removing contaminants from the air already present inside. This keeps the air quality at a steady pace. The primary purpose of ventilation is to prepare healthy air for the breathing of people in that place. The different types of ventilation are as follows:

❖ **Natural Ventilation** is a process where the difference in pressure between air inside and outside a building creates an envelope of circulation. The air filters itself through the windows and doors of the structure. Natural or traditional ventilation systems depend on natural forces such as wind and thermal buoyancy to drive outdoor air throughout the building's openings. Well-designed natural ventilation could be used to access higher levels of daylight.

❖ **Mechanical Ventilation** is used in most buildings as it is easier to control the quality of the indoor air environment. However, it should be done carefully as to not compromise on the overall quality of the indoor environment. Mechanical fans conduct mechanical ventilation. Fans can be installed in windows or walis directly or in air ducts to supply air to or from the room.

❖ **Hybrid Ventilation** (mixed mode) depends on natural driving forces to prepare the desired flow rate. When natural ventilation has a very low flowrate, the role of mechanical ventilation is prominent. When natural ventilation is not acceptable alone, exhaust fans can be installed to increase the ventilation rate. These have enough pre-testing and planning in order to work properly.

❖ **Spot Ventilation** is another kind of ventilation. In order to improve the effectiveness of both natural and mechanical ventilation systems, spot ventilation came into existence. In other words, it is better to say that it is an auxiliary system. This involves deploying local exhaust fans, the same as those used in the bathrooms or kitchens. It removes the moisture and inside air pollution at its source, and as a result, it improves the usefulness of the ventilation system.

AIR CONDITIONING

Air conditioning is the process of giving comfort to the occupant in a particular space irrespective of any external climatic conditions. It can be defined as the treatment of indoor air in order to control certain conditions required for human comfort. The desirable conditions may be temperature, humidity, dust particle level, odor level, and air motion. It is known that the physical properties of air can be controlled by cooling, heating, humidification, and dehumidification. These processes may be employed to maintain specific conditions desirable for comfort. Thus,

simultaneous control of temperature, humidity, air motion, and cleanliness is known as air conditioning. Air conditioning systems are broadly classified as follows:

❖ **Comfort Air Conditioning-** The objective of this is to provide thermal comfort to the occupants. Thermal comfort may be defined as the state of mind that expresses satisfaction with its surroundings.

❖ **Industrial Air conditioning** - It is the process of providing air at required temperature and humidity to perform a specific industrial process successfully.

Following are the important equipments used for air conditioning:

❖ Air circulation fan.

❖ Air-conditioned

❖ Supply duct

❖ Supply outlet (grill)

❖ Return outlet duct

❖ Filter

FACTORS AFFECTING AIR CONDITIONING

The four important factors for comfort conditioning are to be observed and maintained:

❖ **Temperature:** The control of temperature is necessary in air conditioning. Even though the outdoor temperature is varying, the indoor temperature is maintained to be constant which is the desired condition. The heat may be either removed or added to the conditioned space depending upon the surrounding conditions. The person may feel comfortable when the temperature is 20°C.

❖ **Humidity:** Humidity control means an increase or a decrease in moisture content inside the space to be air-conditioned. It is necessary not only for human comfort but also to increase the working capability. In summer, the relative humidity should be 60% and in winter it should it should be 40%. Purity/Cleanliness: It is one of the most important factors which affect the air

conditioning. In addition to the control of temperature and humidity for human comfort, it is necessary to clean air, i.e., to make the indoor air free from dust, dirt, and odor. It is necessary that proper filtration and purification of air should be done and the supply of air free from dust and dirt should be made in air-conditioned space.

❖ **Air Motion:** Air motion or proper circulation of air is also a factor affecting the human comfort. In order to maintain constant temperature throughout the conditioned space, it is necessary that there should be equal distribution of conditioned air in the space. The air movement is maintained at the desirable velocity of about 8 m/min using appropriate distribution system, grills, etc.

TYPE OF AIR-CONDITIONING

Based on the working conditions and position air conditioning can be broadly classified as follows:

❖ Window air-conditioning system

❖ Split air-conditioning system

❖ Package air-conditioning system

❖ Centralized air-conditioning system

Window air conditioner is the most commonly used air conditioner for single rooms. In this air conditioner all the components, namely the compressor, condenser, expansion valve or coil, evaporator and cooling coil are enclosed in a single box. This unit is fitted in a slot made in the wall of the room, or more commonly a window sill.

Split type air conditioners are named because they split the components of a traditional air conditioning system into two individual units - one indoor and one outdoor. The outdoor unit houses the compressor and condenser components, while the indoor unit contains the distribution and filter components.

Packaged Air Conditioner: This type of air conditioner is preferred if more than two rooms or a larger space at your home or office needs to be cooled. There are two possible arrangements with the package unit. In the first one, all the components, namely the compressor, condenser (which can be air cooled or water cooled), expansion valve and evaporator are housed in a single box. The

cooled air is thrown by the high capacity blower, and it flows through the ducts laid through various rooms. In the second arrangement, the compressor and condenser are housed in one casing. The compressed gas passes through individual units, comprised of the expansion valve and cooling coil, located in various rooms.

Central air conditioning is used for cooling big buildings, houses, offices, entire hotels, gyms, movie theaters, factories etc. If the whole building is to be air conditioned, then putting individual units in each of the rooms is very expensive making this a better option. A central air conditioning system is comprised of a huge compressor that has the capacity to produce hundreds of tons of air conditioning. Cooling big halls, malls, huge spaces, galleries etc is usually only feasible with central conditioning units.

ADVANTAGES AND DISADVANTAGES OF AIR-CONDITIONING

Advantages

❖ Filters the air, improving air quality.

❖ Dehumidifies the ambient air, providing greater comfort.

❖ Easily control the temperature using a simple wall control unit.

Disadvantages

❖ Spending too much time in an air-conditioned room may have a bad effect on your skin as air conditioning may have a drying effect on it and the mucous membranes.

❖ Almost every kind of air-conditioning creates some ambient noise.

❖ The central air-conditioning can transmit infectious respiratory diseases and airborne fungi and dust can cause allergic reactions.

❖ A more comfortable environment makes people lazy and they may start avoiding going out in the sun.

❖ Increase in electricity bills.

ACOUSTICS AND SOUND INSULATION

Acoustics is the science of sound, which deals with origin, propagation and auditory sensation of sound and also with design and construction of different building units to set optimum condition for producing and listening speech music. Acoustic property of building is based on acoustic nature of building materials and how sound is transmitted through the adjacent structural elements. Noise is unwanted sound, that is considered as a nuisance in buildings for residential or domestic purposes. The buildings must possess good sound insulation property to have good acoustic feature. Sound insulation of buildings is a property that must be considered in the initial stages of planning. Planning for the structural elements, to make them sound proof is one of the consideration.

Sound insulation is a kind of measure to prevent the sound waves from permeating. It is demonstrated by the sound transmission loss which is expressed by the difference of decibels between the incident sound and permeated sound. The sound insulation property of building materials is the ability in the reduction of sound across a partition. For a good conventional office building construction, the sound insulation is experienced well when it is in the range of 45dB. The unwanted and unexpected sound is always considered to be a noise and that really is a question of the acoustic property of the building.

FACTORS AFFECTING ACOUSTICS OF BUILDINGS

❖ **Site selection** - Site of building should be away from market area or densely populated areas to avoid origin of sound.

❖ **Volume and shape of building** - Both factors should be designed and calculated as per the location of site and purpose of building.

❖ **Interior spaces and planning -** Internal division of spaces should be as per function and purpose of building. Circulation of people should also be considered.

❖ **Height of building** - Height affects the reflection and reverberation factors of acoustics.

❖ **Function and purpose of building** - Whether residential, commercial, public hall, recording studio, institutional, etc.

ACOUSTIC PROPERTIES OF BUILDING MATERIALS

It is always necessary to have a pre-planning, mainly for the building constructions that are prone to noise disturbances. Awareness about the acoustic properties of building materials to some extent would help us to have a right choice on the material to be selected when acoustics is a concerned factor. Acoustics properties of some of the materials are explained below:

❖ **Acoustic properties of Masonry, Concrete or Stone materials:** Mass and rigidity property are the two factors that make a material to be highly noise resistant. The concrete wall is highly efficient than masonry. Masonry material made floor or wall do perform appreciably. Massive materials like stone, concrete can stop high sound waves that are less resistant to less massive materials. Concrete slabs do perform well in the sound insulation activity.

❖ **Acoustic properties of Wood and Related Products:** These are less dense than masonry. They have a smaller performance in sound isolation. Woods are more massive, hence they are added to certain interior walls to increase the massiveness. Plywood, which is used in multilayer in interiors, is used to make it sound proof. It can reflect sound which can be considered as an important property for sound treatment. It resonates easily which promotes absorption of sound, some of which pass through the material and some reflects.

❖ **Acoustic properties of Steel:** Based on performance and structure, steel is one of the best materials for sound insulation. Because of high cost, it has less application. It is highly dense and massive in nature. Steel carries the sound through vibration within the material. This sound transfer is called as the structure-borne vibration. The normal case is airborne vibration which is not appreciable.

❖ **Acoustic properties of Glass & Transparent materials:** The glass is massive in nature. There is a new development of absorptive glass-like materials that have the property to absorb more sound waves instead of reflecting. The material is made as a transparent foil thinner in nature with tiny holes. Their application comes in sound studios.

❖ **Acoustic Insulating Materials:** Foam, fiberglass, rock wool etc. can be considered as the familiar insulating materials.. The fiberglass material gains higher sound absorption property. These materials absorb sound by reducing the velocity of particles that carry the sound waves in the air. Under low velocity, the pressure is high. Now wood materials absorb more sound at high pressure. Sound waves gain higher pressure at room boundaries. So, care must be taken in the arrangement of boundaries or walls.

❖ **Acoustic Properties of Rubber and Plastic:** The known materials are vinyl, neoprene etc. These materials are used to make low cost economical acoustical devices. But their use is almost considered limited. They can be used as mechanical isolators for floating glass, by preventing vibrations of the diaphragm to be transmitted to the walls.

ADVANTAGES OF ACOUSTIC IN CONSTRUCTION

The advantages of acoustics in construction are:

❖ Accurate sound frequency and intensity can be achieved

❖ Privacy of space is maintained without any disturbance

❖ The cost of extra acoustic material used in interior can be reduced

❖ More carpet area can be utilized with proper planning and designing

❖ All acoustical factors are studied and considered right from designing process of a building

❖ In auditorium, acoustic planning results in evenly distribution of sound, seating arrangement contributes to absorption of sound, uneven thickness of wall surfaces results in reflection of sound

DAMP PROOFING

The damp proof course (DPC) is generally applied at basement levels, which restricts the movement of moisture through walls and floors. Dampness is the presence of hydroscopic or gravitational moisture in the building. One of the basic requirements of the building is that it should remain dry or free from moisture traveling through walls, roofs and doors. The causes of dampness may be

❖ Moisture rising up from the ground to the walls

❖ Rain water travel from wall tops

❖ Rain showers against external walls

❖ Condensation

❖An effective damp proofing material should have the following properties:

❖ It should be impervious.

❖ It should be strong and durable and should be capable of withstanding both dead as well as live loads without damage.

❖ It should be dimensionally stable.

❖ It should be free from deliquescent salts like sulpates, chlorides, and nitrates.

The materials commonly used to check dampness can be divided into the following three categories:

❖ **Flexible Materials:** Materials like bitumen felts (which may be hessian based or fiber/glass fiber-based), plastic sheeting (polythene sheets), etc.

❖ **Semi-rigid Materials:** Materials like mastic, asphalt, or a combination of materials or layers.

Rigid Materials: Materials like first-class bricks, stones, slate, cement concrete, etc**.**

SELECTION OF MATERIALS FOR DAMP PROOF COURSE IN BUILDINGS

The choice of material to function as an effective damp proof course requires a judicious selection. It depends upon the climate and atmospheric conditions, nature of the structure, and the situation where DPC is to be provided. The points to be kept in view while making selection of DPC materials are briefly discussed below:

❖ **DPC above ground level:** For DPC above ground level with wall thickness generally not exceeding 40 cm, any one of the types of DPC materials above may be used. Cement concrete is adopted material for DPC at plinth level, 38 to 50mm thick layer of cement concrete M15 serves

the purpose under normal conditions. In the case of a damp and humid atmosphere, a richer mix of concrete should be used. The concrete is further made dense by adding waterproofing materials in its ingredients during the process of mixing. It is used to apply two coats of hot bitumen over the third surface of the concrete DPC.

❖ **DPC Material for floors, roofs:** For greater wall thickness or where DPC is to be laid over large areas such as floors, roofs, etc., the choice is limited to flexible materials that provide a lesser number of joints like mastic, asphalt, bitumen felts, plastic sheets, etc. Bitumen felts should be adequately bonded to the surface with bitumen and laid with joints properly lapped and sealed.

❖ **DPC Material for differential thermal movements:** In parapet walls and other such situations, materials like mastic, asphalt, bitumen felts, and metal (copper or lead) are recommended. It is vital to ensure that the DPC material is flexible to avoid any damage or puncture of the material due to differential thermal movement between the material of the roof and the parapet.

❖ **DPC material for Cavity Walls:** In cavity wall construction, like cavity over the door or window, it should be bridged by flexible material like bitumen felt, strips or lead, etc.

METHODS OF DAMP PROOFING

The general methods of damp proofing are:

❖ **Membrane damp proofing:** In this method of damp proofing a water repellent membrane or damp proof course (D.P.C.) is introduced in between the source of dampness and the part of building adjacent to it. Damp proofing course may consist of flexible materials such as bitumen, mastic asphalt, bituminous felts, plastic or polythene sheets, metal sheets, cement concrete. Damp proofing course may be provided either horizontally or vertically in floors, walls etc. Provision of Damp Proofing

Course in basement is normally termed as 'Tanking'.

❖ **Integral damp proofing:** This consist of adding certain water proofing compounds of materials to the concrete mix so that it becomes impermeable. The quantity of water proofing compound to be added to cement depends upon the manufacturer's recommendations. In general one kilogram of water proofing compound is added with one bag of cement to render the mortar or concrete water proof.

❖ **Surface treatment:** In the surface treatment method a layer of water repellent substances or compounds are applied on these surfaces through which moisture enters. Pointing and plastering of the exposed surfaces must be done carefully, using water proofing agents like sodium or potassium silicates, aluminum or zinc sulphates, barium hydroxide and magnesium sulphates etc. Surface treatment is effective only when the moisture is superficial and is not under pressure. Sometimes, exposed stone or brick wall face may be sprayed with water repellent solutions.

❖ **Cavity wall construction:** Cavity wall construction is an effective method of damp prevention. In this method the main wall of a building is shielded by an outer skin wall, leaving a cavity between the two. The cavity prevents the moisture from travelling from the outer to the inner wall.

❖ **Guniting:** In this method of damp proofing, an impervious layer of rich cement mortar is deposited under pressure over the exposed surfaces for water proofing or over pipes, cisterns etc. for resisting the water pressure. The operation is carried out by use of a machine known as cement gun. It consists of a machine having arrangements for mixing materials and a compressor for forcing the mixture under pressure through a 50 mm dia flexible hose pipe. The nozzle is kept at a distance about 75 to 90 cm from the surface to be gunited. The mortar mix of desired consistency and thickness can be deposited to get an impervious layer. Since the material is applied under pressure, it ensures dense compaction and better adhesion of the rich cement mortar and hence the treated surface becomes water proof.

❖ **Pressure grouting:** This consists of forcing cement grout under pressure, into cracks, voids, fissures and so on present in the structural components of the building, or in the ground. Thus the structural components and the foundations which are liable to moisture penetration are consolidated and are thus made water-penetration-resistant. This method is quite effective in checking the seepage of raised ground water through foundations and sub- structure of a building.

TWO MARKS QUESTIONS AND ANSWERS

1. Write about Shallow foundation and deep foundation.

Based on the depth, foundation is broadly classified into two types. If the depth of the foundation is less than or equal to its breadth, then it is called as shallow foundation. If the depth of the foundation is greater than its breadth, then it is known as deep foundation.

2. What is a strip footing?

A strip footing is provided for a load-bearing wall. The width of the footing is generally two three times the thickness of the wall. A strip footing is also provided for a row of columns which are so closely spaced that their spread footings overlap or nearly touch each other. It is more economical to provide a strip footing than to provide a number of spread footings in one line. A strip footing is also known as continuous footing.

3. What is a composite pile?

When the piles are made from more than one material they are known as composite pile. These piles are made from concrete and wood. These piles are used in those areas where the water table is up. These piles are used in such conditions just because concrete and wood both are good water absorbers.

4. What are the factors to be considered for selection of suitable foundation type for a building?

The type of foundation is selected based on the following factors:

- ❖ Building height
- ❖ Load condition
- ❖ Soil type
- ❖ Type of building (residential, administrative, warehouse)

5. List the types of rubble masonry.

The types of rubble masonry are:

- ❖ Coursed Rubble Masonry
- ❖ Uncoursed Rubble Masonry
- ❖ Dry Rubble Masonry
- ❖ Polygonal Masonry
- ❖ Flint Masonry

6. What is Ashlar Masonry?

Ashlar masonry is constructed using accurately dressed stones that possess uniform and fine joints. The thickness of the joints ranges about 3mm which is arranged in various patterns. The size of the stone blocks must be in proportion with the thickness of the walls.

7. Define brick masonry.

Brick masonry is built with bricks bonded together with mortar. For all permanent buildings lime or cement mortars are used. But for temporary sheds mud mortar may be used. Brick masonry strength depends on the type of bond and materials used for construction. They play an important role in providing strength, stability, and durability to the brick masonry.

8. Write about Flemish bond.

In this type of bond each course comprises of alternate header and stretcher. Alternate courses start with stretcher and followed by header. Flemish bond is also known as Dutch bond. To break the vertical joints queen closers are required, if a course starts with header. Every header is centrally supported on the stretcher below it. The thickness of Flemish bond is minimum one full brick.

9. Define Zig-zag bond.

Zig Zag Bond is very similar to herring-bone bond. The only difference is that in this case the bricks are laid in a zig-zag pattern. It is mostly adopted in brick-paved flooring.

10. What do you mean by plastering?

Plastering in buildings refers to the process of applying mortar coats on the surfaces of walls, columns, ceiling to get smooth finish. Plastering covers defective workmanship in the construction of a given piece of masonry; and, also it conceals cheap/unsound quality of material used in building up the masonry. It is only after plastering that an appropriate base is ready to further decorate the surface by white-washing, colour-washing, distempering, or painting.

11. Define Pointing.

Pointing is the process of finishing the exposed joints in the masonry, instead of plastering the entire surface of the masonry. It consists of raking the joints to a depth of 10 mm to 20 mm and filling it with richer mortar mixes. Pointing gives perfection to joints, which is the weaker part of masonry. It also gives aesthetic view of the masonry.

12. Compare between plastering and pointing.

The following are some of the differences between plastering and pointing

Plastering

It is applied on the entire wall surface

It gives smooth surface finish

Defective workmanship in masonry can be covered up by plastering

It acts as a base for white washing works

Pointing

It is done only at the exposed joints

It does not provide smooth surface

Well built masonry work can be shown by doing pointing work at the joints

Further finishing works like white washing cannot be done

13. What are the purpose of Cavity Walls?

The major purposes of cavity walls are as follows:

❖ Damp Prevention

❖ Thermal Insulation

❖ Sound Insulation

❖ Efflorescence Prevention

14. What is a Diaphragm wall?

Diaphragm wall is method of creating cast in-situ reinforced concrete retaining wall using slurry supported trench method. They are also known as slurry walls. These walls provide rigid, cost effective solution for permanent retaining wall and shafts with less construction joints.

15. Name the different types of Formwork.

Various types of formwork used in construction are Timber Formwork, Steel Formwork, Aluminum Formwork, Plywood Formwork, Fabric Formwork and Plastic Formwork.

16. Define Shoring

Shoring is a temporary structure used to prevent the collapse of the main under-construction structure. The most commonly shoring support is required during the early stage of construction which is excavation. It is a momentary support, which is used during the repair or original construction of buildings and in excavations.

17. List some of the components of a scaffolding

The components of scaffoldings are standards, ledgers, braces, put logs, transoms, bridle, boarding, guard rail and toe board.

18. What is Underpinning?

Underpinning is a method for repair and strengthening of building foundations. There are situations where a failure in foundation or footing happens unexpectedly after the completion of whole structure. Under such a situation, a remedial method has to be suggested to regain the structural stability. The method of underpinning helps to strengthen the foundation of an existing building or any other infrastructure.

19. Write about pitched roof.

A sloping roof is known as pitched roof. These are suitable in those areas where rainfall/ snowfall are very heavy. The pitched roofs are available in various forms as Gable Roof, Hip Roof, Gambrel Roof, Deck Roof and Mansard or club roof.

20. Define flooring.

Flooring is the permanent covering of a floor using any finishing material applied over the floor structure to provide a walking surface. The purpose of floor is to provide a level surface capable of supporting the occupants of the building, furniture, equipment and some time interior wall.

21. Write about Expansion Joints.

The expansion joint depends upon the context of the change of temperature. These joints are provided when the length of the building is greater than 30m and temperature changes by 50°C then a 10 mm expansion joint is provided. The extent of the structure depends on the coefficient of linear expansion of the material. An expansion joint should be provided at the point where the structure changes its direction.

22. List some of the fire extinguishing equipments.

Every building should have the suitable fire extinguishing equipments depending upon the importance of the building.

(a) Manual fire extinguishing elements

(b) Fire Hydrant

(c) Automatic Water Sprinkler systems

23. Write short notes on Natural Ventilation.

Natural Ventilation is a process where the difference in pressure between air inside and outside a building creates an envelope of circulation. The air filters itself through the windows and doors of the structure. Natural or traditional ventilation systems depend on natural forces such as wind and thermal buoyancy to drive outdoor air throughout the building's openings.

24. What are the different types of air conditioning?

Based on the working conditions and position air conditioning can be broadly classified as follows:

❖ Window air-conditioning system

❖ Split air-conditioning system

❖ Package air-conditioning system

❖ Centralized air-conditioning system

25. How do you explain damp proof course?

Dampness is the presence of hydroscopic or gravitational moisture in the building. One of the basic requirements of the building is that it should remain dry or free from moisture traveling through

walls, roofs and doors. The damp proof course (DPC) is generally applied at basement levels, which restricts the movement of moisture through walls and floors.

REVIEW QUESTIONS

1. Explain in detail about building foundations.

2. List different bonds in Stone masonry. Explain in detail.

3. Name the different types of bonds in brick masonry and explain with sketches.

4. What is scaffolding? List and explain the different types of Scaffolding.

5. Explain in detail about plastering and pointing.

6. What is the function of roof? Explain the different types of roof.

7. Discuss in detail about different types of flooring.

8. With neat sketches explain about underpinning.

9. Discuss in detail about formwork and its types.

10. What is shuttering? Explain its types.

11. Write short notes on cavity wall and diaphragm wall.

12. Explain in detail about fire protection and acoustic protection

13. Explain the different types of joints in buildings with sketches.

14. How will you provide ventilation and air conditioning in buildings?

15. Mention the methods of providing DPC. What are the requirements of an ideal material for damp proofing?

UNIT IV

CONSTRUCTION EQUIPMENTS

SYLLABUS

Selection of equipment for earthwork excavation, concreting, material handling and erection of structures - Dewatering and pumping equipment.

* Construction equipments

* Earthwork equipments

* Excavators, Loaders, Scrappers

* Graders, Dozers, Trenchers

* Concreting equipments

* Batching plant,Mixers

* Pumps and pipeline

* Vibrators, Shotcrete gun

* Material handling/Erection equipments

* Hoists

* Conveyors

* Cranes

* Trucks

* Dewatering / Pumping equipments

* Centrifuges

* Vacuum filters

* Filter presses

* Drying beds

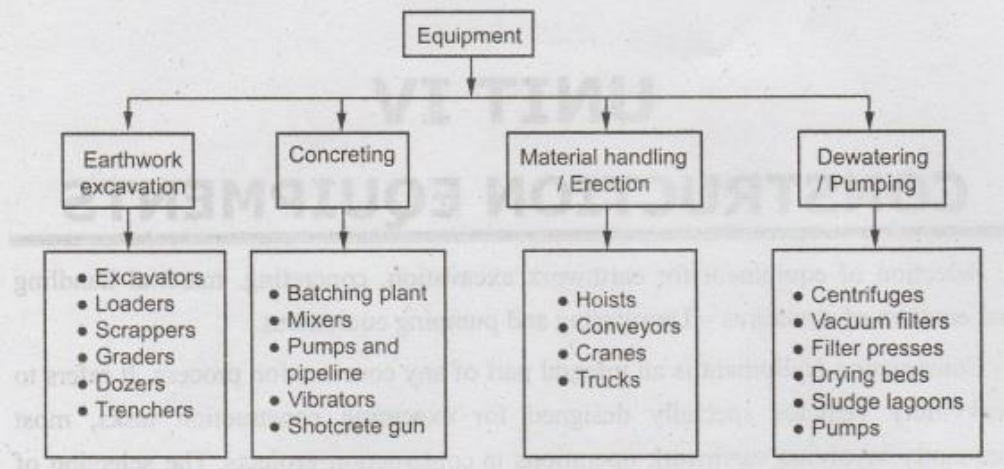
* Sludge lagoons

* Pumps

Construction equipment is an integral part of any construction process. It refers to heavy-duty vehicles specially designed for executing construction tasks, most frequently involving earthwork operations in construction projects. The selection of appropriate type and size of construction equipment depends on the required amount of time and volume of work to be done. Proper use of appropriate equipment contributes to the economy, quality, safety, speed and timely completion of the project. There are various types of construction equipments used in the construction industry and few of the pivotal ones are discussed in this chapter.

CONSTRUCTION EQUIPMENTS

Construction equipment includes of a variety of heavy machines used in the construction industry. These machines are used to perform work such as excavating, concreting, loading and unloading materials, driving material and tools into and out of the site, moving materials from one location to another, feeding material into a machine for processing, retrieving materials from a machine for processing or handling of raw materials by transporting them to another location for processing, and site clearance. Dewatering is also one of the biggest challenges faced in construction industry. Improper dewatering leads to interruption in scheduled works, which might cause loss in money and time. Hence appropriate dewatering methods and pumping should be adopted in site for uninterrupted construction works at site. Different types of construction equipments used for earthwork excavation, concreting, material handling and erection of structures, dewatering and pumping equipments are listed below.



EARTHWORK EQUIPMENTS

Commercially wide ranges of excavating equipments are available in construction industry. It requires a much greater care and consideration in selecting the most suitable machine for a particular job. While selecting excavating equipment, the following factors should be considered.

❖ Nature of work

❖ Method of operation

❖ Duration of the job

❖ Machine specification

❖ Installation and operations costs

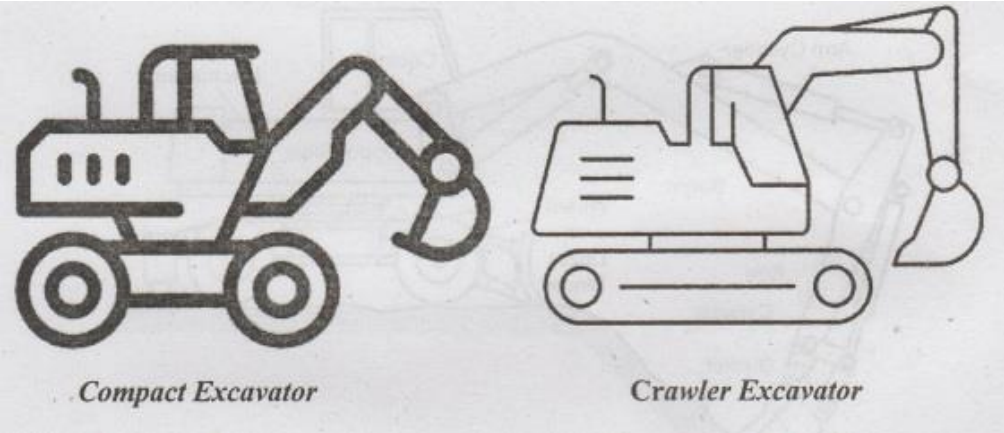
❖ Maintenance and spare costs

The different types of earthwork equipments are as follows:

(i) Excavators: Excavators are heavy construction equipment consisting of a boom, arm, bucket, and cab on a rotating superstructure atop an undercarriage with tracks or wheels. These machines are used mainly for digging purposes as well as various lifting and carrying tasks in various applications. All movement and functions of the excavator are accomplished through the use of

hydraulic fluid, in addition with rams or motors. Based on their size and working type excavators are classified as follows:

*** Compact Excavator:** A compact or mini excavator is tracked or wheeled vehicle with an approximate operating weight from 0.7 to 7.5 tons. It generally includes a standard backfill blade and features independent boom swing. Hydraulic Excavators are somewhat different from other construction equipment in that all movement and functions of the machine are accomplished through the transfer of hydraulic fluid. The compact excavator's work group and blade are activated by hydraulic fluid acting upon hydraulic cylinders. The excavator's slew (rotation) and travel functions are also activated by hydraulic fluid powering hydraulic motors.



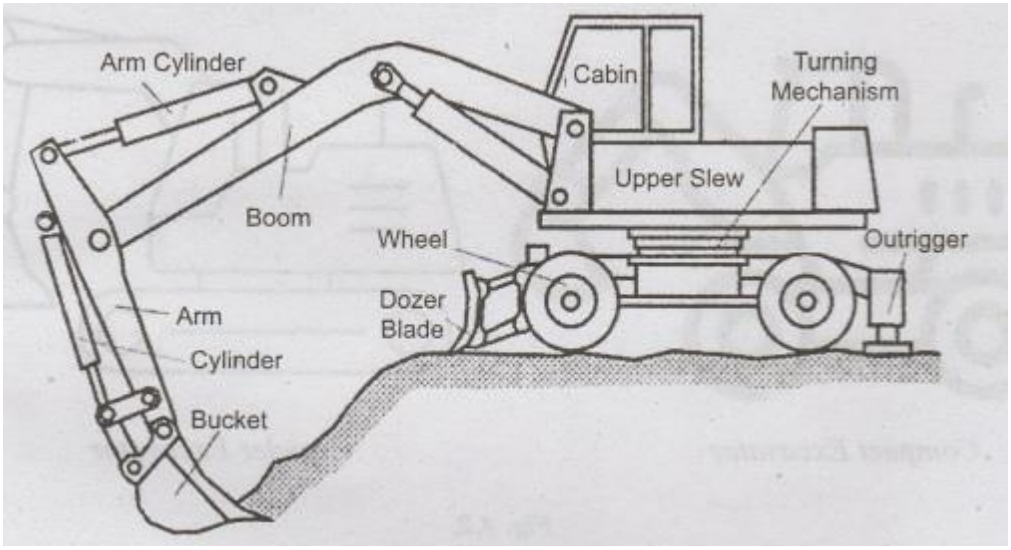
*** Crawler Excavator:** It is of two types namely mini and heavy crawler.

