Learning Material

UNIT-I

Properties of a good building stone:

The following are the qualities or requirements of a good building stone.

1. **Crushing strength:** The compressive strength of stones usually varies from 60-200 N/mm^2. But the stones used in structural purposes must possess a crushing strength greater than100 N/mm^2

2. **Appearance**: Good building stone should be a uniform colour, and free from clay holes, spots of other colour bands etc. It must be capable of preserving the colour for long time.

3. **Durability**: A good building stone should be durable. The factors like heat and cold, alternative wet and dry, dissolved gases in rain, high wind velocity etc. affect the durability.

4. **Fracture**: For good building stone its fracture should be sharp, even and clear.

5. **Hardness**: If the coefficient of hardness is

   Greater than 17, treated as hard used in road works.

   Between 14 to 17, medium hardness,

   Less than 14 is said be poor hardness.

6. **Percentage wear**: For a good building stone, the percentage wear should be equal to or less than 3 percent.

7. **Resistance to fire**: A good building stone should be fire resistant. Usually Sandstone and some argillaceous stones resist fire quite well than siliceous stones.

8. **Specific gravity**: For a good building stone the specific gravity lies between 2.3-2.5.

9. **Texture**: A good building stone should have compact fine crystalline structure which is free from cavities, cracks or patches of stuff or loose material.

10. **Water absorption:** For a good building stone, the percentage absorption by weight after 24 hours should not exceed 0.60.

11. **Seasoning**: Stones should be well seasoned before putting into use. A period of about 6 to 12 months is considered to be sufficient for proper seasoning.

12. **Toughness Index**: From the Impact test, according to the value of toughness index

    Less than 13 – Not tough,

    Between 13 and 19 – Moderate,

    Greater than 19- high

Relation to their Structural Requirements:

Common Varieties of Stones:

Granite:

1. Igneous rock
2. Composed of quart, feldspar and mica minerals
3. Available in grey, green, brown, pink and red
4. Hard and durable
5. High resistance to weathering
6. The texture varies with its quality
7. Specify gravity 2.7 and compressive strength 700 to 1300 kg/cm^2
8. Used for ornamental, road metal, railway ballast, aggregate for concrete; for construction of bridges, piers and marine works etc.

Basalt:

1. Igneous rock
2. It is compact, hard and heavy
3. Available in red, yellow grey, blue and greenish black colour
4. Specific gravity is 3 and compressive strength varies 1530 to 1890 kg/cm^2.
5. Used for ornamental, rail road ballast, aggregates for concrete etc.

Sand Stone:

1. Sedimentary rock
2. It is available in variety of formations fine grained, coarse grained compact or porous
3. Available in white, green, blue, black, red and yellow.
4. Specific gravity 2.65 to 2.95
5. Compressive strength is 650kgs / cm^2
6. Used for ashlar works

Lime Stone:

1. Sedimentary rock.
2. It is available in a variety of forms which differ from one another in colour, compaction, texture,
hardness and durable
3. Used for paving, road metal etc

Marble

1. Metamorphic rock
2. Available in white, blue, green, yellow, black and red colour
3. High compactness
4. Suitable for decorative works, wall lining columns, pile, table slabs, hearths, tiled floors, stair case etc.

Slate:

1. Metamorphic rock
2. Non-absorbent, compact fine grained and produce metallic ringing sound when struck

3. Available in black, dark blue, grey, reddish brown etc.
4. Used for providing damp proof course, paving dados etc

<u>Selection of stones for various works</u>:

The selection of the nature and quality of stone for various engineering works is governed by the following factors

i. The purpose in view
ii. Cost of stone,
iii. Its ornamental value and durability

Suitability various types of stones for different purposes and situation is briefly discussed below

a. For face work, in general marble, granite and close-grained sand stone are used in the form of thin slabs (veneers) where the structure subjected to adverse weather effects.
b. For pillars, balustrade, pedestals, columns statues and door and window sill and paving stone, granite, marble and compact lime stone can be recommend because they can take good polish.
c. For ornamental works such as moulding and carvings, fine grained sand stone, fine grained marble and fine grained granite are used.
d. For bridges, piers, docks, break-waters and other marine structures the stone should be very hard, heavy, strong and durable granite and gneiss are recommended for this purpose
e. For road metal, stones should be hard, tough, resistant to abrasion and durable. Basalt and course-grained granite are generally recommended for this purpose.
f. For railway ballast, the stone should be hard, dense, durable, tough and easily workable sandstone, compact lime stone, trap and quartzite are commonly used
g. In situation like steps, doors sills, pavingsetc where there is a regular flow of traffic, stone should be hard, dense, easily workable and durable. Marble, slates and sand stones are commonly use in such places.
h. In fire proof construction, compact sand stone should always be preferred.

<u>Classification of Rocks:</u>

Building stones are obtained from rocks occurring in nature and are classified in three ways.

1. Geological classification
2. Physical classification

3. Chemical classification

I. Geological Classification:

This classification is based upon the geological formation of rocks. According to this classification, the rocks are of the following types.

a. **Igneous rocks:** Rocks that are formed by cooling of Magma (molten rock material) are known as igneous rocks.

Eg: Granite, Basalt and Dolerite etc.

b. **Sedimentary rocks:** These rocks are formed from the deposition of products of weathering of the pre-existing rocks.

Examples: gravel, sandstone, limestone, gypsum, lignite etc.

c. **Metamorphic rocks.** These rocks are formed by the change in characteristics of the pre-existing rocks. Igneous as well as sedimentary rocks are changed in properties when they are subject to great heat and pressure. This process is known as metamorphism.

Examples: Quartzite, Schist, Slate, Marble and Gneiss.

II. Physical Classification:

This classification based on the general structure of rocks. According to this, the rocks are classified into three types,

a. **Stratified Rocks:** These rocks possess planes of stratification or cleavage and such rocks can be easily split along these planes

Eg: sedimentary rocks

b. **Un-stratified rocks:** These rocks don't possess any plane of stratification or cleavage.

Eg: Igneous rocks

c. **Foliated Rocks:** These rocks have a tendency to split up in a definite direction only.

Eg: Metamorphic rocks.

III. Chemical Classification:

This classification is based upon the chemical composition of the rocks. According to this classification rocks are classified into three types.

a. **Siliceous rocks:** In these rocks, silica is predominant. These rocks are hard, durable and not easily affected by weathering agencies.

Eg: Granite, Quartzite, etc.

b. Argillaceous Rocks: In these rocks, clay (alumina) is predominant. The rocks may be dense and compact or may be soft.

Eg: slate, Laterite etc.

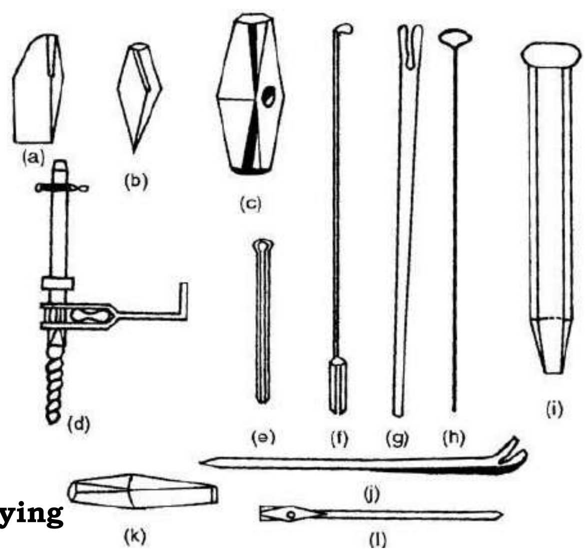
c. Calcareous rocks: In these rocks, calcium carbonate is predominant. The durability of these rocks will depend upon the other constituents present in the rock.

Eg: Lime Stone, marble etc.

Stone Quarrying:
The only operation involved in the production of natural stone is the quarrying process. The open part of the natural rock from which useful stone is obtained is known as *quarry.* While selecting a quarry site, the points to be borne in mind are availability of sufficient quantity of the stone of desired quality, proper transportation facilities, cheap local labour, problems associated with drainage of rain water, location of important and permanent structures in the vicinity and site for dumping refuse.

Stone Quarrying Tools

Some of the quarrying tools shown in figure are wedge, pin, hammer, dipper or scraping spoon, tamping bar, priming needle, jumper, borer, claying iron, crow bar.



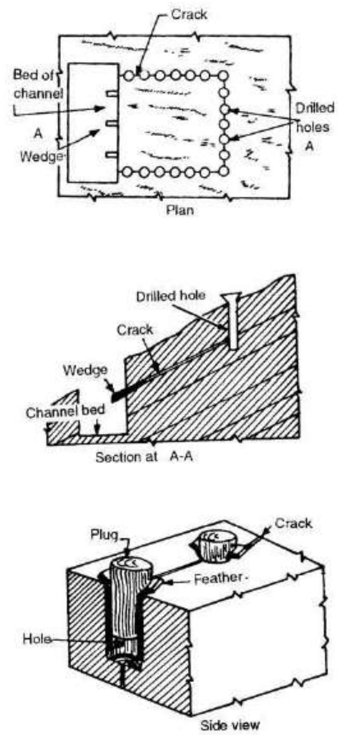
Methods of Quarrying

Rocks suitable for the manufacture of stone materials are called *useful minerals* and the operations involved in obtaining minerals are called *mining.* In the process of mining, voids formed are called *excavations,* and the mined deposits are the *quarries.* The purpose of quarrying is to obtain stones for various engineering purposes. A knowledge of various quarrying methods is essential but does not make one very much more competent to choose or specify a stone for building work. Depending upon the nature and surface of rocks and the purpose for which stones are needed, quarrying is done by excavating, wedging, heating or blasting.

Excavating: Stones buried in earth or under loose overburden are excavated with pick axes, crow bars, chisels, hammers, etc.

Wedging: This method of quarrying is suitable for costly, soft and stratified rocks such as sandstone, limestone, laterite, marble and slate.

About 10–15 cm deep holes, at around 10 cm spacing, are made vertically in the rock. Steel pins and wedges or plugs (conical wedges) and feathers (flat wedges) as shown in Fig. 3.4 are inserted in them. The latter arrangement of plugs and feather is better. These plugs are then struck simultaneously with sledge hammer. The rock slab splits along the lines of least resistance through holes. In case of soft rocks, dry wooden pegs are hammered in the holes and water is poured over them. The pegs being wet swell and exert pressure causing the rocks to crack along the line of holes. Then, the wedges are placed on the plane of cleavage (the joint of two layers) on the exposed face of rock and are hammered. The slab is completely detached and taken out with the help of crow bars and rollers. In this method, the wastage is minimum and the slabs of required size and shape can be quarried.



Heating is most suitable for quarrying small, thin and regular blocks of stones from rocks, such as granite and gneiss. A heap of fuel is piled and fired on the surface of rock in small area. The two consecutive layers of the rock separate because of uneven expansion of the two layers. The loosened rock portions are broken into pieces of desired size and are removed with the help of pick-axes and crow-bars. Stone blocks so obtained are very suitable for coarse rubble masonry. Sometimes, intermediate layers are to be separated from the top and bottom layers. In such a case, the intermediate layer is heated electrically and the expansion separates it from the other two.

Blasting: Explosives such as blasting powder, blasting cotton, dynamite and cordite are used. The operations involved are boring, charging, tamping and firing.

Boring: Holes are drilled or bored in the rock to be dislodged. For vertical holes, jumper is used whereas for inclined or horizontal holes, boring bars are used. One person holds the jumper exactly in the place where hole is to be made. The other person strikes it up and down and rotates it simultaneously. Water is poured in the hole regularly during the operation to soften the rock and facilitate drilling. The muddy paste generated in the process is removed from holes by scrapping. For hard rocks, machine drilling is employed instead of hand drilling.

Charging The holes are dried completely and the required amount of charge is placed in the holes. For drying the holes, rag is tied in the scrapper and is moved in the hole from where it absorbs the moisture, if any. In case it is found that water is oozing into the hole, water-tightness is ensured inside the hole.

Tamping: After placing the charge in the hole, a greased priming needle, projecting a little outside the hole, is placed in the hole which is then filled up with damp clay or stone dust in layers tamped sufficiently with a braccd tamping rod. The priming needle should be kept on rotating while tamping is going on. This is done so that the needle remains loose in the hole. The priming needle is then taken out and 60 to 75 per cent of space created by withdrawal of needle is filled with gun powder. A Bickford fuse, a small rope of cotton coated with tar, is placed just touching the needle. The other end of the fuse is kept of sufficient length so that the person igniting it can move away to a safe place. Blasting powder and cordite are ignited by means of a fuse, whereas gun cotton and dynamite are exploded by detonation.

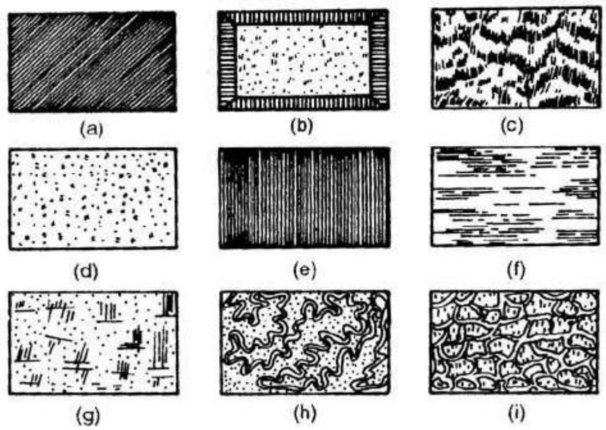
Precautions in Blasting:

Accidents may take place during blasting. Following are some of the points which should be taken note of

- Blasting should not be carried out in late evening or early morning hours. The blasting hours should be made public and a siren should warn the workmen and nearby public timely to retire to a safe distance.
- The danger zone, an area of about 200 m radius, should be marked with red flags.
- First aid should be available.
- The number of charges fired, the number of charges exploded and the misfires should be recorded.
- Explosives should be stored and handled carefully.
- Detonators and explosives should not be kept together.
- Cartridges should be handled with rubber or polythene gloves.
- A maximum of 10 bore holes are exploded at a time and that also successively and not simultaneously.

<u>DRESSING OF STONE</u>

A quarried stone has rough surfaces, which are dressed to obtain a definite and regular shape. Dressing of stones is done immediately after quarrying and before seasoning to achieve less weight for transportation. Dressing of stone provides pleasing appearance, proper bedding with good mortar joints, special shapes for arches, copings, pillars, etc. The various types of dressed stones are shown in Figure.



a) Stroked	(d) Sparrow picked	(g) Combed
b) Punched	(e) Tooled	(h) Vermiculated
c) Rock faced	(f) Sawn	(i) Reticulated

<u>COMPOSITION OF BRICK EARTH</u>:

Following are the constituents of good brick earth.

Alumina: - It is the chief constituent of every kind of clay. A good brick earth should contain 20 to 30 percent of alumina. This constituent imparts plasticity to earth so that it can be moulded. If alumina is present in excess, raw bricks shrink and warp during drying and burning.

Silica: - A good brick earth should contain about 50 to 60 percent of silica. Silica exists in clay either as free or combined form. Presence of silica prevents cracks, shrinking and warping of raw bricks. It thus imparts uniform shape to the bricks. Durability of bricks depends on the proper proportion of silica in brick earth. Excess of silica destroys the cohesion between particles and bricks become brittle.

Lime: – A small quantity of lime, usually 10 percent is desirable in finely powdered state to prevent shrinkage of raw bricks. Excess of lime causes the brick to melt and hence, its shape is lost due to the splitting of bricks.

Iron Oxide- A small quantity of Iron Oxide to the extent of 5 to 6 percent is desirable in good brick to impart impermeability, durability, red colour to bricks. Excess of oxide of iron makes the bricks dark blue or blackish.

Magnesia- A small quantity of magnesia usually less than 1 percent is present in brick earth. It helps the brick to melt slowly while burning and reduces warping. But excess of magnesia gives yellow tint and leads to the decay of bricks.

MANUFACTURE OF BRICKS:

The manufacturing of brick, the following operations are involved

1. Preparation of clay
2. Moulding
3. Drying
4. Burning

1. Preparation of clay :-The preparation of clay involves following operations

a)Unsoiling- Top layer of 20cm depth is removed as it contain impurities such as vegetation, twigs, leaves, pebbles etc.

b)Digging – After the removal of top layer, additives like flyash, loam etc are spread over the clay and it is dug and puddled for watering and subsequent weathering.

c)Weathering - Clay dug out from ground is spread on level ground about 60cm to 120cm heaps. Clay is exposed to atmosphere from few weeks to full season.

e)Blending - Clay is mixed with water and is added with any ingredient to be added. Clay is then spread out followed by turning it up and down in vertical direction**.**

f)Tempering - Clay is brought to a proper degree of plasticity by tempering. The whole mass is kneaded or pressed under the feet of men or cattle. For large scale, tempering is usually done in pug mill as shown below.

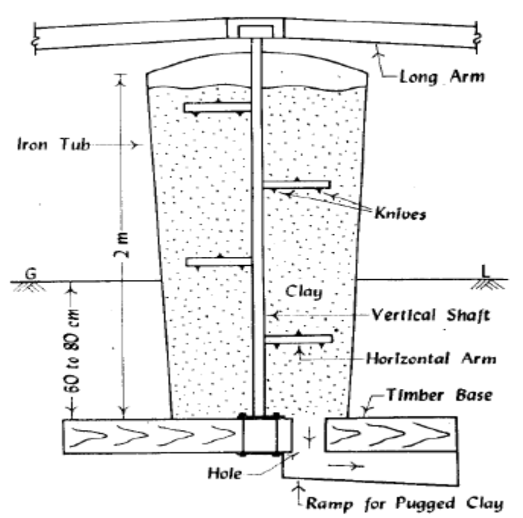


Fig- Pug Mill

Clay mixed with water is placed in pug mill from the top. When the vertical shaft is rotated by using electric, steam or diesel means or turned by pair of bullocks. Clay is thoroughly mixed up by the actions of horizontal arms and knives. When clay has been sufficiently pugged, hole at the bottom of tub, is opened and the pugged earth is taken out from ramp for the next operation of moulding.

2. Moulding:- Clay, which is prepared form pug mill, is sent for the next operation of moulding.
Following are the two ways of moulding.
I.HandMoulding
II.MachineMoulding

I. Hand Moulding:
Moulds are rectangular boxes of wood or steel, which are open at top and bottom. Steel moulds are more durable and used for manufacturing bricks on large scale. Bricks are moulded by hand moulding in two ways.
a) Ground moulded bricks
b) Table moulded bricks

(a)Ground moulded bricks: Ground is first made level and fine sand is sprinkled over it. Mould is dipped in water and placed over the ground and filled with the clay. Extra clay is removed by wooden or metal strike. After the mould is filled, forcibly the mould is then lifted up and raw brick is left on the ground.
Ground moulded bricks of better quality and with frogs on their surface are made by using a pair of pallet boards and a wooden block
(b)Table moulded bricks: Process of moulding these bricks is just similar to ground moulding bricks. The entire process of filling is done on a table of size about 2m x 1m to which the mould will be fixed.

II.Machine moulding: This method proves to be economical when bricks in huge quantity are to be manufactured at once.. It is also helpful for moulding hard and stiff clay. These machines are broadly classified in two categories
(a) Plastic clay machines
(b) Dry clay machines
a)Plastic clay machines: This machine consists of a rectangular opening of size equal to length and height of a brick. Pugged clay is placed in the machine and as it comes out through the opening, it is cut into strips by wires fixed in frames, so there bricks are called wire cut bricks.
b)Dry clay machines: In these machines, strong clay is first converted into powder form and then water is added to form a stiff plastic paste. Such paste is placed in mould and pressed by machine to form hard and well-shaped bricks.

These bricks are stronger than ordinary hand moulded bricks. They carry distinct frogs and exhibit uniform texture.

<u>3. Drying:</u> The damp bricks, if burnt directly without drying, are likely to be cracked and distorted. Hence moulded bricks are dried before they are taken for the next operation of burning. Bricks are laid along and across the stock in alternate layers. The drying of brick can be done as outlined below.
(i)Artificial drying – Drying by tunnels usually at 120 ^{0}C for about 1 to 3 days
(ii)Circulation of air- Stacks are arranged in such a way that sufficient air space is left between them for free circulation of air.
(iii)Drying yard- Special yards can be prepared at slightly higher level to prevent the accumulation of rain water
Duration – Usually about 3 to 10 days are required for the bricks to become dry (upto 3 percent moisture)
Screens – Screens may be provided to prevent the bricks from direct exposure to wind or sun.

<u>4.Burning:</u>

This is very important operation in the manufacturing of bricks. Burning imparts hardness, strength and makes them dense & durable. Burning of bricks is done either in clamps or in kilns.

- Clamps are temporary structures and they are adopted to manufacture bricks on small scale.
- Kilns are permanent structures and they are adopted to manufacture bricks on a large scale.

<u>A.Clamp Burning:</u> A typical clamp is shown in the figure below

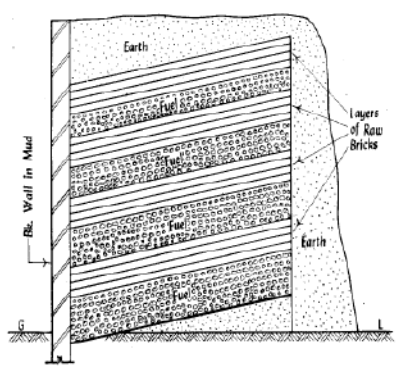


Fig.Clamp

(1) A clamp is trapezoidal shape in plan with one end is slightly in excavation and the other end is raised at an angle of 15^0 from ground level
(2) A brick wall with mud is constructed on the short end and a layer of 70cm to 80cm thick fuel (grass, cow dung, ground nuts, wood or coal) laid on the floor.
(3) A bricks layer consisting of 4 or 5 courses of raw bricks is laid with small spaces between them for circulation of air

(4) A second layer of fuel is then placed, and over it another layer of raw bricks is placed. The total height of clamp(3m - 4 m) is filled with alternate layers of brick and fuel.

(5) When clamp is completely constructed, it is plastered with mud on sides and top and filled with soil to prevent the escape of heat

(6) The period of burning is about one to two months and usually the same time is required for cooling.

(7) Burnt bricks are taken out from the clamp after cooling.

Advantages:

(i) The bricks produced would be tough and strong because burning and cooling are gradual.

(ii) Burning in clamps proves to be cheap and economical.

(iii) No skilled labour and supervision are required for the construction of clamps.

(iv) There is considerable saving of fuel in clamps.

Disadvantages:

(i) Bricks may distort in shape and size.

(ii) It is very slow process.

(iii) It is not possible to regulate the heat in a clamp.

(iv) Quality of brick is not uniform

<u>B.Kiln Burning:</u>

A kiln is a large oven, which is used to burnt bricks. The following are the two types of kilns.

1) Intermittent kilns

2) Continuous kilns

<u>1) Intermittent kilns:</u>These are intermittent (intervals) in operation, which means that they are loaded, fired, cooled and unloaded in intervals.

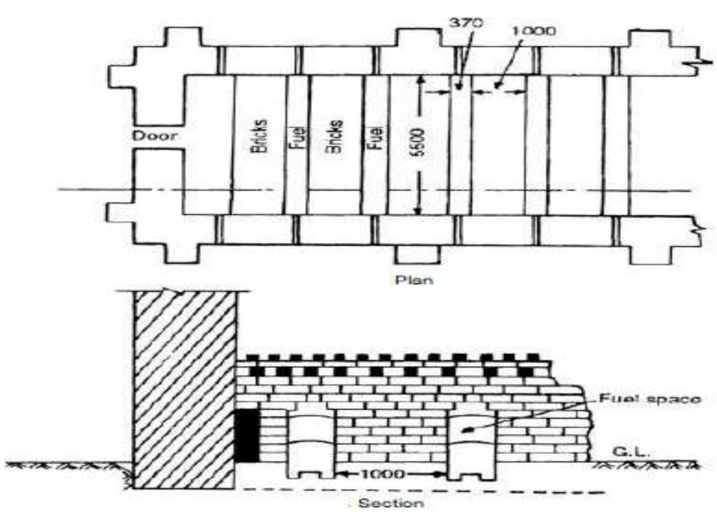


Fig. Intermittent kiln

Intermittent kilns are of two types. They are
a) Intermittent up-draught kilns
b) Intermittent down-draught kilns

a) Intermittent up-draught kiln: This kiln is rectangular with thick outside walls. Wide doors are provided at each end for loading and unloading of kilns. A temporary roof may be installed to protect from rain and it is removed after kiln is fired. Flues are provided to carry flames or hot gases through the body of kiln.

(i) Raw bricks are laid in rows of 2 to 3 bricks and height of 6 to 8 bricks with 2 bricks spacing between rows
(ii) Fuels is filled in the spacings.
(iii) Each door is built up with dry bricks and are covered with mud or clay
(iv) The kiln is then fired for a period of 48 to 60 hours draught rises in the upward direction from bottom of kiln and brings about the burning of bricks.
(v) Kiln is allowed to cool down and bricks are then taken out
(vi) Same procedure is repeated for the next burning

Bricks manufactured by intermittent up draught kilns are better than those prepared by clamps.

But bricks burnt by this process are non-uniform, supply of bricks is also not continuous and there is wastage of fuel & heat.

(b) Intermittent down-draught kilns:

These kilns are rectangular or circular in shape. They are provided with permanent walls and closed tight roof. Floor of the kiln has opening which are connected to a common chimney stack through flues.

Working procedure is same as up-draught kiln. But it is so arranged in this kiln that hot gases are carried through vertical flues upto the level of roof and they are then released. These hot gases move down ward by the chimney draught and in doing so, they burn the bricks.

Advantages:

(i) Bricks are evenly burnt
(ii) Performance of this kiln is better than that of up-draught kiln
(iii) This kiln is particularly suitable for burning of structural clay tiles, terra-cota because of close control of heat.

<u>2. Continuous kilns:</u>

These kilns are continuous in operations. This means that loading, firing, cooling and unloading are carried out simultaneously in these kilns. There are two types of continuous kilns.
a) Bull's trench kiln
b) Hoffman's kiln

a) Bull's Trench kiln: This kiln may be of rectangular, circular or oval shape in the plan. It is constructed in a trench excavated in ground either fully under-

ground or partially projecting above the ground. Openings are provided in the outer walls to act as flue holes.
Dampers are in the form of iron plates and they are used to divide the kilns in suitable sections . It is most widely used kiln in India.

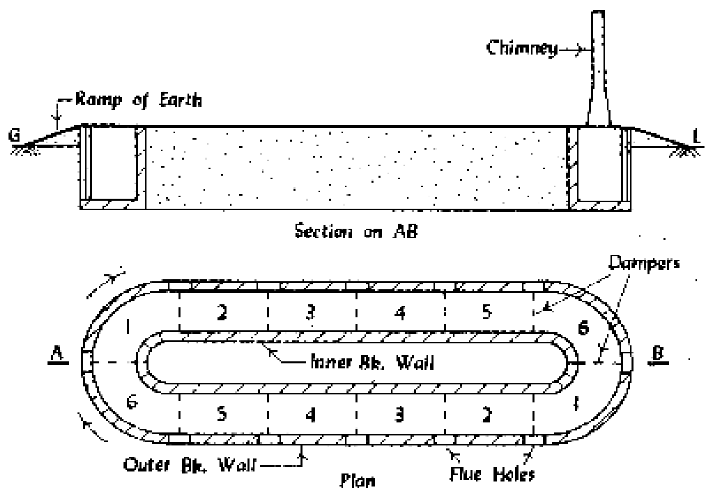


Fig. Bull's trench kiln

The bricks are arranged in such a way that flues are formed. Fuel is placed in flues and it is ignited through flue holes.
The top surface is covered with earth and ashes to prevent the escape of heat. Usually two movable iron chimneys are employed to form draught.
These chimneys are placed in advance of section being fired. Hence, hot gases leaving the chimney warm up the bricks in next section. Each section requires about one day to burn. The tentative arrangement for different sections may be as follows
Section 1 – loading
Section 2 – empty
Section 3 – unloading
Section 4 – cooling
Section 5 – Burning
Section 6 – Heating

b) Hoffman's kiln: This kiln is constructed over ground and hence, it is sometimes known as flame kiln. It is circular in plan and it is divided into a number of compartments or chambers. A permanent roof is provided and hence the kiln can even function during rainy season. The below figure shows plan and section of Hoffman's kiln with 12 chambers

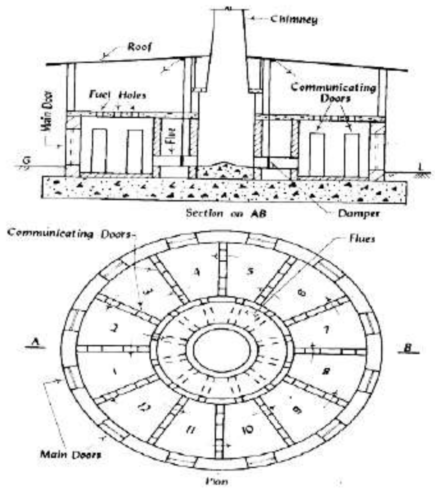


Fig. Hoffman's kiln

The tentative operations in various chambers are
Chamber 1 - loading
Chamber 2 to 5 – drying and pre-heating
Chambers 6 and 7 - burning
Chambers 8 to 11 - cooling
Chamber 12 – unloading

Though the initial cost in installing this kiln is high, it has the following advantages
(i) Good quality of bricks are produced
(ii) It is possible to regulate heat inside the chambers through fuel holes
(iii) Supply of bricks is continuous and regular
(iv) There is considerable saving in fuel due to pre heating of raw bricks by flue gases

COMPARISION BETWEEN CLAMP AND KILN BURNING OF BRICKS:

No.	Item	Clamp-burning	Kiln-burning
1.	Capacity	About 20000 to 100000 bricks can be prepared at a time.	Average 25000 bricks can be prepared per day.
2.	Cost of fuel	Low as grass, cow dung, litter, etc. may be used.	Generally high as coal dust is to be used.
3.	Initial cost	Very low as no structures are to be built.	More as permanent structures are to be constructed
4.	Quality of bricks	Percentage of good quality bricks is small about 60% or so.	Percentage of good quality bricks is more about 90% or so.
5.	Regulation of fire	It is not possible to control or regulate fire during the process of burning	Fire is under control throughout the process of burning.
6.	Skilled supervision	Not necessary through-out the process of burn-ing.	Continuous skilled super vision is necessary.
7.	Structure	Temporary structure.	Permanent structure.
8.	Suitability	Suitable when bricks are to be manufactured on a small scale and when the demand of bricks is not continuous.	Suitable when bricks are to be manufactured on a large scale and when there is continuous demand of bricks.
9.	Time of burn-ing and cool-ing.	It requires about 2 to 6 months for burning and cooling of bricks.	Actual time for burning of one chamber is about 24 hours and only about 12 days are required for cooling of bricks.
10.	Wastage of heat.	There is considerable wastage of heat from top and sides and hot flue gas is not properly utilised.	Hot flue gas is used to dry and pre-heat raw bricks. Hence wastage of heat is the least.

QUALITIES/ CHARACTERISTICS OF GOOD BRICK:

- Bricks should be table moulded and well burnt in kilns.
- Colour of the bricks should be dark red.
- Bricks must free from cracks and with sharp and square edges.
- Bricks should be of uniform shape and should be of standard size.
- Bricks should give clear ringing sound when struck each other.

- Bricks when broken should show a bright homogeneous and compact structure free from voids.
- Bricks should not absorb water more than 15 percent by weight for first class bricks and 20 percent by weight for second class bricks, when soaked in water for a period of 24 hours.
- Bricks should be sufficiently hard so as no impression should be left on brick surface, when it is scratched with finger nail.
- Bricks should possess low thermal conductivity and they should be sound proof.
- Bricks should not break when dropped flat on hard ground from a height of about one meter.
- Bricks, when soaked in water for 24 hours, should not show deposits of white salts when allowed to dry in shade.

MASONRY

Stone Masonry: The art of building a structure in stone with any suitable masonry is called stone masonry.

Types of Stone Masonry:

Stone masonry may be broadly classified into the following two types:

1. Rubble Masonry 2. Ashlar Masonry

1.Rubble Masonry:

a. Random rubble Masonary:

In this masonary the stones are placed at random without caring for the size and shape of the stones. The courses are not regular. The stones are hammer dressed face, sides and beds. The busting on faces should not project more than 40mm, on the exposed face and 12mm if the face is to plastered.

b. Course Rubble of 1st Sort:

Coursed rubble stone masonary consists of a facing of selected stones hammer dressed at faces and joints. They are set in regular coarses of uniform thickness from bottom to top.

c. Course Rubble of 2nd Sort:

It is constructed similar to coursed rubble of 1st sort on the front face. The backing and hearting will be constructed as random rubble masonary.