(a) Mini-Crawler Excavator: With a wide range of available sizes and features like Power tech engines, zero-tail-swing, offset boom, multiple attachments and ultra comfortable operator stations, there's mini excavator to fit every job. Hydraulic management system, which helps by balancing hydraulic pressure and flow and sensing when extra power is needed without draining other systems.

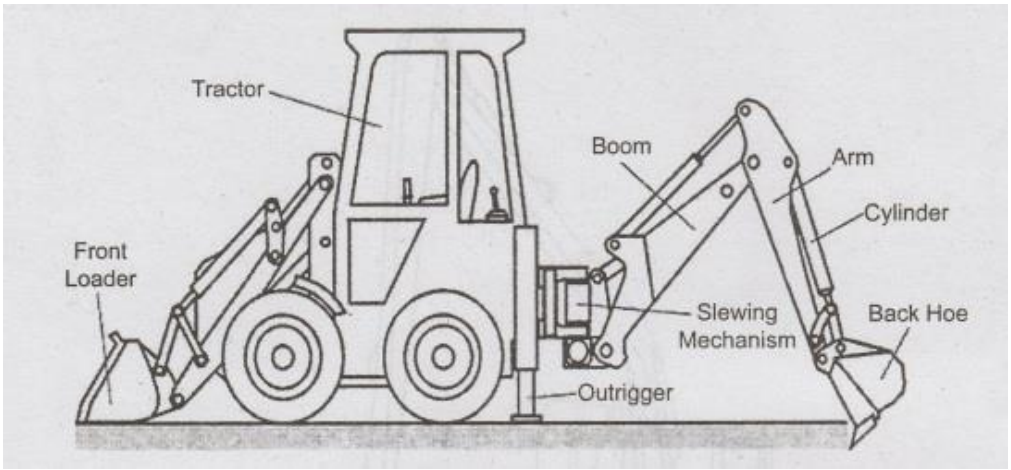
(b) Heavy Crawler Excavator: Crawler excavator gets the job done with muscle, control and peerless productivity. Efficient, cool-running engines and enhanced hydraulics make these the most-reliable and hardest-working excavators yet. Climb into one of these best-in-class cabs and unleash a mighty workhorse to tackle toughest jobs.

*** Wheeled Excavators:** Wheeled excavators easily navigate streets and hard surfaces to deliver powerful bucket forces in well-balanced, high-stability gritos bit machines. Even with all that

muscle outside, operators find quiet comfort lovan brinside spacious air conditioned cabs. Low effort levers deliver smooth rolom boom and bucket control.

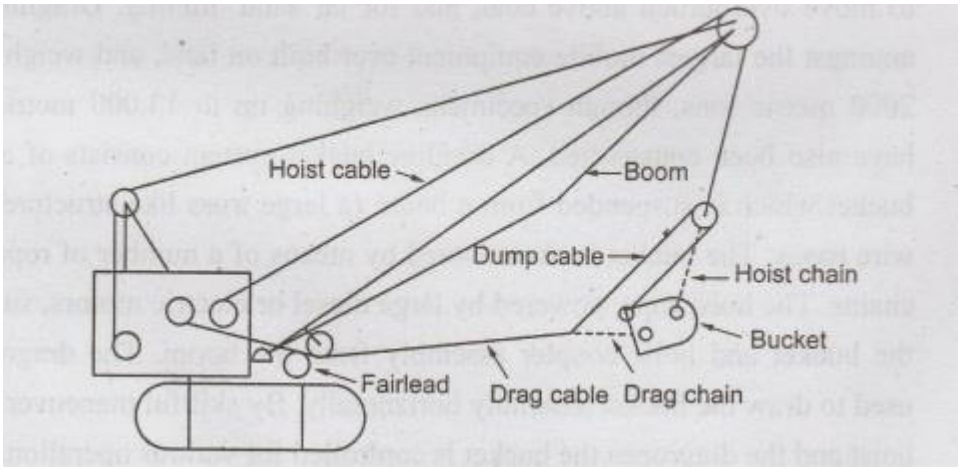


*** Backhoe excavator:** Backhoe excavator, also called a excavator and commonly shortened to backhoe, is a heavy equipment vehicle that consists of a tractor fitted with a shovel/bucket on the front and a small backhoe on the back. Due to its relatively small size and versatility, backhoe loaders are very common in urban engineering and small construction projects such as building a small house, fixing urban roads, etc., Backhoe deliver versatility and power in a cost-efficient package, whether placing pipe, busting up blacktop or digging deep. Each model features excavator-style boom, bucket and hydraulics. Crowd power, swing torque and boom and dipper stick lift are impressive and high pressure hydraulics are powerful and quick. Easy-to-operate controls smoothly blend functions.

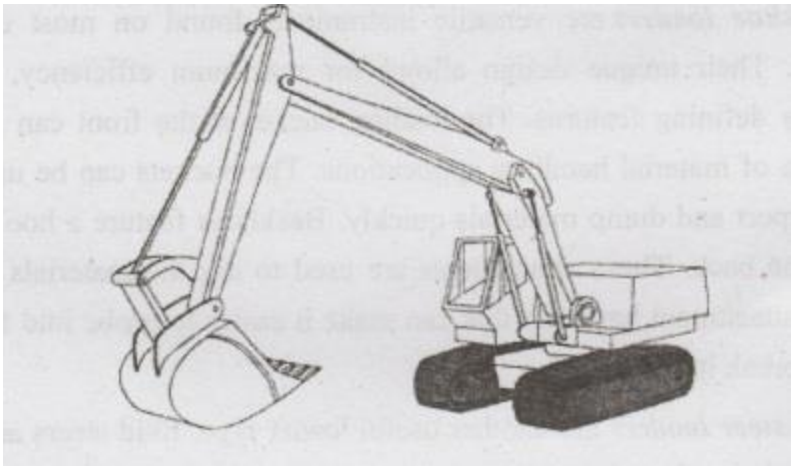


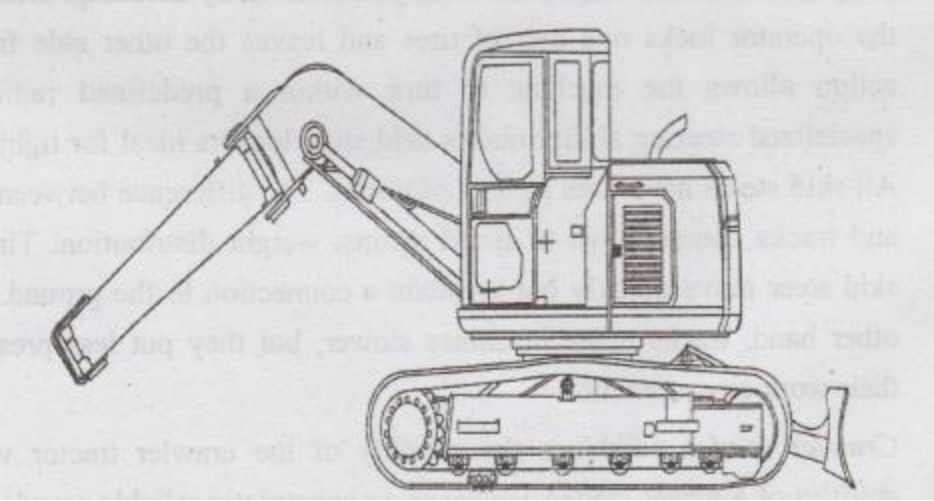
*** Dragline Excavator:** Dragline Excavation Systems are heavy equipment used in civil engineering and surface mining. Smaller types are used for road and port construction. The larger types are used in striping operations to move overburden above coal, and for tar sand mining. Draglines are amongst the largest mobile equipment ever built on land, and weigh about 2000 metric tons, though specimens weighing up to 13,000 metric tons have also been constructed. A dragline bucket system consists of a large bucket which is suspended from a boom (a large truss like structure) with wire ropes. The bucket is maneuvered by means of a number of ropes and chains. The hoist rope, powered by large diesel or electric motors, supports the bucket and hoist coupler assembly from the boom. The dragrope is used to draw the bucket assembly horizontally. By skillful maneuver of the hoist and the dragropes the bucket is controlled for various operations.

*** Long Reach Excavator:** The long reach excavator or high reach excavator is a development of the excavator with an especially long boom arm, which is primarily used for demolition. Instead of excavating ditches, the long reach excavator is designed to reach the upper stories of buildings that are being demolished and pull down the structure in a controlled fashion. Today it has largely replaced the wrecking ball as the primary tool for demolition.



*** Suction Excavator:** A suction excavator or vacuum excavator is a construction vehicle that removes earth from a hole on land or removes heavy debris on land, from various places, by powerful suction through a wide suction pipe which is up to a foot or so diameter. The suction inlet air speed may be up to 100 meters/second. The suction nozzle may have two handles for a man to hold it by; those handles may be on a collar which can be rotated to uncover suction release openings (with grilles over) to release the suction to make the suction nozzle drop anything which it has picked up and is too big to go up the tube. The end of the tube may be toothed. This helps to cut earth when use for excavating; but when it is used to suck up loose debris and litter, some types of debris items may snag on the teeth. The earth to be sucked out may be loosened first with a compressed-air lance or a powerful water jet.





* **Power Shovel:** A power shovel is also known as stripping shovel or front shovel or electric mining shovel. It is a bucket equipped machine, usually electrically powered, used for digging and loading earth or fragmented rock and for mineral extraction.

(ii) Loaders: A foader is a heavy equipment machine often used in construction, to load materials such as excavated earth, sand, rock, gravel, asphalt, demolition debris, logs, raw minerals and recycled material into or onto another type of machinery such as a dump truck, conveyor belt, feed- hopper, or railcars. The loaders may be of the following types:

* **Backhoe loaders** are versatile instruments found on most construction sites. Their unique design allows for maximum efficiency, with these many defining features. The loading bucket at the front can suit a wide range of material handling applications. The buckets can be used to load, transport and dump materials quickly. Backhoes feature a hoe attachment on the back. These attachments are used to dig the materials directly. A hoe attachment has teeth that can make it easier to probe into the material and break it apart.

* **Skid steer loaders** are another useful loader type. Skid steers are excellent for light work and a fast-paced job site. These four-wheeled tools feature a unique movement design, allowing you to steer by skidding. During use, the operator locks one pair of tires and leaves the other side free. The action allows the machine to turn within a predefined radius. The specialized steering ability makes skid steer loaders ideal for tight spaces. All skid steers have tires instead of tracks. The difference between wheels and tracks comes down to speed against weight distribution. Tires let a

skid steer move quickly but maintain a connection to the ground. On the other hand, tracks make machines slower, but they put less pressure on their work environment.

*** Crawler loader** combines the stability of the crawler tractor with the abilities of a wheel loader. However, to construct a reliable crawler loader it requires more than simply attaching a loader bucket onto a crawler tractor. It must be designed with its specific purpose in mind to ensure it has the strength to withstand heavy excavating. The introduction of hydraulic excavators diminished the market for the crawler loader because it was unable to match the excavator's lifting power and flexibility. However, crawler loaders are capable of maneuvering across the entire construction site under its own power, whereas most hydraulic excavators require towing or transport.

*** Wheel loaders** are excellent options for shoveling large volumes in a short time. These are perfect for loading jobs where machines need to wheel about and move materials. Wheel loaders also serve as multi-purpose machines, and there's an array of work attachments can be fit onto a wheel loader to immediately have it doing other work. Wheel loaders have the latest technology and built-in toughness to work in the most challenging applications. This may includes a variety of types, such as:

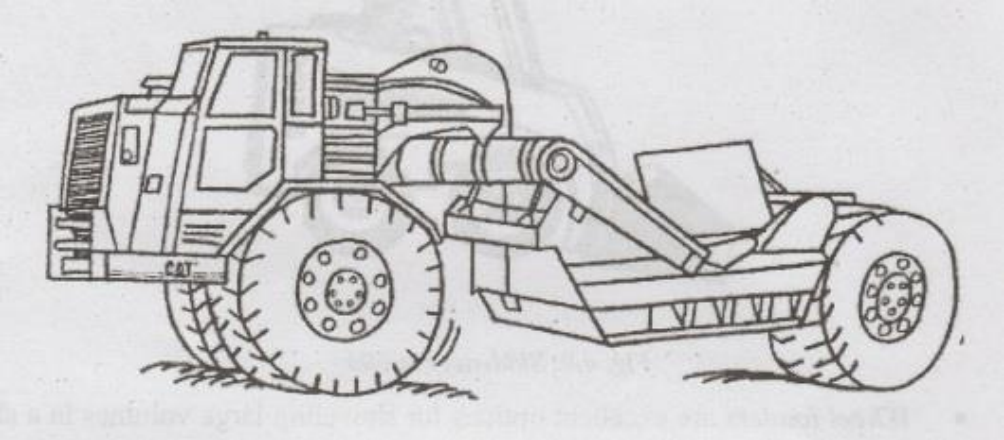
❖ Compact wheel loaders

❖ Small wheel loaders

❖ Medium wheel loaders

❖ Large wheel loaders

(iii) Scrapers: Scrapers are used for earth moving in construction, mining and agriculture industries and often is the plant hire machine of choice over vast areas and on levelling projects. They are used to remove layers of earth across a vast area of land. They typically have very large rubber tires and are often motorized, though some are tow-behind machines and allow you to quickly and easily move product around your site to get the job done When the scraper machine and it's attached trailer pass over an area of dirt to be removed, the operator drops a sharp horizontal blade located in the trailer, or otherwise known as the bowl, into the soil below. As the scraper machines moves forward, dirt is collected or scraped up into the bowl where it is then later collected when it becomes full. Scrapers may be classified as follows:



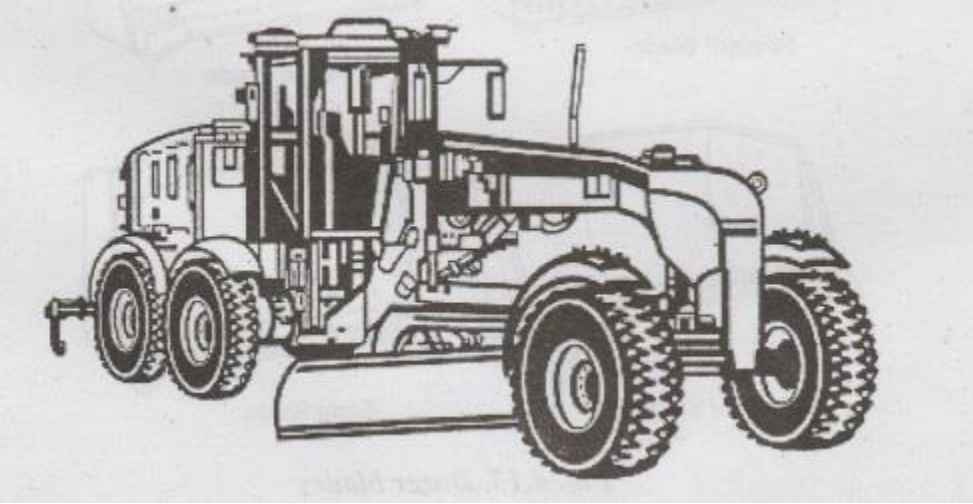
*** Single Engine Wheeled Scrapers:** The single-engine wheeled scraper is perhaps the most common type of scraper. It consists of a bowl, an apron that is drops over a load of earth for transport, and an ejector that relies on hydraulics to get rid of a load once you have successfully moved it. With hydraulics, each separate function can operate separately, as well, making these exceptionally versatile machines.

*** Dual Engine Wheeled Scrapers:** For terrains that are a little tougher than your average job site, the dual engine wheeled scraper machine would be required. This scraper machine Dual-engine wheeled scrapers are another bangin great option if you are hauling earth for a short distance. This type of evo solo scraper has two engines, with one controlling the front wheels and the other powering the rear. This style of scraper is also highly effective for short hauls and narrow cut-and-fill areas on job sites.

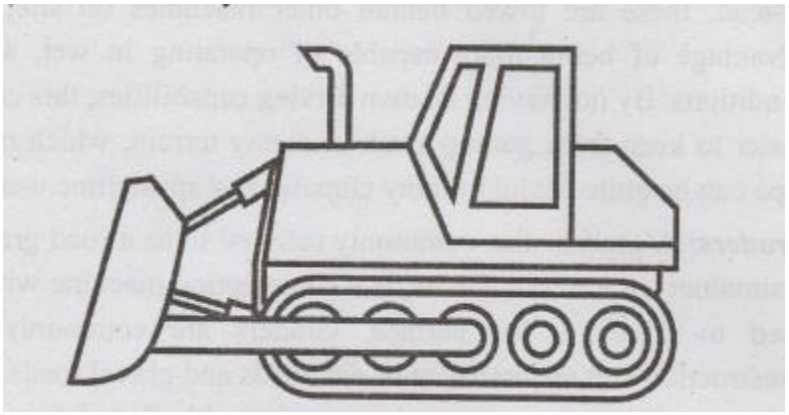
*** Elevating Scrapers:** Rather than rely on an apron like other scrapers, an elevating scraper uses an elevator that is either hydraulically or electrically driven. This elevator loads materials into a raised bowl that can then dump out a load by sliding the bowl's floor backwards, with the elevator capable of being reversed to help evenly and completely finish an offload.

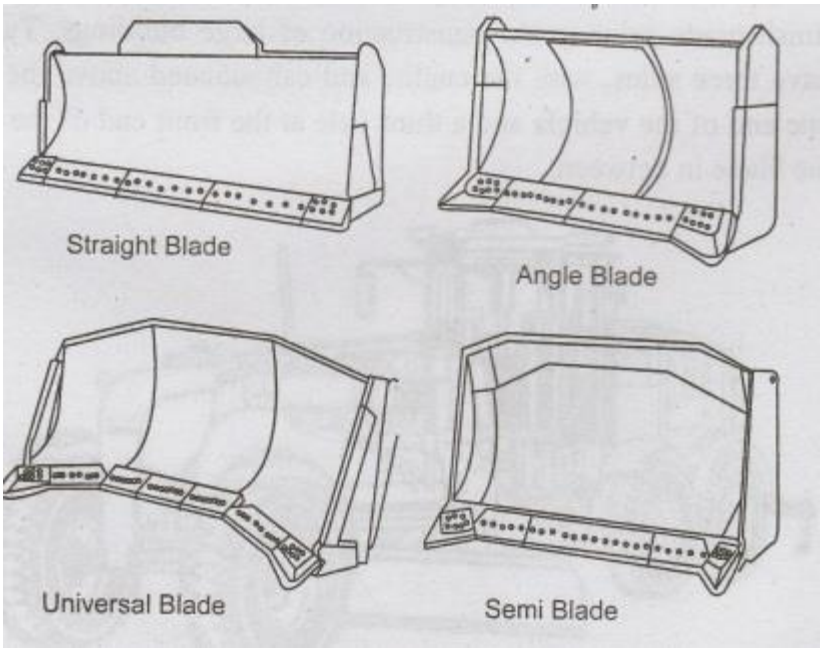
*** Pull Type Scrapers:** Finally, pull-type scrapers are not motorized at all. Instead, these are towed behind other machines on site, but offer the advantage of being more capable of operating in wet, soft and sandy conditions. By not having its own driving capabilities, this can also make it easier to keep from getting stuck in messy terrain, which means the pull- type can be quite useful in rainy climates and springtime weather.

(iv) Graders: A grader, also commonly referred to as a road grader, a blade, a maintainer, or a motor grader, is a construction machine with a long blade used to create a flat surface. Graders are commonly used in the construction and maintenance of dirt roads and gravel roads. They are used to prepare the base course and to create a wide flat surface for the asphalt to be placed on. Graders are also used to set native soil foundation pads to finish grade prior to the construction of large buildings. Typical models have three axles, with the engine and cab situated above the rear axles at one end of the vehicle and a third axle at the front end of the vehicle, with the blade in between.



Motor graders are classified depending on the arrangement of their frame. There are two types of categories graders can fall under: Rigid frame motor grader and Articulated frame motor grader. Today, most graders manufactured are articulated frame graders. This is as they are more useful in smaller construction spaces where there is less room to move or turn around. Small motor graders are perfect for landscaping jobs, road maintenance and other tasks that need to be completed in a tight space, whereas large motor graders are typically used for larger scale projects, such as highways and motorway construction.





(v) Dozers: Bulldozers are strong machines that mainly assist with pushing, digging, excavating, and leveling materials like soil and debris at a work bob site. They come with large, heavy blades with which soil is scraped and pushed. Some come with other modifications like rippers in the rear to help break down tough ground.

Different bulldozer blades serve different purposes, and can handle different types of materials and can handle a range of load weights.

*** Straight Blades (S-Blade):** An S-blade is the shortest type of blade a dozer can use and does not have side wings. This blade attaches to the arm in the lower back corners of the blade. Thanks

to its shape, the straight blade is best for fine-grained and medium- to hard-density materials. The drawback is that its straight shape limits the dozer's lifting and carrying capabilities. Some of the best tasks for s-blades include stumping, back-filling, grading and evening soil.

*** Angle Blade:** This type of blade attaches to the center of the bulldozer's panel. Its location is useful for moving debris to the side since it can angle close to 30 degrees left or right. Due to this, an angle blade is considered a two-way blade. It's a great choice for projects involving soft- to medium- hard-density soils, snow, and gravel. Some of the best tasks for angle blades include stumping, shaping, stripping and ditching.

*** Universal Blade (U-Blade):** A U-blade has large side wings and a curved shape that makes it ideal for pushing materials across long stretches of land. The wings keep material from spilling over when in motion. Like S- Blades, they also attach to the lower back corners of the blade. It's the www.largest blade type in both height and width and is best used with soft- to medium-density soil. Some of the best tasks for u-blades include ditching, hauling, pushing and crowning.

*** S-U (Semi-U) Blade:** This blade combines features from the S-blade and the U-blade to give it stronger penetration and better overall versatility and is also known as cushion blade. It's narrower, less curved, and its side wings are smaller compared to a normal U-blade. This design makes it ideal for pushing soil across long distances. It's best used to push soft- to medium-density sand and soil. Some of the best tasks for an s-u blade include crowning, moving heavy material, stumping and ditching.

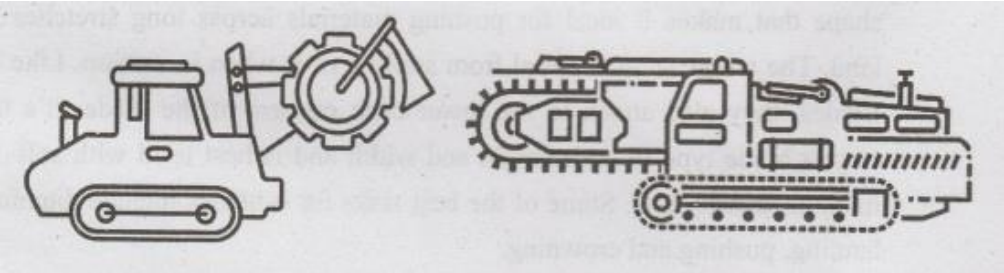
There are many different bulldozer types to choose from depending on terrain, project type, and similar other criteria. Types of bulldozers are as follows:

*** Crawler Bulldozer:** A crawler is sometimes referred to as a track bulldozer and looks most similar to a tractor. This heavyweight is great for moving heavy materials from one area to another. This bulldozer is ideal for traversing dense and irregular terrain since the tracks give it great traction. Larger crawlers have rippers that assist with crushing and clearing dense terrain.

*** Wheel Bulldozer:** This machine is sometimes referred to as a tire bulldozer and is normally larger than a crawler. A wheel dozer is more maneuverable than a crawler since its tires offer better overall handling. It also has completely articulated hydraulic steering and moves on a smaller axis. This machine is also ideal to use for soft or sensitive ground since the tires are gentler than tracks.

*** Mini Bulldozer:** This smaller bulldozer is also known as a compact bulldozer. A mini dozer is great for projects that require more maneuverability and versatility than larger machinery. Thanks

to its small size, a compact bulldozer can perform well in different types of projects that require tasks like grading and clearing lots.



(vi)Trenchers: Trenchers or ditchers are similar to excavators in the sense that they penetrate the earth, breaking soil and rock, and remove it from the ground. Trenchers are heavy machines designed for excavating. They have a metal chain with teeth made of high-strength steel. This allows the machine to tear into the ground, lifting and moving massive amounts of earth. Because of the sheer size and strength of the machine, trenchers are capable of tearing through heavy tree root systems and densely packed earth. An excavator produces a ditch that is significantly wider at the top than the bottom, leaving you with a lot of backfill to deal with. But a trencher produces exactly what the name implies, a clean trench with a flat bottom and smooth walls. Trenchers come in three types as follows:

* **Chain trenchers:** Chain trenchers have a chainsaw-like design. They use a digging belt or chain to cut into the ground. Due to their flexibility, chain trenchers can cut narrow and deep trenches for utility companies.

* **Wheel trenchers:** Wheel trenchers, also called rockwheels, have a toothed metal wheel that can be used for hard or soft soils. Wheel trenchers work best in areas where there are many rock formations.

* **Micro trenchers:** Micro trenchers are used for cutting "micro trenches". These are micro ones with dimensions significantly smaller than those cut by conventional trenchers ranging from 0.5 to 2 inches wide and around 2 feet in depth.

CONCRETING EQUIPMENTS

Concreting equipments are very much significant for the construction field. Using concrete in construction typically involves an extensive amount of labor. From mixing to pouring the concrete onto slabs, many workers have to work together to ensure the process goes well. With great quality concrete equipment machinery, quality construction can be attained in a lesser measure of time. Aside from potentially reducing labor costs, concrete equipment also lessens the risk of human error while allowing companies to finish projects much faster. Here are some of the most common concrete equipments used in construction:

(i) Concrete Batching Plant: Concrete batching plant, mixes various materials to form concrete. These materials include sand, aggregate, slag, cement, fly ash, and water among others. The batching plant comprises of adequate capacity gravel & sand hoppers, weighing conveyor suspended on electronic load cells, reversible drum type mixer unit, cement bin with screw conveyor, rubber belt type charging conveyor, cement batcher, PLC based control panel.

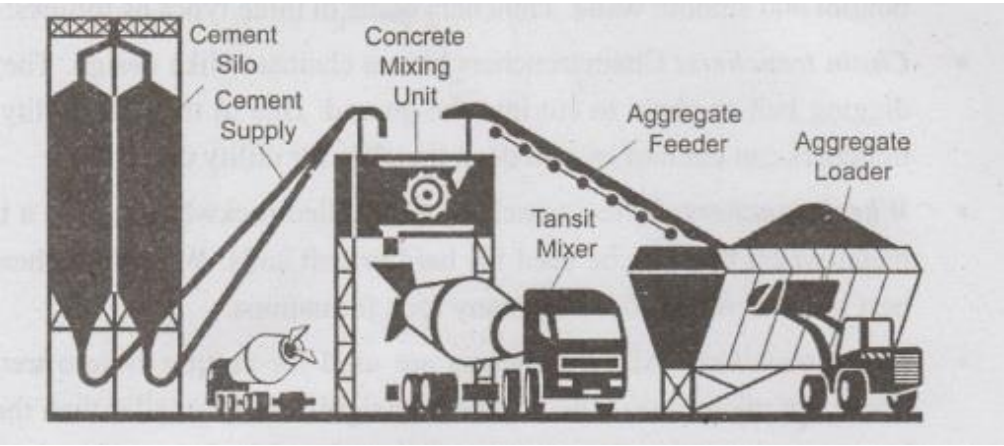
Concrete batching plants come in various types:

❖ Dry mix concrete plant

❖ Wet mix concrete plant

❖ Mobile concrete plant

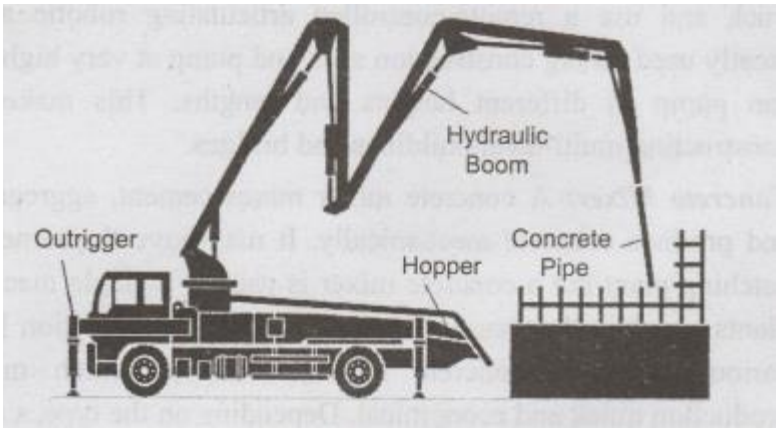
❖ Stationery concrete plant

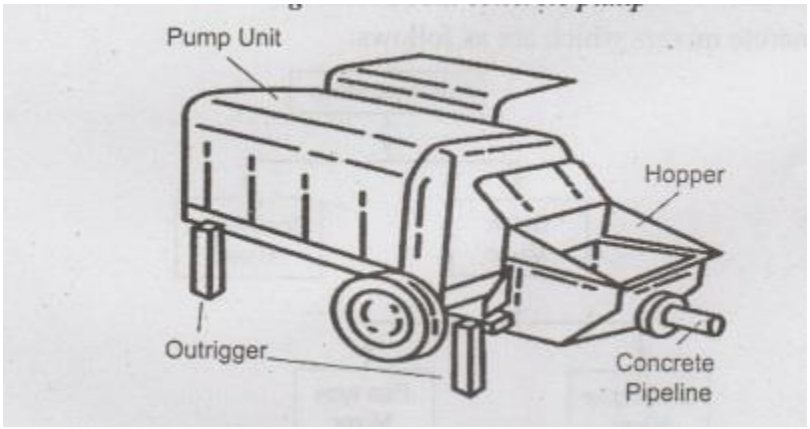


Mobile plants are used by temporary site projects and projects that don't require much concrete. But projects like large buildings, ports, bridges, tunnels and dams use stationary ones. Mobile batching plants can be used wet or dry and has a wide array of configurations and production types including Ready Mix, Precast & Prestressed, Central Mix, and RCC. Mobile Concrete Batching

plant models are nowadays fully automatic. 20 cum/hr batching plant, 30 cum/hr concrete plant, 45 cum/hr, 60 cum/hr, 90 cum/hr, 120 cum/hr batching plant are a portion of the famous types of cement grouping plants utilized by the construction organizations.