2. Ashlar masonry:

The stone masonry in which finely dressed stones are laid in cement or lime mortar is known as ashlars masonry. In this masonry are the courses are of uniform height, all the joints are regular, thin and have uniform thickness. This type of masonry is much costly as it requires dressing of stones.

Suitability: This masonry is used for heavy structures, architectural buildings, high piers and abutments of bridges.

- Ashlars masonry is further sub divided into the following types:
- Ashlars fine or coarse ashlar masonry
- Random coarse ashlars masonry
- Rough tooled ashlar masonry
- Rock or quarry faced ashlars masonry
- Chamfered ashlars masonry
- Block in coarse masonry
- Ashlar facing

Ashlar fine or coarsed ashlar masonry: In this type of stone masonry stone blocks of same height in each course are used. Every stone is fine tooled on all sides. Thickness of mortar is uniform through out. It is an expensive type of stone masonry as it requires heavy labor and wastage of material while dressing. Satisfactory bond can be obtained in this type of stone masonry.

Random coursed ashlar masonry: This type of ashlar masonry consists of fine or coursed ashlar but the courses are of varying thicknesses, depending upon the character of the building.

Rough tooled ashlar masonry: This type of ashlar masonry the sides of the stones are rough tooled and dressed with chisels. Thickness of joints is uniform, which does not exceed 6mm.

Rock or quarry faced ashlar masonry: This type of ashlar masonry is similar to rough tooled type except that there is chisel-drafted margin left rough on the face which is known as quarry faced.

Chamfered ashlar masonry: It is similar to quarry faced except that the edges are bevelled or chamfered to 450 for depth of 2.5 cm or more.

Block-in course masonry: It is the name given to a class of ashlar masonry which occupies an intermediate place between rubble and ashlars. The stones are all squared and properly dressed. It resembles to coursed rubble masonry or rough tooled ashlar masonry.

Ashlar facing: Ashlar facing is the best type of ashlars masonry. Since this is type of masonry is very expensive, it is not commonly used throughout the whole thickness of the wall, except in works of great importance and strength. For economy the facing are built in ashlars and the rest in rubble.

MASONARY

Types of Masonary:

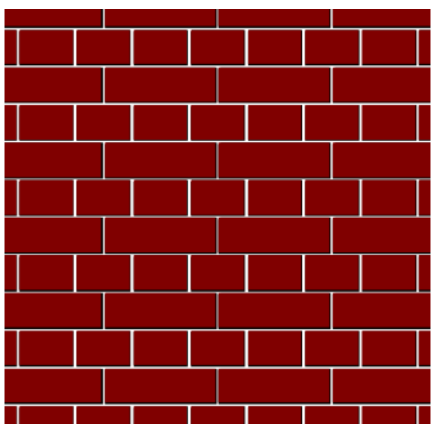
The most commonly used types of bonds in brick masonry are

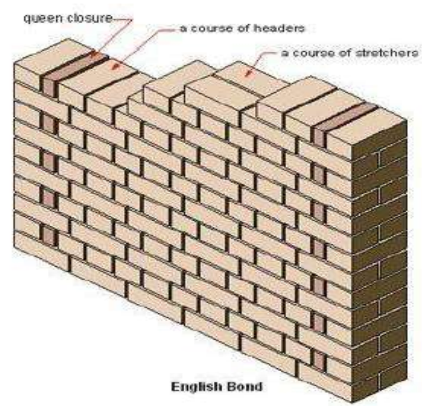
1. English bond
2. Flemish bond
3. Rat trap bond

English bond:

English bond in brick masonry has one course of stretcher only and a course of header above it, i.e. it has two alternating courses of stretchers and headers. Headers are laid centered on the stretchers in course below and each alternate row is vertically aligned.

To break the continuity of vertical joints, quoin closer is used in the beginning and end of a wall after first header. A quoin close is a brick cut lengthwise into two halves and used at corners in brick walls.





English Bond Isometric view of English bond

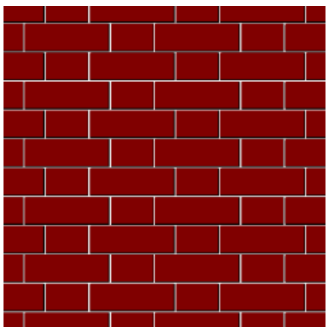
Flemish bond:

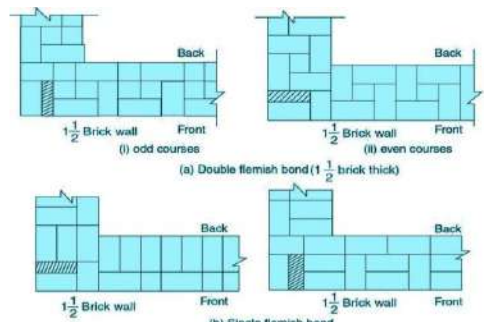
For the breaking of vertical joints in the successive courses, closers are inserted in alternate courses next to the quoin header. In walls having their thickness equal to odd number of half bricks, bats are essentially used to achieve the bond.

Flemish bond, also known as Dutch bond, is created by laying alternate headers and stretchers in a single course. The next course of brick is laid such that header lies in the middle of the stretcher in the course below, i.e. the alternate headers of each course are centered on the stretcher of course below. Every alternate course of Flemish bond starts with header at the corner.

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. For the breaking of vertical joints in the successive courses, closers are inserted in alternate courses next to the quoin header. 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 are classified as:

1. Single Flemish Bond 2.Double Flemish Bond

Single Flemish bond 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 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.

<u>Rat trap bond:</u>

Rat trap bond is a brick masonry method of wall construction, in which bricks are placed in vertical position instead of conventional horizontal position and thus creating a cavity (hollow space) within the wall.

This gives the wall with an internal cavity bridged by the rowlock. This is the major reason where virgin materials like brick clay and cement can be considerably saved. This adds this technology to the list of Green building technologies and sustainability for an appropriate option as against conventional solid brick wall masonry.

This cavity adds an added advantage as it adds a Green building feature of help maintain improved thermal comfort and keep the interiors colder than outside and vice versa.

The Rat trap bond construction is a modular type of masonry construction. Due care must be taken while designing the wall lengths and heights for a structure. The openings and wall dimensions to be in multiples of the module. Also the course below sill and lintel to be a solid course by placing bricks on edge. The masonry on the sides of the openings also to be solid as will help in fixing of the opening frame.

Rat trap bond

Cavity wall:

It consists of two separate walls called leaves or skins, with a cavity or gap in between. The two leaves of a cavity wall will have the same thickness. If it is a non-load bearing wall, the internal leaf may be thicker than the external leaf, to meet the structural requirements. The two potions of the wall is connected together by metal pins or bonding bricks at a suitable interval.

It prevents the dampness to enter and acts as sound insulation. Generally there are provided at the outer walls of the buildings. The size of cavity varies from 4-10cms. The inner and outer skins or leaves should not be less than 10cms.

Advantages of Cavity Walls

(a) There is no possibility of the moisture travelling from the outer wall to the inner wall.

(b) The layer of air in the cavity being non-conductor of heat, it reduces the transmission of heat from the external face to internal one. Cavity walls have 25% greater insulating value than solid walls. This acts as damp barrier, reduces the cooling cost of the building.

(c) These have good sound insulation property.

(d) They are economical.

Precautions:

(a) Damp proof course should be laid separately for two walls.

(b) The cavity should be properly drained and ventilated by providing weep holes.

(c) Cavity should be kept clear of dropping of mortar or brick, rubbish etc during construction.

(d) Vermin's or mosquitoes should not be there in the cavity wall.

Partition Wall - A wall made of bricks, studding glass, wood etc. for the purpose of dividing the one room/portion from another.

Types of Partition walls:

- Brick Partitions
- Clay block Partitions
- Concrete Partitions
- Glass Partitions
- Asbestos sheets or gas sheets Partitions
- Blaster Slab Partitions
- Timber Partitions

Requirements of partition walls:

- It should be thin so that the maximum floor area can be utilized.
- It should provide privacy in such a way that inhabitants feel comfortable with respect to sight and sound.
- It should be light in weight.
- The wall must have fire resisting properties so that in a sudden short circuit or any other reason, it could not catch fire.
- The material used for the wall must be durable.
- It should not be subjected to white-ant or fungus. **White ant*** or termite is a small insect which feeds on wood.
- It should be economical and simple in construction.
- It should be rigid enough to bear the vibrations caused due to the loads.
- It should be able to support sanitary fittings and heavy fixtures.

BUILDING MATERIALS AND CONSTRUCTION

DEPARTMENT OF CIVIL ENGINEERING

UNIT-II

Course Objectives:

- To learn the properties, classification and manufacturing process of materials such as wood, lime and cement and familiarize with various methods of construction.

Syllabus:

Wood

Classification of various types of woods used in buildings, Structure of wood, Properties - Seasoning of timber; Defects in timber.

Lime and cement

Various ingredients of lime, Constituents of lime stone ; Classification of lime ; Cement: Composition, Cement Manufacturing Process, Various types of cements, their properties and uses; Various field and laboratory tests for Cement.

Learning Outcomes:

Student will be able to

- Apply the knowledge of manufacturing process and composition of building materials and concrete.

Learning Material

Introduction:

Wood is a hard and fibrous substance which forms a major part of the trunk and branches of a tree. It can also be defined as a natural polymeric material which practically does not age. Wood as a building material falls in two major classes—natural and man-made. With the advances in science and technology, wood in its natural form as timber, lumber, etc. is being rapidly replaced by composite wood materials in which natural wood is just a basic ingredient of a matrix or a laminate. The latter are found to be more useful and adaptable as they may be treated chemically, thermally or otherwise as per requirements. Some examples are plywood, fibreboards, chipboards, compressed wood, impregnated wood, etc. Wood has many advantages due to which it is preferred over many other building materials. It is easily available (this won’t be true after some years) and easy to transport and handle, has more thermal insulation, sound absorption and electrical resistance as compared to steel and concrete.

Classification of various types of woods used in buildings:

Many wood based products have been developed to economise on the use of timber. These wood products are manufactured under controlled conditions in factories. As such, these have desired shape and dimensions, appearance, strength and durability. Some of these are described below

Veneers

The primary process in the manufacture of wood based products is veneering which produces thin sheets of wood known as veneers. The thickness of veneers varies from 0.4 to 0.6 mm. In no case it should exceed 1 mm. The most suitable wood for this purpose is walnut. However other species like teak, sissoo, 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. Depending on the cutting process, the veneers are classified as rotary veneers (Fig.) and sliced veneers (Fig.). These are used in the manufacture of plywood and other laminated boards

Classification

Veneers are classified into two types or surfaces namely, Type A and Type B. The quality requirements in the terms of permissible defects for the two types of surfaces are given in Table. The maximum numbers of categories of defects permitted are restricted and are given in Table.

Dimensional Tolerances

Following tolerance are permitted on the dimensions.

Dimension	Tolerance
Length	+6 mm
Width	+3 mm
Squareness	0.2 %
Edge straightness	0.2 %

Quality Requirements of Veneers

S. No.	*Defect Categories*	*Type of Surfaces*	
		A	*B*
(i)	Discolouration	Nil	5 percent
(ii)	Dote*	50 mm/m^2	150 mm/m^2
(iii)	Insect hole	Scattered up to 12 holes/m^2	Scattered up to 24 holes/m^2
(iv)	Joints	One joint for every multiple of 200 mm provided, no individual piece is less than 100 mm in width	No restriction
(v)	Knots (dead)	2 No. up to 12 mm dia/m^2	4 No. up to 20 mm dia/m^2
(vi)	Pin knots (dead)	2 No./m^2	6 No. m^2
(vii)	Pin knots (live)	No restriction	No restriction
(viii)	Knots (tight)	6 No. upto 25 mm dia/m^2	No restriction
(ix)	Patches	4 patches/m^2 provided. They are all tight patches and do not mar the appearance	Any number provided they are all tight patches and do not mar the appearance
(x)	Splits	2 splits, each not more than 1 mm wide and length not more than 100 mm	3 splits, each not more than 4 mm wide and length not more than 150 mm
(xi)	Swirl	Unlimited, provided they do not mar the appearance	No restriction

*It is an early stage of dacay characterized by local discolouration of wood most frequently in the form of streaks along the grain but sometimes as spots.

Permissible Categories of Defects

Types of Surfaces	*Maximum Number of Categories of Permissible defects per square metre*
A	3
B	5

Plywood

A wood panel glued under pressure from an odd number (usually 3 to 13) of layers/piles of veneers is known as plywood (Fig.). 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 piles which have grain directions perpendicular to that in the face are termed as cross bands. Plywood may be classified upon direction of grains in the plies and on the type of adhesive used. 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.

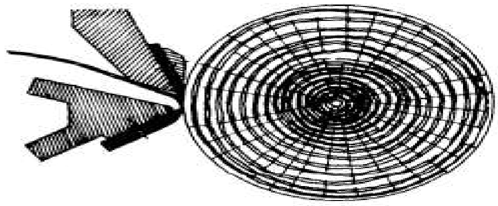
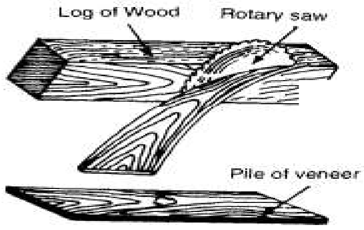


Fig. 4.23 Rotary Cutting



Fia. 4.24 Sliced Veneer

Fig. 4.25 Plywood

Classification

Based on grades: Plywood for general purposes should be of the following two grades, depending upon the bond strength developed by the adhesive used for bonding the veneers:

(a) Boiling water resistant or BWR Grade, and

(b) Moisture resistant or MR Grade.

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. The thickness of plywood boards for general and structural purposes should be as given in Table

Thickness of Plywood Boards (IS: 303 and 10701)

Board	*Thickness (mm)*	
	General Purpose	*Structural Purpose*
3 ply	3, 4, 5, 6	4
5 ply	5, 6, 8, 9	6, 9
7 ply	9, 12, 15, 16	12, 16
9 ply	12, 15, 16, 19	16, 19
11 ply	19, 22, 25	19, 25
Above 11 ply	On order	

Tolerances

The following tolerances on the nominal sizes of finished boards should be permissible:

Dimension	*Tolerance*	
	General Purpose	*Structural Purpose*
(a) Length	+6 mm –0 mm	+6 mm –0 mm
(b) Width	+3 mm –0 mm	+3 mm –0 mm
(c) Thickness		
1. less than 6 mm	±10%	±10%
2. 6 to 9 mm	±5 %	±7 %
3. above 9 mm		±5 %
(d) Squareness	± 0.2%	0
(e) Edge straightness	±0.2%	0

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

Advantages:

1. It has good strength both along as well as across the grains.

2. The wood shrinks or swells more across the grains. Since plywood has cross-grained construction, the tendency to shrink or swell is reduced.

3. 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.

4. Plywood can be curved into desired shapes.

Uses

These are extensively used for partitions, ceilings, doors, concrete form work, plywood boards, laminated boards (built-up boards with core strips up to 7 mm wide and 7 mm thick) and block boards (built-up boards) etc.

Fibre boards:

These boards built up of felting from wood or vegetable (wood wastes, waste paper, agricultural wastes, etc.) are classified by the process of their moulding. If the boards are moulded by wet process, the main bond is by the felting of woody fibres and not by added glue. For the boards moulded by dry process, the bond between the pre-dried fibres is improved by adding 4–8% of synthetic resin. For better performance wood preservatives and other admixtures are often added to the pulp. Insulating boards are not compressed during manufacture. Fibre boards are manufactured in various densities like soft, medium and hard. The soft boards are used for walls and ceilings. Medium boards find their application in panelling, partition walls, doors and windows. Hard boards have one surface smooth and the other one textured. These have higher densities, better mechanical properties, and improved moisture and termite resistances.

The strength and weather properties of hard boards can be improved by oil tempering and such boards are known as tempered hard boards. Some of the trade names of hard boards are Masonite. Celotex. Essex boards, etc.