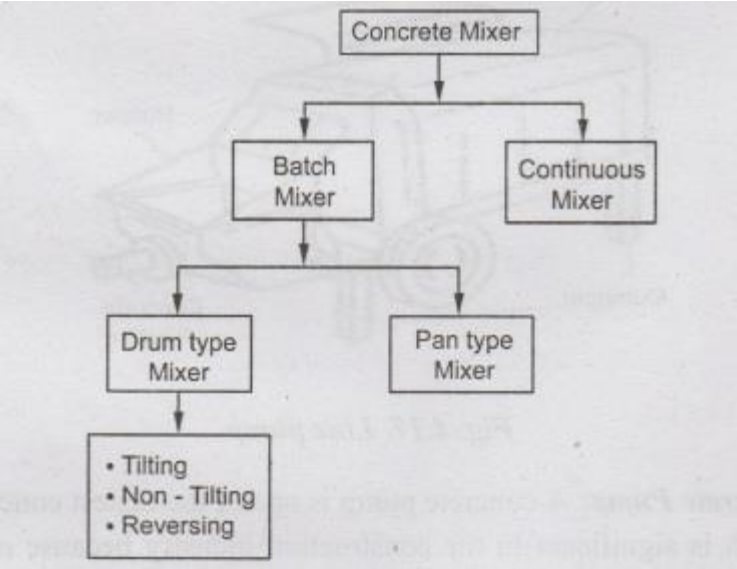
Stationary concrete batching has seen an up surging rise in demand and manufacturers are modifying new models based on the customer need. These types are furnished with twin shaft mixers for maximized capacity and are also available with planetary mixers and batch sizes could be modified. The Stationary Plants are available in various capacities ranging from 30 m3 to 240 m3 per hour of compacted concrete. In stationary concrete plants, the aggregates are stored in horizontal bins. The gathering conveyor belt runs below the bins where the weighing of aggregates takes place and the aggregates are then discharged onto the charging conveyor. Pneumatically operated gates are provided for discharge of the aggregate on to the gathering conveyor. The material is all weighed accurately and transferred to the twin shaft mixer through a slinger conveyor. Nowadays batching plants also come with the skip hoist and belt arrangement option for mixer loading and a modular PLC-based control system with real-time control and data management. An admixture dosing unit and a standard cement screw conveyor are also a part of the stationery batching plant.





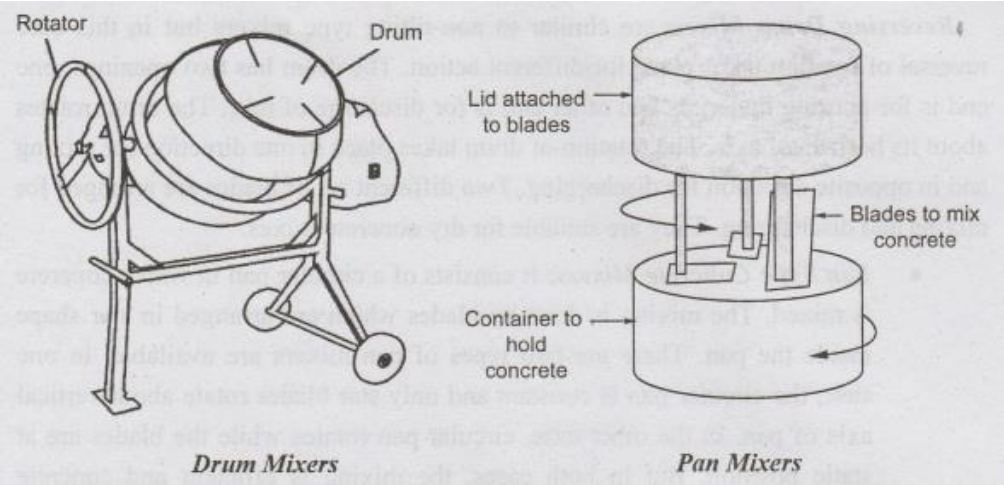
(ii) Concrete Pump: A concrete pump is one of the fastest concrete equipment which is significant in the construction industry because of its reliability and cost-effectiveness. A concrete pump is used to transport concrete from the production to the casting area. It works by having one piston drawing the concrete from the source and another one pushes it into the discharge pipe. Concrete pumps save the labor cost, time, and material with high power consumption are used for pumping the concrete from the mixer and send it directly to the construction site. There are two types of concrete pumps namely line pumps and boom concrete pumps. The line pump is mounted on a truck and placed on a trailer. Line pumps normally pump concrete at lower volumes than boom pumps and are used for smaller on to the volume volume concrete concrete placing applications such as sidewalks, small constructions and mostly ground slabs. Boom pumps are attached to a truck and use a remote-controlled articulating robotic arm. They are mostly used on big construction sites and pump at very high volumes, as it can pump in different heights and lengths. This makes it ideal for constructing multi-level buildings and bridges.

(iii) Concrete Mixer: A concrete mixer mixes cement, aggregates and water and produce concrete mechanically. It may have the same function as a batching plant but a concrete mixer is usually a single machine. Batching plants, on the other hand, belongs to a whole production line. There are various types of concrete mixers available which makes concrete production quick and economical. Depending on the type, a concrete mixer can produce concrete by batch or continuously. There are two broad types of concrete mixers which are as follows:



*** Batch Concrete Mixers:** Batch mixers are widely used machines for concrete mixing. Concrete mix obtained by this mixer is collected batch by batch and time by time. So, it is called as batch mixer. After pouring all the materials into pan or drum, it mixes all of those for some time and

finally discharges. This process is repeated until required amount of concrete mix is obtained. In general Batch mixers are two types namely drum type and pan type.



*** Drum Type Mixers:** Drum type mixers concrete ingredients are mixed in a drum which is actually in double conical frustum shape. These are classified into the following types:

Tilting Drum Mixers means the drum will discharge concrete by tilting downwards. It is rapid discharge process and used for larger projects. Rapid means it delivers concrete by gravity that is tilting the drum downwards because of this the concrete mix obtained will be not subjected to segregation. Low workability concrete which contains larger size aggregates of size greater than 7.5cm are also mixed efficiently with this type of tilting mixers. But the mixing efficiency depends on the shape of the drum, angle of the drum, size of blades and angle of blades. The only disadvantage of this mixer is sticking of concrete to bottom of drum.

Non-Tilting Drum Mixers are not allowed to tilt and the drum rotates about its horizontal axis. For the discharge of concrete a chute is arranged in inclined position which will receives the concrete mix from drum and discharges out. In this case, the drum is opened at two ends and contains blades inside the drum for mixing. Here materials are poured through one end and mix is collected through another end. Rapid discharge of concrete is not possible in this case. Due to this delay, the concrete may be vulnerable to segregation. So, this type of mixers is generally used for small projects.

Reversing Drum Mixers are similar to non-tilting type mixers but in this case reversal of rotation takes place for different action. The drum has two openings, one end is for pouring materials and other end is for discharge of mix. The drum rotates about its horizontal axis. The rotation of drum

takes place in one direction for mixing and in opposite direction for discharging. Two different set of blades are arranged for mixing and discharging. They are suitable for dry concrete mixes.

*** Pan Type Concrete Mixers:** It consists of a circular pan in which concrete is mixed. The mixing is done by blades which are arranged in star shape inside the pan. There are two types of pan mixers are available. In one case, the circular pan is constant and only star blades rotate about vertical axis of pan. In the other case, circular pan rotates while the blades are at static position. But in both cases, the mixing is efficient and concrete mixture is collected through central hole provided in the pan. The rotating star blades contain special blades called scrapper blades which will make concrete not to stick to the pan. The blades can also be adjusted in height, so there is no room for concrete to store in the pan. These are more efficient type of concrete mixers.

*** Continuous Concrete Mixers:** In this type of mixer, loading, mixing and discharging of mix is continuously done until the work is complete or work break occurs. The loading of materials is done continuously by screw feeders. Continuous mixtures are used for very large projects such as construction of high rise buildings, dams, bridges, etc.

(iv) Concrete Vibrator: Concrete vibrator is a mechanical device used to create vibration in wet concrete to compact the concrete. Concrete vibrator is fixed with motor and connected with a needle that creates the vibration inside the concrete mix and remove the all air in between the concrete mix. Vibration gives more strength and life to concrete. This concrete equipment is almost used by the entire civil industry from small civil work to large construction. Concrète vibrator can be of various types as given under: cont

❖ Internal Vibrator

❖ External Vibrator

❖ Table Vibrator

❖ Surface vibrator

*** Internal or Needle Vibrators:** Internal or Needle Vibrators are most commonly used vibrator for concrete. It consists of a steel tube with one end closed and rounded, having an eccentric vibrating element inside it. This steel tube called poker is connected to an electric motor or a diesel engine through a flexible tube. They are available in size varying from 40 to 100 mm diameter. The diameter of the poker is decided from the consideration of the spacing between the reinforcing bars in the form- work. The frequency of vibration varies up to 15000 rpm. The period of vibration

required may be of the order of 30 seconds to 2 minute. The concrete should be placed in layers not more than 600mm high.

*** External or Shutter Vibrators:** These vibrators are clamped rigidly to the form work at the pre-determined points so that the form and concrete are vibrated. They consume more power for a given compaction effect than internal vibrators. These vibrators can compact upto 450mm from the face but have to be moved from one place to another as concrete progresses. These vibrators operate at a frequency of 3000 to 9000 rpm. The external vibrators are more often used for pre-casting of thin in-situ sections of such shape and thickness as they cannot be compacted by internal vibrators.

*** Surface Vibrators:** These are placed directly on the concrete mass. These best suited for compaction of shallow elements and should not be used when the depth of concrete to be vibrated is more than 250 mm. Very dry mixes can be most effectively compacted with surface vibrators. The surface vibrators commonly used are pan vibrators and vibrating screeds. The main application of this type of vibrator is in the compaction of small slabs, not exceeding 150 mm in thickness, and patching and repair work of pavement slabs.

*** Table Vibrator:** The vibrating table consists of a rigidly built steel platform mounted on flexible springs and is driven by an electric motor. The normal frequency of vibration is 4000 rpm. The vibrating tables are very efficient in compacting stiff and harsh concrete mixes required for manufacture of precast elements in the factories and test specimens in laboratories.

Most construction projects use internal vibrators as they are usually cheaper and offer more flexibility. But for vertical constructions like walls, an external vibrator is more suitable.

(v) Shotcrete Machine: Shotcrete machines are used for concrete spraying applications at the construction sites. It is a method of applying concrete proposed at high velocity primarily on a vertical or overhead surface. It is a mortar or high-performance concrete conveyed through a hosepipe and pneumatically shot at high force at the back surface. The force of this spraying action leads to compaction of the concrete which then forms layers of concrete to the necessary thickness. The impact created by the application consolidates the concrete. Even though the hardened properties of shotcrete are related to those of conservative cast-in-site concrete, the nature of the settlement process results in an excellent bond with most substrates, and rapid capabilities, particularly on composite forms or shapes. It has proved to be the greatest method for the construction of curved surfaces.

The shotcrete process needs less formwork and can be more cost-effective than traditionally placed concrete. It is applied by a wet- or dry-mix process. The wet-mix shotcrete method mixes all components with water before the introduction into the delivery hose. The dry-mix process adds water to the fusion at the nozzle. It is used in repairs and new construction also it is suitable for curved and thin elements. Because of their compact designs, these are useful at locations where space is at premium. Lining of water tanks, mines, swimming pools and backfilling of tunnel construction are some applications where these shotcrete machines are used.

MATERIAL HANDLING EQUIPMENTS

Materials handling is loading, moving and unloading of materials. To perform the action safely and economically, different types of tackles, gadgets and equipments are used, which are called as material handling equipments. The essential requirements of a good materials handling system may be summarized as:

❖ Efficient and safe movement of materials to the desired place.

❖Timely movement of the materials when needed.

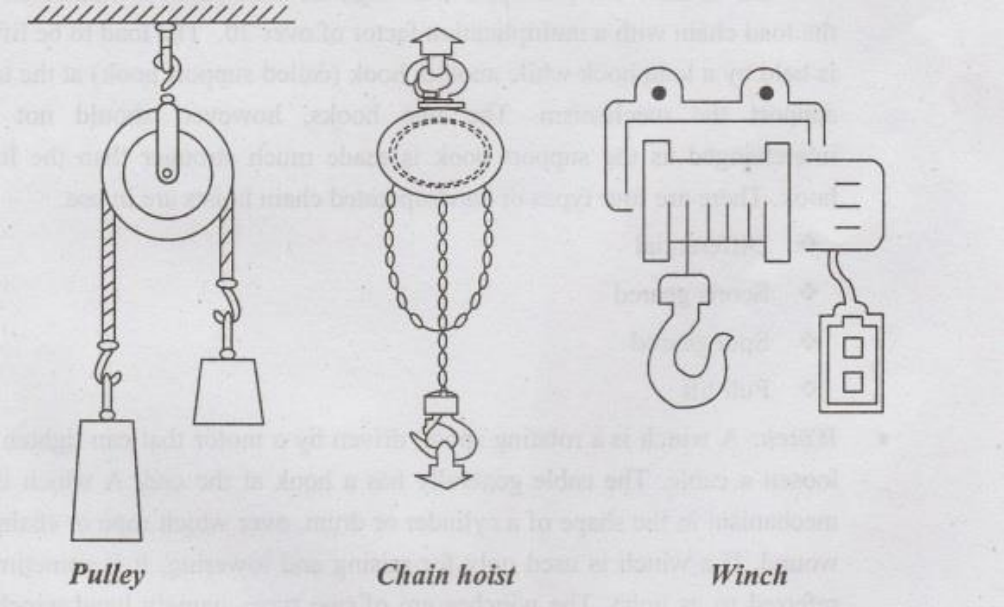
❖ Supply of materials at the desired rate.

❖ Storing of materials utilizing minimum space.

❖ Lowest cost solution to the materials handling activities.

Material Handling equipment's are used in movement of bulk, packaged, & individual products as per the work requirement. Broadly material handling equipment's can be classified into the following categories:

(i) Hoists: Hoist is a device for raising or lowering a load by means of a drum or wheel lift to which wraps the rope or chain. It can be operated by hand, is driven electrically or pneumatically, and the chain or wire rope fibers are used as lifting device. The load connected to the lifting means of a lifting hook. Following are the widely used hoisting equipments:



*** Pulley** is a wheel on an axle or shaft that is designed to support movement and change of direction of a cable or belt along its circumference. Pulleys are used in a variety of ways to lift loads, apply forces, and to transmit power. The assembly of the wheel, axle, and supporting shell is referred to as a "block." A pulley may also be called a sheave or drum and may have a groove between two flanges around its circumference. The drive element of a pulley system can be a rope, cable, belt, or chain that runs over the pulley inside the groove. The pulley and sheave blocks suitable for lifting rough surfaces and heavy loads. For this purpose, the chains and wire ropes are used. The alloy chains are best suited for hoisting operation. The weakest component of this system is the load hook. The hook fails by straightening. Once the hook gets elongated or straightened, it should be replaced.

*** Chain hoist:** The chain hoists are the popular mechanism for lifting loads of upto tonnes. The system consists of two sets of chains, namely the hand and load chain. The hand chains are particularly useful for the isolated location, where an electric motor or other types of mechanical equipments are not available. The pull applied through the hand chain is transmitted to the load chain with a multiplication factor of over 20. The load to be lifted is held by a load hook while another hook (called support hook) at the top, support the mechanism. The two hooks, however, should not be interchanged as the support hook is made much stronger than the load hook. There are four types of hand-operated chain hoists are in use.

❖ Differential

❖ Screw geared

❖ Spur geared

❖ Pull lift

* **Winch:** A winch is a rotating spool, driven by a motor that can tighten or loosen a cable. The cable generally has a hook at the end. A winch is a mechanism in the shape of a cylinder or drum, over which rope or chain is wound. If a winch is used only for raising and lowering, it is sometimes referred to as hoist. The winches are of two types namely hand winches and power winches.

(ii) Conveyors: Conveyors are useful for moving material between two fixed workstations, either continuously or intermittently. They are mainly used for continuous or mass material handling operations, and most suitable for operations where the flow is more or less steady. Conveyors may be of various types, with rollers, wheels or belts to help move the material along, and may be power-driven or may roll freely. The decision to provide conveyors must be taken with care, since they are usually costly to install. However, they are less flexible and, where two or more converge, it is necessary to coordinate the speeds at which the two conveyors move. Various types of conveyors used for material handling are discussed below:

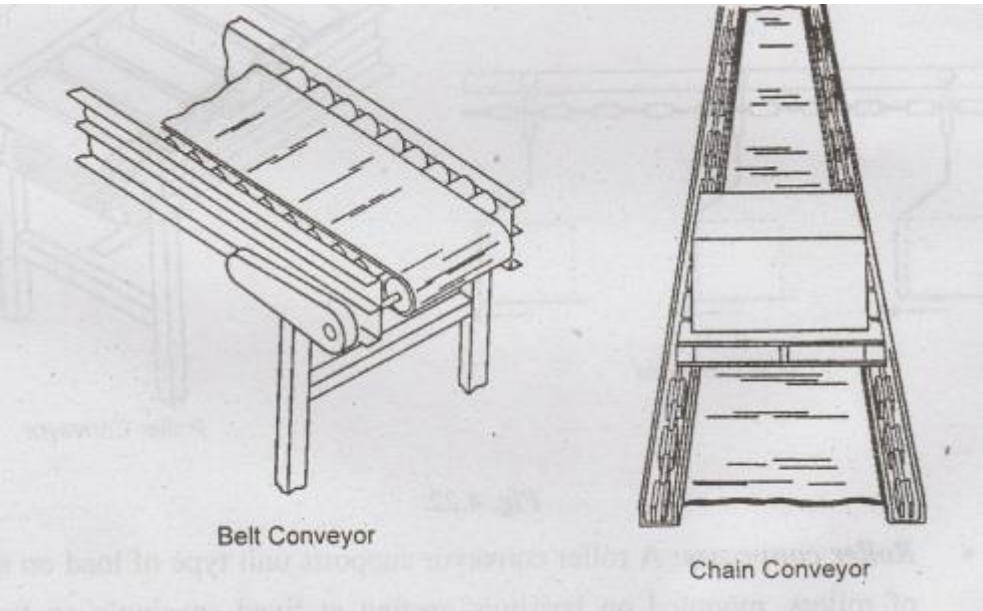
* **Belt conveyors:** A belt conveyor consists of an endless flat and flexible belt of sufficient strength, made of fabric, rubber, plastic, leather or metal, which is laid over two metallic flat pulleys at two ends, and driven in one direction by driving one of the two end pulleys. Material is placed on this moving belt for transportation. The active half of the belt is supported by idler rollers or slider bed. The return half of the belt may or may not be supported, as it generally does not carry any additional load other than its own weight. The endless belt is kept tight by a belt tensioning arrangement. Types of belt conveyor are:

❖ Flat Belt Conveyor

❖ Troughed Belt Conveyor

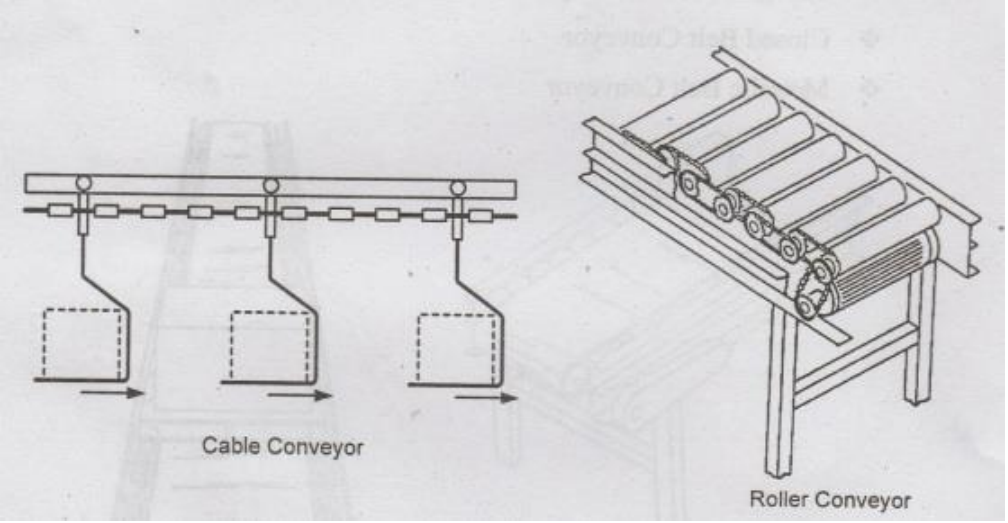
❖ Closed Belt Conveyor

❖ Metallic Belt Conveyor



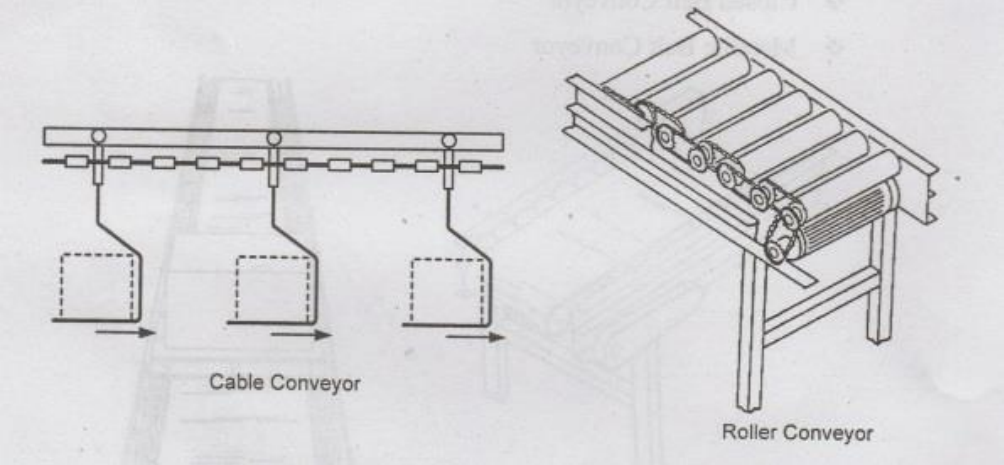
*** Chain conveyors:** The term chain conveyor means a group of different types of conveyors used in diverse applications, characterized by one or multiple strands of endless chains that travel entire conveyor path, driven by one or a set of sprockets at one end and supported by one or a set of sprockets on the other end. Materials to be conveyed are carried directly on the links of the chain or on specially designed elements attached to the chain. The load carrying chain is generally supported on idle sprockets or guide ways. The endless chains are kept tight by suitable chain tensioning device at the non-driven end. Different types of chain conveyors are Apron or Pan Conveyor and Cross-Bar or Arm Conveyor. no

*** Cable conveyors:** These conveyors form a distinct group of materials handling equipment to transport people and bulk materials in load carrying buckets, using overhead moving cables and/or wire ropes and are com- posed of one or more spans from the loading point to the discharge point/points covering long distances upto several kilometers. These conveyors are also known as ropeways or aerial tramways.



*** Roller conveyors**: A roller conveyor supports unit type of load on a series of rollers, mounted on bearings, resting at fixed spacing's on two side frames which are fixed to stands or trestles placed on floor at certain intervals. A roller conveyor essentially coveys unit loads with at least one rigid, near flat surface to touch and maintain stable equilibrium on the rollers, like ingots, plates, rolled stock, pipes, logs, boxes, crates, moulding vboxes etc. The spacing of rollers depend on the size of the unit loads to be carried, such that the load is carried at least by two rollers at any point of time. Roller conveyors are classified into two types according to the principle of conveying action as Unpowered or Idle Roller Conveyor and Powered or Live Roller Conveyor.

*** Screw conveyors:** A screw conveyor consists of a continuous or interrupted helical screw fastened to a shaft which is rotated in a U-shaped trough to push fine grained bulk material through the trough. The bulk material slides along the trough by the same principle a nut prevented from rotating would move in a rotating screw. The load is prevented from rotating with screw by the weight of the material and by the friction of the material against the wall of the trough. A screw conveyor is suitable for any pulverized or granular non viscous material, and even at high temperature. The conveyor is particularly suitable for mixing or blending more than one material during transportation, and also for controlling feed rate of materials in a processing plant. It is also not suitable for large- lumped, packing or sticking materials.

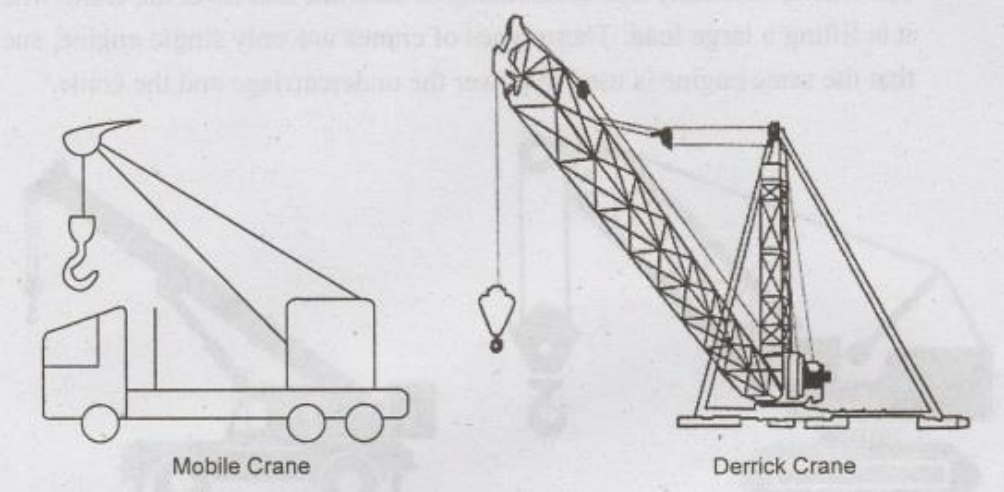


*** Chute conveyors:** Chute Conveyor is one of the least expensive methods of conveying material. It is the simplest example of gravity-operated conveyor. Chutes are inclined connections between two systems of materials handling equipment or production equipment, in the form of troughs of definite geometrical cross section or pipes, which convey unit or bulk load by gravity. A chute may connect two conveying mechanisms, two process equipment or may be installed between one materials handling equipment and one processing equipment. Depending on the load to be handled, chutes are made of various size, shape and material.

(iii) Cranes: A crane is a piece of heavy machinery that is a tower or platform that is equipped with cables and pulleys. Cranes have a long history of being a staple in construction that reaches back thousands of years. It was during the industrial revolution that cranes became integral to the modernization of the world, replacing the manual pulley system with an engine and an operator that preceded them. There are various types of cranes used in civil engineering construction works. They are used to lift and lower materials. The most common types of cranes used in the construction industry are discussed below:

*** Derrick Crane**: A derrick is a special type of crane in which the distance from the end of the jib to the pillar can be changed. The derrick cranes are of two types, namely Guy derrick and Stiff leg derrick. A guy derrick consists essentially of a pivoted pillar that is braced by guy ropes, and a jib that is attached at the base of the pillar. The inclination of the jib is controlled by a tackle that connects the top ends of the pillar and jib. The hoisting rope extends from the end of the jib, over the top of the pillar, to the base of the pillar, where it is fastened to a drum. A stiff leg derrick is similar to a guy derrick except that its jib is movable and may be secured at different heights on the tower, or pillar. Stiff leg derricks are used mostly in building construction. Guy derrick can be constructed up to 200 tonnes capacity. In stiff leg type derricks, the guy wires are replaced by trussed structure. This type of derricks is suitable for loads from 10 to 50 tonnes.

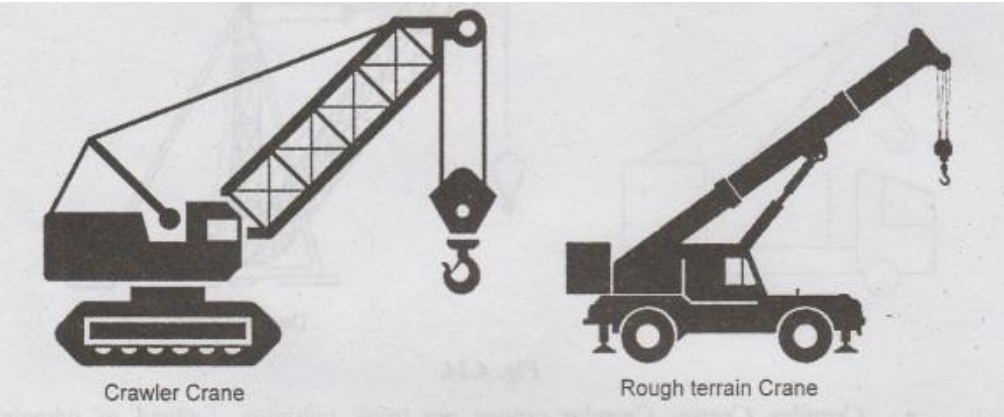
*** Mobile Cranes:** This is the most basic type of crane and consists of a steel truss or telescopic boom mounted on some kind of mobile platform. This platform could be wheeled, a rail or even a cat truck. The boom is hinged at the bottom and can be raised or lowered by cables or hydraulic cylinders. Some mobile cranes are even able to be driven on the highway. Their ability to navigate around job sites and carry large amounts of weight makes mobile cranes a very popular addition to many projects. In most cases, they don't require much effort to assemble or setup.



*** Crawler Crane:** Crawler cranes are track vehicles. Instead of wheels, crawlers are built on an undercarriage fitted with a pair of rubber tracks. Though this limits the crawler's turning capacity, the tracks make it possible to use on soft ground and sites with limited improvement without sinking. Their main advantage is that it can move mostly on any surface of the earth due to its crawlers as it transfers its load to a great area. Hence it can be used at unprepared sites without worrying about anything. Some crawler cranes have an attached telescopic arm that allows it to change its size, making them highly adaptable on many terrains. It is very heavy and move on tracks hence mobility is not easy and take more time and will cost more money. But it can be moved by trucks easily and without costing much money.