Classification

Hard boards are classified as medium, standard or normal and tempered hard boards depending upon the density. The requirements of hard boards are given in Tables

Requirements of Hardboards

Type of Board	*Average density ($10^3 \times Kg/m^3$)*	*Thickness (mm)*	*Bending strength (Modulus of rupture) average (MPa)*	*Maximum water absorption by mass after 24 hrs immersion (%)*
			6	
Medium	Min. 0.35	8	6	40
hardboard	Max. 0.80	10		
		12		
Standard	More than	3	30	40
hardboard	0.80	4		
		5		
		6	30	30
		7		
Tempered	1.2	3		
hardboard		4		
		5	50	20
		6		
		9		

Thickness of Hardboards

Type	*Nominal thickness (mm)*	*Tolerance (mm)*
Medium hardboard	6	± 0.5
	8	± 0.7
	10	± 0.7
	12	± 0.9
Standard hardboard	3	
	4	± 0.4
	5	
	6	± 0.5
	9	± 0.7

Width and Length of Hardboards

Type	*Width (m)*	*Maximum tolerance on Width (mm)*	*Length (m)*	*Maximum tolerance on length (mm)*
Medium hardboard	1.2		1.2,1.8,2.4	
Standard hardboard	1,2	± 3	3.0,3.6,4.8	± 5
Tempered hardboard	1.2		and 5.5	

Uses

They are widely used for wall and ceiling cladding, partitions, doors, perforated acoustic tiles, railway carriages, bus bodies, etc.

Particle board / chip-boards:

They are manufactured from particles of wood or other ligno cellulose materials which are agglomerated, formed and pressed together by the use of an organic binder together in the presence of heat, pressure or moisture. They are manufactured from small timber pieces and wood wastes. The latter is first converted into small chips. The moisture content of chips is reduced to a certain percentage and then some gluing material, usually phenol formaldehyde, is sprayed. The chips are then spread to form a mat and then pressed in a hydraulic press in presence of heat and moisture.

Particle boards avoid wastage of timber as in its making the entire volume of the fallen tree can be utilized. The trees used for making particle boards are eucolyptus, subabool, and rubber wood, and waste of saw mill. These boards provide dimensional stability, smooth uniform surface, and no difficulty in nailing.

Classification

Depending on density these are classified as given in Table

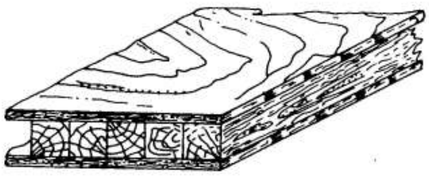
Uses

These are widely used in buildings, partitions, ceilings, floor slabs, doors, furniture, etc.

Block boards

The core of black boards is made up of strips of wood each not exceeding 25 mm in width, forming a slab, glued between at least two surface veneers (Fig.). Veneers used for cross bands and faces are either rotary cut or sliced and should be reasonably smooth. Cross band thickness varies between 1–3 mm and face veneers between 0.5 to 1.5 mm in thicknesses. These are available in thicknesses of 12, 15, 19, 25, 30, 35, 40 and 50 mm. The directions of the grains of the core blocks run at right angles to that of the adjacent outer veneers.

Block Boards are available in sizes 2400 × 1200, 2100 × 1200, 1200 × 900, 1800 × 1200, 1800 × 900 mm. Following tolerances are permitted.



Block Board

Types and Properties of Wooden Particle Boards

Type	*IS:3129 Low Density*	*IS: 12406 Medium Density*					*IS: 3478 High Density*			
		FPS	*FPT*		*XPS*	*XPT*	*Type 1*		*Type 2*	
			FPT1	*FPT2*			*Grade A*	*Grade B*	*Grade A*	*Grade B*
Maximum Moisture Content(%)	16	15					3-7	5-16	5-10	5-16
Minimum Modulus of Rupture (N/mm²)	1.5	11	12.5	11	2	1				
Density (Kg/m³)	<400	500-900					1200	900	1200	900
Minimum Tensile Strength (N/mm²)		0.8	0.4	0.3	1.2	0.4	35	30	25	20
Water Absorption (24 hr)%		50	20	80	80	80	10	25	15	25
Sizes (mm) Length	3650, 3000, 2700 2400, 1800, 1500 1000, 900, 600, 450 and 300	4850, 3650, 3000, 2750, 2400 2100, 1800, 1500, 1200, 1000 and 900					1800, 1500, 1200, 1000, 900, 600, 450			
Width	1800, 1500, 1200, 1000, 900, 600 450 and 300	1850, 1800, 1500, 1200, 900 and 650					1500, 1200, 1000, 900, 450			
Thickness	12, 16, 19, 22, 25 27, 30, 35, 40, 45, 50	6, 9, 12, 15, 18, 19, 22, 25, 27 30, 35, 40					4, 6, 9, 12, 16, 20, 25, 30, 35, 40, 50			
Tolerances (mm) Length Width Thickness	± 8 ± 8 ± 1 (for above 25 mm) ± 0.8 (up to and including 25 mm)	± 8 ± 8 ± 2.5 ± 5					± 8 ± 8 ± 2.5 ± 5			

Note: **Flat Pressed Single Layer (FPS)**
Flat Pressed Three Layer Multilayer and Graded (FPT)
Extrusion Pressed Solid (XPS)
Extrusion Pressed Tabular (XPT)

Length + 6 mm
– 0mm
Width + 3 mm
– 0 mm
Thickness
Less than 6 mm ± 10 percent
6 mm and above ± 5 percent
Edge Straightness—2 mm per 1000 mm
Squareness—2 mm per 1000 mm

The grades and types of block boards are represented as:

ICOM Interior grade commercial type
IDEC Interior grade decorative type
XCOM Exterior grade commercial type
XDEC Exterior grade decorative type

These are further sub-graded as Grade I and Grade 2. Grade I is exterior grade used for bus bodies, railways coaches, prefabricated houses, etc. and Grade 2 is interior grade used for furniture, partition, panelling, ceiling,etc.

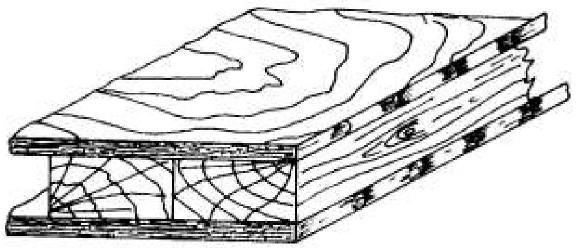
Uses

These are extensively used for construction of railways carriages, bodies of buses, marine and river-crafts, partitions, furniture etc.

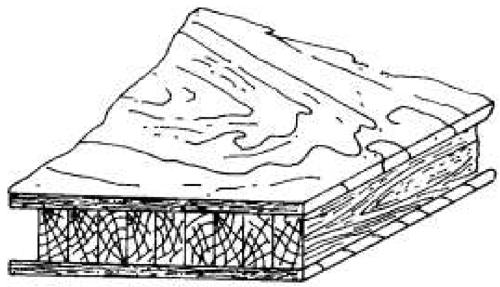
Batten boards and lamin boards

Batten boards have core made up of 80 mm wide wood pieces as shown in Fig, forming a slab glued between at least two surface veneers.

Whereas, Lamin boards have a core of strips, each not exceeding 7 mm in thickness as shown in Fig., glued together to form a slab which in turn is glued between two or more outer veneers. The directions of the grains of the core block run at right angles to that of the adjacent outer veneers.



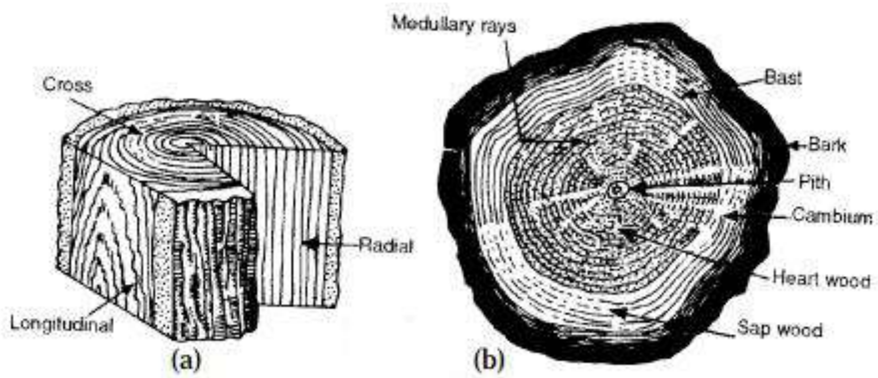
Batten Board



Lamin Board

<u>Structure of wood:</u>

A tree can be divided into three portions, crown—composed of branches and leaves, trunk, and roots. The trunk accounts for about 80 per cent of the total bulk of wood. Figure shows the structure of well grown timber from trunk of the exogenous tree. The structure of timber visible to naked eye or at a small magnification is called macro structure, and that apparent only at great magnifications, the micro structure. Macro structure of the timber can be studied by cutting the trunk in three directions. In the cross-sectional and radial ducts, the following main parts of a tree, e.g. bark, cambium, sap wood, heart wood and pith, become readily apparent. Each of the components has a specific function. The bark protects the wood against mechanical damage. Its inner layer, called bast conveys the nutrients from the crown downwards and stores them. The function of cambium is to grow wood cells on the inside and smaller bast cells on the outside. The sapwood assists in the life process of tree by storing up starch and conducting sap. The cells in the sap wood are active. The heart wood gives a strong and firm support to the tree. With the growth of tree, the cells in the inner older portion of trunk gradually become inactive and lifeless, but do not decay. This portion of the trunk is called heart wood. At the centre of the cross-section is the pith, a small area occupied by friable tissues consisting of thin walled, loosely connected cells called pith. In a felled tree, it easily crumbles and rots. In the cross-sectional direction, nutrients pass from bast to the heart through groups of cells running at right angles to the cambium layers and are referred to as medullary rays.



Cross Section of a Tree

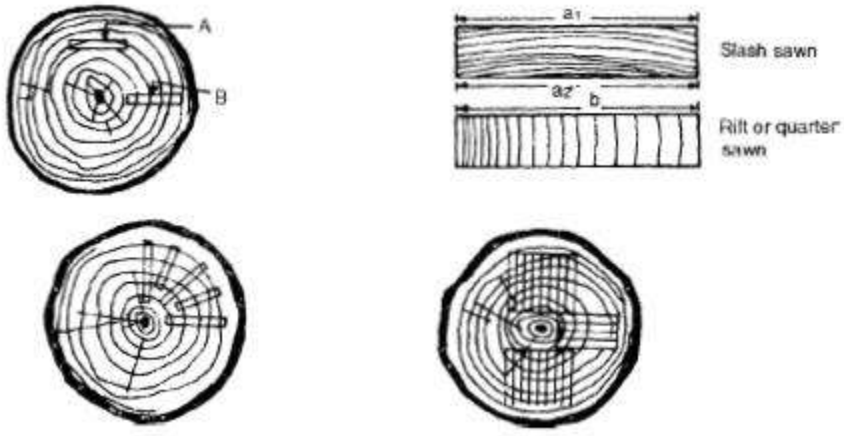
<u>Properties of wood:</u>

<u>Physical properties:</u>

Density and specific weight all the mechanical properties of clear wood are related to its density, which varies directly with the apparent specific gravity. The true specific gravity of wood is approximately equal for all species and averages 1.54, whereas the specific weight and apparent specific gravity vary with density of wood. The percentage of moisture in the wood has a very large effect upon the specific weight and hence true comparisons of this property can only be made on dry specimens

Bulk density depends on the volume of pores and moisture content of the wood. For most wood species, the bulk density is less than density. Bulk density value is used to determine the quality factor which is the ratio of compressive strength to the bulk density. It is 0.6 for pine and 0.57 for oak.

Moisture movement Water is found in three portions of wood: (1) it constitutes over 90 per cent of the protoplasm in the living cells; (2) it saturates the cell walls; (3) it fills, more or less completely, the pores of the life less cells. Timber is liable to shrink or swell with the movement of moisture.



Methods of Converting Timber

Shrinkage is the reduction in linear and volumetric dimensions in drying of wood. Evaporation of capillary water is not accompanied by shrinkage, the latter taking place only when hygroscopic moisture evaporates. Because of structural non-uniformity, wood shrinks or swells irregularly in various directions. Linear shrinkage along the fibres lies between 0.1 and 0.3 per cent, in radial direction between 3 and 6 per cent and in tangential direction between 7 and 12 per cent. In general, the radial shrinkage of wood is 60 percent of the tangential, and the longitudinal shrinkage is negligible. Therefore, the volumetric shrinkage is practically 1.6 times the tangential shrinkage.

Swelling is the capacity of wood to increase both its linear and volumetric dimensions when it absorbs water. Swelling of wood along the length of fibres ranges from 0.1 to 0.8 per cent, 3 to 5 per cent in the radial direction and 6 to 12 per cent in the tangential direction.

Heat conductivity is quite low. The coefficient of heat conductivity along the fibres is 1.8 times greater than that across the fibres and averages 0.15 to 0.27 K cal/mh°C. As the bulk density of wood increases and its moisture content decreases, the amount of air entrapped inside cavities decreases, the effect being greater heat conductivity of wood.

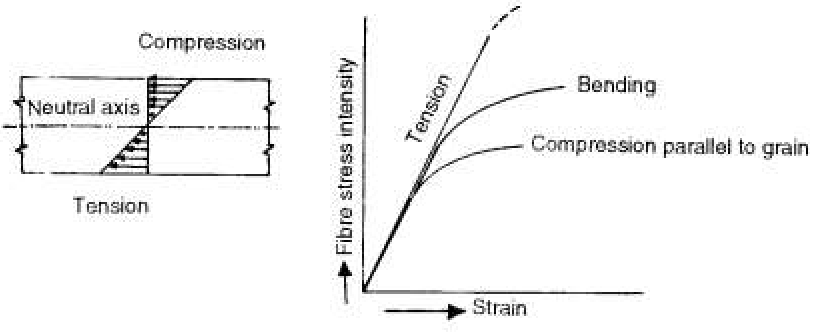
Sound conductivity; The velocity of sound in wood is 2 to 17 times greater than that in air and as such wood may be considered to have high sound conductivity.

Resistance to action of alkalies Wood is not affected by weak alkali solution but decays in an acid medium (pH< 4).

<u>Mechanical properties:</u>

Engineers, architects and carpenters must be well versed with the mechanical properties of timber. In order that the engineer may properly design columns and beams for various parts of wooden structures, he must be thoroughly conversant with the strength and stiffness of the available classes of timber.

Sress-strain relationship: Wood has three principal axes—longitudinal, radial and tangential— along which properties are fairly constant. Since wood is a non isotropic material, it has three values of modulus of elasticity varying by as much as 150 to 1, three shear moduli varying by 20 to 1, and six Poisson's ratios varying by 40 to 1. There is no sharply defined elastic limit in wood but there is a proportional limit. However, the stress-strain diagram in any direction is fairly straight over a considerable range before it gradually curves off. It is a ductile material. The relative stress-strain curves for direct tension, direct compression and bending stress intensities parallel to the grain in fig show that in both, direct compression and bending, the proportional limit is in the vicinity of 65 to 75 per cent of the ultimate strength. For all practical purposes, there is no proportional limit in direct tension



Stress Strain Curves Parallel to the Grain

Compressive strength when subjected to compressive force acting parallel to the axis of growth, wood is found to be one of the strongest structural material. Columns and posts are, therefore, often fashioned of it. However, compressive strength perpendicular to fibres of wood is much lower than that parallel to fibres of wood. Compressive strength parallel to fibres, at 15 per cent moisture content, varies from 30.0 to 77.5 N/mm^2. Furthermore, a knowledge of the compressive strength is of value in estimating strength in bending since experiments have demonstrated that the yield point of wooden beams is determined by the compressive strength of the wood. When wood is subjected to compression parallel to the grain, it may fail through collapsing of the cell walls or through lateral bending of the cells and fibres.

Tensile strength when a properly shaped wooden stick is subjected to tensile forces acting parallel to the grain it is found to have greater strength that can be developed under any other kind of stresses. Indeed, the tensile strength of wood parallel to the grain is so great that much difficulty is encountered in designing end connections so that the tensile strength of a piece can be developed. Therefore, wood tension members are rarely used. Tensile strength parallel to the fibres is of the order 80.0 to 190.0 N/mm^2.