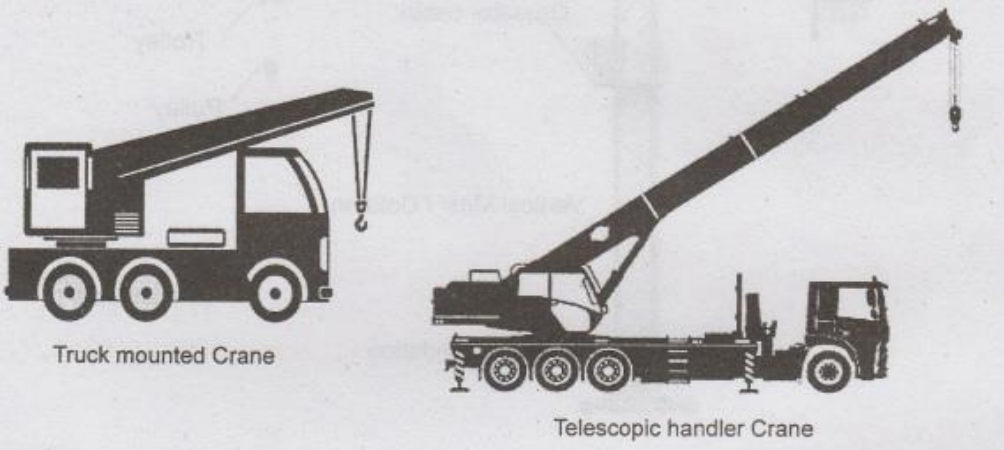
*** Rough Terrain Crane:** A rough terrain crane is built similarly to a crawler crane, but instead of tracks, the undercarriage is outfitted with four large rubber tires that are typically equipped with four-wheel drive. A normal vehicle mounted crane cannot be used in off road applications, hence rough terrain cranes are used. Outriggers are used for stabilizing the crane while working. They contain only one engine which means that same engine is used for undercarriage and crane. Rough terrain cranes are also fitted with telescopic booms and outriggers to improve stability and make mobility much more manageable in tight and rough areas. The outriggers can extend vertically and

horizontally to stabilize and level the crane when it is lifting a large load. These types of cranes use only single engine, such that the same engine is used to power the undercarriage and the crane.

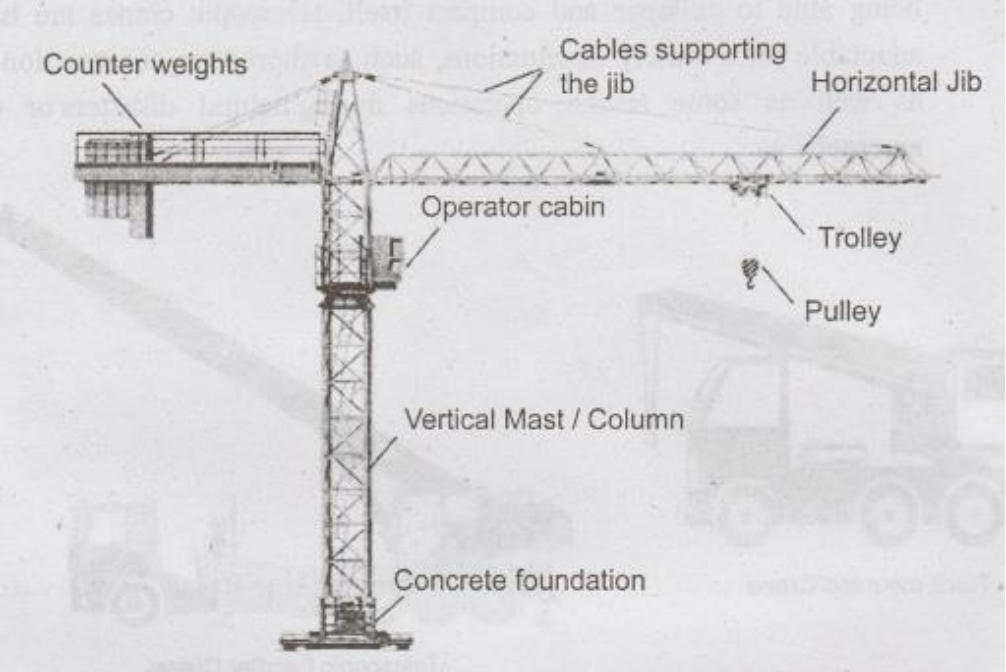


*** Truck Mounted Crane:** These types of cranes are mounted on a rubber tire truck and provide excellent mobility. The outriggers will extend vertically or horizontally and are used to stabilize and level the crane when it is hoisting a load of materials. Truck-mounted cranes are made up of two parts: the carrier (truck), and the boom (arm). Due to their unique build, they're able to travel easily on the road with no unique set up or transportation equipment. Its main advantage is that it can travel on highways itself, which makes it easy and less expensive. It does not need any other vehicles to transport it. They can be rotated up to 180 degrees. But some of them rotate up to 360 degrees but these are more expensive.

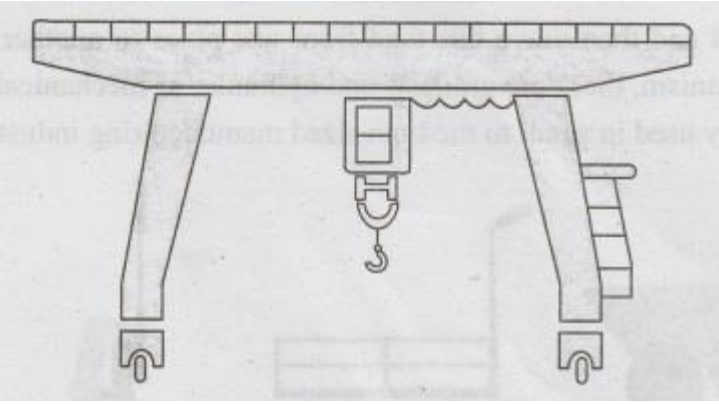
*** Telescopic Handler Cranes:** Telescopic cranes are equipped with a boom (arm) outfitted with a hydraulic cylinder that allows it to change length, like a telescope. The boom has a number of tubes that are fitted inside each other. Then hydraulic mechanisms extend or retract the tubes to length or shorten the boom. Although it's considered a fixed crane, many telescopic cranes are mounted on a truck to transport to and from different worksites. Their main purpose is to handle loads and install frame trusses in buildings. They are designed too simple to improve workability. They can rotate up to 360 degrees and also have outriggers to maintain its stability. They look like forklift trucks. Due to the unique nature of their boom being able to collapse and compact itself, telescopic cranes are highly adaptable for a variety of situations, such as short-term construction jobs as well as some rescue operations during natural disasters or other emergencies.



*** Tower Cranes:** A tower crane is considered to be a modern form of a balance crane and is the mostly used cranes in today's world. Usually, they are fixed to the ground in concrete base or attached to the side of structures. They can lift load up to 30 tons approximately. Due to their size, tower cranes are equipped with an operating cab that controls the entire crane. The operators of the crane mostly use radio signals as a medium for communication to hook or unhook the load. Tower cranes have their jib extending horizontally from the mast (tower part), which itself rests on a concrete base. A travelling jib is able to move up and down, while the fixed jib has an operating dolly that moves materials horizontally. The engine (called a slewing unit) that controls the rotation of the crane sits on the top of the mast. Counterweights are also provided to make the crane more stable while swinging the boom. Due to their size, tower cranes are built along with the building, growing alongside it; once the building is complete, the process is reversed. Commonly used in the construction of tall buildings, tower cranes are awesome machines that offer amazing lifting capabilities.



*** Overhead / Gantry Crane:** The Gantry cranes or overhead cranes are the indispensable machines in factories, workshops. These types of cranes are also known as suspended cranes. In large workshops, there are separate machines for fabrications or repairs of the machine parts. The machine or the components, which are to be repaired, can be transferred to the place of fabrication or assembly with the help of Gantry cranes. Larger overhead cranes (also known as goliath cranes) can be found in use in shipyards and large outdoor manufacturing plants. The hoist is set on a trolley which will move in one direction along one or two beams, which move at angles to that direction along elevated or ground level tracks, often mounted along the side of an assembly area. The most significant difference between a bridge and gantry crane is that the gantry crane is supported by two a- frame steel legs and is typically built on a track.



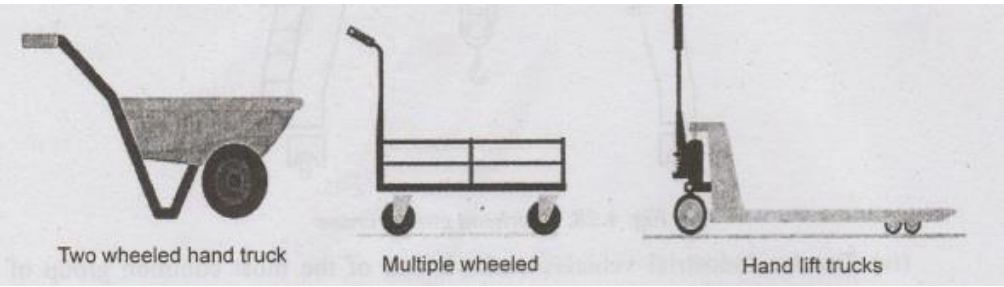
(iv) Trucks: Industrial vehicles/trucks is one of the most common group of materials handling equipment used in industry as well as in day to day distribution of goods in warehouses, large stores, etc. The entire range of industrial vehicles/trucks is generally sub-classified into two group's namely non-powered truck, (also called hand trucks) and powered trucks. The operation and constructional features of some of the common types of industrial trucks are discussed below:

*** Hand trucks:** Hand trucks, as the name implies, have no source of motive power, these are generally moved manually or are attached to other powered moving equipment/units. Hand trucks are classified into three sub groups (i) 2-Wheel hand truck, (ii) multiple-wheel hand truck and (iii) Hand lift truck.

Two-wheel Hand Trucks are generally used for moving unit or unitized loads like bricks, cement bags, barrels, packages etc. by pushing the truck manually. Basically it consists of two long handles fixed by a number of cross bars which from the frame to carry the load. Two wheels mounted on an axle are fixed on far end of the frame. Two short legs are generally fixed to the two handles at the other end to allow the hand truck to stay in a horizontal position during loading and unloading of the truck.

Multiple-wheel Hand Trucks generally consists of a platform or framework mounted on 3 or 4 or more number of wheels. The truck is generally provided with a handle for pushing or pulling the platform. Certain trucks are provided with no handle or detachable handle.

Hand Lift Trucks are provided with a mechanism of lifting its platform, which can be rolled under a pallet or skid, and raised to lift the pallet or skid with load to clear the ground and then move this load from one place to another. Depending on the lifting mechanism, these are grouped into hydraulic or mechanical type. Hand lift trucks are widely used in small to medium sized manufacturing industries.



*** Powered trucks:** When a vehicle / truck contain its own source of motive power, it is called a powered truck. Power trucks are divided into several categories of equipment. The wide varieties of powered industrial trucks have been classified into the following six groups as

* mode of action

* power source

* type of wheel

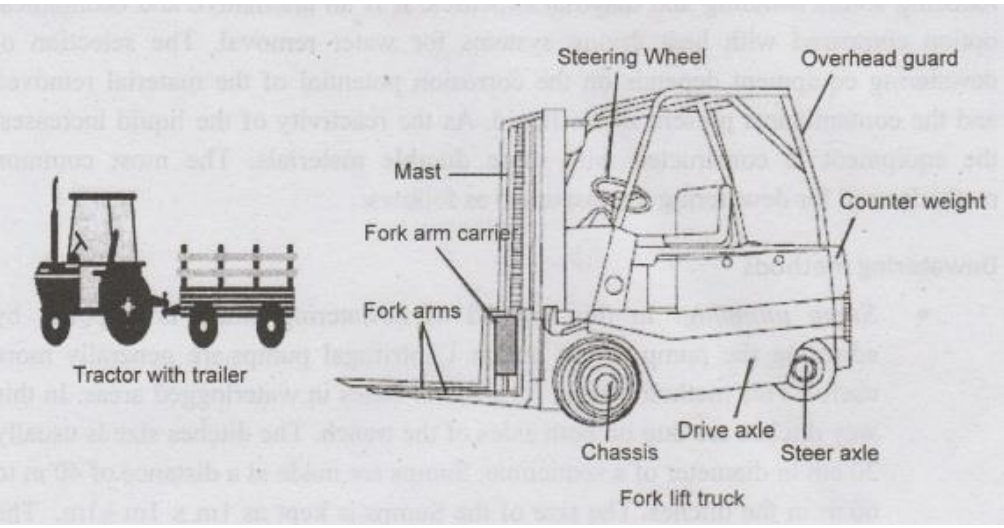
* mode of control

* height of lift

* mode of travel

The powered trucks can be further subdivided into Forklift Truck, Tractor and Dump Trucks.

Fork lift trucks are the most versatile, useful and widely used equipment as industrial lift trucks. These are self loading, counterbalanced, powered, wheeled vehicles, with the operator seating on the vehicle, designed to raise, move and lower load on forks or other attachments fastened to a mast which is fixed in front of the vehicle to allow lifting and stacking of loads. Forklift trucks are used for lifting, lowering, stacking, unstacking, loading and unloading and maneuvering of medium to large weight, uniform shaped unit loads, intermittently. The capacity of this equipment varies from 1 tonne to 60 tonnes. However, the limitations of this equipment are it usually requires pallet/skid/ container for lifting and requires skilled operator. It is suitable for short hauls with a travel speed of 10-15 kmph.



Tractor is a vehicle, having its own source of motive power, used as a prime material handling equipment. It gives motion to another or a group of other vehicles which do not have their own motive power, such as trailers, semitrailers, etc. Tractors have many uses as construction

equipment like earthmoving, aggregates, cement bags, bricks and even water container carrying works. While their primary purpose may be to pull or push loads, they are also used as mounts for many types of accessories, such as front-end shovels, bulldozers and others. There are types and sizes to fit almost any job for which they are usable. Tractors may be divided into two major types as crawler tractors and wheel tractors.

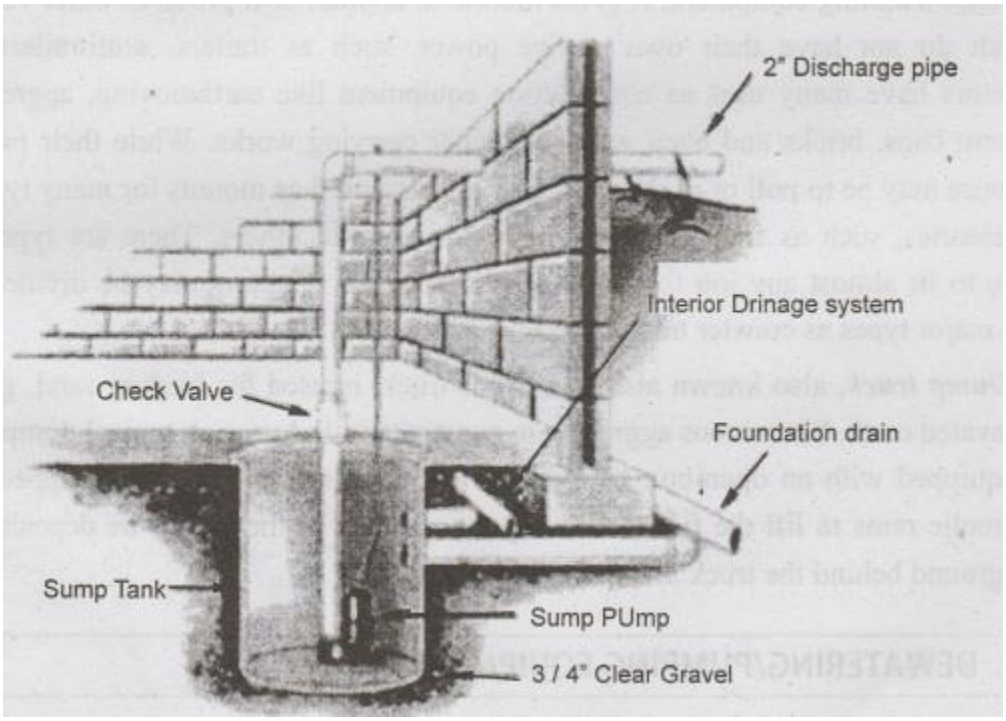
Dump truck, also known also as a tipper truck, is used for hauling sand, gravel, excavated earth, bituminous aggregate in construction industry. A typical dump truck is equipped with an open-box bed, which is hinged at the rear and equipped with hydraulic rams to lift the front, allowing the material in the bed to be deposited on the ground behind the truck at the site of delivery.

DEWATERING/PUMPING EQUIPMENTS

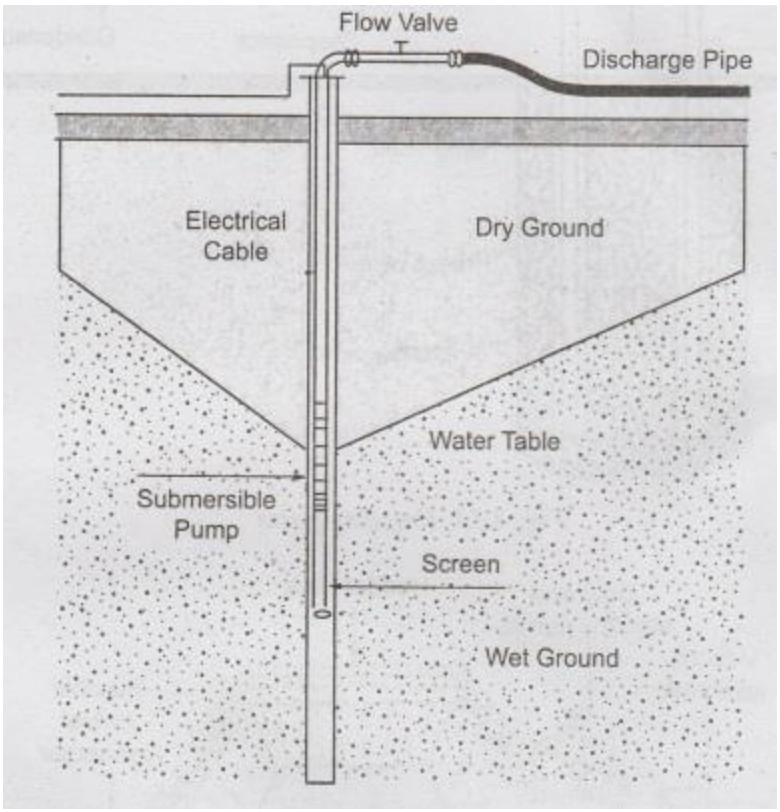
Dewatering equipment are used to perform dewatering on construction sites, which is defined as the process of separating water from another material like saturated soil or sludge. The separation of water is performed by using a force generated by vacuum or centrifugal motion. Dewatering equipment saves money by reducing solids handling and disposal expenses. It is an alternative and economical option compared with heat drying systems for water removal. The selection of dewatering equipment depends on the corrosion potential of the material removed and the contaminants present in the liquid. As the reactivity of the liquid increases, the equipment is constructed with more durable materials. The most common methods used for dewatering are discussed as follows:

Dewatering methods

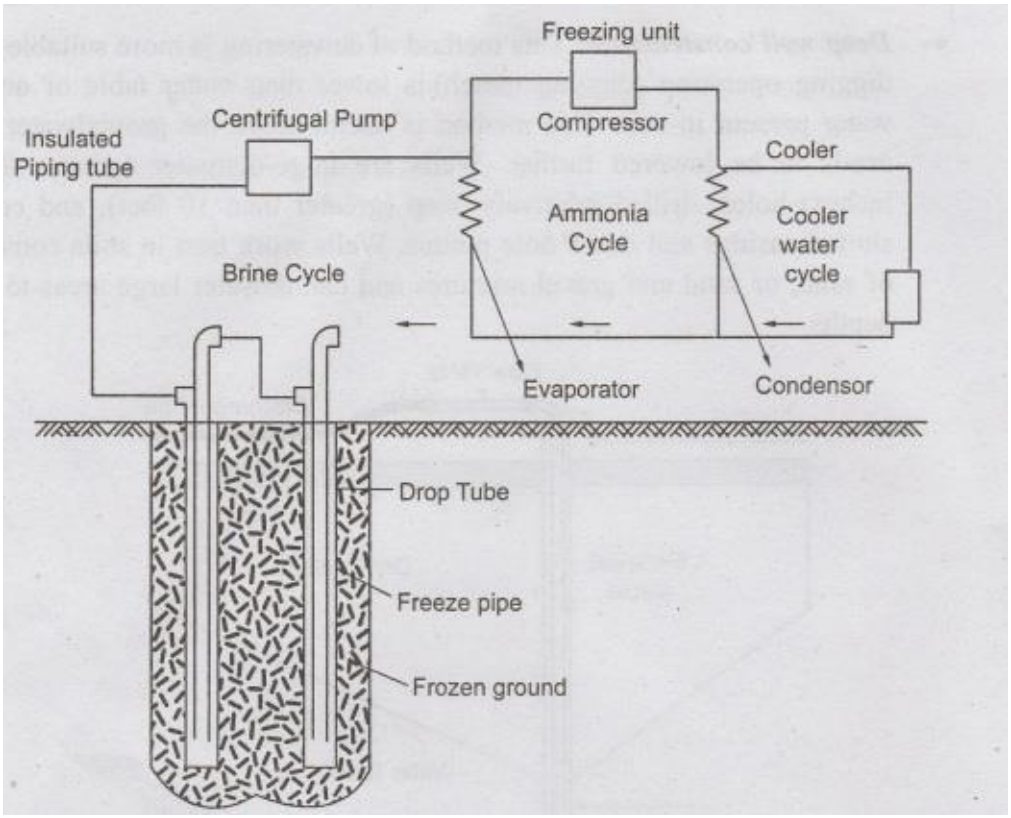
* **Sump pumping:** In this method of dewatering water is disposed by adjusting the pump of the trench. Centrifugal pumps are generally more useful. This method is used for shallow bases in waterlogged areas. In this way ditches are dug on both sides of the trench. The ditches size is usually 20 cm in diameter of a semicircle. Sumps are made at a distance of 40 m to 60 m in the ditches. The size of the Sumps is kept as 1m x 1m xlm. The water flows into the ditches and collects in the Sumps. Water is pumped out from the Sumps continuously.

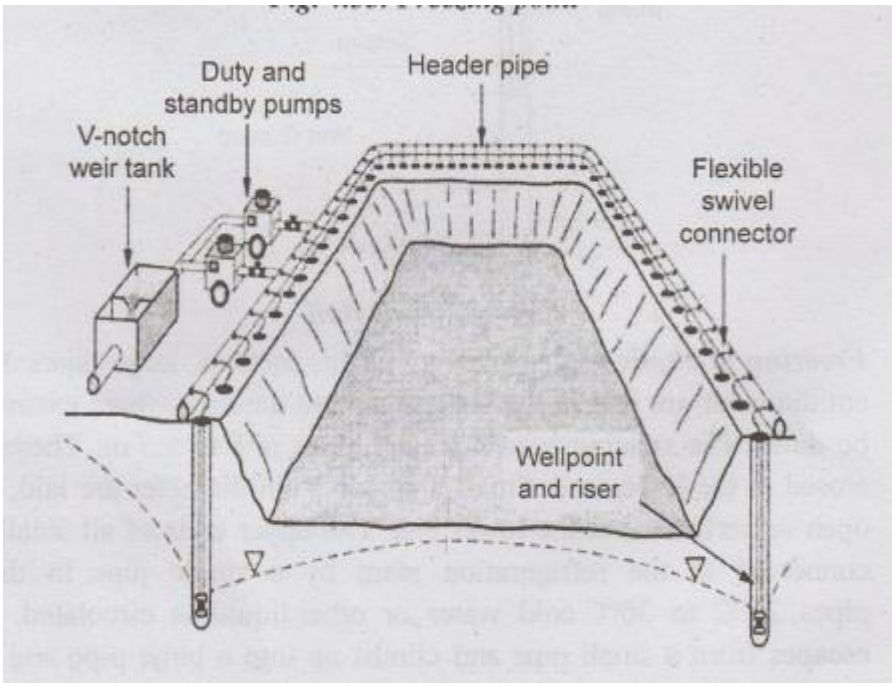


*** Deep well construction:** This method of dewatering is more suitable when digging operation (digging trench) is lower than water table or artesian water present in soil. This method is useful when the groundwater level needs to be lowered further. Wells are large-diameter (greater than 6 inches) holes, drilled relatively deep (greater than 10 feet), and contain slotted casings and down hole pumps. Wells work best in soils consisting of sand, or sand and gravel mixtures and can dewater large areas to great depths.



*** Freezing methods of dewatering:** In this method, large pipes of 10 to 15 cm diameter are laid in the ground around the area where excavation is to be done. The spacing between such pipes is 1 to 1.5 m. These pipes are closed at the lower end. Small pipes of 5 cm diameter are laid, which are open or perforated at the lower end. The upper ends of all small pipes are connected to the refrigeration plant by a single pipe. In these small pipes, 23°C to 30°C cold water or other liquid is circulated. Coldwater escapes from a small pipe and climbs up into a large pipe and returns to the refrigeration plant. This cold water freezes the moist soil and forms a wall of frozen clay.





*** Well points:** In this method of dewatering the ground water flow is te diverted into deep well-points in the ground and the part to be excavated is kept free from ground water. Well points are prepared at a distance of about 1m around the area to be excavated. Water is released at the rate of

20 to 25 liters per second at these well points, which causes the soil to be dug and the well point to sink deeper into the ground. The water edge is maintained for a short time even after the well point has reached the prescribed depth. This creates annular space around the well point as the rises. The water flow is then stopped and filtered material like sand and gravel is filled in the annular space around the well point which stops the filling of soil particles as well as debris at the well point. Well - points are attached to the header with riser, tee-piece, and Swinger arm. The header pipe is paired with a suction pump to create a vacuum in the well-point and riser, so that water from the surrounding land enters the header through the well-point and descends to the ground water table. Well point systems may be single stage or multiple stage:

Single stage system: Water can be lifted from a depth of 5 m with a suction pump. Therefore this method is used where the depth of excavation does not exceed 5 m. The plant is not disturbed until the excavation work is completely completed.

Multiple stage system: When excavation depth is more than 5 m below ground level (W.T.), well-point system is done in phases. In the first stage excavation is carried out to a depth of 5m by arranging the required well-points. In the second stage additional well points are dug into the ground and excavated to a further depth of 5m. This is a way, how well-points are arranged and excavated to a greater depth. The sides of the excavation are given a proper slope.

*** Cement grouting:** Cement grout is a mixture of cement, sand and, water. In this process several holes are made in the ground. Cement grout is forcibly inserted into each of these holes. The grout is filled in the hall until the grout comes out of the hall. Cement grout freezes in stone cracks and clay cavities, making the stone or clay water-tight and monolithic. Minimal channels of resistance are prepared before starting grouting in soft soil. For this at a short distance two bottom perforated pipes are pushed into the soil and water is forcibly inserted in one of them and water is forcibly inserted in the first pipe till water appears in the other pipe. In this way, minimum barrier channel is formed between the two pipes. In this way many other minimal barrier channels are formed in the soil. Then the cement slurry is forcibly inserted in the pipe through which the water has inserted. It is inserted by force and the cement slurry is continued to be inserted until cement slurry appears in the second, perforated pipe. Hence a waterproof layer is formed by forcibly inserting grout into the soil around the channel. And that way the springs of water in the base trenches can be stopped. He or

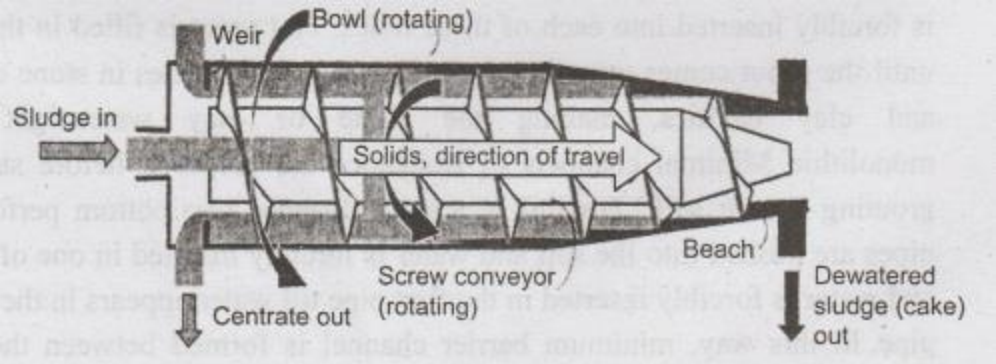
*** Chemical consolidation** of soils: In this method of dewatering, the soil around the area to be excavated is hardened with a solution of chemical compounds like silicate of soda and calcium chloride. In this method also pipes are lowered into the ground. When a pipe is lowered into the

ground, a chemical is forced into it. The first chemical insertion is done after the pipe reaches the appropriate depth. The pipe is then slowly pulled out and at the same time another chemical is forcibly inserted into the pipe. The chemical reaction between these two chemicals makes the soil hard. This method is very costly.

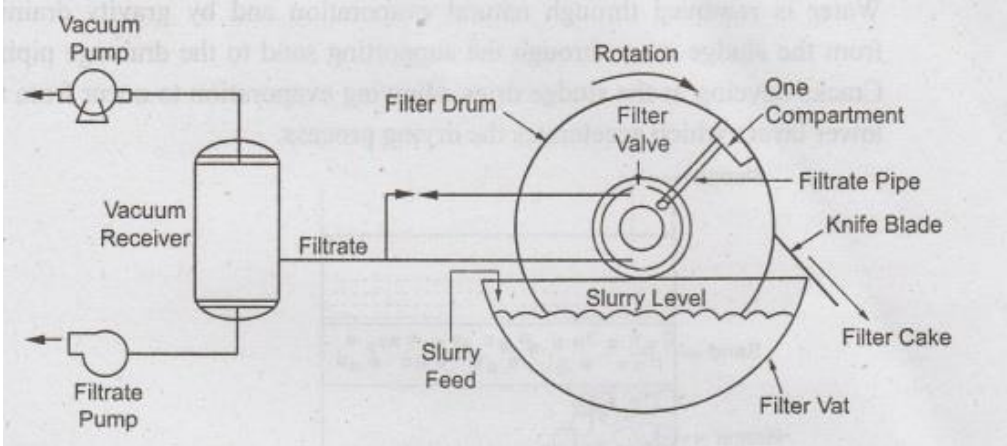
Dewatering equipments

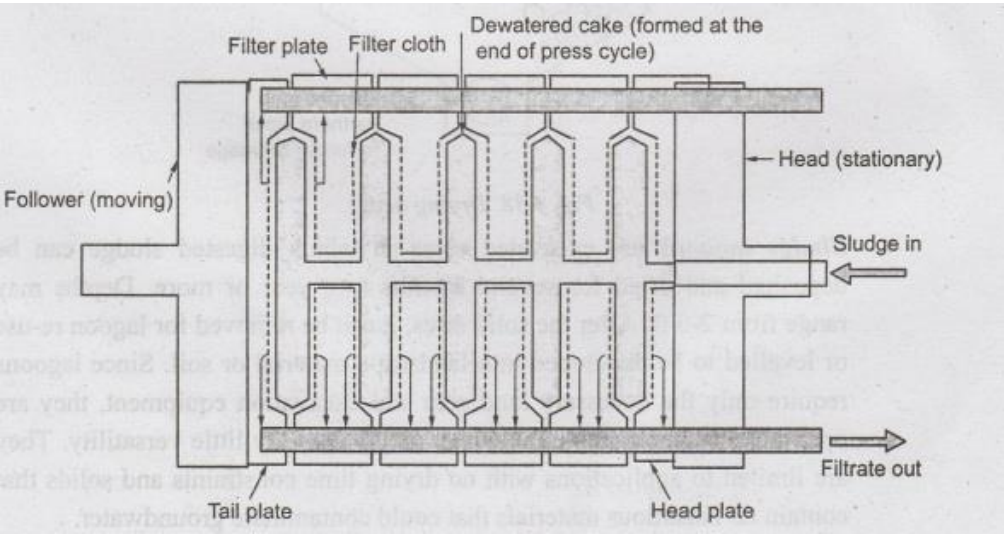
The type of dewatering equipment to be used will depend on the corrosion potential of the material, such as sludge, to be pumped, hazardous contaminants, and so on. Equipment may need to be constructed with durable materials. There are a number of different types of dewatering equipment:

* **Centrifuges** separate solids from liquids through sedimentation and centrifugal force. A bowl, spinning at high speed, separates the water from the solids which are compacted against the bowl walls. Centrifuges remove solids from liquids through the process of sedimentation and centrifugal force. The solids sludge is fed through the stationary feed tube. The sludge moves with acceleration through the ports in the conveyor shaft, which is then distributed to the periphery of the bowl.