Bending strength: Wood well withstands static bending, owing to which it is widely employed for elements of buildings, e.g. beams, slabs, rafters, trusses, etc. The initial failure of long beams of uniform width is indicated by a wrinkling of the overstressed compression fibres, much like the failures which occur in compression prisms. Final failure of such beams is generally in tension. It is accompanied more or less by snapping as the individual fibres begin to break when the maximum load is reached. Very dry specimens sometimes fail very suddenly in tension before any wrinkling of the compression fibres is noticeable. However, green test pieces fail silently in compression without rupturing of the tensile fibres. Short deep beams fail by horizontal shear suddenly, and this is more common in well seasoned timber of structural sizes than in green timbers or in small beams. Very often shear failures result from defects.

Shearing strength: Wood has low shearing strength of 6.5–14.5 N/mm^2 along the fibres. Resistance of wood to cutting across the fibres is 3 to 4 times greater than that along the fibres, but pure shear generally does not take place since the fibres are also subjected to crushing and bending.

Stiffness in a timber structure is often of as much importance as strength, but it is much more frequently neglected in designing. Floors must be sufficiently stiff so that they will not deflect appreciably under working loads as else they give one the feeling of insecurity. Likewise, the deflection of rafters should be limited, if it is desirable, to avoid the disagreeable appearance of a sagged roof. In general, denser woods are stiffer. A green timber is less stiff than when seasoned. The structural sizes of timber are about as stiff as the clear small sticks.

Toughness: A wood which has a large capacity to resist shock or blows is called tough. In order to be tough a wood must have both strength and flexibility. Hardwood as a class excels in toughness. Long leaf pine is the only one of the conifers possessing much toughness.

In general, green wood is tougher than seasoned wood. Toughness is best measured by the energy of the blow required to rupture a beam in transverse impact.

Cleavability is the measure of the ease with which wood may split. Most hardwoods split more easily along radial planes than along tangential surfaces. Since splitting is accomplished by wedging apart the longitudinal elements, it is closely related to tension, across the grain. Woods which must be fastened by nails and screws should have a high resistance to splitting. Among the conifers, with an exception of longleaf pine, the difference in cleavage strength in the two directions is not great

Hardness is defined and measured as resistance to indentation and resistance to scratching. Both are important properties in woods used for finishing and for furniture. These properties, together with the ability to wear without splintering, determine the wearing resistance of wood for floors and pavements. Aside from the indentation tests no satisfactory type of test has been devised to measure these properties

Characteristics of good timber:

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

1. Narrow annual rings, closer the rings greater is the strength.
2. Compact medullary rays.
3. Dark colour.
4. Uniform texture.
5. Sweet smell and a shining fresh cut surface.
6. When struck sonorous sound is produced.
7. Free from the defects in timber.
8. Heavy weight.
9. No woolliness at fresh cut surface.

Seasoning of timber:

Some of the objects of seasoning wood are as follows:

1. Reduce the shrinkage and warping after placement in structure.
2. Increase strength, durability and workability.
3. Reduce its tendency to split and decay.
4. Make it suitable for painting.
5. Reduce its weight.

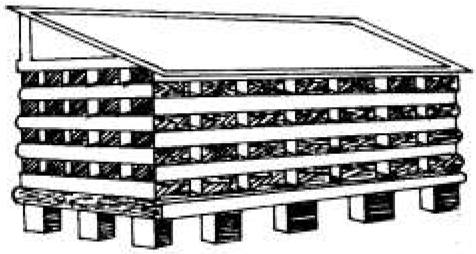
Methods of seasoning of timber:

Timber can be seasoned naturally or artificially

Natural air seasoning:

The log of wood is sawn into planks of convenient sizes and stacked under a covered shed in cross-wise direction in alternate layers so as to permit free circulation of air. The duration for drying depends upon the type of wood and the size of planks. The rate of drying is however very slow.

Air seasoning reduces the moisture content of the wood to 12–15 per cent. It is used very extensively in drying ties and the large size structural timbers.



Shed for Air Seasoning of Timber

Artificial air seasoning:

The prevalent methods of artificial seasoning are as follows:

Water seasoning: The logs of wood are kept completely immersed in running stream of water, with their larger ends pointing upstream. Consequently the sap, sugar, and gum are leached out and are replaced by water. The logs are then kept out in air to dry. It is a quick process but the elastic properties and strength of the wood are reduced.

Boiling in water or exposing the wood to the action of steam spray is a very quick but expensive process of seasoning

Kiln seasoning is adopted for rapid seasoning of timber on large scale to any moisture content. The scantlings are arranged for free circulation of heated air with some moisture or superheated steam. The circulating air takes up moisture required from wood and seasons it. Two types of kilns, the progressive Fig and the compartment Fig are in use. For most successful kiln-seasoning the timber should be brought to as high a temperature as it will stand without injury before drying is begun; otherwise the moisture in the hot outer fibers of the wood will tend to flow towards the cooler interior. With kiln drying there is a little loss in strength of timber, usually less than 10 per cent. Also, the wood is more thoroughly and evenly dried, thus reducing the hygroscopicity of the wood.

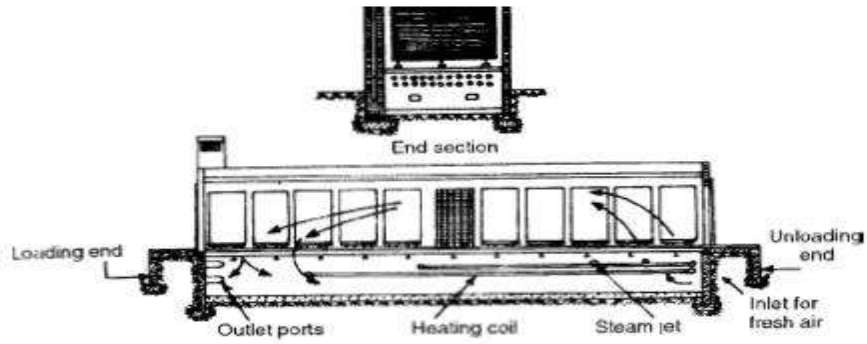


Fig. 4.3(a) Progressive Kiln

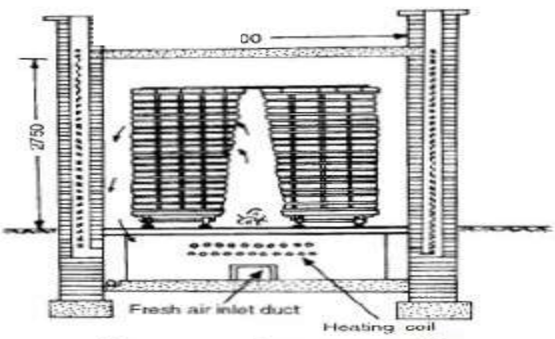


Fig. Compartment Kiln

Chemical or salt seasoning:

An aqueous solution of certain chemicals have lower vapour pressures than that of pure water. If the outer layers of timber are treated with such chemicals the vapour pressure will reduce and a vapour pressure gradient is setup. The interior of timber, containing no salts, retains its original vapour pressure and, therefore, tends to dry as rapidly as if there had been no treatment. The result is to flatten the moisture gradient curves, to reduce the slope of the curves, and consequently to reduce the internal stresses induced during drying. Since it is these stresses which are responsible for defects such as checks, etc. a chemically treated timber will exhibit fewer defects. Common salt or urea are generally used; the latter is preferred as the corrosive action of common salt is a drawback.

Electric seasoning:

The logs are placed in such a way that their two ends touch the electrodes. Current is passed through the setup, being a bad conductor, wood resists the flow of current, generating heat in the process, which results in its drying. The drawback is that the wood may split

MC. Neills process has no adverse effects; it is the best method although most expensive. The timber is stacked in a chamber with free air space (l/3rd of its capacity) and containing products of combustion of fuels in the fire place. The time required for complete seasoning is 15 to 60 days.

Defects in timber

Defects can occur in timber at various stages, principally during the growing period and during the conversion and seasoning process. The defects in the wood as shown in Fig. 4.4 are due to irregularities in the character of grains. Defects affect the quality, reduce the quantity of useful wood, reduce the strength, spoil the appearance and favour its decay.

Defects due to abnormal growth

Following are some of the important defects commonly found in wood due to abnormal growth or rupture of tissues due to natural forces.

Checks is a longitudinal crack which is usually normal to the annual rings. These adversely affect the durability of timber because they readily admit moisture and air

Shakes are longitudinal separations in the wood between the annual rings. These lengthwise separations reduce the allowable shear strength without much effect on compressive and tensile values. The separations make the wood undesirable when appearance is important. Both the shakes and checks if present near the neutral plane of a beam they may materially weaken its resistance to horizontal shear.

Heart shake occurs due to shrinkage of heart wood, when tree is over matured. Cracks start from pith and run towards sap wood. These are wider at centre and diminish outwards.

Cup shake appears as curved split which partly or wholly separates annual rings from one another. It is caused due to excessive frost action on the sap present in the tree, especially when the tree is young.

Star shake are radial splits or cracks wide at circumference and diminishing towards the centre of the tree. This defect may arise from severe frost and fierce heat of sun. Star shakes appear as the wood dries below the fibre saturation point. It is a serous fault leading to separated log when sawn.

Rindghall

Is characterised by swelling caused by the growth of layers of sapwood over wounds after the branch has been cut off in an irregular manner. The newly developed layers do not unite properly with the old rot, thereby leaving cavities, from where decay starts.

Knots are bases of twigs or branches buried by cambial activity of the mother branch. The root of the branch is embedded in the stem, with the formation of annual rings at right angles to those of the stem.

The knots interrupt the basic grain direction of the wood, resulting in a reduction of its strength. In addition these affect the appearance of the wood. A dead knot can be separated from the body of the wood, whereas live knot cannot be. Knots reduce the strength of the timber and affect workability and cleavability as fibres get curved. Knots are classified on the basis of size, form, quality and occurrence.

Size Pin knot (under 12 mm), small knot (12–20 mm), medium knot (20–40 mm) and large knot (over 40 mm).

Form "Round knot and spike knot (a round knot exposed by sawing lengthwise

Quality: Sound knot—as hard and solid as the surrounding wood, decayed knot—contains advanced decay and is softer than the surrounding wood, encased knot—the annual rings fail to grow into the fibres of the surrounding wood, tight knot—a knot so securely fastened that it holds its position in the finished product.

Occurrence: Single knot—when wood fibres deflect around one knot, cluster knot—when wood fibres deflect about two or more knots as a unit and, branch knot—two or more knots radiating from a common centre.

End splits are caused by greater evaporation of sap at the end grains of log and can be reduced by painting the exposed end grains with a water proof paint or capping the exposed end with hoop iron bandage.

Twisted fibres are caused by wind constantly turning the trunk of young tree in one direction.

Upsets are caused by the crushing of fibres running transversely during the growth of the tree due to strong winds and unskilled felling consequently resulting in discontinuity of fibres.

Foxiness is a sign of decay appearing in the form of yellow or red tinge or discolouration of over-matured trees.

Rupture is caused due to injury or impact.

LIME AND CEMENT

Introduction

Until the invention of Portland cement, lime was used as the chief cementing material in the building construction both for mortar and plasters. Most of the ancient palaces, forts, temples, monuments, etc., have been built with lime. Though Portland cement has almost replaced lime, but still at places, where lime is available locally and during the period of shortage of ordinary Portland cement lime provides a cheap and alternative to cement. Usually, lime in free-state is not found in nature. The raw material for the manufacture of lime (CaO) in calcium carbonate which is obtained by the calcination of lime stone. The varieties of limestone commonly used in the construction industry are tufa, limestone boulders and kankars. Lime can also be obtained by the calcination of shell, coral, chalk and other calcareous substances. Coral and shells are sea animals. White chalk is a pure limestone whereas kankar is an impure limestone.

Coral lime is claimed to be the purest source of lime. Lime is obtained by burning limestone at a temperature of about 800°C.

$$\underset{\text{Limestone}}{CaCO_3} + 42.52\text{ kcal} \xrightarrow[\text{Calcination}]{\text{Heating}} \underset{\text{Quick lime}}{CaO} + CO_2$$

Various ingradients of lime

Pure lime stone is called calcite and that containing magnesite is called dolomitic limestone. The mineral containing calcium carbonate and magnesium carbonate in equimolecular quantities is called dolomite. **Stone lime** is almost pure lime obtained by calcination of limestone and is used for making lime-sand mortar for superstructures; lime-surkhi mortar for substructures and: lime terracing and flooring. Stone lime has hydraulic properties.

Kankar lime is an impure lime obtained by calcination of kankars dug out from underground sources. These occur in the form of nodules and compact blocks. It is suitable for making lime sand mortars for substructures. It is commonly used for making hydraulic lime.

Shell lime is very pure lime obtained by calcination of shells of sea animals and corals. It is used for lime punning, white wash and colour wash, soil stabilization and glass production.

Magnesium lime is manufactured from dolomite and contain magnesia more than 5 per cent. It is used for making mortar and plaster.

Constituents of lime

Quick lime Pure lime, generally called quick lime, is a white oxide of calcium. Much of commercial quick lime, however, contains more or less magnesium oxide, which gives the product a brownish or grayish tinge. Quick lime is the lime obtained after the calcination of limestone. It is also called caustic lime. It is capable of slaking with water and has no affinity for carbonic acid. The specific gravity of pure lime is about 3.40.

Fat lime has high calcium oxide component and, sets and hardens by the absorption of CO2 from atmosphere. These are manufactured by burning marble, white chalk, calcareous tufa, pure lime stone, sea shell and coral.

Hydraulic lime contains small quantities of silica, alumina, iron oxide in chemical combination with calcium oxide component. These are produced from carboniferous limestones and magnesian limestone. It has the property to set and harden under water.

Hydrated When quick lime is finely crushed, slaked with a minimum amount of water, and screened or ground to form a fine homogeneous powder the product is called hydrated lime. **Lump** is the quick-lime coming out of the kilns.

Milk is a thin pourable solution of slaked lime in water.

Characteristics of lime

1. Lime possesses good plasticity and is easy to work with.

2. It stiffens easily and is resistant to moisture.

3. The excellent cementitious properties make it most suitable for masonry work.

4. The shrinkage on drying is small because of its high water retentivity.

Uses

In construction slaked lime is mainly used to make mortar for laying masonry and plastering. When so used quick lime should be completely hydrated by slaking from 3 to 14 days, depending upon the kind of lime, temperature, and slaking conditions. Hydrated lime, although immediately usable, is usually improved by soaking overnight or longer. Hydrated lime is often added to Portland cement mortar in proportions varying from 5 to 85 per cent of the weight of the cement to increase plasticity and workability. Most of the historical buildings had been plastered in lime. Lime punning—about 3 mm thick shell lime layer to improve the plastered surfaces and to give a shining appearance—is used very commonly now a days in the new structures. Some of the other uses of lime are manufacture of lime bricks, artificial stones, paints, glass; as stabilizer for soils and as a flux in metallurgical processes.

Classification of lime

According to the percentage of calcium oxide and clayey impurities in it, lime can be classified as lean, hydraulic and pure lime. Since magnesium oxide slakes slowly, an increase in its percentage decreases rate of hydration and so is with clayey impurities as well.

Lean or poor lime: It consists of CaO + MgO 80 to 85% with MgO less than 5% and clayey impurities of about more than 7 per cent in the form of silica, alumina and iron oxide. It sets on absorbing CO_2 from atmosphere.

Characteristics:

1. Slaking requires more time and so it hydrates slowly. Its expansion is less than that of fat lime.

2. It makes thin paste with water.

3. Setting and hardening is very slow.

4. The colour varies from yellow to grey.

Uses

It gives poor and inferior mortar and is recommended for less important structure.

Hydraulic lime

It is a product obtained by moderate burning (900°-1100°C) of raw limestone which contains small proportions of clay (silica and alumina) 5-30 per cent and iron oxide in chemical combination with the calcium oxide content (CaO + MgO 70-80% with MgO less than 5%). In slaking considerable care is required to provide just sufficient water and no excess, since an excess would cause the lime to harden. Depending on the percentage of clay present these are classified further as, feebly, moderately and eminently hydraulic limes. It sets under water.

Feebly has less than 5-10 per cent of silica and alumina and slakes slowly, after few minutes (5 to 15). The setting time is twenty one days. It is used in damp places and for less important structures.

Moderately has 10-20 per cent of impurities, slakes sluggishly after 1-2 hours. The setting time is seven days. It is used in damp places.

Eminently has clayey impurities 20-30 per cent and slakes with difficulty. Its initial setting time is 2 hours and final setting time is 48 hours. It is used in damp places and for all structural purposes.

Pure, rich or fat lime

It is soft lime (CaO + MgO more than 85% with MgO less than 4%) obtained by the calcination of nearly pure limestone, marble, white chalk, oolitic limestone and calcareous tufa. Also known as white washing lime should not have impurities of clay and stones, more than 5 per cent. Fat lime is nearly pure calcium oxide and when it is hydrated with the required amount of water the solid lumps fall to a soft fine powder of $Ca(OH)_2$ and the high heat of hydration produces a cloud of steam. It sets on absorbing CO_2, from atmosphere.

Characteristics

1. Slaking is vigorous and the volume becomes 2-3 times.

2. It sets slowly in contact with air, and hence is not suitable for thick walls or in wet climate.

3. If kept under water a fat lime paste does not lose its high plasticity and consequently does not set and hard.

4. Sp. gr. of pure lime is about 3.4.

Uses

Fat lime finds extensive use in making mortar, matrix for concrete, base for distemper and in white wash, manufacturing of cement, and metallurgical industry.

Classification (IS 712)

Bureau of Indian standards has classified lime into class A, B, C, D, E and F based on the purpose of its use in construction.

CLASS-A eminently hydraulic lime is used for making mortar and concrete for construction and foundation works, i.e. for structural purposes.

Characteristics

(i) The colour is grey.

(ii) Calcium oxide and clay are 60-70 and 25 per cent respectively.

(iii) Slakes with difficulty.

(iv) Sets and hardens read readily under water with initial setting time 2 hours and final setting time 48 hours.

CLASS-B Semi hydraulic lime

Is used for masonry mortars, flooring and for concrete in ordinary constructions and plaster undercoat.

Characteristics

(i)The colour is grey.

(ii) Contains 70 per cent calcium oxide and 15 per cent clay.

(iii) Slakes and sets at slow rate taking about a week to set under water.

CLASS-C Fat lime is used for finishing coat in plastering, white washing and with puzzolana in mortars.

Characteristics

(i)The colour is white.

(ii) Slakes vigorously and increases to three times its original volume

(iii) Contains about 93 per cent calcium oxide and about 5-7 per cent clay.

CLASS-D Magnesium **or dolomitic lime** is used for finishing coat in plastering and white washing.

Characteristics

(i) The colour is white.

(ii) Contains about 85 per cent calcium and magnesium oxides.

(iii) Slakes promptly.

(iv) Sets slowly.

CLASS-E Kankar lime is used for making masonry mortars, plastering and white washing.

Characteristics

(i) The colour is grey

(ii) Contains 20 per cent calcium oxide, 5 per cent magnesium oxide and remaining impurities.

(iii) Slakes and sets slowly.

CLASS-F Silicious dolomitic lime used for undercoat and finishing coat of plaster.

Various types of cements

Introduction:

Assyrians and Babylonians were perhaps the first to use clay as cementing material. In ancient monuments, e.g. forts, places of worship and defence structures, stones have been invariably used as a construction material with lime as the binder. Records show that Egyptians have used lime and gypsum as cementing materials in the famous pyramids. Vitruvius, a Roman scientist, is believed to be the first to have the know how about the chemistry of the cementitious lime. One of the most notable examples of Roman work is the Pantheon. It consists of a concrete dome 43.43m in span.

Types of cements

Rapid hardening Portland cement has high lime content and can be obtained by increasing the C_3S content but is normally obtained from OPC clinker by finer grinding (450 m_2 /kg). The basis of application of rapid hardening cement (RHC) is hardening properties and heat emission rather than setting rate. This permits addition of a little more gypsum during manufacture to control the rate of setting. RHC attains same strength in one day which an ordinary cement may attain in 3 days. However, it is subjected to large shrinkage and water requirement for workability is more. The cost of rapid hardening cement is about 10 per cent more than the ordinary cement. Concrete made with RHC can be safely exposed to frost, since it matures more quickly.

Properties:	Initial setting time	30 minutes (minimum)
	Final setting time	10 hours (maximum)
	Compressive strength	
	1 day	16.0 N/mm^2
	3 day	27.5 N/mm^2

Uses

It is suitable for repair of roads and bridges and when load is applied in a short period of time.

Super sulphated Portland cement is manufactured by intergrinding or intimately blending a mixture of granulated blast furnace slag not less than 70 per cent, calcium sulphate and small quantity of 33 grade Portland cement. In this cement tricalcium aluminate which is susceptible to sulphates is limited to less than 3.5 per cent. Sulphate resisting cement may also be produced by the addition of extra iron oxide before firing; this combines with alumina which would otherwise form C_3A, instead forming C_4AF which is not affected by sulphates. It is used only in places with temperature below 40°C.

Properties: It has low heat of hydration and is resistant to chemical attacks and in particular to sulphates. Compressive strength should be as follows:

72 ± 1 hour	$\nless$	15 N/mm^2
168 ± 2 hours	$\nless$	22 N/mm^2
672 ± 4 hours	$\nless$	30 N/mm^2

It should have a fineness of 400 m^2 /kg. The expansion of cement is limited to 5 mm. The initial setting time of the cement should not be less than 30 minutes, and the final setting time should not be more than 600 minutes.

Uses

Super-sulphated Portland cement is used for similar purpose as common Portland cement. But owing to its higher water-resisting property, it should be preferred in hydraulic engineering installations and also in constructions intended for service in moist media. RCC pipes in ground water, concrete structures in sulphate bearing soils, sewers carrying industrial effluents, concrete exposed to concentrated sulphates of weak mineral acids are some of the examples of this cement. This cement should not be used in constructions exposed to frequent freezing-and-thawing or moistening-and-drying conditions.

Portland Slag cement

It is manufactured either by intimately inter grinding a mixture of Portland cement clinker and granulated slag with addition of gypsum or calcium sulphate, or by an intimate and uniform blending of Portland cement and finely ground granulated slag. Slag is a non-metallic product consisting essentially of glass containing silicates and alumina silicates of lime and other bases, as in the case of blast-furnace slag, which is developed simultaneously with iron in blast furnace or electric pig iron furnace. Granulated slag is obtained by further processing the molten slag by rapid chilling or quenching it with water or steam and air. The slag constituent in the cement varies between 25 to 65 per cent.

Properties

The chemical requirements of Portland slag cement are same as that of 33 grade Portland cement. The specific surface of slag cement should not be less than 225 m^2 /kg. The expansion of the cement should not be more than 10 mm and 0.8 per cent when tested be Le Chatelier method and autoclave test, respectively. The initial and final setting times and compressive strength requirements are same as that for 33 grade ordinary Portland cement.

Uses

This cement can be used in all places where OPC is used. However, because of its low heat of hydration it can also be used for mass concreting, e.g., dams, foundations, etc.

Low heat Portland cement To limit the heat of hydration of low heat Portland cement (LHC), the tricalcium aluminate component in cement is minimised and a high percentage of dicalcium silicate and tetracalcium alumino ferrite is added. The heat of hydration should not be more than 272 and 314 J/g at the end of 7 and 28 days respectively. The rate of development of strength is slow but the ultimate strength is same as that of OPC. To meet this requirement, specific surface of cement is increased to about 3200 cm^2 /g.

properties

Less heat is evolved during setting low heat Portland cement. When tested by Le Chatelier method and autoclave test the expansion should not be more than 10 mm and 0.8%, respectively. The minimum initial setting time should not be less than 60 minutes, and the final setting should not be more than 600 minutes.

The compressive strength should be as follows.

72 ± 1 hour	$\nless$ 10 N/mm^2
168 ± 2 hours	$\nless$ 16 N/mm^2
672 ± 4 hours	$\nless$ 35 N/mm^2

Uses

It is most suitable for large mass concrete works such as dams, large raft foundations, etc.

Air entraining cement

Vinsol resin or vegetable fats and oils and fatty acids are ground with ordinary cement. These materials have the property to entrain air in the form of fine tiny air bubbles in concrete.

Properties Minute voids are formed while setting of cement which increases resistance against freezing and scaling action of salts. Air entrainment improves workability and water/cement ratio can be reduced which in turn reduces shrinkage, etc.

Uses

Air entraining cements are used for the same purposes as that of OPC.

Water proof cement

It is manufactured by adding stearates of Ca and Al and gypsum treated with tannic acid, etc. at the time of grinding.

Properties

It is resistant to penetration of water.

Uses

Water retaining structures like tanks, reservoirs, retaining walls, swimming pools, bridge piers, etc.

High alumina cement

This is not a type of Portland cement and is manufactured by fusing 40 per cent bauxite, 40 per cent lime, 15 per iron oxide with a little of ferric oxide and silica, magnesia, etc. (Table 5.5) at a very high temperature.

The alumina content should not be less than 32%. The resultant product is ground finely. The main cement ingredient is monocalcium aluminate CA which interacts with water and forms dicalcium octahydrate hydroaluminate and aluminium oxide hydrate.

$2(CaO.AL_2O_3.10H_2O) + H_2O = 2CaO.Al_2O_3.8H_2O + 2Al(OH)_2$

The dicalcium hydro aluminate gel consolidates and the hydration products crystallise. The rate of consolidation and crystallisation is high leading to a rapid gain of strength. Since C3A is not present, the cement has good sulphate resistance.

able 5.5 Composition of a Typical High Alumina Cement

Composition	*Percentage*
Al_2O_3, TiO_2	43.5
Fe_2O_3, FeO, Fe_3O_4	13.1
CaO	37.5
SiO_2	3.8
MgO	0.3
SO_3	0.4
Insoluble material	1.2
Loss on ignition	0.2

Properties:It is not quick setting: initial setting time (minimum) is 30 minutes, even up to 2 hours. The final setting time should not exceed 600 minutes. It attains strength in 24 hours, high early strength, high heat of hydration and resistance to chemical attack. Compressive strength after one day is 30.0 N/mm^2 and after 3 days it is 35.0 N/mm^2 . After setting and hardening, there is no free hydrated lime as in the case of ordinary Portland cement. The fineness of the cement should not be less than 225 m^2 /kg. The cement should not have expansion more than 5 mm.

Uses:It is resistant to the action of fire, sea water, acidic water and sulphates and is used as refractory concrete, in industries and is used widely for precasting. It should not be used in places where temperature exceeds 18°C.

Various field and laboratory tests for cement

Physical tests

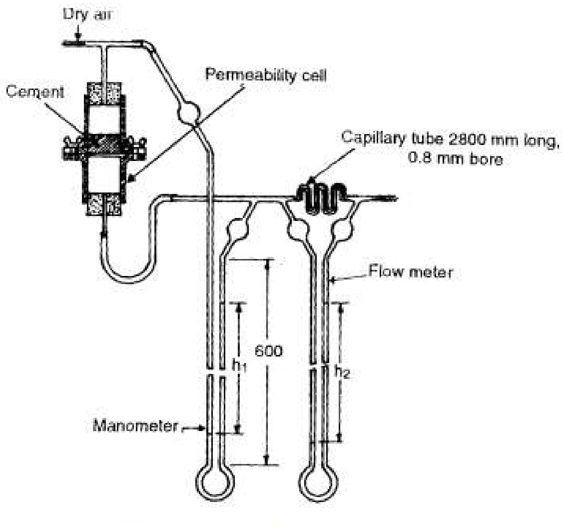
1. **Fineness test**

The degree of fineness of cement is the measure of the mean size of the grains in it. There are three methods for testing fineness: the sieve method—using 90 micron (9 No.) sieve, the air permeability method— Nurse and Blains method and the sedimentation method— Wagner turbid meter method. The last two methods measure the surface area, whereas the first measures grain size. Since cement grains are finer than 90 micron, the sieve analysis method does not represent true mean size of cement grains. Also, the tiny cement grains tend to conglomerate into lumps resulting in distortion in the final grain size distribution curves. Considering these demerits, fineness is generally expressed in terms of specific area, which is the total surface area of the particles in unit weight of material.

2. **Air Permeability method**

The fineness of cement is represented by specific surface, i.e. total surface area in cm^2 per gram or m^2 per kilogram of cement and is measured by Lea and Nurse apparatus or by wagner turbidimeter.. The Lea and

Nurse apparatus shown in Fig. essentially consists of a permeability test cell—where cement is placed and air pressure is applied, flow meter—to determine the quantity of air passing per second through its capillary tube per unit difference of pressure, and manometer—to measure the air pressure.



Permeability Apparatus

To determine the fineness, a cement sample of 20 mm height is placed on a perforated plate (40 micron perforations) and air pressure is applied. The manometer is connected to the top of the permeability cell and the air is turned on. The lower [illegible] permeability cell is then slowly connected to the other end of the manometer. The rate of flow is so adjusted that the flowmeter shows a pressure difference (h2) of 30-50 cm. The reading (h1) in the manometer is recorded. The process is repeated till the ratio h1/h2 is constant. The specific surface is given by the expression

$$S = \frac{14}{d(1-\Psi)} \sqrt{\frac{A\Psi^2}{KL}} \sqrt{\frac{h_1}{h_2}}$$

where L = thickness of cement layer
A = area of cement layer
d = density of cement
Ψ = porosity of cement (0.475)
h_2 = flowmeter reading
h_1 = manometer reading

K is the flowmeter constant and is obtained by

$$Q = \frac{K h_2 d_1}{\mu}$$

where μ = viscosity of air
d_1 = density of kerosene
Q = quantity of air passed per second

$$= \frac{V}{t}\frac{P-p}{P}$$

where P = atmospheric pressure

p = vapour pressure of water at room temperature

The minimum specific surface for various cements should be as specified in Table 5.3.

Minimum Specific Surfaces of Cements

Type of cement		*Specific surface not less than cm^2/g*
Ordinary Portland Cement	(OPC)	2250
Rapid Hardening Cement	(RHC)	3250
Low Heat Cement	(LHC)	3250
Portland Puzzolana Cement	(PPC)	3000
High Alumina Cement	(HAC)	2250
Super Sulphate Cement	(SSC)	4000

3. Wagner turbity meter method L.A.Wagner developed a turbidity-meter to estimate the surface area of one gram of cement. The cement is dispersed uniformly in a rectangular glass tank filled with kerosene. Then, parallel light rays are passed through the solution which strike the sensitivity plate of a photoelectric cell. The turbidity of the solution at a given instant is measured by taking readings of the current generated by the cell. By recording the readings at regular intervals while the particles are falling in the solution, it is possible to secure information regarding the grading in surface area and in size of particle. Readings are expressed in sq. cm per gram.

4. Consistency test

This is a test to estimate the quantity of mixing water to form a paste of normal consistency defined as that percentage water requirement of the cement paste, the viscosity of which will be such that the Vicat's plunger penetrates up to a point 5 to 7 mm from the bottom of the Vicat's mould.

Importance

The water requirement for various tests of cement depends on the normal consistency of the cement, which itself depends upon the compound composition and fineness of the cement.

Test procedure

300 g of cement is mixed with 25 per cent water. The paste is filled in the mould of Vicat's apparatus (Fig.) and the surface of the filled paste is smoothened and levelled. A square needle 10 mm x 10 mm attached to the plunger is then lowered gently over the cement paste surface and is released quickly. The plunger pierces the cement paste. The reading on the attached scale is recorded. When the reading is 5-7 mm from the bottom of the mould, the amount of water added is considered to be the correct percentage of water for normal consistency.

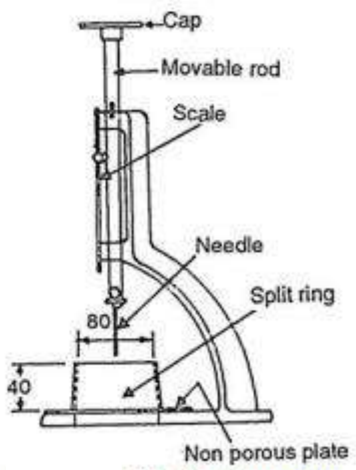
5.Determination of initial and final setting times of cement

When water is added to cement, the resulting paste starts to stiffen and gain strength and lose the consistency simultaneously. The term setting implies solidification of the plastic cement paste. Initial and final setting times may be regarded as the two stiffening states of the cement. The beginning of solidification, called the initial set, marks the point in time when the paste has become unworkable. The time taken to solidify completely marks the final set, which should not be too long in order to resume construction activity within a reasonable time after the placement of concrete. Vicat's apparatus used for the purpose is shown in Fig.