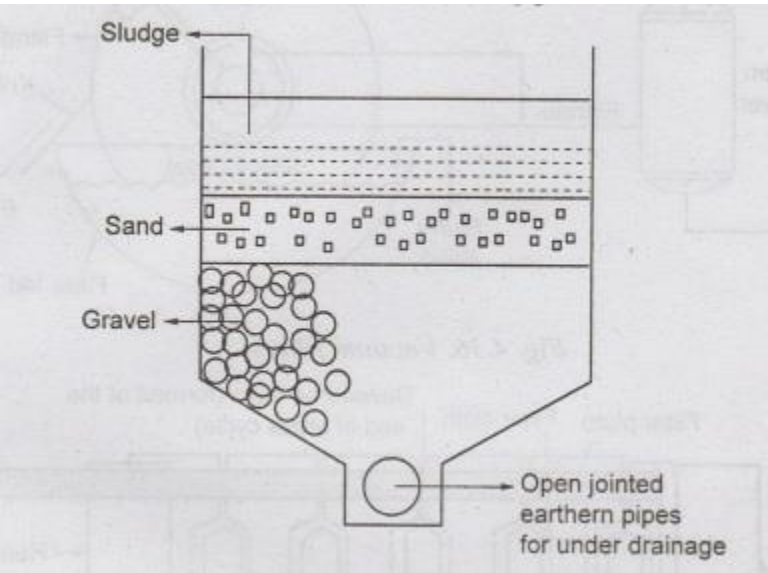
* **Vacuum filters** involve creating a vacuum to draw out water from solids. They can dry solids enough to eliminate the need for subsequent steps such as digestion or heat treatment before disposal, incineration, or usage. A vacuum filter is an equipment that creates a vacuum to draw water from the solids. The filter consists of a drum submerged on a cake or sludge. A filtering medium is placed over the drum. The whole arrangement of valves and pipes is such that vacuum is applied to the inner side of the filter medium when the drum rotates. The rotation of the drum draws water from the sludge. When the drum carries the sludge to the atmosphere, the cake layer formed is chipped by a knife blade.





*** Filter presses** use a porous press to separate solids from liquids. Solids are captured in pores between two or more porous plates, and built up on the surface. Water is forced through the pores either from plate pressure by pushing the plates together or from a build-up of solids pressure by continuously pushing solids into the cavities. This equipment uses a filter medium to separate solids from the liquids. A filter press captures the solids in the pores between two or more porous plates. bom

*** Drying beds** consist of perforated or open joint drainage pipes laid within a gravel base. Sludge is placed on top of a sand layer and allowed to dry. Water is removed through natural evaporation and by gravity draining from the sludge mass through the supporting sand to the drainage piping. Cracks develop as the sludge dries, allowing evaporation to occur from the lower layers which accelerates the drying process.



*** Sludge lagoons** are excavated areas in which digested sludge can be deposited and dried for several months to a year or more. Depths may range from 2-6 ft. After the solid dries, it can be removed for lagoon re-use or levelled to be developed into landscape material or soil. Since lagoons require only the necessary land area and excavation equipment, they are operationally inexpensive; however, they have very little versatility. They are limited to applications with no drying time constraints and solids that contain no hazardous materials that could contaminate groundwater.

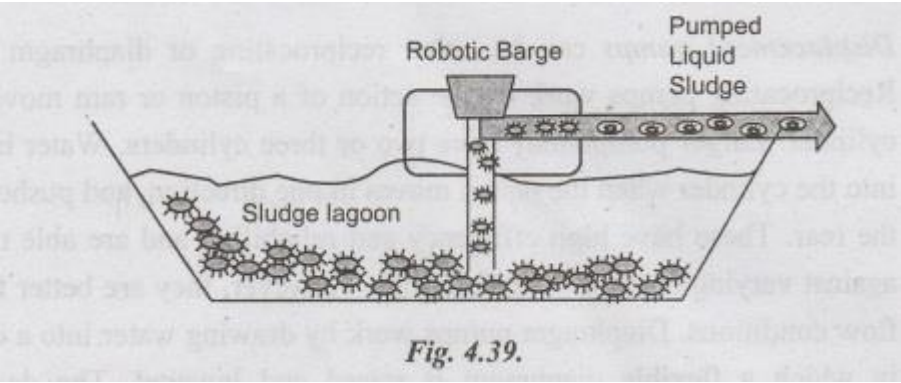


Fig. 4.39.

Pumps simply remove liquid from a volume of liquid, whereas dewatering equipment separates water from another material such as soil or sludge. They can be used for a number of different operations, including:

❖ To keep water out of foundations, pits, tunnels, and other excavations.

❖To lower the water table below excavation level.

❖To pump water out of cofferdams.

❖To supply water for jetting, sluicing and other general purposes.

❖To drying solids and foundation grouting.

The choice of pumping equipment depends on various factors, such as:

❖ The type of liquid to be pumped

❖ The amount of liquid to be moved

❖ The rate at which the liquid needs to be moved

❖ The height of the suction lift - distance from the water to the pump

The different types of pump used for dewatering are discussed below:

* **Centrifugal pumps** contain a rotating impeller which creates a vortex that sucks air out of the hose. Water rises to the pump as a result of atmospheric pressure. Priming involves filling the pump casing with liquid before the pump is started. This is done to prevent the casing becoming filled with vapours or gases that inhibit pumping. Self-priming pumps have a reserve supply of water in the impeller chamber. Air-operated centrifugal pumps, often known as 'sump pumps', consist of a small centrifugal pump fixed to an air motor. These are often used in tunnels and foundation pits to handle sewage, oil or sludge

* **Displacement pumps** can be either reciprocating or diaphragm pumps. Reciprocating pumps work by the action of a piston or ram moving in a cylinder. Larger pumps may have two or three cylinders. Water is drawn into the cylinder when the piston moves in one direction, and pushed out at the rear. These have high efficiency and reliability, and are able to pump against varying heads at a uniform rate. However, they are better for low- flow conditions. Diaphragm pumps work by drawing water into a cylinder in which a flexible diaphragm is raised and lowered. The downward motion of the diaphragm pushes the water out through the delivery pipe. They can pump liquids containing 10-15% solids, and are suitable for work where the flow of water varies greatly.

* **Submersible pumps** can be used for lowering groundwater or removing water from a deep sump. The pump unit is suspended from the rising main or, if a flexible hose is used, from a wire cable. The pump consists of a centrifugal unit and motor mounted in a single cylindrical unit with a space between pump and casing which allows the water to move upwards to the rising main. They are intended for heavy duty work that involves lifting gritty water.

* **Air lift pumps** consist, not of moving parts, but of a long vertical pipe connected to a supply of compressed air. The air carries the water up the pipe to the discharge area. Air lift pumps are often used for moving silt from the base of a cofferdam.

TWO MARKS QUESTIONS AND ANSWERS

1. What are the equipments used for earthwork excavation?

The equipments used for earthwork excavation are:

* Excavators

* Loaders

* Scrappers

* Graders

* Dozers

* Trenchers

2. Name the equipments used for concrete works.

The equipments used for concreting are:

* Batching plant

* Mixers

* Pumps and pipeline

* Vibrators

3. List the factors to be considered for selecting excavating equipment.

While selecting excavating equipment, the following factors should be considered:

* Nature of work

* Method of operation

* Duration of the job

* Machine specification

* Installation and operations costs

* Maintenance and spare costs

4. Write short notes on compact excavator.

A compact or mini excavator is tracked or wheeled vehicle with an approximate operating weight from 0.7 to 7.5 tons. It generally includes a standard backfill blade and features independent boom swing. Hydraulic Excavators are somewhat different from other construction equipment in that all movement and functions of the machine are accomplished through the transfer of hydraulic fluid.

5. Discuss briefly about Backhoe excavator.

Backhoe excavator is a heavy equipment vehicle that consists of a tractor fitted with a shovel/bucket on the front and a small backhoe on the back. Due to its relatively small size and versatility, backhoe loaders are very common in urban engineering and small construction projects such as building a small house, fixing urban roads, etc.,

6. List the different types of wheel loaders.

Wheel loaders may include a variety of types, such as:

* Compact wheel loaders

* Small wheel loaders

* Medium wheel loaders

* Large wheel loaders

7. Name the different types of scrappers.

The different types of scrappers used in construction are:

* Single Engine Wheeled Scrapers

* Dual Engine Wheeled Scrapers

* Elevating Scrapers

* Pull Type Scrapers

8. Write short notes on graders.

A grader, also commonly referred to as a road grader, a blade, a maintainer, or a motor grader, is a construction machine with a long blade used to create a flat surface. Graders are commonly used in the construction and maintenance of dirt roads and gravel roads. They are used to prepare the base course and to create a wide flat surface for the asphalt to be placed on.

9. Discuss briefly about Dozers.

Bulldozers or simply dozers are strong machines that mainly assist with pushing, digging, excavating, and leveling materials like soil and debris at a ptwork site. They come with large, heavy blades with which soil is scraped and He pushed. Some come with other modifications like rippers in the rear to help la break down tough ground.

10. What is the function of a trencher?

Trenchers are heavy machines designed for excavating. They have a metal chain with teeth made of high-strength steel. This allows the machine to tear into of the ground, lifting and moving massive amounts of earth. Because of the sheer size and strength of the machine, trenchers are capable of tearing through heavy tree root systems and densely packed earth. A trencher produces exactly, a clean trench with a flat bottom and smooth walls.

11. List the types of trenchers.

Trenchers come in three types as follows:

* Chain trenchers

* Wheel trenchers

* Micro trenchers

12. Briefly write about concrete batching plant.

Concrete batching plant, mixes various materials to form concrete. These materials include sand, aggregate, slag, cement, fly ash, and water among others. The batching plant comprises of adequate

capacity gravel & sand hoppers, weighing conveyor suspended on electronic load cells, reversible drum type mixer unit, cement bin with screw conveyor, rubber belt type charging conveyor, cement batcher, PLC based control panel.

13. Name the types of concrete batching plants.

Concrete batching plants are of various types as follows:

* Dry mix concrete plant

* Wet mix concrete plant

* Mobile concrete plant

* Stationery concrete plant

14. List the types of concrete mixers.

There are two broad types of concrete mixers which are as follows:

* Batch Mixers

Drum type

* Tilting

* Non-tilting

* Reversing

Pan type

* Continuous mixer

15. Write short notes on Concrete Vibrators.

Concrete vibrator is a mechanical device used to create vibration in wet babe concrete to compact the concrete. Concrete vibrator is fixed with motor and connected with a needle that creates the vibration inside the concrete mix and remove the all air in between the concrete mix. Vibration gives more strength and life to concrete. This concrete equipment is almost used by the entire civil industry from small civil work to large construction**.**

16. What are the essential requirements of a good materials handling system?

The essential requirements of a good materials handling system may be summarized as:

* Efficient and safe movement of materials to the desired place.

* Timely movement of the materials when needed.

* Supply of materials at the desired rate.

* Storing of materials utilizing minimum space.

* Lowest cost solution to the materials handling activities.

17. What do you mean by hoist?

Hoist is a device for raising or lowering a load by means of a drum or wheel lift to which wraps the rope or chain. It can be operated by hand, is driven electrically or pneumatically, and the chain or wire rope fibers are used as lifting device. The load connected to the lifting means of a lifting hook. Pulley, chain hoists and winch are the widely used hoisting equipments:

18. Write short notes on conveyor.

Conveyors are useful for moving material between two fixed workstations, either continuously or intermittently. They are mainly used for continuous or mass material handling operations, and most suitable for operations where the flow is more or less steady. Conveyors may be of various types, with rollers, wheels or belts to help move the material along, and may be power-driven or may roll freely. The decision to provide conveyors must be taken with care, since they are usually costly to install.

19. Define crane.

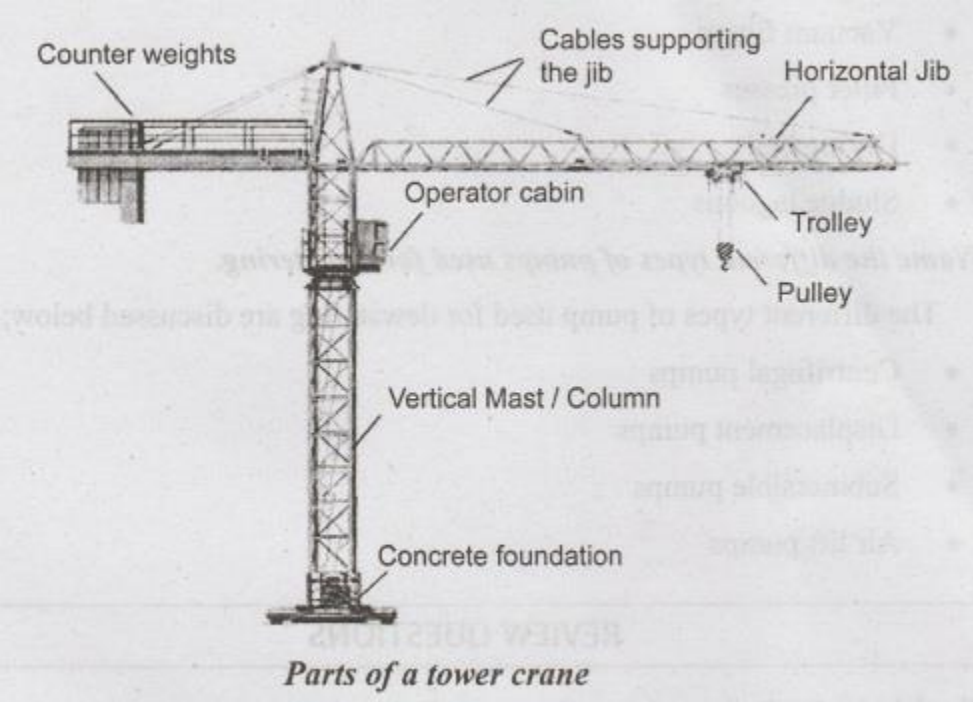
A crane is a piece of heavy machinery that is a tower or platform that is equipped with cables and pulleys. Cranes have a long history of being a staple in construction that reaches back thousands of years. It was during the industrial w revolution that cranes became integral to the modernization of the world, be replacing the manual pulley system with an engine and an operator that preceded bns them.

20. Write about derrick crane.

A derrick is a special type of crane in which the distance from the end of the jib to the pillar can be changed. The derrick cranes are of two types, namely Guy derrick and Stiff leg derrick. Guy derrick can be constructed up to 200 tonnes capacity. In stiff leg type derricks, the guy wires are replaced by trussed to nestructure. This type of derricks is suitable for loads from 10 to 50 tonnes.

21. Draw a tower crane and name its parts.

A tower crane is considered to be a modern form of a balance crane and is the mostly used cranes in today's world. Usually, they are fixed to the ground in concrete base or attached to the side of structures. They can left load up to 30 tons approximately.



Parts of a tower crane

22. Write about forklift trucks.

Fork lift trucks are the most versatile, useful and widely used equipment as industrial lift trucks. These are self loading, counterbalanced, powered, wheeled vehicles, with the operator seating on the vehicle, designed to raise, move and lower load on forks or other attachments fastened to a mast which is fixed in front of the vehicle to allow lifting and stacking of loads. Forklift trucks are used for lifting, lowering, stacking, unstacking, loading and unloading and maneuvering of medium to large weight, uniform shaped unit loads, intermittently.

23. What do you understand by the term dewatering?

Dewatering is defined as the process of separating water from another material like saturated soil or sludge. The separation of water is performed by using a force generated by vacuum or centrifugal motion. The selection of dewatering equipment depends on the corrosion potential of the material removed and the contaminants present in the liquid.

24. List the equipments used for dewatering.

The different types of dewatering equipment used are:

* Centrifuges

* Vacuum filters

* Filter presses

* Drying beds

* Sludge lagoons

25. Name the different types of pumps used for dewatering.

The different types of pump used for dewatering are discussed below:

* Centrifugal pumps

* Displacement pumps

* Submersible pumps

* Air lift pumps

REVIEW QUESTIONS

1. Explain in detail about the earth excavating equipments.

2. Explain about the types of earthwork equipment. Also list the information needed to select the proper equipment.

3. Discuss in detail the different types of loaders.

4. Enumerate the different types of dozers in detail.

5. With a neat sketch explain the components of a scraper.

6. Explain about trenching and the equipments used for trenching.

7. Discuss different types of concreting equipments with neat sketches

8. Write in detail about concrete batching plants.

9. Enumerate in detail about different types of concrete pumps.

10. Explain about the types of material handling equipments and explain with a neat

sketch about any four material handling equipments?

11. Discuss in detail about different types of conveyors.

12. Explain in detail about different types of cranes.

13. Enumerate in detail about different types trucks.

14. Write in detail about the various methods for dewatering.
15. Explain in detail about the equipments needed for dewatering and pumping.

UNIT V

CONSTRUCTION PLANNING

SYLLABUS

Introduction to construction planning - Scheduling for activities - Critical path method (CPM) and PERT network modelling and time analysis Case illustrations.

* Construction planning

* Necessity for planning

* Types of construction planning

* Stages of construction planning

* Construction scheduling

* Classification of scheduling

* Methods of scheduling

* Network analysis

* Network diagram representation

* CPM

* PERT

* Difference between CPM & PERT

* Solved Examples

Construction planning is a primary and demanding activity in the construction management and execution of construction projects. It involves the selection of technology, the definition of work tasks, the estimation of the required resources and durations for individual tasks, and the identification of any relations among the different work tasks. A good construction planning is the basis for estimating the budget and the work schedule. Developing the construction plan is a critical task in the management of construction, even if the plan is not prepared or otherwise formally recorded. In addition to these technical aspects of construction planning, it may also be necessary to make administrative decisions about the relationships between project participants and even which organizations to be included in a project.

CONSTRUCTION PLANNING

Construction planning is an important step when constructing a structure because it summarizes the project and provides guidelines to complete the project in a successful manner. Project in-charges recognize that having a systematic construction plan can save them resource, time and money. Construction planning is the specific process a construction manager uses to lay out how they will manage and execute a construction project, from building design to completion. It lists the activities and schedule for each part of the construction process. A construction plan defines

the scope of work, sets timelines, allocates resources, and establishes communication protocols. It is like a master plan, which ensures the construction project runs smoothly and meets all its deadlines, budget constraints, and quality standards.

NECESSITY FOR CONSTRUCTION PLANNING

Planning is the most important technique of the management. Planning means preparation for the future. It is a thought process requiring the use of planning abilities, resource management, foresight and good decision making. Planning is therefore a course of action to achieve the desired results. Construction planning team should consider the experience gained from past, present and even future weightage in the planning process. Planning is essential to ensure proper utilization of human and material resources to achieve the objectives of the project. Since planning involves the future, it has to be flexible. If at any stage of the project, the expected results are not achieved accordingly to the initial planning, then a revised planning approach is to be adopted. Re-thinking is an important feature of planning. Construction project planning includes the estimate, budget, time schedule, sequences of completion of each activity of the project, resource and manpower planning.

CLASSIFICATION OF CONSTRUCTION PROJECTS

Depending on the nature of the construction facility, major construction projects are classified as follows:

❖ **Building Projects:** Buildings constitute the largest segment of construction business providing shelter and services for habitation, educational, recreational, social and commercial needs. These are mostly designed by engineering firms and architects and financed by Governments, Public and Private Sectors. biug

❖ **Infrastructure Projects:** These projects involve the use of large quantity of bulk materials like earth, steel and concrete. These projects include dams, canals, highways, airport, railways, bridges, docks and harbours, nuclear and thermal power plants and other specialized construction. These are designed by specialist engineering firms.

❖ **Industrial Projects:** These include steel mills, petroleum refineries and many other manufacturing and processing industries. These projects involve heavy investment and are again designed by specialist firms.

❖ **Special-Purpose Projects:** These include projects for protecting the environment, utility service complex operations, etc. and involve the nitors experience of specialized agencies.

STEPS IN THE CONSTRUCTION PLANNING

The following are the steps to be followed in a construction planning:

(i) Project initiation: Every construction project, either big or small, needs to start with a feasibility of the project and the steps to be processed to get the job done. The first step in planning would be to find out the problem or identify the opportunity to be seized. This is necessary to be able to Silos formulate practical and realistic objectives. Generally project starts with a project initiation document (PID), which describes:

❖ The number of workers needed, including contractors and subcontractors such as plumbers and electricians.

❖ Materials needed for the design and building plans.

❖ Total cost estimate of the project, including labor, materials, equipment, fees, and permits.

(ii) Creating the project plan: Next step is the creation of project plan. Here the project initiation document turns into a more concrete construction plan by setting goals that are S.M.A.R.T.

Specific: Specific goals of the project like deadlines for key milestones are fixed. Measurable: Details should be clear in the plan in such a way that, if an activity is completed in the deadline, its achievement rate should be measured or assessed easily.

Attainable: Deadlines for key milestones should be arrived considering the availability of the resources. Buffer time should also be available, in case if alternate sources have to be used. Then only the planned activities can be attained without any lag in the schedule.

Realistic: The goals need to be within the abilities of the project manager. Activities should be planned in a realistic manner considering the required time bound. Instead, if the activities are planned in a hurry to finish, then it may leads to failure.

Timely: A specific time frame should be fixed within which practically the project goals can be achieved.

(iii) Executing the plan: Succeeding step is to execute the plan. After creating a high-level project timeline, including major milestones and key deliverables, details should be mapped out at each project stage. Team meetings should be arranged frequently to discuss about the project plan and construction schedule. Each person of the project team should be addressed individually by the project manager, to narrate the expectations from them and their queries if any should be answered.

(iv) Tracking the project progress: The next step is to accurately track the performance of the construction project team and ensure that the milestones are completed. In the event of an unsuccessful project, this process helps to figure out the reasons for failure and it can be avoided in the future project planning. Successful construction managers typically use key performance indicators (KPIs) to monitor the performance of their projects. Key performance indicators include:

❖ Project objectives

❖ Project performance

❖ Quality of construction

❖ Time schedule

(v) Evaluation of the project: The last step is to evaluate the project after completion. The lessons learned and data gathered from the project will help to approach the next project in a constructive manner. This work will serve as the pre-construction planning for the next project.

With the help of the clearly-defined construction project plan and a way to track performance and obstacles, it is well-equipped to execute an even more successful construction planning process the next time around. A concluding meeting with the project team should be conducted to discuss about the performance of the individuals. To formally close the project, actual project budget should be compared with the original planned budget and the final project report should be drafted to share with the key stakeholders.

OBJECTIVES OF CONSTRUCTION PLANNING.

The main objective of planning is to execute the project most economically within the time schedule. Effective planning includes the following factors:

❖ Each element of the project should be properly designed.

❖ Selecting proper equipment and machinery accordingly to the nature of the project.

❖ Arranging proper maintenance facility for equipment and machinery near the project site to avoid hindrance due to breakdown.

❖ Procuring materials well in advance and stocking at the site to avoid delay due to insufficient storage.

❖ Employing well trained and experienced staff in the project to carry over the activities effectively.

❖ Providing welfare schemes for the staff and workers such as medical and recreational facilities.

❖ Encouraging workers by providing activity based incentives.

❖ Arranging constant flow of funds for completing the project successfully.

❖ Ensuring proper safety measures for the workers such as proper ventilation, proper arrangement of light and water.

PRINCIPLES OF CONSTRUCTION PLANNING

The following points are the principles of construction planning:

❖ The plan should present the information in an easily understandable manner, irrespective of the complex situation in the project.

❖ The plan should be realistic, flexible and comprehensive.

❖ The plan should provide a source for project monitoring and control process.

TYPES OF CONSTRUCTION PROJECT PLANNING

There are several construction project planning methods that project managers can use depending on the scale of the project and the industry they are working with. The following are some of the most common types of construction project planning

❖ **Strategic planning:** When developing a strategic construction project plan, the project manager may meet with corporate planners and the client to odt to sam determine the requirements and expectations, in order to satisfy both the user and the owner of the project. After gathering this data, the project 159 manager creates a master construction delivery plan with specific guidelines to ensure the team completes the project on time.

❖ **Operational planning**: This type of planning may take place after the client approves a strategic plan. In this phase, the project teams come together to expertise a detailed plan with strategic goals and activity steps. They agree on deadlines and work together to complete documents with reports**.**

❖ **Business planning:** A manager usually develops the business plan at the beginning of a project. This type of planning describes the project and includes a chart of what the project should look like, guidelines to execute the project and tasks for specific team members. The business plan also includes a bid for the project and a contract for the client to sign.

❖ **Resource planning:** Creating a resource plan ensures that each project a company is currently working has sufficient staff, materials and resources necessary to be completed successfully and on time. To keep everything organized, project managers often create milestone dates and deadlines, as well as a list of where they plan to allocate necessary resources. This can be beneficial if multiple projects are in progress at the same time.

STAGES OF CONSTRUCTION PLANNING

The various stages in the planning process are:

❖ **Preplanning:-** This is the first stage of planning before a decision has been taken to start the project. During this stage, the objectives are to be clearly pointed and a general framework of the project should be formulated. Also justification for starting the project, a cost benefit analysis and investment alternatives are to be given.

❖ **Detailed Planning:** Second stage of planning includes the preparation of bae detailed design, detailed working drawings, specifications and detailed bill of quantities. Also these type of

planning shows the breaking up of the entire project into small component jobs and also establishing the sequences of various operations and allocation of time duration to the different activities in the project.

❖ **Monitoring and Control:** This is the last phase of planning, which involves monitoring the progress of the project according to the proposed schedule. Also, this stage includes the updating of the schedule, considering the actual progress of the project and preparing revised schedule regarding the availability of the various resources

ADVANTAGES OF CONSTRUCTION PLANNING

The following are the advantages of construction planning:

❖ The contractor can get a clear scenario about the sequence of work, since the construction plan is detailed through sketches, bar charts etc.

❖ It helps to maintain the financial cash flow of the contractor through proper resource management.

❖ Labour requirement can also be managed properly through appropriate planning for each activity.

❖ Various sub activities of the project can also be identified and actual work can be measured easily by the contractor.

❖ The client will know exactly how long it will take to complete the project.

LIMITATIONS OF PLANNING

The following are the limitations of construction planning:

❖ The effectiveness of the plan depends upon the correctness of assumptions.

❖ In certain big projects planning is expensive and might delays action.

❖ Planning encourages a false sense of security.

CONSTRUCTION SCHEDULING

Construction scheduling can be defined as the process of listing all the activities to be carried out with the planned start and completion dates. It is an entire blueprint which shows how the project will be executed and the sequential relationship among the various activities or operations in a project so that work can be carried out in an orderly and effective manner. The schedule outlines project milestones and tracks project progress to keep everything on time and on budget. It's the backbone of a successful project management for construction. The steps involved in construction scheduling are:

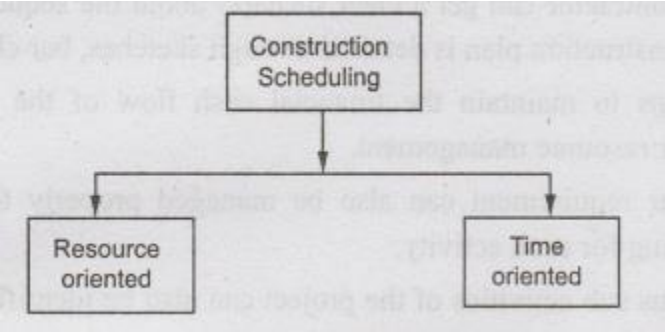
❖ The project is divided into number of operations and the sequences of these operations can be derived after knowing their relationship properly.

❖ The quantity of work involved in each operation has to be calculated. besiver an

❖ The time required for completion of the project and different activities are to be calculated.

CLASSIFICATION OF SCHEDULING

In general, construction scheduling is classified based on two aspects:



Resource-oriented scheduling is one of the most thoughtful construction scheduling methods. As the name suggests, this scheduling technique focuses on identifying the resources available for the construction projects and utilizing them efficiently to avoid wastage while ensuring timely and effective completion. It also reviews the resources, the parties and activities that will need the resources, and the particular time at which it will be required to manage the process efficiently. In time oriented scheduling, the prominence is on determining the completion of the project with the given priority relationships among the activities. Most scheduling software is time-oriented, although practically all of the programs have the capability to introduce resource constraints.