The initial setting time may be defined as the time taken by the paste to stiffen to such an extent that the Vicat's needle is not permitted to move down through the paste to within 5 ± 0.5 mm measured from the bottom of the mould. The final setting time is the time after which the paste becomes so hard that the angular attachment to the needle, under standard weight, fails to leave any mark on the hardened concrete. Initial and final setting times are the rheological properties of cement.

Test procedure

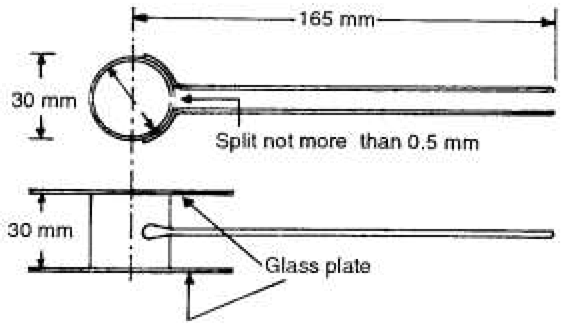
A neat cement paste is prepared by gauging cement with 0.85 times the water required to give a paste of standard consistency. The stop watch is started at the instant water is added to the cement. The mould resting on a nonporous plate is filled completely with cement paste and the surface of filled paste is levelled smooth with the top of the mould. The test is conducted at room temperature of 27± 2°C. The mould with the cement paste is placed in the Vicat's apparatus as shown in Fig.and the needle is lowered gently in contact with the test block and is then quickly released. The needle thus penetrates the test block and the reading on the Vicat's apparatus graduated scale is recorded. The procedure is repeated until the needle fails to pierce the block by about 5 mm measured from the bottom of the mould. The stop watch is pushed off and the time is recorded which gives the initial setting time. The cement is considered to be finally set when upon applying the needle gently to the surface of test block, the needle makes an impression, but the attachment fails to do so.



Vicat's Apparatus

6.Lechatelier method

The apparatus is shown in Fig. The mould is placed on a glass sheet and is filled with neat cement paste formed by gauging 100 g cement with 0.78 times the water required to give a paste of standard consistency. The mould is covered with a glass sheet and a small weight is placed on the covering glass sheet. The mould is then submerged in the water at temperature of 27°-32°C. After 24 hours, the mould is taken out and the distance separating the indicator points is measured. The mould is again submerged in water. The water is now boiled for 3 hours. The mould is removed from water and is cooled down. The distance between the indicator points is measured again. The difference between the two measurements represents the unsoundness of cement.



Le-chatelier Apparatus

7.Auto-clave test

The 25 × 25 × 250 mm specimen is made with neat cement paste. After 24 hours the moulded specimen is removed from the moist atmosphere, measured for length, and so placed in an autoclave at room temperature that the four tides of each specimen are at least exposed to saturated steam. The temperature of the autoclave is raised at such a rate that the gauge pressure of the steam rises to 2.1 N/mm2 in 1 to 1 ¼ hours from the time the heat is turned on. The pressure is maintained for 3 hours. Then the heat supply is shut off and the autoclave is cooled at such a rate that the pressure is less than 0.1N/mm2 at the end of the hour. The autoclave is then opened and the test specimens are placed in water at temperature of 90°C.The temperature is gradually brought down to 27±2°C in 15 minutes.

The specimens are maintained at this temperature for next 15 minutes and are then taken out. The length of the specimen is measured again. The difference in the two measurements gives the unsoundness of the cement.

8.Compressive strength

Compressive strength is the basic data required for mix design. By this test, the quality and the quantity of concrete can be cotrolled and the degree of adulteration can be checked.

The test specimens are 70.6 mm cubes having face area of about 5000 sq. mm. Large size specimen cubes cannot be made since cement shrinks and cracks may develop. The temperature of water and test room should be 27°± 2°C. A mixture of cement and standard sand in the proportion 1:3 by weight is mixed dry with a trowel for one minute and then with water until the mixture is of uniform colour. Three specimen cubes are prepared. The material for each cube is mixed separately. The quantities of cement, standard sand and water are 185 g, 555 g and (P/4) + 3.5, respectively where P = percentage of water required to produce a paste of standard consistency. The mould is filled completely with the cement paste and is placed on the vibration table. Vibrations are imparted for about 2 minutes at a speed of 12000±400 per minute. The cubes are then removed from the moulds and submerged in clean fresh water and are taken out just prior to testing in a compression testing machine.

Compressive strength is taken to be the average of the results of the three cubes. The load is applied starting from zero at a rate of 35 N/sq mm/minute. The compressive strength is calculated from the crushing load divided by the average area over which the load is applied.The result is expressed in N/mm^2 . The minimum specified strength for some of the cements is given in Table

Minimum Specified Strength in N/mm^2

Type/Days	1 day	3 days	7 days	28 days
Ordinary Portland cement (33 grade)	-	16.0	22.0	33.0
Portland Puzzolana cement	-	16.0	22.0	33.0
Low heat Portland cement	-	10.0	16.0	35.0
Rapid hardening cement	16.0	27.5	-	-
High alumina cement	30.0	35.0	-	-

9.Tensile strength

The tensile strength may be determined by Briquette test method or by split tensile strength test.

Importance

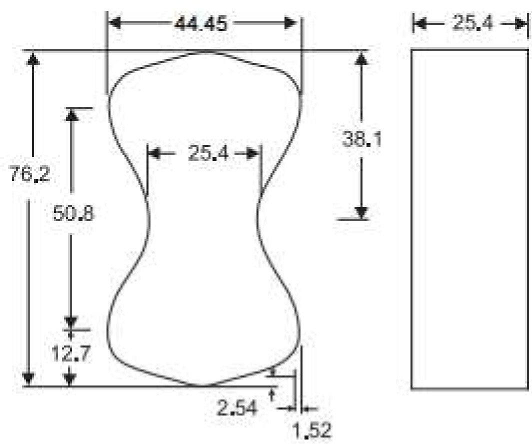
The tensile strength of cement affords quicker indications of defects in the cement than any other test. Also, the test is more conveniently made than the compressive strength test. Moreover, since the flexural strength, is directly related to the tensile strength this test is ideally fitted to give information both with regard to tensile and compressive strengths when the supply for material testing is small.

10.Briquette method

A mixture of cement and sand is gauged in the proportion of 1:3 by weight. The percentage of water to be used is calculated from the formula (P/5) + 2.5, where P = percentage of water required to produce a paste of standard consistency. The temperature of the water and the test room should be 27° ± 2°C. The mix is filled in the moulds of the shape shown in Fig.

After filling the mould, an additional heap of mix is placed on the mould and is pushed down with the standard spatula, until the mixture is level with the top of the mould.

This operation is repeated on the other side of the mould also. The briquettes in the mould are finished by smoothing the surface with the blade of a trowel. They are then kept for 24 hours at a temperature of 27° ± 2°C and in an atmosphere having 90 per cent humidity. The briquettes are then kept in clean fresh water and are taken out before testing. Six briquettes are tested and the average tensile strength is calculated. Load is applied steadily and uniformly, starting from zero and increasing at the rate of 0.7 N/sq mm of section in 12 seconds.



Dimensions of Standard Briquette

Ordinary Portland cement should have a tensile strength of not less than 2.0 N/mm^2 after 3 days and not less than 2.5 N/mm^2 after 7 days.

11.Specific gravity test

The specific gravity of hydraulic cement is obtained using Le-Chatelier flask shown in Fig.

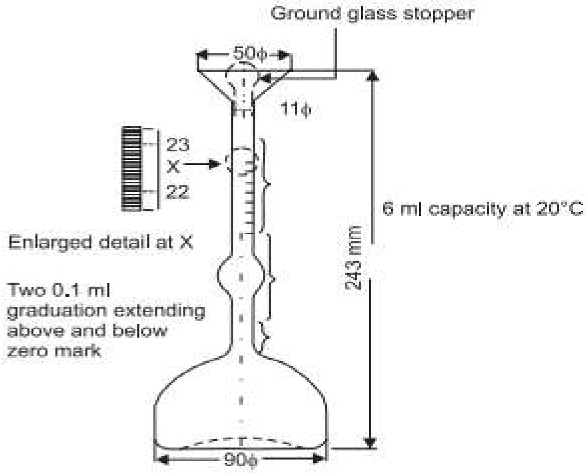


Fig. 5.13 Le-Chatelier Flask for Specific Gravity Test

Test procedure

The flask is filled with either kerosene free of water, or naphtha having a specific gravity not less than 0.7313 to a point on the stem between zero and 1-ml mark. The flask is immersed in a constant temperature water bath and the reading is recorded. A weighed quantity of cement (about 64 g of Portland cement) is then introduced in small amounts at the same temperature as that of the liquid. After introducing all the cement, the stopper is placed in the flask and the flask rolled in an inclined position, or gently whirled in a horizontal circle, so as to free the cement from air until no further air bubbles rise to the surface of the liquid. The flask is again immersed in the water-bath and the final reading is recorded. The difference between the first and the final reading represents the volume of liquid displaced by the weight of the cement used in the test.

$$\text{Specific gravity} = \frac{\text{Weight of cement}}{\text{Displaced volume of liquid in ml}}$$

Assignment-Cum-Tutorial Question

A. Questions testing the remembering / understanding level of students

I) Objective Questions

1. The age of the trees can be predicted by

(a) Length of the medullary rays (b) Counting number of rings

(c) By measuring the diameter of pith (d) By the thickness of bark

2.Which of the following is caused by fungus in timber

(a) Upsets (b) Foxiness

(c) Dry rot (d) Wet rot

3.Tensile strength of wood parallel to grains is about how many times of its compressive strength

(a) 2 (b) 3

(c) 4 (d) 5

4.Plywood has great strength and stiffness

(a) across the grains (b) Along the grains

(c) Both (a) and (b) (d) Tangential to the grains

5.The bound water (by weight)% required for complete hydration of cement is about

(a) 15 (b) 23

(c) 38 (d) 40

6.If P is the standard consistency of the cement, the amount of water used in conducting the intial setting time test on cement is

(a) 0.65P (b) 0.85P

(c) 0.6P (d) 0.8P

7.High alumina cement is produced by fusing together a mixture of

(a) Limestone and bauxite (b) Limestone, bauxite and gypsum

(c) Limestone, gypsum and clay (d) Limestone

8. Quick lime coming out of the kiln is also known as

(a) Hydrated lime (b)Lump lime

(c) Fat lime (d) Hydraulic lime

9. Which of the following is not an objective of seasoning of timber

(a) Reduction in shrinkage and warping (b) Reduction in weight

(c) Increase in strength and durability (d) Reduction in natural defects

10.The drawback of electric seasoning of timber is

(a) Checks (b) Splitting

(c) Cracks (d) Reduced Strength

11.Seasoning of timber is necessary to

(a) Increase the fire resistance (b) Increase the vermin resistance

(c) Reduce the microbial substances (d) Expel the moisture present in timber

12.How many days, a timber may require for natural seasoning?

(a) 20 months (b) 4-6 Months

(c) 1 year (d) 2 years

13.The lime that sets on absorbing carbon-dioxide from atmosphere is

(a) Lean lime (b) Feebly hydraulic lime

(c) Rich lime (d) Fat lime

14.To produce low heat cements, it is necessary to reduce the compound

(a) C_3S (b) C_2S

(c) C_3A (d) C_4AF

15.Before testing setting time of cement one should test the cement for

(a) soundness (b) strength

(c) fineness (d) consistency

16. Which of the following is caustic lime

(a) Quick lime (b)Fat lime

(c) Milk Lime (d) Hydraulic lime

II) Descriptive Questions

1. State the qualities you will consider in selecting timber for construction purposes?
2. Discuss the properties of steel in relation to construction use.
3. Why is it necessary to provide odd number of veeners in plywood?
4. Write the important properties of fiber-reinforced plastics.
5. State the harmful effects of silica, sulphates and alkalis in lime.
6. Explain the various tests on cement?
7. Describe how the compounds of clinker affect the properties of cement.
8. What is the purpose of adding gypsum while manufacturing cement?
9. Describe various defects in timber?
10. Explain the properties of galvanized iron.
11. How is seasoning done on a large scale?
12. Describe the different varieties of lime.
13. Explain the classification of lime?
14. What are the ingredients of Portland cement? State their function.
15. Describe the setting and hardening of cement?
16. Write a short note on rapid hardening cement.
17. . Which of the following statement regarding the cement fineness is NOT correct.
    a. Fine cement is more liable to suffer from shrinkage cracking than a coarse cement.
    b. Fine cement will show faster rate of hardening than coarse cement.
    c. Fine cement shows faster rate of heat evolution and total quantity of heat evolved is much larger than coarse cement.

    d. Fine cement shows the same setting time as coarse cement.

C. Questions testing the analysing/ evaluating ability of students.

1. Suggest suitable timber for the following purposes. Substantiate your answer with reasons

   a. Doors

   b. Scaffolding

   c. Purlins

   d. Railway sleepers

2. Which lime will you recommend for white washing and plastering? Give the reasons for the choice.

BUILDING MATERIALS AND CONSTRUCTION

DEPARTMENT OF CIVIL ENGINEERING

UNIT-III

Course Objectives:

- To learn the properties, classification and manufacturing process of materials such as wood, lime and cement and familiarize with various methods of construction.

Syllabus: Classification of Aggregate-Coarse and Fine aggregates, Particle Shape and Texture, bond & Strength of Aggregate, Specific gravity, Bulk density, porosity and absorption, Moisture content of Aggregate, Bulking of sand.

Learning Outcomes:

Upon successful completion of course, the students will be able to

- Apply the knowledge of manufacturing process and composition of building materials and concrete.

AGGREGATES

INTRODUCTION:

Aggregates are crystalline or granular rocks that are extracted for use in the construction industry. Aggregates are the materials basically used as binding material in the production of mortar and concrete. They are derived from igneous, sedimentary and metamorphic rocks or manufactured from blast furnace slag, etc. Aggregates form the body of the concrete, reduce the shrinkage and affect the economy. They occupy 70-80 per cent of the volume and have considerable influence on the properties of the concrete. It is therefore significantly important to obtain appropriate type and quality of aggregates at site. They should be clean, hard, strong, and durable and graded in size to achieve utmost economy from the paste. Earlier aggregates were considered to be chemically inert but the latest research has revealed that some of them are chemically active and also that certain types exhibit chemical bond at the interface of aggregates and cement paste. To increase the bulk density of concrete aggregates are used in two different sizes—the bigger ones known to be coarse aggregate (grit) and the smaller ones fine aggregate (sand). The coarse aggregate form the main matrix of concrete and the fine aggregate from the filler matrix between the coarse aggregate.

CLASSIFICATION OF AGGREGATES:

Aggregates are classified based on

- **Geological Origin**
- **Size**
- **Shape**
- **Unit Weight**

1. **Based on Geological Origin:**

The aggregates may be classified into natural aggregates and artificial aggregates.

Natural Aggregates: These are obtained by crushing from quarries of igneous, sedimentary or metamorphic rocks. Gravels and sand reduced to their present size by the natural agencies also fall in this category. The most widely used aggregate are from igneous origin. Aggregates obtained from pits or dredged from river, creek or sea are most often not clean enough or well graded to suit the quality requirement. They therefore require sieving and washing before they can be used in concrete.

Artificial Aggregates: Broken bricks, blast furnace slag and synthetic aggregates are artificial aggregates. Broken bricks known as brick bats are suitable for mass concreting, for example, in foundation bases. They are not used for reinforced concrete works. Blast furnace slag aggregate is obtained from slow cooling of the slag followed by crushing. The dense and strong particles as obtained are used for making precast concrete products. The specific gravity of these ranges between 2–2.8 and bulk density 1120–1300 kg/m^3. The blast furnace slag aggregate has good fire resisting properties but are responsible for corrosion of reinforcement due to sulphur content of slag. Synthetic aggregates are produced by thermally processed materials such as expanded clay and shale used for making light weight concrete

2. **Based on Size:**

According to size aggregates are classified as coarse aggregate, fine aggregate and all-in- aggregate.

Coarse Aggregate: Aggregate retained on 4.75 mm sieve are identified as coarse. They are obtained by natural disintegration or by artificial crushing of rocks. The maximum size of aggregate can be 80 mm. The size is governed by the thickness of section, spacing of reinforcement, clear cover, mixing, handling and placing methods. For economy the maximum size should be as large as possible but not more than one-fourth of the minimum thickness of the member. For reinforced sections the maximum size should be at least 5 mm less than the clear spacing between the reinforcement and also at least 5 mm less than the clear cover.