Scheduling can be further classified into different types according to the requirement for which it is done. The various types of construction schedules can be listed as follows:

❖ Construction Material Schedule

❖ Labor Schedule

❖ Equipment Schedule

❖ Financial Schedule

❖ Control Schedule

❖ Organization Schedule

❖ Summary Schedule

METHODS OF SCHEDULING

Construction scheduling can be done depending on the nature of the project. The various methods of scheduling are discussed as follows:

❖ Gantt chart

❖ Q Scheduling

❖ Last Planner System

❖ Line of Balance

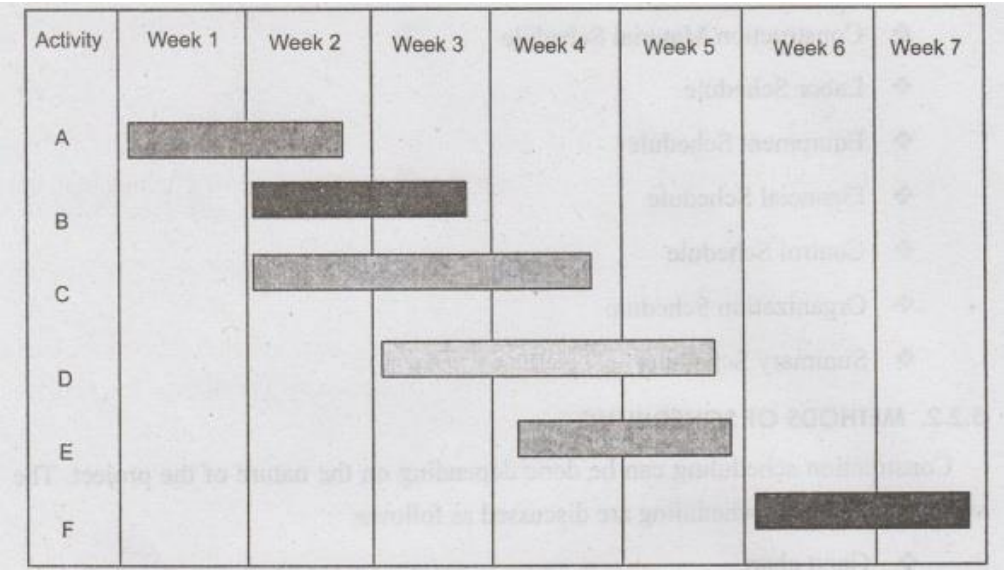
❖ Work breakdown structure

❖ Critical Path Method (CPM)

❖ Program Evaluation and Review Technique (PERT)

Gantt chart:

Henry Gantt (1861-1919), an American mechanical engineer, designed the Gantt chart. Gantt chart is a common construction scheduling method which utilizes the bar charts to depict the plan and the progress of the project. The unique aspect of this scheduling technique is that it highlights the dependency of one task or activity on the other to be completed efficiently in the given time. These are also known as bar charts. A Gantt chart helps in scheduling, managing, and monitoring specific tasks and resources in a project. The chart shows the project timeline, which includes scheduled and completed work over a period. The Gantt chart aids project managers in communicating project status or plans and also helps ensure the project remains on track.



The above figure shows a bar chart which has 6 distinct activities A, B, C, D, E and F which are to be performed in 7 weeks. The chart can be explained as follows:

❖ Activity A is the first activity and it extends upto 2 weeks.

❖ Activity B and C can be started simultaneously, since they are independent of each other.

❖ Activity D can be started only after completion of activity A.

❖ Activity E starts when activity B is completed.

❖ Activity D and E completes in the same time.

❖ Activity F is the last activity and it starts after completion of D and E.

❖ Total duration of the project is 7 weeks.

***Q Scheduling:** Quantitative scheduling, also known as Q scheduling, uses bar charts to visualize resource quantities and the locations in which the resources will be used. It is a different type of construction scheduling method. It focuses on scheduling the materials and equipment used in the project. It provides a clear description of the materials used and required in the project through a bar chart. This type of scheduling essentially provides support against delays due to improper material management. It is one of the least common scheduling methods in construction. It is only used when tasks are repeated, but variable quantities of resources are used.

❖ **Last Planner System:** The last planner system is a unique scheduling method that is more like a planner than a method or tool. The last planner system bridges the gap between the teams or workers. It also devised a construction project schedule to not miss out on the important details. It (atnavel smoothens the communication to follow the schedule efficiently and complete the project on time. It is also termed as Pull planning. This scheduling technique establishes vital project milestones, like the project completion date, then works backward to outline the steps to achieve each milestone quickly and efficiently. The defining features of pull planning are strong collaboration and the backward timeline.

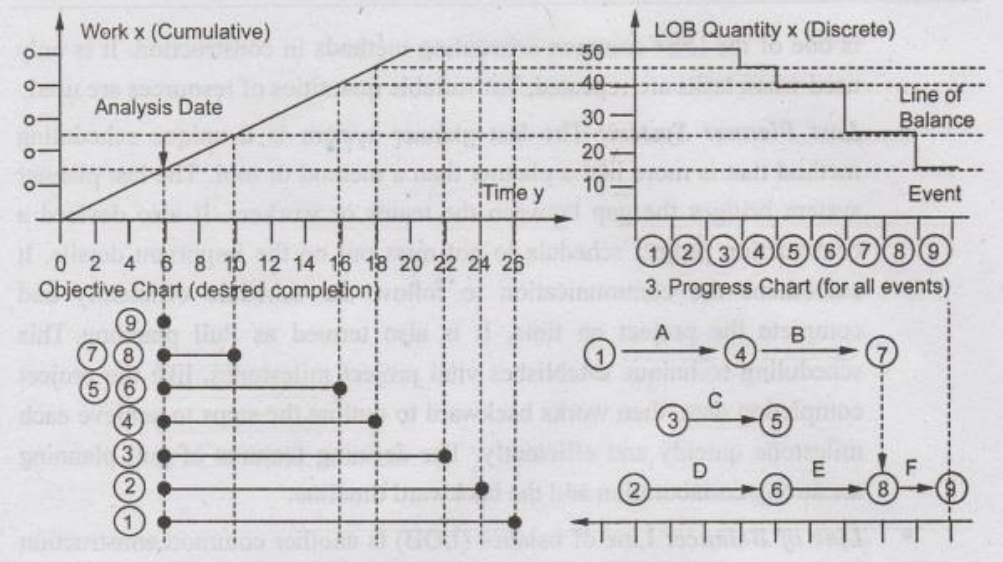
❖ **Line of Balance:** Line of balance (LOB) is another common construction scheduling method. This scheduling method is usually implied in projects that include repetitive activity. The balance scheduling method measures the cost, time, and project completion plan and ensures nothing falls behind the schedule. These type of schedules are very uncommon but are sometimes used when a construction project consists of highly repeatable and similar tasks. These are most commonly used for roadways, pipes, and other horizontal construction projects. For repeated work activities, they allow for intensive cost and time optimization, and it is also much easier to change and update line of balance schedules. LOB is a management control process for collecting, measuring, and presenting facts relating to time, cost, and accomplishment. It shows the process, status, background, timing, and phasing of the project activities, thus providing management with measuring tools that help:

❖ Comparing actual progress with a clear objective plan.

❖ Examining only the deviations from established plans, and gauging their degree of severity with respect to the remainder of the project.

❖ Receiving timely information concerning trouble areas and indicating areas where appropriate corrective action is required. is opsig anbla

❖ Forecasting future performance.



Scheduling with LOB

For preparing a line of balance schedule, the following procedures should be adopted:

❖ Prepare a logic diagram.

❖ Estimate the man-hours required to complete each operation.

❖ Choose buffer times which will guard against the risk of interface between operations.

❖ Calculate the required output target in order to meet a given project completion date.

❖ Complete the LOB schedule.

❖ Examine the schedule and assess possible alternatives to bring about a more 'balanced' schedule.

Advantages of Line of Balance (LOB)

The benefits of using the LOB technique are

❖ A better understanding of the amount of work taking place at a certain time in a specific place.

❖ Optimized resources for a large number of repeated work activities.

❖ Allows easier cost and time optimization analysis.

❖ Easy to modify, update and change the schedule.

❖ Better management of subcontractors and resources.

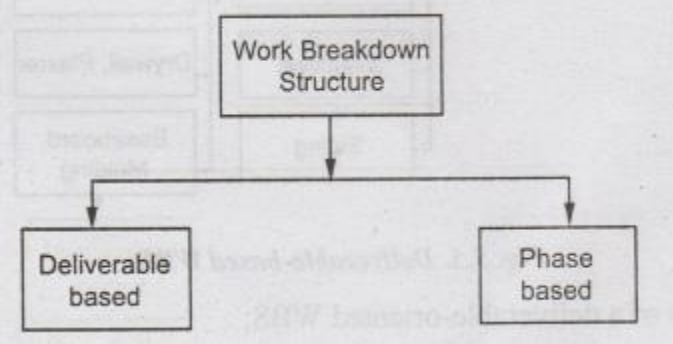
❖ Identifies issues in advance.

Work breakdown structure:

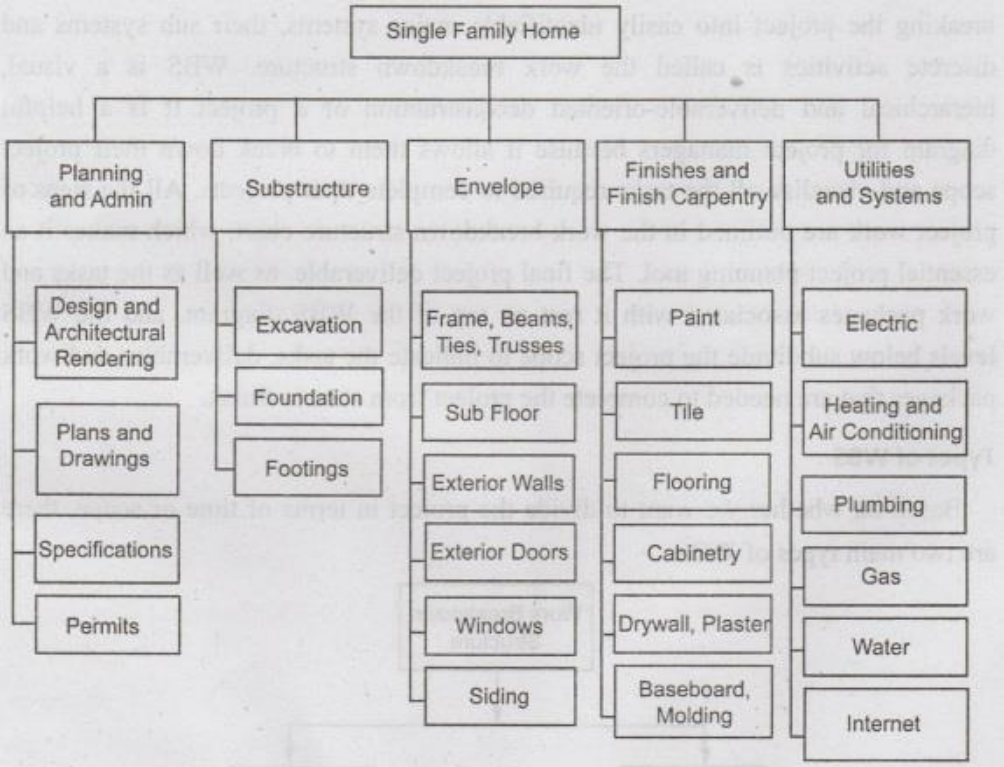
The Work breakdown structure (WBS) is the tool that is used to record and communicate the project deliverables and sub-deliverables as well as the accomplishments and sub-accomplishments. In any construction project, the various activities that make up the project have to be clearly identified. The process of breaking the project into easily identifiable major systems, their sub systems and discrete activities is called the work breakdown structure. WBS is a visual, hierarchical and deliverable-oriented deconstruction of a project. It is a helpful diagram for project managers because it allows them to break down their project scope and visualize all the tasks required to complete their projects. All the steps of project work are outlined in the work breakdown structure chart, which makes it an essential project planning tool. The final project deliverable, as well as the tasks and work packages associated with it rest on top of the WBS diagram, and the WBS levels below subdivide the project scope to indicate the tasks, deliverables and work packages that are needed to complete the project from start to finish.

Types of WBS

Based on whether we want to divide the project in terms of time or scope, there are two main types of WBS:



(i) Deliverable-based WBS: A deliverable-based WBS initially breaks down the project into all the major areas of the project scope as control accounts, and then divides those into project deliverables and work packages. Many construction specialists favor a deliverable-oriented (or product-oriented) WBS, which revolves around tangible deliverables, not processes. In construction, the elements of a deliverable-oriented WBS are physical components of the building or interim deliverables that you need in order to produce pieces of the building. Interim deliverables can include plans and specifications. The components of a deliverable-oriented WBS are nouns rather than verbs, because this particular structure focuses on the physical products of a project rather than on processes.



The advantages of a deliverable-oriented WBS:

❖ It simplifies the process of cost estimating.

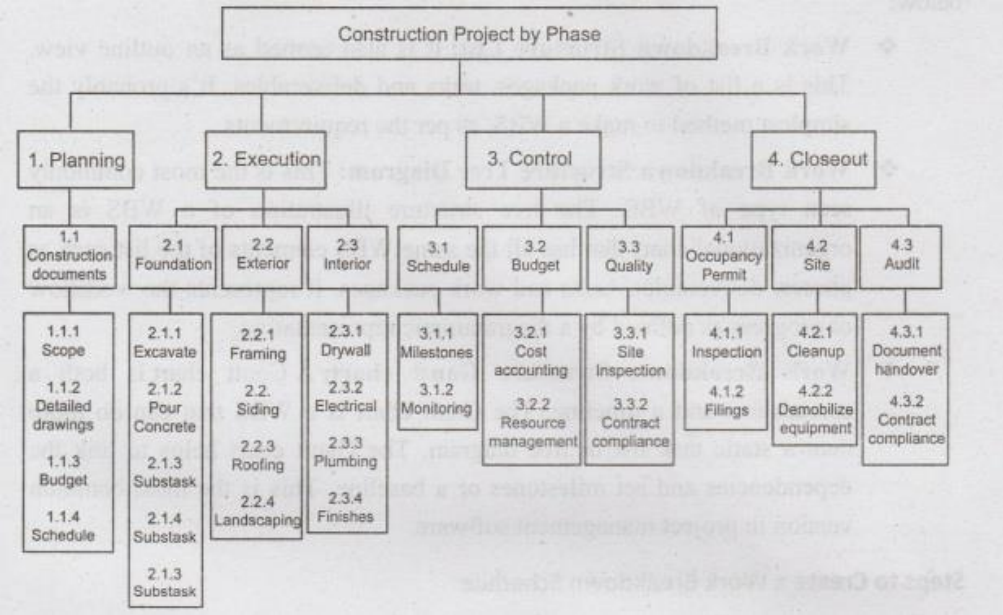
❖ It allows us to see the total work scope.

❖ It clarifies the relationships among elements.

❖ It can be used during all project phases.

❖ It's easier to modify as the project changes.

❖ It supports earned value management.



(ii) Phase-Based WBS: Alternatively, a phase-based WBS divides construction into steps or stages. This kind of WBS focuses on the processes you require to achieve the deliverables. Verbs rather than nouns appear in this type of WBS. This kind of document is also known as a process-oriented, task-oriented, or activity-oriented work breakdown structure. A construction manager divides the project into its component gojni i activities. In the graphical representation of a phase-based WBS, these qactivities often proceed in chronological order. The phase-based WBS TOY 101 2sharose in part to ease the transition from a deliverable WBS to a project schedule. Planners translate the deliverables into activities and milestones, then create a project schedule network diagram. This diagram, which consists of boxes and corresponding arrows indicating the flow of work, is the basis of the project schedule.

Types of WBS Schedule

The various types of work breakdown structure schedule charts are discussed below:

❖ **Work Breakdown Structure List:** It is also termed as an outline view. This is a list of work packages, tasks and deliverables. It's probably the simplest method to make a WBS, as per the requirements.

❖ **Work Breakdown Structure Tree Diagram**: This is the most commonly seen type of WBS. The tree structure illustration of a WBS is an organizational chart that has all the same WBS

elements of the list such as phases, deliverables, tasks and work packages. It represents the workflow or progress as defined by a diagrammatic representation.

❖ **Work Breakdown Structure Gantt chart:** A Gantt chart is both a spreadsheet and a timeline. The Gantt chart is a WBS that can do more than a static task list or tree diagram. The Gantt chart helps to link the dependencies and set milestones or a baseline. This is the most common version in project management software.

Steps to Create a Work Breakdown Schedule

To create a WBS for a construction project, there are six simple steps to be followed:

❖ Define the Project Scope, Goals and Objectives - Project goals and objectives set the rules for defining the project scope. Project scope, team members, goals and objectives should be documented in the project charter.

❖ Identify Project Phases & Control Accounts - The next level down is the project phases: larger project activity statements are split into a series of phases that will take it from conception to completion. Control accounts can also be created, which are task categories for different work areas which can be tracked.

❖ **List the Project Deliverables -** Project deliverables should be listed and the work needed for those project deliverables are also noted (sub-deliverables, work packages, resources, participants, etc.).

❖ **Set WBS Levels** - The WBS levels make the work breakdown structure as a "hierarchical deconstruction of the project scope". The final project deliverables are to be started and all the deliverables and work packages needed to get there from the start.

❖ **Create Work Packages -** The deliverables are split down into every single task and subtask that is necessary to deliver them. These are then grouped into work packages.

❖ **Choose Task Owners -** With the tasks now laid out, it can be assigned to the project team. Each team member will be provided with the work management tools, resources and authority they need to get the job done.

❖ **Critical Path Method:** The critical path method is one of the most common construction scheduling methods, and it is also called a critical path analysis. This type of schedule is developed by creating a network diagram highlighting the sequence of tasks and projects following the specific path. The CPM creates a schedule based on critical activities, which must be completed before another activity can begin. Once critical activities are identified, they are scheduled in sequence to determine the least amount of time a construction project can be completed.

❖ **Program Evaluation and Review Technique (PERT):** The program evaluation and review technique is one of the most critical construction scheduling methods. This is because it pays more attention to analyze all the individual project activities. In other words, PERT evaluates and reviews the project's activities in progress and evaluates the time duration in which they will be completed.

USES OF CONSTRUCTION SCHEDULING

The main uses of construction scheduling can be listed as follows:

❖ Construction scheduling gives information regarding the quantity of work, labour, machinery, equipment etc required for a particular period.

❖ The progress of the work and the expenditure can be checked and duly adjusted.

❖ The project can be completed systematically and effectively.

ADVANTAGES OF CONSTRUCTION SCHEDULING

The major benefits of construction scheduling are as follows:

❖ The resources required at various phases of work execution can be listed and duly procured thereby preventing the shortage and overbuying of resources.

❖ The alternative methods of work execution can be evaluated and the most feasible alternative can be selected.

❖ The work progress can be well monitored and evaluated.

❖ Construction scheduling delivers the starting and completion dates of each activity and thus optimization of resources can be managed.

❖ It prevents undue delay and extension of time.

❖ It helps to complete the entire project within the planned approved budget preventing cost overrun

CPM AND PERT NETWORK MODELLING AND TIME ANALYSIS

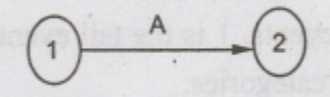
Any project involves planning, scheduling and controlling a number of interrelated activities with use of limited resources like, men, machines, materials, money and time. The projects may be extremely large and complex such as construction of a power plant, a highway, a shopping complex, ships and aircraft. It is required that managers must have a dynamic planning and scheduling system to produce the best possible results and also to react immediately to the changing conditions and make necessary changes in the plan and schedule.

A convenient analytical and visual technique of PERT and CPM prove extremely valuable in assisting the managers in managing the projects. PERT and CPM are basically time-oriented methods in the sense that they both lead to determination of a time schedule for the project. The significant difference between two approaches is that CPM is an activity oriented network while PERT is event oriented. CPM has single time estimate which is assumed to be deterministic and PERT has three time estimates for activities and uses probability theory to find the chance of reaching the scheduled time.

NETWORK DIAGRAM REPRESENTATION

In a network representation of a project the following representations are used:

Activity: Any individual operation which utilizes resources and has an end and a beginning is called activity. An arrow is commonly used to represent an activity with its head indicating the direction of progress in the project.



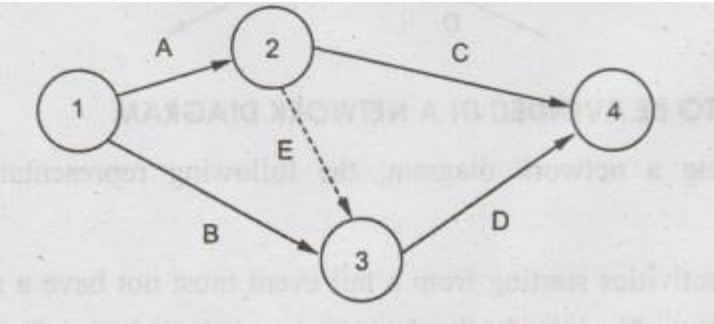
Here 'A' is the activity. These are classified into four categories:

(i) Predecessor activity - Activities that must be completed immediately prior to the start of another activity are called predecessor activities**.**

(ii) Successor activity - Activities that cannot be started until one or more of other activities are completed but immediately succeed them are called successor activities.

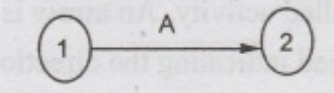
(iii) Concurrent activity - Activities which can be accomplished concurrently are known as concurrent activities. It may be noted that an activity can be a predecessor or a successor to an event or it may be concurrent with one or more of other activities.

(iv) Dummy activity An activity which does not consume any kind of resource and time is called a dummy activity. Dummy activities are simply used to represent a connection between events in order to maintain logic in the network. It is represented by a dotted line in a network.



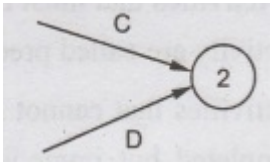
In the above example, A and B are preceding activities. C is dependent on activity A and D is dependent on activity B. Also A and B are concurring activities, since they are starting at the same time. Activity E is the dummy activity and it is marked as dotted line.

❖ **Event:** An event represents a point in time signifying the completion of some activities and the beginning of new ones. This is usually represented by a circle in a network which is also called a node or connector.

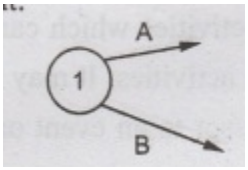


Here '1' and '2' are called events. 1 is the tail event and 2 is the head event. The events are classified in to three categories:

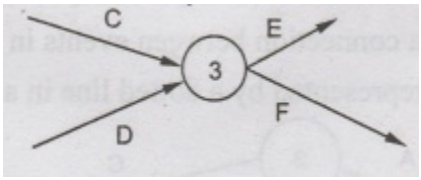
(i) Merge event - When more than one activity comes and joins an event such an event is known as merge event.



(ii) Burst event - When more than one activity leaves an event such an event is known as burst event.



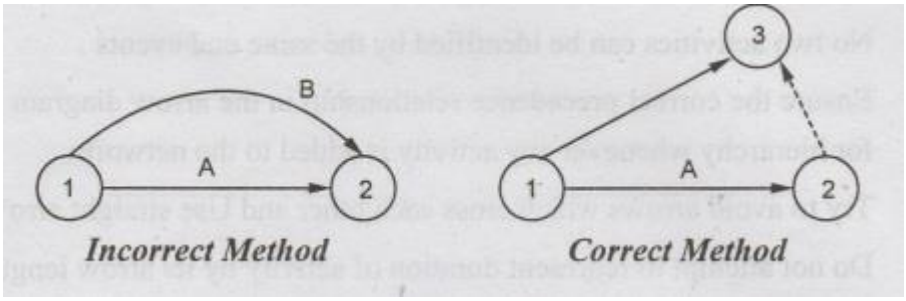
(iii) Merge and Burst event - An event may be merge and burst event at the same time as with respect to some activities it can be a merge event and with viorespect to some other activities it may be a burst event.b



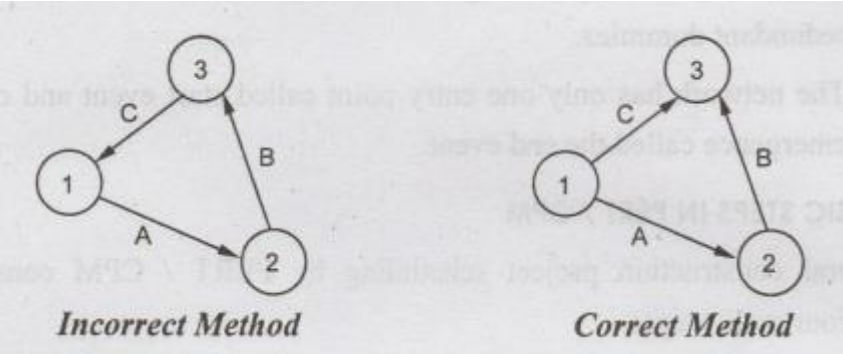
ERRORS TO BE AVOIDED IN A NETWORK DIAGRAM

While drawing a network diagram, the following representations should be avoided:

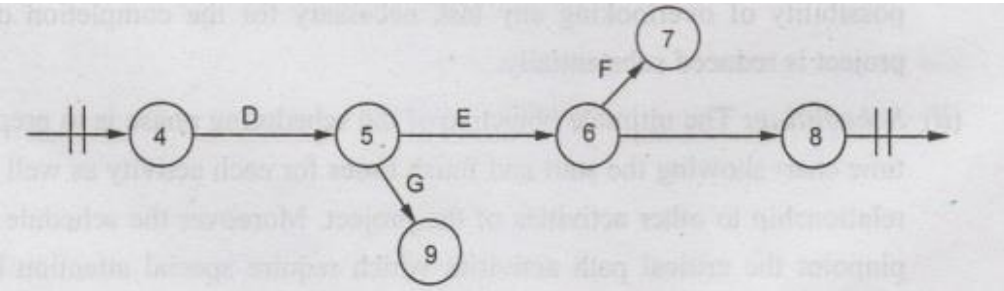
(i) Two activities starting from a tail event must not have a same end event. To ensure this, it is absolutely necessary to introduce a dummy activity.



(ii) Looping error should not be formed in a network, as it represents performance of activities repeatedly in a cyclic manner.



(iii) Dangling: To disconnect an activity before the completion of all activities in a network diagram is known as dangling. As shown in the figure activities (59) and (6-7) are not the last activities in the network. So the diagram is wrong and indicates the error of dangling



RULES FOR DRAWING NETWORK DIAGRAM

For a perfect network diagram, the following rules should be followed:

❖ Each activity is represented by one and only one arrow in the network

❖ No two activities can be identified by the same end events

❖ Ensure the correct precedence relationship in the arrow diagram and check for hierarchy whenever any activity is added to the network

❖ Try to avoid arrows which cross each other and Use straight arrows

❖ Do not attempt to represent duration of activity by its arrow length

❖ Use arrows from left to right. Avoid mixing two directions, vertical and standing arrows may be used if necessary.

❖ Use dummies freely in rough draft but final network should not have any redundant dummies.

❖ The network has only one entry point called start event and one point of emergence called the end event.

BASIC STEPS IN PERT / CPM

In general construction project scheduling by PERT / CPM consists of the following four main steps:

(i) Planning: The planning phase is started by splitting the total project in to small projects. These smaller projects in turn are divided into activities and are analyzed by the department or section. The relationship of each activity with respect to other activities are defined and established and the corresponding responsibilities and the authority are also stated. Thus the possibility of overlooking any task necessary for the completion of the project is reduced substantially.

(ii) Scheduling: The ultimate objective of the scheduling phase is to prepare a time chart showing the start and finish times for each activity as well as its relationship to other activities of the project. Moreover the schedule must pinpoint the critical path activities which require special attention if the project is to be completed in time. For non-critical activities, the schedule must show the amount of slack or float times which can be used advantageously when such activities are delayed or when limited resources are to be utilized effectively.

(iii) Resource allocation: Allocation of resources is performed to achieve the desired objective. A resource is a physical variable such as labour, finance, equipment and space which will impose a limitation on time for the project. When resources are limited and conflicting, demands are made for the same type of resources a systematic method for allocation of resources become essential. Resource allocation usually incurs a compromise and the choice of this compromise depends on the judgment of managers.

(iv) Controlling: The final phase in project management is controlling. Critical path methods facilitate the application of the principle of management by expectation to identify areas that are critical to the completion of the project. By having progress reports from time to time and updating

the network continuously, a better financial as well as technical control over the project is exercised. Arrow diagrams and time charts are used for making periodic progress reports. If required, a new course of action is determined for the remaining portion of the project.

In addition to these basic steps essentially, there are six steps which are common to both the CPM and PERT techniques. They are listed as follows:

(i) Define the Project and all of its significant activities or tasks. The Project (made up of several tasks) should have only a single start activity and a single finish activity.

(ii) Develop the relationships among the activities. Decide which activities must precede and which must follow others.

(iii) Draw the "Network" connecting all the activities. Each Activity should have unique event numbers. Dummy arrows are used where required to avoid giving the same numbering to two activities.

(iv) Assign time and/or cost estimates to each activity

(v) Compute the longest time path through the network. This is called the critical path.

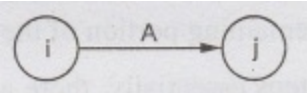
(vi) Use the Network to help plan, schedule, and monitor and control the sonog project.

CRITICAL PATH METHOD IN NETWORK ANALYSIS

Critical Path Method (CPM) was developed in the late 1950s as a method to resolve the issue of increased costs due to inefficient scheduling. Since then, CPM has become popular for planning projects and prioritizing tasks. It helps to break down complex projects into individual tasks and gain a better understanding of the project's flexibility. The Key Concept used by CPM is that a small set of activities, which make up the longest path through the activity network control the entire project. Such activity is called as critical activity. A critical path in project management is the longest sequence of activities that must be finished on time in order for the entire project to be complete. Any delays in critical tasks will delay the rest of the project. Non-critical activities can be re-planned, rescheduled and resources for them can be reallocated flexibly, without affecting the whole project. CPM revolves around discovering the most important tasks in the project

timeline, identifying task dependencies, and calculating task durations. CPM has single time estimate which is assumed to be deterministic.

Basic Scheduling Computations in CPM



The basic notations used in CPM can be explained as follows:

For the given example,

(i,j) = Activity "A" with tail event "i" and head event "j"

E_i = Earliest occurrence time of event i

E_j = Latest al owable occurrence time of event j

D_{ij} = Estimated completion time of activity (i, j)

$(E_S)_U$ = Earliest starting time of activity (i, j)

$(E_F)_{ij}$ = Earliest finishing time of activity (i, j)

$(L_S)_{ij}$ = Latest starting time of activity (i, j)

$(L_f)_{ij}$ = Latest finishing time of activity (i, j)

(i) Determination of Earliest time (E_j): Forward Pass computation

Step 1

The computation begins from the start node and move towards the end node. For easiness, the forward pass computation starts by assuming the earliest occurrence time of zero for the initial project event.

Step 2

Earliest starting time of activity (i, j) is the earliest event time of the tail end event

i.e. $\mathbf{(E_s)_{ij} = E_i}$

Earliest finish time of activity (i, j) is the earliest starting time + the activity time

i.e. $(E_f)_{ij} = (E_s)_{ij} + D_{ij}$ **or** $(E_f)_{ij} = E_i + D_{ij}$

Earliest event time for event j is the maximum of the earliest finish times of all activities ending in to that event

i.e. E_j **= max [**$(E_f)_{ij}$ **for all immediate predecessor of (i, j)] or**

$E_j = \max [E_i + D_{ij}]$

(ii) Backward Pass computation (for latest allowable time)

Step 1

For ending event assume E = L.

Also all E's have been computed by forward pass computations.

Step 2

Latest finish time for activity (i, j) is equal to the latest event time of event j.

i.e. $(L_f)_{ij} = L_j$

Step 3

Latest starting time of activity (i, j) = the latest completion time of (i, j) - the activity time bollo ons omisioak

i.e. $(L_s)_{ij} = (L_f)_{ij} - D_{ij}$ **or** $(L_s)_{ij} = L_j - D_{ij}$

Step 4

Latest event time for event " is the minimum of the latest start time of all activities originating from that event

i.e**.** L_i **= min [**$(L_s)_{ij}$ **for all immediate successor of (i, j)] min** $[L_f)_{ij} - D_{ij}] = \min [L_j - D_{ij}]$

(iii) Determination of floats and slack times

There are three kinds of floats as follows:

❖ **Total float -** The amount of time by which the completion of an activity could be delayed beyond the earliest expected completion time without affecting the overall project duration time.

$(T_f)_{ij}$ Latest start - Earliest start) for activity (i −j)

i.e. = $\mathbf{(T_f)_{ij} = (L_s)_{ij} - (E_s)_{ij}}$ **or** $\mathbf{(T_f)_{ij} = (T_L - T_E) - t_{ij}}$

❖ **Free float** The time by which the completion of an activity can be delayed beyond the earliest finish time without affecting the earliest start of a subsequent activity.

$(F_f)_{ij}$ = Total float - Head event slack

i.e. $\mathbf{(F_f) = (E_j - E_i) - t_{ij}}$

❖ **Independent float -** The amount of time by which the start of an activity can be delayed without effecting the earliest start time of any immediately following activities, assuming that the preceding activity has finished at its latest finish time. The negative independent float is always taken as zero.

$(I_f)_{ij}$ = Free float - Tail event slack

i.e. $(I_f)_{ij} = (E_j - L_i) - t_{ij}$

❖ **Event slack -** It is defined as the difference between the latest event and earliest event times.

Head event slack = $L_j - E_j$

Tail event slack = $L_i - E_i$

(iv) Determination of critical path

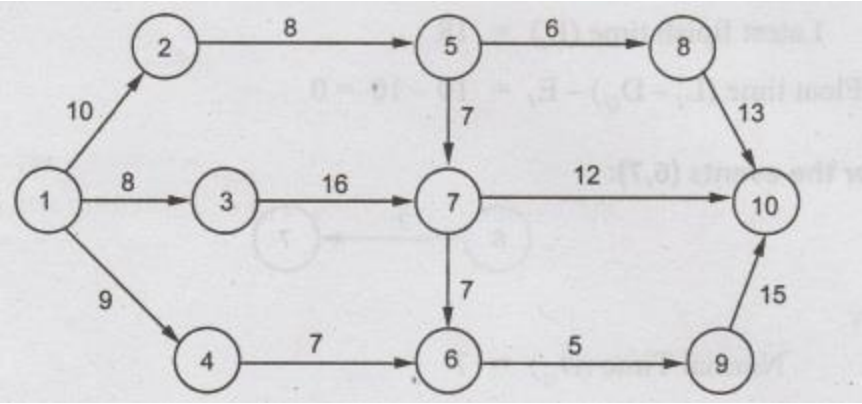
❖ **Critical event** - The events with zero slack times are called critical events. In other words the event i is said to be critical if $E_i = L_i$

❖ **Critical activity -** The activities with zero total float are known as critical activities. In other words an activity is said to be critical if a delay in its start will cause a further delay in the completion date of the entire project.

❖ **Critical path -** The sequence of critical activities in a network is called critical path. The critical path is the longest path in the network from the starting event to ending event and defines the minimum time required to complete the project.

Example 1 :

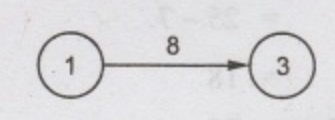
Determine the early start and late start in respect of all node points and identify critical path for the following network.



Solution:

In the networks shown, there are many paths by which the last event can be achieved.

Consider the events (1, 3):



Here,

Normal Time (D_{ij}) = 8

Earliest Start time (E_i) = 0 (Event 1 has no preceding event E_i = 0)

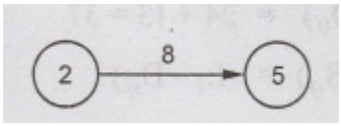
Earliest finish time ($E_i + D_{ij}$) = 0+8=8

Latest start time (LS_{ij}) = (L_i-D_{ij}) = 9-8=1

Latest finish time (L_i) = 9

Float time (L_i -D_{ij}) – E_i = 1-0 = 1

Consider the events (2,5):



Here,

Normal Time (D_{ij}) = 8

Earliest Start time (E_i) = 10

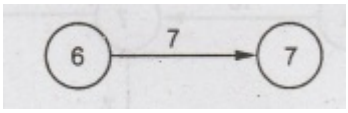
Earliest finish time ($E_i + D_{ij}$) = 10+8 =18

Latest start time (LS_{ij}) = ($L_i - D_{ij}$) = 18-8=10

Latest finish time (L_i) = 18

Float time ($L_i - D_{ij}$) - E_i = 10-10 = 0

Consider the events (6,7):



Normal Time (D_{ij}) = 7

Earliest Start time (E_i) = 16

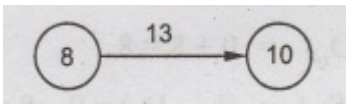
Earliest finish time ($E_i + D_{ij}$) = 16+7 =23

Latest start time (LS_{ij}) = ($L_i - D_{ij}$) = 25-7=18

Latest finish time (L_i) = 25

Float time ($L_i - D_{ij}$) - E_i = 18-16 = 2

Consider the events (8, 10):



Here,

Normal Time (D_{ij}) = 13

Earliest Start time (E_i) = 24

Earliest finish time ($E_i + D_{ij}$) = 24+13 =37

Latest start time (LS_{ij}) = ($L_i - D_{ij}$) =37-13=24

Latest finish time (L_i) = 37

Float time ($L_i - D_{ij}$) - E_i = 24-24 = 0

Likewise all the other nodes can be solved and network analysis table can be

Network Analysis Table

Activity (i, j)	Normal Time (D_{ij})	Earliest Time		Latest Time		Float Time $(L_i - D_{ij}) - E_i$
		Start (E_i)	Finish $(E_i + D_{ij})$	Start $(L_i - D_{ij})$	Finish (L_i)	
(1, 2)	10	0	10	0	10	0
(1, 3)	8	0	8	1	9	1
(1, 4)	9	0	9	1	10	1
(2, 5)	8	10	18	10	18	0
(3, 7)	16	8	24	9	25	1
(5, 7)	7	18	25	18	25	0
(6, 7)	7	16	23	18	25	2
(5, 8)	6	18	24	18	24	0
(6, 9)	5	16	21	17	22	1
(7, 10)	12	25	37	25	37	0
(8, 10)	13	24	37	24	37	0
(9, 10)	15	21	36	22	37	1

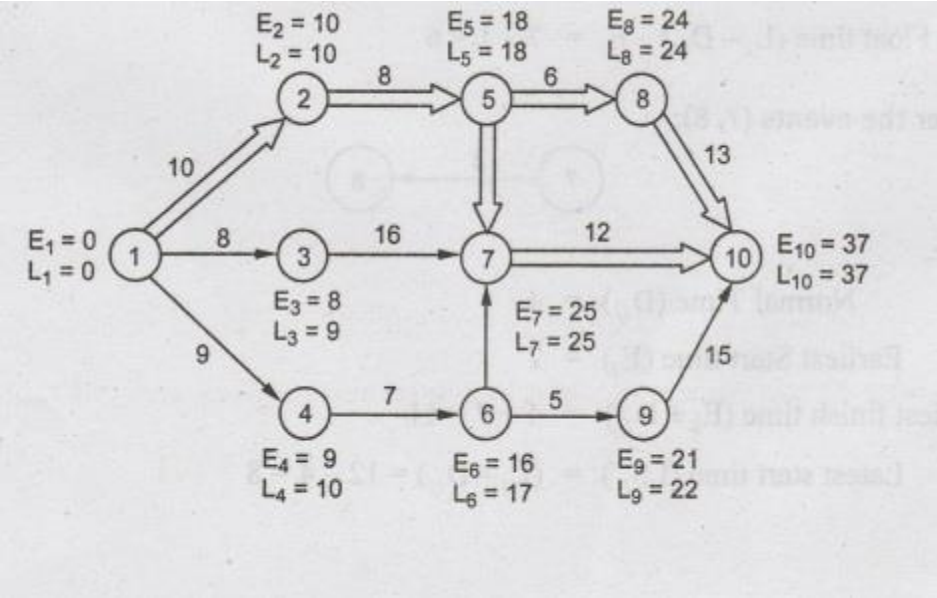
From the table, the critical nodes are (1, 2), (2, 5), (5, 7), (5, 8), (7, 10) and (8, 10)

From the table, there are two possible critical paths

(i) 1→2→5→ 8 → 10

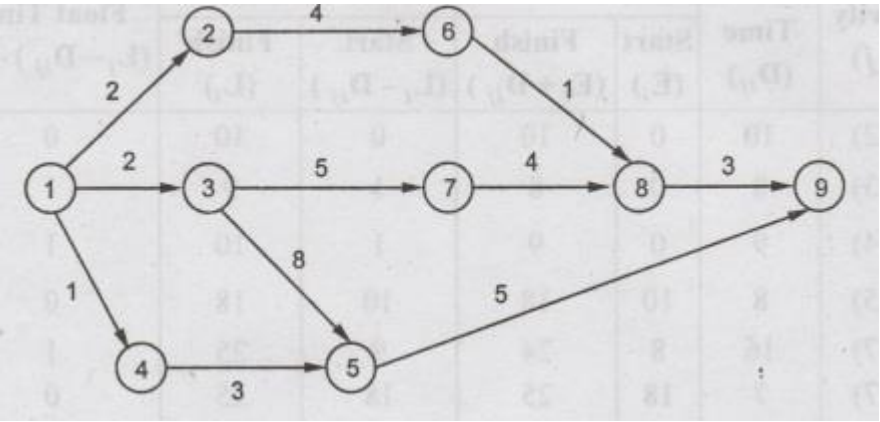
(ii) 1→2→ 5→710

Calculation of E and L for each node is shown in the network below:



Example 2

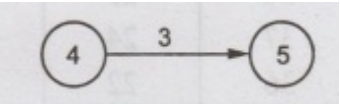
Find the critical path and calculate the slack time for the following network



Solution:

The earliest time and the latest time are obtained as shown below:

Consider the events (4, 5):



Here,

Normal Time (D_{ij}) = 3

Earliest Start time (E_i) = 1

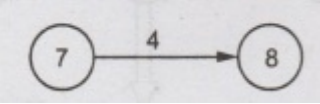
Earliest finish time ($E_i + D_{ij}$) = 3 + 1 = 4

Latest start time (LS_{ij}) = ($L_i - D_{ij}$) = 10- 3 = 7

Latest finish time (L_i) = 7

Float time ($L_i - D_{ij}$) - E_i = 7 - 1 = 6

Consider the events (7, 8):



Here,

Normal Time (D_{ij}) = 4

Earliest Start time (E_i) = 7

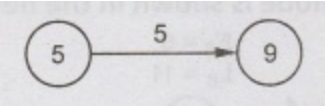
Earliest finish time ($E_i + D_{ij}$) = 4 + 7 = 11

Latest start time (LS_{ij}) = ($L_i - D_{ij}$) = 12-4= 8

Latest finish time (L_i) = 12

Float time ($L_i - D_{ij}$) - E_i = 8 - 7 = 1

Consider the events (5, 9):



Here,

Normal Time (D_{ij}) = 5

Earliest Start time (E_i) = 10

Earliest finish time ($E_i + D_{ij}$) = 10+5 = 15

Latest start time (LS_{ij}) = ($L_i - D_{ij}$) = 15-5 = 10

Latest finish time (L_i) = 15

Float time ($L_i - D_{ij}$) - E_i = 10-10 = 0

Likewise all the other nodes can be solved and network analysis table can be framed:

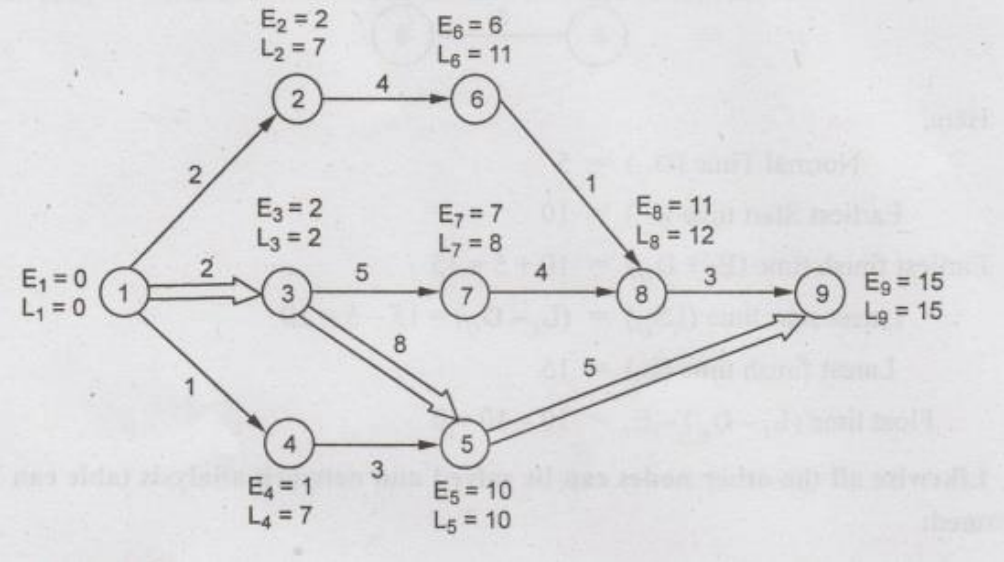
Network Analysis Table

Activity(i, j)	Normal Time (D_{ij})	Earliest Time		Latest Time		Float Time $(L_j - D_{ij}) - E_i$
		Start (E_i)	Finish ($E_i + D_{ij}$)	Start ($L_j - D_{ij}$)	Finish (L_j)	
(1, 2)	2	0	2	5	7	5
(1, 3)	2	0	2	0	2	0
(1, 4)	1	0	1	6	7	6
(2, 6)	4	2	6	7	11	5
(3, 7)	5	2	7	3	8	1
(3, 5)	8	2	10	2	10	0
(4, 5)	3	1	4	7	10	6
(5, 9)	5	10	15	10	15	0
(6, 8)	1	6	7	11	12	5
(7, 8)	4	7	11	8	12	1
(8, 9)	3	11	14	12	15	1

From the above table, the critical nodes are the activities (1, 3), (3, 5) and (5,9)

The critical path is 1→3→ 5→ 9

Calculation of E and L for each node is shown in the network below:



Example 3

A project has the following times schedule

Activity	Times in weeks	Activity	Times in weeks
(1 – 2)	4	(5 – 7)	8
(1 – 3)	1	(6 – 8)	1
(2 – 4)	1	(7 – 8)	2
(3 – 4)	1	(8 – 9)	1
(3 – 5)	6	(8 – 10)	8
(4 – 9)	5	(9 – 10)	7
(5 – 6)	4		

Construct the network and compute :

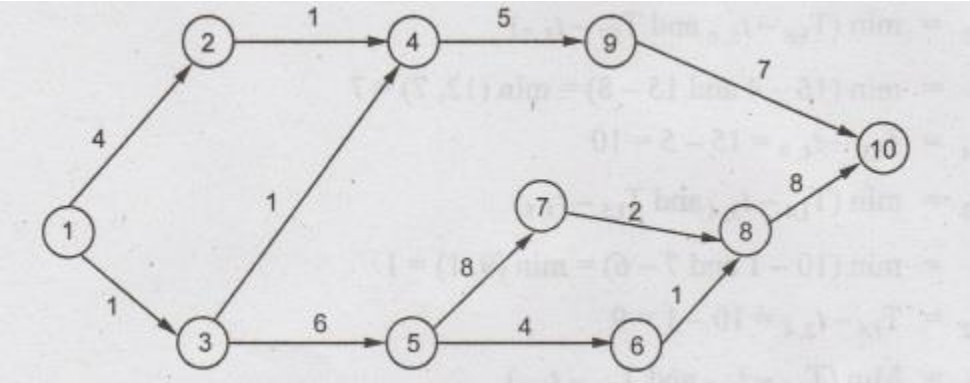
1. T_E and T_L for each event

2. Float for each activity

3. Critical path and its duration

Solution:

The network diagram can be drawn as shown below:



To determine the critical path, the earliest time TE and latest time T1 for each of the TL activity of the project is to be computed.

To calculate TE for all activities,

$T_{E1} = 0$

$T_{E2} = T_{E1} + t_{1,2} = 0 + 4 = 4$

$T_{E3} = T_{E1} + t_{1,3} = 0 + 1 = 1$

$T_{E4} = \max (T_{E2} + t_{2,4} \text{ and } T_{E3} + t_{3,4}) = \max (4 + 1 \text{ and } 1 + 1) = \max (5, 2) = 5$

$T_{E5} = T_{E3} + t_{3,6} = 1 + 6 = 7$

$T_{E6} = T_{E5} + t_{5,6} = 7 + 4 = 11$

$T_{E7} = T_{E5} + t_{5,7} = 7 + 8 = 15$

$T_{E8} = \max (T_{E6} + t_{6,8} \text{ and } T_{E7} + t_{7,8}) = \max (11 + 1 \text{ and } 15 + 2) = \max (12, 17)$

$= 17$

$T_{E9} = T_{E4} + t_{4,9} = 5 + 5 = 10$

$T_{E10} = \max (T_{E9} + t_{9,10} \text{ and } T_{E8} + t_{8,10}) = \max (10 + 7 \text{ and } 17 + 5) = \max (17, 22)$

$= 22$

To calculate T, for all activities

TL10 = TE10 = 22

$$T_{L9} = T_{E10} - t_{9,10} = 22 - 7 = 15$$

$$T_{L8} = T_{E10} - t_{8,10} = 22 - 5 = 17$$

$$T_{L7} = T_{E8} - t_{7,8} = 17 - 2 = 15$$

$$T_{L6} = T_{E8} - t_{6,8} = 17 - 1 = 16$$

$$T_{L5} = \min (T_{E6} - t_{5,6} \text{ and } T_{E7} - t_{5,7})$$

$$= \min (16 - 4 \text{ and } 15 - 8) = \min (12, 7) = 7$$

$$T_{L4} = T_{L9} - t_{4,9} = 15 - 5 = 10$$

$$T_{L3} = \min (T_{L4} - t_{3,4} \text{ and } T_{L5} - t_{3,5})$$

$$= \min (10 - 1 \text{ and } 7 - 6) = \min (9, 1) = 1$$

$$T_{L2} = T_{L4} - t_{2,4} = 10 - 1 = 9$$

$$T_{L1} = \text{Min} (T_{L2} - t_{1,2} \text{ and } T_{L3} - t_{1,3})$$

$$= \text{Min} (9 - 4 \text{ and } 1 - 1) = 0$$

From the above values TE and T can be tabulated as follows:

Event No.:	1	2	3	4	5	6	7	8	9	10
T_E:	0	4	1	5	7	11	15	17	18	25
T_L:	0	12	1	13	7	16	15	17	18	25

Using the above table, float can be calculated as follows:

Float = T_L (Head event) - T_E (Tail event) - Duration

For event 1,2 = 12-0-4=8

1,3 = 1-0-0=0

2,4 13-4-1=8

3,4 13-1-1=11

3,5 7-1-6=0

4,9 18-5-5=8

5,616-7-4=5

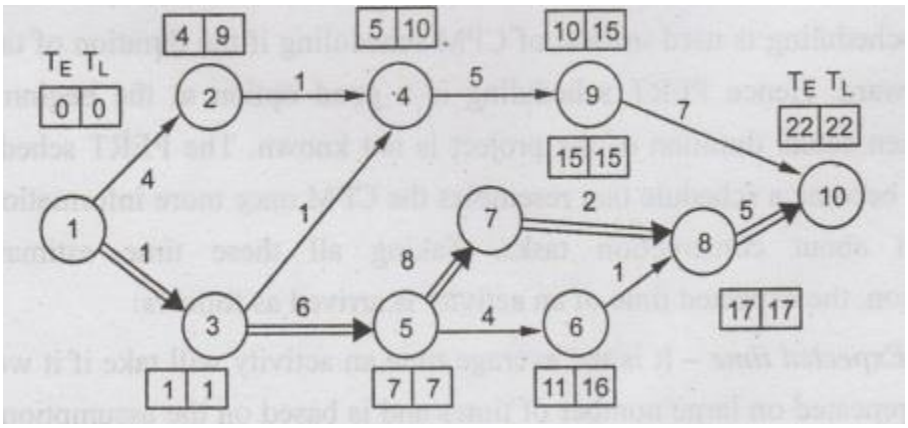
5,7 5-7-8=0

6-8 17-11-1=5

Likewise, the float for all events can be tabulated as follows:

Activity	Duration	T_E (Tail event)	T_L (Head event)	Float
(1 – 2)	4	0	12	8
(1 – 3)	1	0	1	0
(2 – 4)	1	4	13	8
(3 – 4)	1	1	13	11
(3 – 5)	6	1	7	0
(4 – 9)	5	5	18	8
(5 – 6)	4	7	16	5
(5 – 7)	8	7	15	0
(6 – 8)	1	11	17	5
(7 – 8)	2	15	17	0
(8 – 9)	1	17	18	0
(8 – 10)	8	17	25	0
(9 – 10)	7	18	25	0

Calculation of E and L for each node is shown in the network below



The resultant network shows the critical path

1→35→78→10

PROGRAM EVALUATION AND REVIEW TECHNIQUE (PERT) IN NETWORK ANALYSIS

Construction schedulers use PERT to create an initial schedule for a complex project. The process identifies durations of tasks, critical activities, and task dependencies to truly analyze a project before it begins. In the critical path method, the time estimates are assumed to be known with certainty. In certain projects like research and development, new product introductions, it is difficult to estimate the time of various activities. Hence PERT is used in such projects with a probabilistic method usingthree time estimates for an activity, rather than a single estimate:

❖ **Optimistic Time (t_o):** It is the shortest possible time in which the activity can be finished. It assumes that everything goes very well. This is denoted by to.

❖ **Pessimistic Time (t_p)** It represents the longest time the activity could take if everything goes wrong. As in optimistic estimate, this value may be such that only one in hundred or one in twenty will take time longer than this value. This is denoted by tp. ***(t):***

❖ **Most Likely Time (t_m):** It is the estimate of the normal time the activity would take. This assumes normal delays. If a graph is plotted in the time of completion and the frequency of completion in that time period, then most likely time will represent the highest frequency of occurrence. This is denoted by tm.

PERT scheduling is used instead of CPM scheduling if the duration of tasks isn't straightforward. Hence PERT scheduling is a good option at the beginning of a project when actual duration of the project is not known. The PERT schedule may eventually become a schedule that resembles the CPM once more information can be determined about construction tasks. Taking all these time estimates into consideration, the expected time of an activity is arrived as follows:

❖ **Expected time -** It is the average time an activity will take if it were to be repeated on large number of times and is based on the assumption that the activity time follows Beta distribution, this is given by

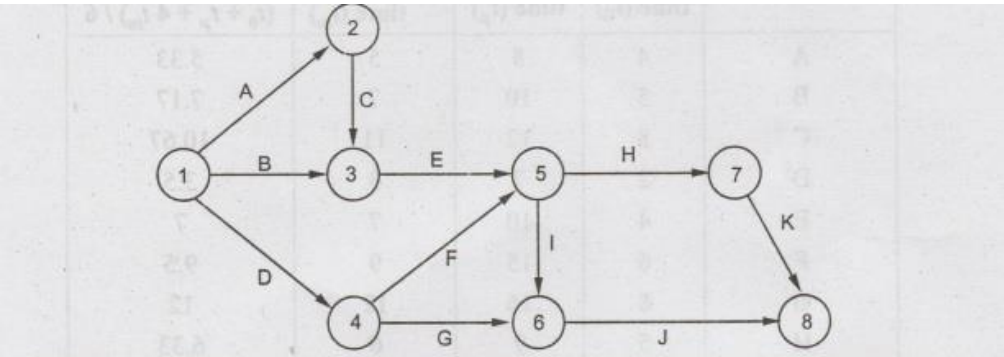
$t_e = (t_o + 4\ t_m + t_p)/6$

❖ **The variance for the activity is given by**

$\sigma^2 = [(t_p - t_0)/6]^2$

Example 1

For the project shown in the figure



Task:	A	B	C	D	E	F	G	H	I	J	K
Least time:	4	5	8	2	4	6	8	5	3	5	6
Greatest time:	8	10	12	7	10	15	16	9	7	11	13
Most likely time:	5	7	11	3	7	9	12	6	5	8	9

Find the earliest and latest expected time to each event and also critical path in the network.

Solution:

For task A, $t_0 = 4, t_p = 8, t_m = 5$

$$t_e = (t_0 + 4t_m + t_p)/6 = (4 + 4(5) + 8)/6 = 32/6 = 5.33$$

For task B, $t_0 = 5, t_p = 10, t_m = 7$

$$t_e = (t_0 + 4t_m + t_p)/6 = (5 + 4(7) + 10)/6 = 43/6 = 7.17$$

For task C, $t_0 = 8, t_p = 12, t_m = 11$

$$t_e = (t_0 + 4t_m + t_p)/6 = (8 + 4(11) + 12)/6 = 64/6 = 10.67$$

For task D, $t_0 = 2, t_p = 7, t_m = 3$

$$t_e = (t_0 + 4t_m + t_p)/6 = (2 + 4(3) + 7)/6 = 21/6 = 3.5$$

For task E, $t_0 = 4, t_p = 10, t_m = 7$

$$t_e = (t_0 + 4t_m + t_p)/6 = (4 + 4(7) + 10)/6 = 42/6 = 7$$

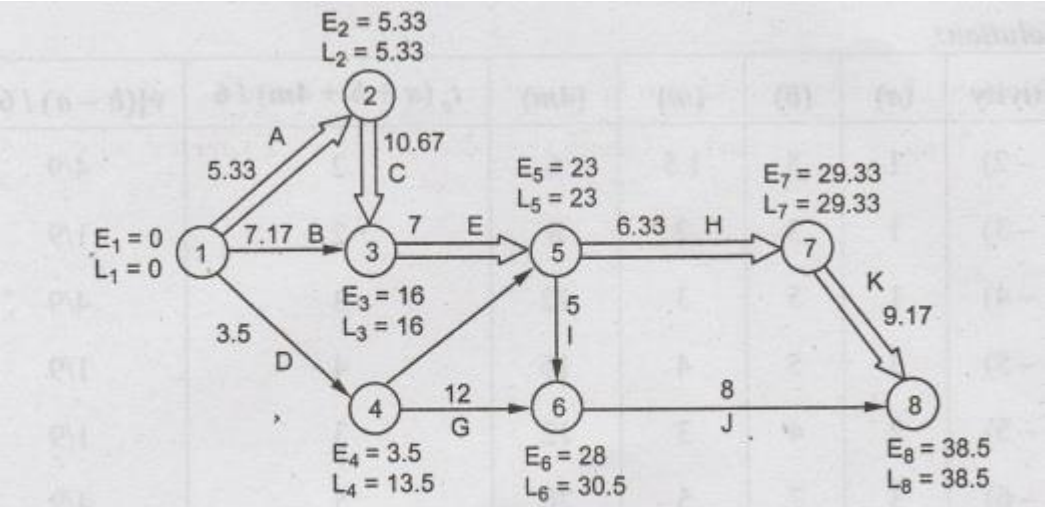
Likewise t_e for all the tasks can be calculated and tabulated as follows:

Task	Least time (t_0)	Greatest time (t_p)	Most likely time (t_m)	Expected time $(t_0 + t_p + 4t_m)/6$
A	4	8	5	5.33
B	5	10	7	7.17
C	8	12	11	10.67
D	2	7	3	3.5
E	4	10	7	7
F	6	15	9	9.5
G	8	16	12	12
H	5	9	6	6.33
I	3	7	5	5
J	5	11	8	8
K	6	13	9	9.17

From the t_e calculated Earliest start time and Earliest finish time can be calculated as follows:

Task	Expected time (t_e)	Start		Finish		Total float
		Earliest	Latest	Earliest	Latest	
A	5.33	0	0	5.33	5.33	0
B	7.17	0	8.83	7.17	16	8.83
C	10.67	5.33	5.33	16	16	0
D	3.5	0	10	3.5	13.5	10
E	7	16	16	23	23	0
F	9.5	3.5	13.5	13	23	10
G	12	3.5	18.5	15.5	30.5	15
H	6.33	23	23	29.33	29.33	0
I	5	23	25.5	28	30.5	2.5
J	8	28	30.5	36	38.5	2.5
K	9.17	29.33	29.33	31.5	38.5	0

The network diagram can be drawn as shown below:



The critical path is **A → C → E → H → K**

ie. 1 → 2 → 3 → 5 → 7→ 8

Example 2

A project has the following characteristics:

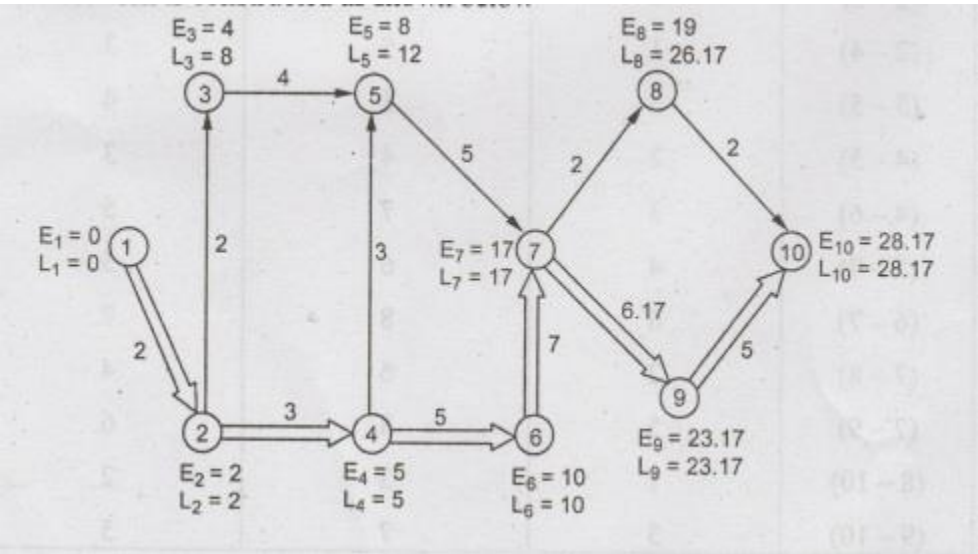
Activity	Most optimistic time (a)	Most pessimistic time (b)	Most likely time (m)
(1 – 2)	1	5	1.5
(2 – 3)	1	3	2
(2 – 4)	1	5	3
(3 – 5)	3	5	4
(4 – 5)	2	4	3
(4 – 6)	3	7	5
(5 – 7)	4	6	5
(6 – 7)	6	8	7
(7 – 8)	2	6	4
(7 – 9)	5	8	6
(8 – 10)	1	3	2
(9 – 10)	3	7	5

Construct a PERT network. Find the critical path and variance for each event.

Solution:

Activity	(a)	(b)	(m)	(4m)	t_e (a + b + 4m) / 6	v[(b – a) / 6]2
(1 – 2)	1	5	1.5	6	2	4/9
(2 – 3)	1	3	2	8	2	1/9
(2 – 4)	1	5	3	12	3	4/9
(3 – 5)	3	5	4	16	4	1/9
(4 – 5)	2	4	3	12	3	1/9
(4 – 6)	3	7	5	20	5	4/9
(5 – 7)	4	6	5	20	5	1/9
(6 – 7)	6	8	7	28	7	1/9
(7 – 8)	2	6	4	16	4	4/9
(7 – 9)	5	8	6	24	6.17	1/4
(8 – 10)	1	3	2	8	2	1/9
(9 – 10)	3	7	5	20	5	4/9

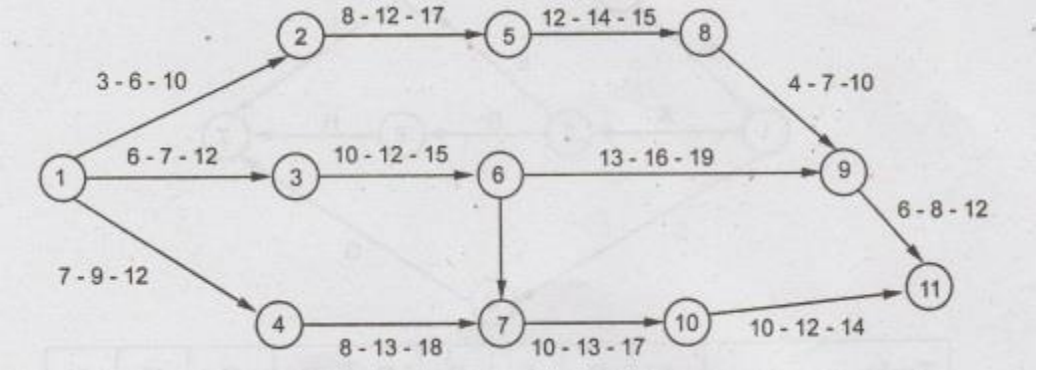
The network is constructed as shown below



The critical path = 1→2→4→6-7-9-10

Example 3

Calculate the variance and the expected time for each activity

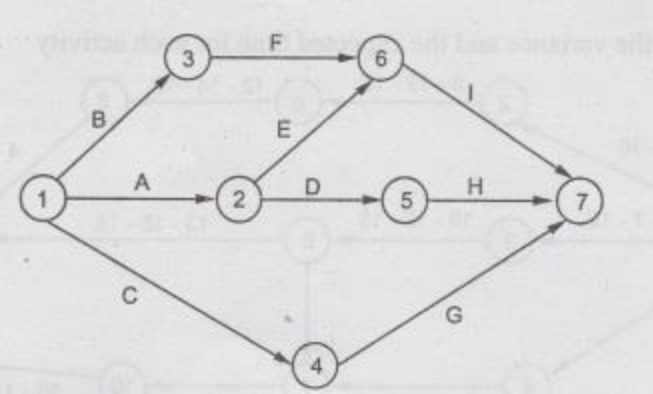


Activity	(t_0)	(t_m)	(t_p)	$t_e = (t_0 + t_p + 4\,t_m) / 6$	$V = [(t_p - t_0) / 6]^2$
(1 – 2)	3	6	10	6.2	1.36
(1 – 3)	6	7	12	7.7	1.00
(1 – 4)	7	9	12	9.2	0.69
(2 – 3)	0	0	0	0.0	0.00
(2 – 5)	8	12	17	12.2	2.25
(3 – 6)	10	12	15	12.2	0.69
(4 – 7)	8	13	19	13.2	3.36
(5 – 8)	12	14	15	13.9	0.25
(6 – 7)	8	9	10	9.0	0.11
(6 – 9)	13	16	19	16.0	1.00
(8 – 9)	4	7	10	7.0	1.00
(7 – 10)	10	13	17	13.2	1.36
(9 – 11)	6	8	12	8.4	1.00
(10 – 11)	10	12	14	12.0	0.66

Example 4

A project is represented by the network as shown below and has the following

data



Task:	A	B	C	D	E	F	G	H	I
Least time:	5	18	26	16	15	6	7	7	3
Greatest time:	10	22	40	20	25	12	12	9	5
Most likely time:	15	20	33	18	20	9	10	8	4

Determine the following

1. Expected task time and their variance

2. Earliest and latest time

Solution:

Activity Least time Greatest time

Activity	Least time (t_0)	Greatest time (t_p)	Most likely time (t_m)	Expected time $(t_0 + t_p + 4\,t_m) / 6$	Variance (σ^2)
(1 – 2)	5	10	8	7.8	0.69
(1 – 3)	18	22	20	20.0	0.44
(1 – 4)	26	40	33	33.0	5.43
(2 – 5)	16	20	18	18.0	0.44
(2 – 6)	15	25	20	20.0	2.78
(3 – 6)	6	12	9	9.0	1.00
(4 – 7)	7	12	10	9.8	0.69
(5 – 7)	7	9	8	8.0	0.11
(6 – 7)	3	5	4	4.0	0.11

Earliest time can be calculated as follows:

$E_1 = 0$

$E_2 = 0+7.8$ 7.8

$E_3 = 0+20=20$

$E_4 = 0+33=33$

$E_5 = 7.8+18=25.8$

$E_6 = \max [7.8 + 20, 20 + 9] = 29$

$E_7 = \max [33 +9.8, 25.8+ 8, 29+ 4] = 42.8$

Latest time can be calculated as follows:

$L_7 = 42.8$

$L_6 = 42.8-438.8$

$L_5 = 42.8-8= 34.3$

$L_4 = 42.8$ 9.833

$L_3 = 38.8-9$ 29.8

L_2 min [34.8-18, 38.8-20]= 16.8

$L_1 = \min [16.8-7.8, 29.8-20, 33-33]=0$

DIFFERENCE BETWEEN PERT AND CPM

❖ PERT is probabilistic in nature. It acknowledges and considers the variability in completion; times of activities and, in turn, the project. Accordingly it is useful for analyzing project scheduling problems with of bozu uncertain completion times of the activitiesinvolved.

❖ CPM is deterministic in nature. It is most appropriately used in projects in ubivib which activity durations are known with certainty. Not only the amount of

time needed to complete various facets of the project but also the amount of resources required for performing each of the activities are assumed to be known and certain.

❖ PERT is useful for projects that are new, non-repetitive, or which involve research and development while CPM is of great value for projects that are repetitive and standardized, like those involving construction activities

❖ PERT focuses primarily on time element and attaches lesser significance to the cost. CPM puts strong emphasis on cost and specifically considers the time-cost relationshipand trade-off.

❖ PERT is event oriented so that probabilities of reaching various events by certain dates may be calculated through event variances. CPM is activity oriented.

ADVANTAGES AND DISADVANTAGES OF PERT AND CPM

PERT/CPM has the following advantages:

❖ A PERT/CPM chart explicitly defines and makes visible dependencies (precedence relationships) between the elements,

❖ PERT/CPM facilitates identification of the critical path and makes this visible,

❖ PERT/CPM facilitates identification of early start, late start, and slack for each activity,

❖ PERT/CPM provides for potentially reduced project duration due to better understanding of dependencies leading to improved overlapping of activities and tasks where feasible.

PERT/CPM has the following disadvantages:

❖ The lack of a timeframe on most PERT/CPM charts makes it harder to show status although colours can help (e.g., specific colour for completed nodes),

❖ When the PERT/CPM charts become unwieldy, they are no longer used to manage the project.

❖ There can be potentially hundreds or thousands of activities and individual dependency relationships will be complicated for big projects.

TWO MARKS QUESTIONS AND ANSWERS

1. Define Construction planning.

Construction planning is a primary and demanding activity in the construction management and execution of construction projects. It involves the selection of technology, the definition of work tasks, the estimation of the required resources and durations for individual tasks, and the identification of any relations among the different work tasks.

2. What is the necessity for construction planning?

Planning is essential to ensure proper utilization of human and material resources to achieve the objectives of the project. Construction project planning includes the estimate, budget, time schedule, sequences of completion of each activity of the project, resource and manpower planning.

3. Classify the different types of construction projects.

Depending on the nature of the construction facility, major construction projects are classified as follows:

❖ Building Projects

❖ Infrastructure Projects

❖Industrial Projects.

❖ Special-Purpose Projects

4. What are the steps involved in the construction planning?

The following are the steps to be followed in a construction planning:

❖ Project initiation

❖ Creating the project plan

❖ Executing the plan

❖ Tracking the project progress

❖ Evaluation of the project

5. What are the objectives of construction planning?

The main objective of planning is to execute the project most economically within the time schedule. Effective planning includes the following factors:

❖ Each element of the project should be properly designed.

❖ Selecting proper equipment and machinery accordingly to the nature of the project.

❖ Arranging proper maintenance facility for equipment and machinery near the project site to avoid hindrance due to breakdown.

❖ Procuring materials well in advance and stocking at the site to avoid delay due to insufficient storage.

6. State the Principles of construction Planning.

The following are the principles of construction planning:

❖ The plan should present the information in an easily understandable manner, irrespective of the complex situation in the project.

❖ The plan should be realistic, flexible and comprehensive.

❖ The plan should provide a source for project monitoring and control process.

7. List the types of construction project planning.

The following are some of the most common types of construction project planning processes:

❖ Strategic planning

❖ Operational planning

❖ Business planning

❖ Resource planning

8. Define resource planning.

Resource planning ensures that each project a company is currently working has sufficient staff, materials and resources necessary to be completed successfully and on time. To keep everything organized, project managers often create milestone dates and deadlines, as well as a list of where they plan to allocate necessary resources. This can be beneficial if multiple projects are in progress at the same time.

9. What are the stages of Construction planning?

The various stages in the planning process are:

❖ Preplanning

❖ Detailed Planning

❖ Monitoring and Control

10. List the advantages of Construction planning.

The following are the advantages of construction planning:

❖ The contractor can get a clear scenario about the sequence of work, since the construction plan is detailed through sketches, bar charts etc.

❖ It helps to maintain the financial cash flow of the contractor through proper resource management.

❖ Labour requirement can also be managed properly through appropriate planning for each activity.

❖ Various sub activities of the project can also be identified and actual work can be measured easily by the contractor.

❖ The client will know exactly how long it will take to complete the project.

11. List the disadvantages of construction Planning.

The following are the disadvantages of construction planning:

❖ The effectiveness of the plan depends upon the correctness of assumptions.

❖ In certain big projects planning is expensive and might delays action.

❖ Planning encourages a false sense of security.

12. Define Construction Scheduling.

Construction scheduling can be defined as the process of listing all the activities to be carried out with the planned start and completion dates. It is an entire blueprint which shows how the project will be executed and the sequential relationship among the various activities or operations in a project so that work roid can be carried out in an orderly and effective manner.

13. What are the steps involved in construction planning?

The steps involved in construction scheduling are:

❖ The project is divided into number of operations and the sequences of these operations can be derived after knowing their relationship properly.

❖ The quantity of work involved in each operation has to be calculated.

❖ The time required for completion of the project and different activities are to be calculated.

14. List the various types of construction schedule.

The various types of construction schedules can be listed as follows:

❖ Construction Material Schedule

❖ Labor Schedule

❖ Equipment Schedule

❖ Financial Schedule

❖ Control Schedule

❖ Organization Schedule

❖ Summary Schedule

15. List the methods of construction scheduling.

Construction scheduling can be done depending on the nature of the project. The various methods of scheduling are discussed as follows:

- ❖ Gantt chart
- ❖ Q Scheduling
- ❖ Last Planner System
- ❖ Line of Balance
- ❖ Work breakdown structure
- ❖ Critical Path Method (CPM)
- ❖ Program Evaluation and Review Technique (PERT)

16. Write about Gantt chart.

Henry Gantt (1861-1919), an American mechanical engineer, designed the Gantt chart. Gantt chart is a common construction scheduling method which utilizes the bar charts to depict the plan and the progress of the project. The unique aspect of this scheduling technique is that it highlights the dependency of one task or activity on the other to be completed efficiently in the given time. These are also known as bar charts. A Gantt chart helps in scheduling, managing, and monitoring specific tasks and resources in a project.

17. What do you mean by Quantitative scheduling?

Quantitative scheduling, also known as Q scheduling, uses bar charts to visualize resource quantities and the locations in which the resources will be used. It is a different type of construction scheduling method. It focuses on scheduling the materials and equipment used in the project. It provides a clear description of the materials used and required in the project through a bar chart.

18. How can you explain LOB?

Line of balance (LOB) is a scheduling method which is usually implied in projects that include repetitive activity. The balance scheduling method measures the cost, time, and project completion plan and ensures nothing falls behind the schedule. These type of schedules are very uncommon but are sometimes used when a construction project consists of highly repeatable and similar tasks. These are most commonly used for roadways, pipes, and other horizontal construction projects.

19. What are the procedures to be followed in LOB?

For preparing a line of balance schedule, the following procedures should be adopted:

❖ Prepare a logic diagram.

❖ Estimate the man-hours required to complete each operation.

❖ Choose buffer times which will guard against the risk of interface between operations.

❖ Calculate the required output target in order to meet a given project completion date.

❖ Complete the LOB schedule.

❖ Examine the schedule and assess possible alternatives to bring about a more 'balanced' schedule.

20. Write short notes on WBS.

The Work breakdown structure (WBS) is the tool that is used to record and communicate the project deliverables and sub-deliverables as well as the accomplishments and sub-accomplishments. WBS is a visual, hierarchical and deliverable-oriented deconstruction of a project. It is a helpful diagram for project managers because it allows them to break down their project scope and visualize all the tasks required to complete their projects.

21. List the advantages of deliverable WBS.

The advantages of a deliverable-oriented WBS are: do It simplifies the process of cost estimating.

❖ It allows us to see the total work scope.

❖ It clarifies the relationships among elements.

❖ It can be used during all project phases.

❖ It's easier to modify as the project changes.

❖ It supports earned value management.

22. What do you mean by CPM?

The critical path method is one of the most common construction scheduling methods, and it is also called a critical path analysis. This type of schedule is developed by creating a network diagram highlighting the sequence of tasks and projects following the specific path. The CPM creates a schedule based on critical activities, which must be completed before another activity can

begin. Once critical activities are identified, they are scheduled in sequence to determine the least amount of time a construction project can be completed.

23. Write short notes on PERT.

The program evaluation and review technique (PERT) is one of the most critical construction scheduling methods. This is because it pays more attention to analyze all the individual project activities. In other words, PERT evaluates and reviews the project's activities in progress and evaluates the time duration in which they will be completed.

24. What is a critical activity?

The activities with zero total float are known as critical activities. In other words an activity is said to be critical if a delay in its start will cause a further delay in the completion date of the entire project.

25. Write about optimistic and pessimistic time.

❖ **Optimistic Time (t_o):** It is the shortest possible time in which the activity can be finished. It assumes that everything goes very well. This is denoted by to.

❖ **Pessimistic Time (t):** It represents the longest time the activity could take if everything goes wrong. As in optimistic estimate, this value may be such that only one in hundred or one in twenty will take time longer than this value. This is denoted by tp.

26. How will you calculate expected time?

Expected time is the average time an activity will take if it were to be repeated on large number of times and is based on the assumption that the activity time follows Beta distribution, this is given by

$t_e = (t_o + 4\ t_m + t_p)/6$

REVIEW QUESTIONS

1. Discuss about construction planning in detail.

2. Elaborate about construction scheduling in detail.

3. What are the different types of scheduling? Explain in detail. 4. Explain in detail about CPM in network analysis.

5. Discuss in detail about PERT.

6. Explain the following terms

(a) Earliest time

(b) Latest time

(c) Total activity slack

(d) Event slack

(e) Critical path

7. What are the rules for drawing network diagram? Also mention the common errors that occur in drawing networks.

8. Explain in detail about LOB.

9. Discuss about WBS in detail.

10. What is the difference between PERT and CPM? Explain.

11. Explain the following terms

(a) optimistic time

(b) Most likely time

(c) Pessimistic time

(d) Expected time

(e) Variance

12. For the following data, draw network. Find the critical path, slack time after calculating the earliest expected time and the latest allowable time

Activity	Duration	Activity	Duration
(1 – 2)	5	(5 – 9)	3
(1 – 3)	8	(6 – 10)	5
(2 – 4)	6	(7 – 10)	4
(2 – 5)	4	(8 – 11)	9
(2 – 6)	4	(9 – 12)	2
(3– 7)	5	(10 – 12)	4
(3 – 8)	3	(11 – 13)	1
(4 – 9)	1	(12 – 13)	7

13. A project schedule has the following characteristics.

Activity	Most optimistic time	Most likely time	Most pessimistic time
(1 – 2)	1	2	3
(2 – 3)	1	2	3
(2 – 4)	1	3	5
(3 – 5)	3	4	5
(4 – 5)	2	5	4
(4 – 6)	3	5	7
(5 – 7)	4	5	6
(6 – 7)	6	7	8
(7 – 8)	2	4	6
(7 – 9)	4	6	8
(8 – 10)	1	2	3
(9 – 10)	3	5	7

Construct a PERT network and find out

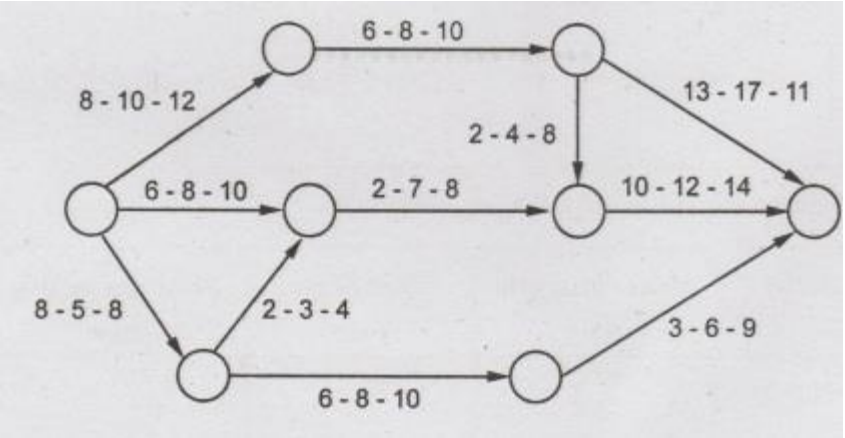
(a) The earliest possible time

(b) Latest allowable time

(c) Slack values

(d) Critical path

14. Calculate the variance and the expected time for each activity



15. Consider a project having activities and their associated time estimates as given in Table:

Activity	Predecessor activity	Time (Days)		
		Optimistic	Most likely	Pessimistic
A	-	2	4	6
B	A	8	12	16
C	A	14	16	30
D	B	4	10	16
E	B,C	6	12	18
F	E	6	8	22
G	D	18	18	30
H	F,G	8	14	32

(a) Draw the network diagram.

(b) Identify the critical path and compute the expected project completion time.

MODEL QUESTION PAPERS

Model Question Paper - 1

CE3302-CONSTRUCTION MATERIALS AND TECHNOLOGY

Answer ALL Questions

1. Name some of the common tests conducted on stone.

Following are different tests on conducted on building stones:

- ❖ Water absorption test
- ❖ Crushing strength test
- ❖ Impact test
- ❖ Abrasion test
- ❖ Acid test

2. Define "slaking of lime".

Slaking of lime is the process, which is the chemical combination of quick lime with water. It has got the tendency of absorbing carbonic acid from the atmosphere in presence of water. It is ordinary pure lime, in white powder form, available in market. Slacked lime is also known as hydrated lime.

3. Write about cup shake in timber.

Cup shakes are caused by the rupture of tissue in a circular direction. It is a curved crack, and it separates partly one annual ring from the other developing one due to non-uniform growth or due to excessive bending of a growing tree during a cyclonic weather. It may prove to be harmful if it covers only a portion of the ring.

4. What are geo synthetics?

Geo fabrics are also called geo synthetics or geotextiles. These are synthetic fabrics which are sufficiently durable to last a good length of time in soil environment used in geotechnical engineering.

5. What is a composite pile?

When the piles are made from more than one material they are known as composite pile. These piles are made from concrete and wood. These piles are used in those areas where the water table is up. These piles are used in such conditions just because concrete and wood both are good water absorbers

6. Distinguish between plastering and pointing.

S.No	Plastering	Pointing
1	It is applied on the entire wall surface	It is done only at the exposed joints
2	It gives smooth surface finish	It does not provide smooth surface
3	Defective workmanship in masonry can be covered up by plastering	Well built masonry work can be shown by doing pointing work at the joints
4	It acts as a base for white washing works	Further finishing works like white washing cannot be done

The following are some of the differences between plastering and pointing

Plastering

It is applied on the entire wall surface

It gives smooth surface finish

Defective workmanship in masonry can be covered up by plastering

It acts as a base for white washing works

Pointing

It is done only at the exposed surface

It does not provide smooth surface

Well built masonry work can be shown by doing pointing work at the joints Further

finishing works like white washing cannot be done

7. Write short notes on graders.

A grader, also commonly referred to as a road grader, a blade, a maintainer, or a motor grader, is a construction machine with a long blade used to create a flat surface. Graders are commonly used in the construction and maintenance of dirt roads and gravel roads. They are used to prepare the base course and to create a wide flat surface for the asphalt to be placed on.

8. Define derrick crane.

A derrick is a special type of crane in which the distance from the end of the jib to the pillar can be changed. The derrick cranes are of two types, namely Guy derrick and Stiff leg derrick. Guy derrick can be constructed up to 200 tonnes capacity. In stiff leg type derricks, the guy wires are replaced by trussed structure. This type of derricks is suitable for loads from 10 to 50 tonnes.

9. What is Construction Scheduling?

Construction scheduling can be defined as the process of listing all the activities to be carried out with the planned start and completion dates. It is an entire blueprint which shows how the project will be executed and the sequential relationship among the various activities or operations in a project so that work can be carried out in an orderly and effective manner.

10. How can you explain LOB?

Line of balance (LOB) is a scheduling method which is usually implied in projects that include repetitive activity. The balance scheduling method measures the cost, time, and project completion plan and ensures nothing falls behind the schedule. These type of schedules are very uncommon but are sometimes used when a construction project consists of highly repeatable and similar tasks. These are most commonly used for roadways, pipes, and other horizontal construction projects.

PART-B

11. (a) Explain in detail about different classification of Bricks.

Ans. Refer Section No: 1.8,

Page No.1.13

[OR]

(b) Discuss in detail about the various tests conducted on lime.

Ans. Refer Section No: 1.16,

Page No. 1.27

12. (a) Name some of the common market forms of timber and explain in detail.

Ans. Refer Section No: 2.1.17,

Page No. 2.17

[OR]

(b) Elaborate in detail fiber reinforced plastic.

Ans. Refer Section No: 2.10.2,

Page No. 2.47

13. (a) List the different types of bonds in brick masonry and explain with bazaini sketches.

Ans. Refer Section No: 3.3.1,

Page No. 3.11

[OR]

(b) Explain in detail about acoustic and sound insulation.

Ans. Refer Section No: 3.19,

Page No.3.69

14. (a) With neat sketches, explain in detail about the earth excavating equipments.

Ans. Refer Section No: 4.2,

Page No. 4.2

[OR]

(b) Explain in detail about the equipments needed for dewatering and pumping.

Ans. Refer Section No: 4.5,

15. (a) What are the different methods of scheduling? Explain in detail.

Page No.4.35

Ans. Refer Section No: 5.2.2,

Page No.5.9

[OR]

(b) Explain in detail about CPM in network analysis.

Ans. Refer Section No: 5.3.5,

Page No.5.24

PART-C (1 x 15 = 15 Marks)

16. (a) Discuss in detail about different types of conveyors.

Ans. Refer Section No: 4.3,

Page No.4.15

(4)

[OR]

(b) A project has the following characteristics:

Activity	Most optimistic time (a)	Most pessimistic time (b)	Most likely time (m)
(1 – 2)	1	5	1.5
(2 – 3)	1	3	2
(2 – 4)	1	5	3
(3 – 5)	3	5	4
(4 – 5)	2	4	3
(4 – 6)	3	7	5
(5 – 7)	4	6	5
(6 – 7)	6	8	7
(7 – 8)	2	6	4
(7 – 9)	5	8	6
(8 – 10)	1	3	2
(9 – 10)	3	7	5

(i) Construct a PERT network.

(ii) Find the critical path and variance for each event.

Ans. Refer Example No.2,

Page No.5.39

Construction Materials And Technology: Model Question Papers

Model Question Paper - 2

B.E./B.Tech DEGREE EXAMINATION.,

CE3302-CONSTRUCTION MATERIALS AND TECHNOLOGY

Answer ALL Questions

1. Define the term Efflorescence.

Efflorescence is defined as the presence of grey or white layer on brick surface by absorbing moisture. It is formed due to the presence of alkalies in bricks. In the efflorescence test, if the presence of alkalies is over 50% then the brick is severely affected by alkalies. Hence more deposits will be visible over the brick surface.

2. What is a lime mortar?

Lime mortar is formed by mixing of lime, sand, and water. The required amount of lime and sand is placed on the ground or tray. The lime and sand are mixed evenly by turning the spades up and down. The water is added till the uniform color and consistency of the mortar area unit is obtained and also the mixture is persistent with spades.

3. How will you define the term water seasoning?

Removal of wood sap by immersing logs into water flow is called water seasoning. It is carried out on the river banks while thicker ends are kept towards upstream. After that, the logs are allowed to dry. This process is time consuming such as 2 to 4 weeks generally.

4. Define FRP

Fiber-reinforced plastic (FRP) composites have transformed the manufacturing sector. FRP composites offer high-end performance at a fraction of the weight and cost of comparable metal materials. Construction, energy,aerospace, and other critical sectors are realizing the benefits of FRP for producing reliable parts and components.

5. What is brick masonry?

Brick masonry is built with bricks bonded together with mortar. It is a structural technique in which the bricks are laid out in a systematic pattern and the joints are filled with mortar to make a solid structure. Brick masonry strength depends on the type of bond and materials used for construction. They ho play an important role in providing strength, stability, and durability to the brick masorry.

6. Write about Shoring.

Shoring is a temporary structure used to prevent the collapse of the main under-construction structure. The most commonly shoring support is required during the early stage of construction which is excavation. It is a momentary support, which is used during the repair or original construction of buildings and in excavations.

7. Name some of the equipments used for earthwork excavation."

The equipments used for earthwork excavation are:

- ❖ Excavators
- ❖ Loaders
- ❖ Scrappers
- ❖ Graders
- ❖ Dozers
- ❖ Trenchers

8. Briefly write about concrete batching plant.

Concrete batching plant, mixes various materials to form concrete. These materials include sand, aggregate, slag, cement, fly ash, and water among others. The batching plant comprises of adequate capacity gravel & sand hoppers, weighing conveyor suspended on electronic load cells, reversible drum type mixer unit, cement bin with screw conveyor, rubber belt type charging conveyor, cement batcher, PLC based control panel.

9. Define Construction planning.

Construction planning is a primary and demanding activity in the construction management and execution of construction projects. It involves the selection of technology, the definition of work tasks, the estimation of the required resources and durations for individual tasks, and the identification of any relations among the different work tasks.

10. What is a critical activity?

The activities with zero total float are known as critical activities. In other words an activity is said to be critical if a delay in its start will cause a further delay in the completion date of the entire project.

PART-B (5 x 13 = 65 Marks)

11. (a) What are the different tests conducted on stones? Explain any two tests.

Ans. Refer Section No: 1.5,

Page No. 1.9

[OR]

(b) Explain in detail about manufacturing process of conventional bricks.

Ans. Refer Section No: 1.9,

12. (a) Discuss in detail about the defects in timber.

Page No. 1.17

Ans. Refer Section No: 2.1.16,

Page No. 2.11

[OR]

(b) Explain in detail about various market forms of aluminium.

Ans. Refer Section No: 2.6.3,

Page No. 2.32

13. (a) Explain the different types of roof with neat sketches.

Ans. Refer Section No: 3.13.2,

Page No. 3.47

ao [OR]

(b) Elaborate in detail joints in concrete.

Ans. Refer Section No: 3.15,

Page No. 3.58

14. (a) Enumerate in detail about different types of loaders.

Ans. Refer Section No: 4.2,

Page No. 4.8

[OR]

(b) With neat sketches explain the different types of cranes.

Ans. Refer Section No: 4.4,

Page No. 4.28

15. (a) Explain the various types and stages in construction planning.

Ans. Refer Section No: 5.1.6, 5.1.7

Page No. 5.5 & 5.6

[OR]

(b) Discuss in detail about PERT in network analysis.

Ans. Refer Section No: 5.3.6,

Page No. 5.36

PART-C (1 x 15 = 15 Marks)

16. (a) Discuss different types of concreting equipments with neat sketches

Ans. Refer Section No: 4.4,

Page No. 4.28

[OR]

(b) A project has the following times schedule

Activity	Times in weeks	Activity	Times in weeks
(1 – 2)	4	(5 – 7)	8
(1 – 3)	1	(6 – 8)	1
(2 – 4)	1	(7 – 8)	2
(3 – 4)	1	(8 – 9)	1
(3 – 5)	6	(8 – 10)	8
(4 – 9)	5	(9 – 10)	7
(5 – 6)	4		

Construct the network and compute:

(i) T_E and T_L for each event

(ii) Float for each activity

(iii) Critical path and its duration

Ans. Refer Example No.3,

Page No. 5.32