Aggregate greater than 20 mm sizes are seldom used for reinforced cement concrete structural members.

Fine Aggregate: Aggregate passing through 4.75 mm sieve are defined as fine. They may be natural sand—deposited by rivers, crushed stone sand—obtained by crushing stones and crushed gravel sand. The smallest size of fine aggregate (sand) is 0.06mm.Depending upon the particle size, fine aggregates are described as fine, medium and coarse sands. On the basis of particle size distribution, the fine aggregates are classed into four zones; the grading zones being progressively finer from grading zone I to grading zone IV (IS: 383).

IS Sieve Designation	Percentage Passing			
	Grading Zone I	Grading Zone II	Grading Zone III	Grading Zone IV
10 mm	100	100	100	100
4.75 mm	90-100	90-100	90-100	90-100
2.36 mm	60-95	75-100	85-100	95-100
1.18 mm	30-70	55-90	75-100	90-100
600 µm	15-34	35-59	60-79	80-100
300 µm	5-20	8-30	12-40	15-50
150 µm	0-10	0-10	0-10	0-15

3. **Based on Shape:**

Aggregates are classified as rounded, irregular, angular, and flaky.

Rounded Aggregates: These are generally obtained from river or sea shore and produce minimum voids (about 32 per cent) in the concrete. They have minimum ratio of surface area to the volume, and the cement paste required is minimum. Poor interlocking bond makes it unsuitable for high strength concrete and pavements.

Irregular Aggregates: They have voids about 36 per cent and require more cement paste as compared to rounded aggregate. Because of irregularity in shape they develop good bond and are suitable for making ordinary concrete.

Angular Aggregates: They have sharp, angular and rough particles having maximum voids (about 40 per cent). Angular aggregate provide very good bond than the earlier two, are most suitable for high strength concrete and pavements; the requirement of cement paste is relatively more.

Flaky Aggregates: These are sometimes wrongly called as elongated aggregate. However, both of these influence the concrete properties adversely. The least lateral dimension of flaky aggregate (thickness) should be less than 0.6 times the mean dimension. For example, the mean sieve size for an aggregate piece passing through 50 mm and retained on 40 mm sieve is (50 + 40)/2 = 45.0 mm. If the least lateral dimension is less than 0.6 × 45 = 27.0 mm, the aggregate is classified as flaky. Elongated aggregate are those aggregate whose length is 1.8 times its mean dimension. Flaky aggregate generally orient in one plane with water and air voids underneath. They adversely affect durability and are restricted to maximum of 15%.

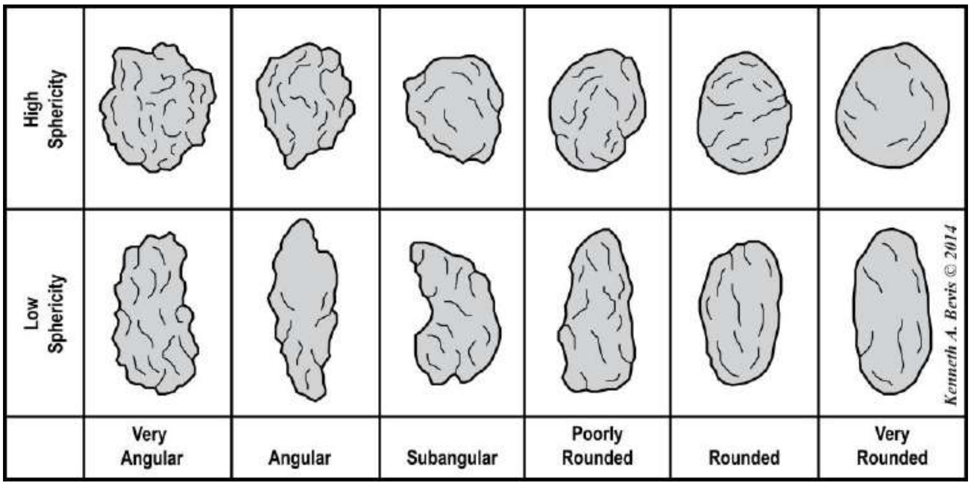
4. **Based on Unit Weight:** Aggregates are classified as normal-weight, heavy-weight and light-weight aggregate depending on weight and specific gravity as given in Table.

Aggregate	Specific gravity	Unit weight	Bulk Density	Examples
Normal-weight	2.5-2.7	23-26	1520-1680	Sand, gravel
Heavy-weight	2.8-2.9	25-29	>2080	Magnetite
Light-weight	-	12	<1120	Pumice, clay

CHARACTERISTICS OF GOOD AGGREGATE:

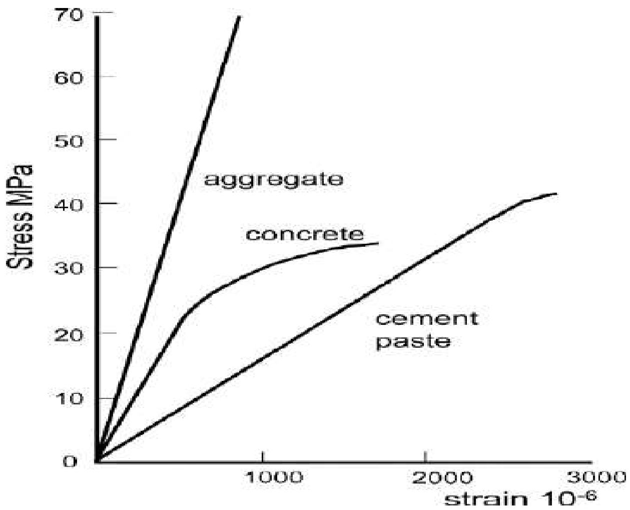
The properties to be considered while selecting aggregate for concrete are strength, particle shape, specific gravity, bulk density, voids, porosity, moisture content and bulking.

Particle shape & texture: The shape influences the properties of fresh concrete more than when it has hardened. Rounded aggregate are highly workable but yield low strength concrete. Same is the case with irregular shaped aggregate. Flaky aggregate require more cement paste, produce maximum voids and are not desirable. Angular shape is the best. Crushed and uncrushed aggregates generally give essentially the same strength for the same cement content. The shape and surface texture of fine aggregate govern its void ratio and significantly affect the water requirement.



Bond strength of aggregate: Due to difference between the coefficients of thermal expansion of paste and aggregate and to the shrinkage of cement paste during hardening, concrete is in a state of internal stress even if no external forces are present. It is reported that the stresses are likely to be greatest at the paste-aggregate interfaces where minute cracks exist, even in concrete that has never been loaded. Under increasing external load, these cracks spread along the interfaces before extending into the paste or aggregate particles. The strength of the bond between aggregate and cement paste thus has an important influence on the strength of concrete. There is no standard test for bond but it is known that the rougher the surface texture of the particles, the better the bond. The role of particle shape is less well understood; the greater specific surface of angular particles should enable greater adhesive force to be developed, but the angular shape probably causes more severe concentrations of internal stress.

Strength of aggregate: The strength should be at least equal to that of the concrete. Rocks commonly used as aggregates have a compressive strength much higher than the usual range of concrete strength. A typical stress-strain curve for aggregate is shown in Figure. The tests conducted for strength evaluation are crushing test, impact-test and ten per cent fines test. Of these the first one is the most reliable. Generally the specifications prescribe 45 per cent for aggregate used for concrete other than wearing surface and 30 per cent for concrete for wearing surfaces, such as runways, roads etc. limit for the crushing value. The toughness of aggregate is measured by impact test. The impact value should not exceed 30 per cent for wearing surface and 45 per cent for remaining concretes. Hardness of aggregate is tested by abrasion test. The abrasion value is restricted to 30 per cent for wearing surfaces and 50 per cent for concrete for other purposes.



Specific gravity: The specific gravity of most of the natural aggregates lies between 2.6-2.7. The specific gravity and porosity of aggregates greatly influence the strength and absorption of concrete. Specific gravity of aggregates generally is indicative of its quality. A low specific gravity may indicate high porosity and therefore poor durability and low strength. The concrete density will greatly depend on specific gravity.

Bulk Density: The bulk density of aggregate depends upon their packing, the particles shape and size, the grading and the moisture content. For coarse aggregate a higher bulk density is an indication of fewer voids to be filled by sand and cement.

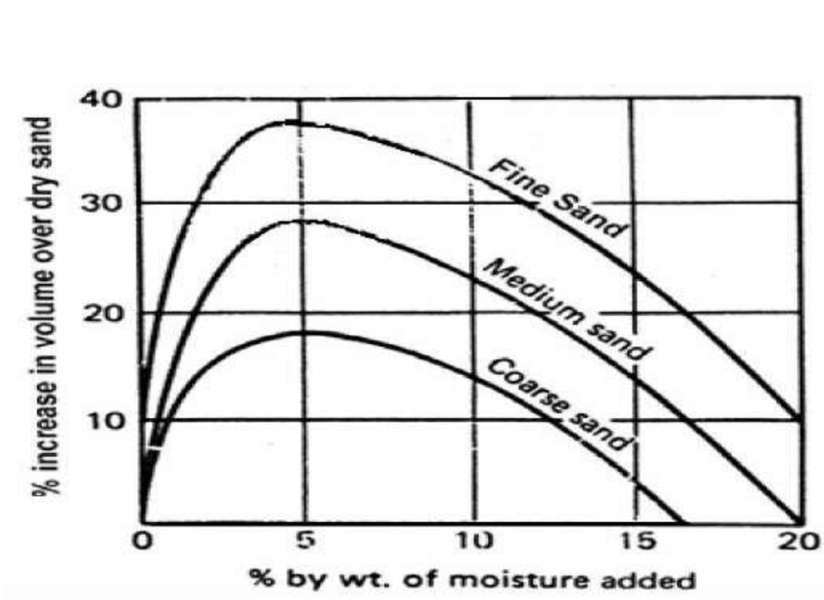
Voids: The void ratio is calculated as

Void ratio = 1 – (Bulk density/ Apparent specific gravity)

Porosity: The entrapped air bubbles in the rocks during their formation lead to minute holes or cavities known as pores. The porosity of rocks is generally less than 20 per cent; the concrete becomes permeable and ultimately affects the bond between aggregate and cement paste, resistance to freezing and thawing of concrete and resistance to abrasion of aggregate. The porous aggregate absorb more moisture, resulting in loss of workability of concrete at a much faster rate.

Moisture Content: The surface moisture expressed as a percentage of the weight of the saturated surface dry aggregate is known as moisture content. High moisture content increases the effective water/cement ratio to an appreciable extent and may render the concrete weak.

Bulking of sand: The increase in the volume of a given mass of fine aggregate caused by the presence of water is known as bulking. The water forms a film over the fine aggregate particles, exerts force of surface tension and pushes them apart increasing the volume. The extent of bulking depends upon the percentage of moisture present in the sand and its fineness. With ordinary sand bulking varies from 15-30 percent. It increases with moisture content up to a certain point (4-6%), reaches maximum, the film of water on the sand surface breaks, and then it starts decreasing. Figure shows the bulking of sand with moisture content.



40
30
20
10
0
5
10
15
20
% increase in volume over dry sand
% by wt. of moisture added
Fine Sand
Medium sand
Coarse sand

DEPARTMENT OF CIVIL ENGINEERING

BUILDING MATERIALS AND CONSTRUCTION

UNIT-4

BUILDING COMPONENTS

Course objectives:

- To understand the knowledge of building components.

Syllabus:

Lintels, Arches, Vaults-Stair cases – Types; Different types of floors, Concrete, Mosaic, and Terrazzo floors. Pitched, Flat and curved Roofs, Lean-to-Roof; Coupled roofs, Trussed roofs-King and Queen Post Trusses, RCC roofs, Madras Terrace/Shell roofs.

Learning outcomes:

Students will be able to

- Enumerate various types of building components
- Explain the importance of building components in construction industry
- Illustrate the concept of roofs

LINTELS:

A lintel is a horizontal member which is placed across the openings like doors, windows etc. It takes the load coming from the structure above it and gives support. It is also a type beam, the width of which is equal to the width of wall, and the ends of which are built into the wall. These are very easy to construct as compared to arches.

Types of Lintels used in Building Construction

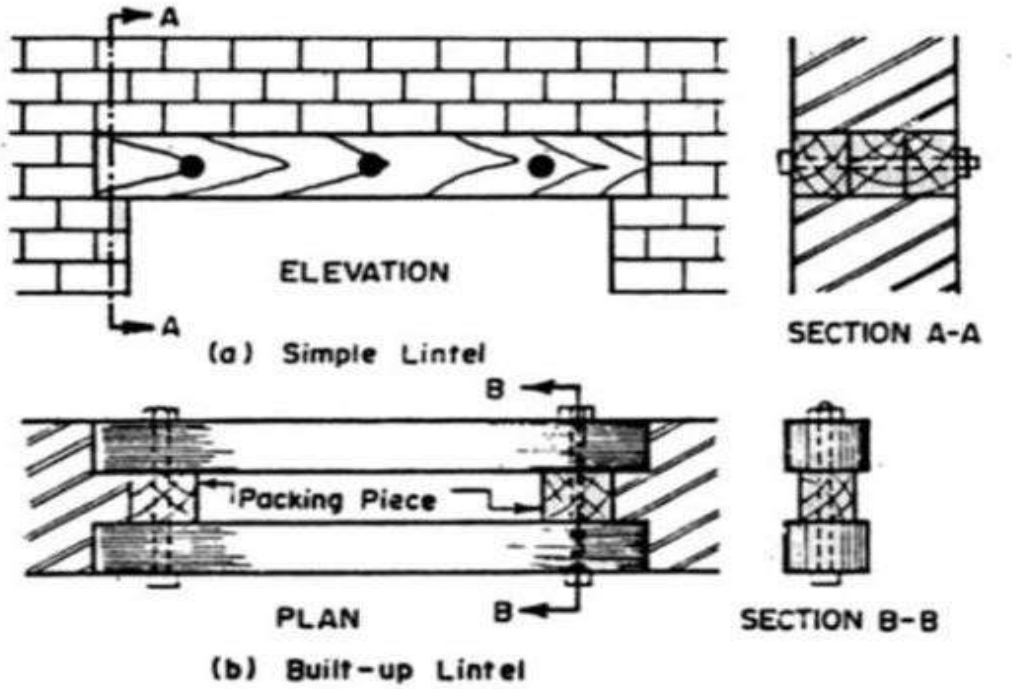
Lintels are classified based on the material of construction as:

1. Timber lintel
2. Stone lintel
3. Brick lintel
4. Reinforced brick lintel
5. Steel lintel
6. Reinforced cement concrete lintel

1.Timber Lintels

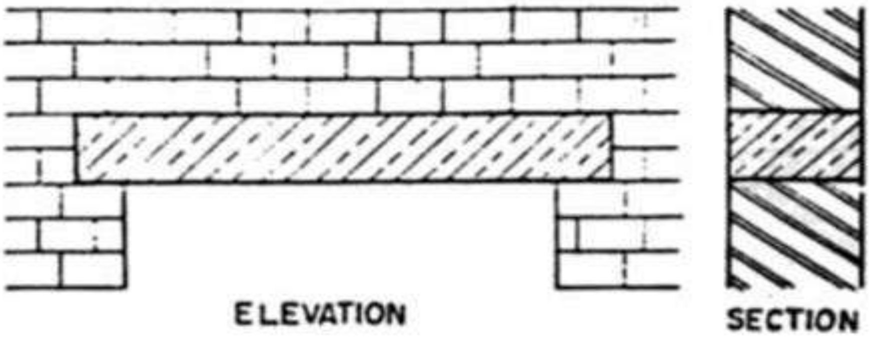
In olden days of construction, Timber lintels were mostly used. But now days they are replaced by several modern techniques, however in hilly areas these are using. The main disadvantages with timber are more cost and less durable and vulnerable to fire.

If the length of opening is more, then lintel is provided by jointing multiple numbers of wooden pieces with the help of steel bolts which was shown in fig (a). In case of wider walls, lintel is composed of two wooden pieces kept at a distance with the help of packing pieces made of wood. Sometimes, timber lintels are strengthened by the provision of mild steel plates at their top and bottom, called as fletched lintels.



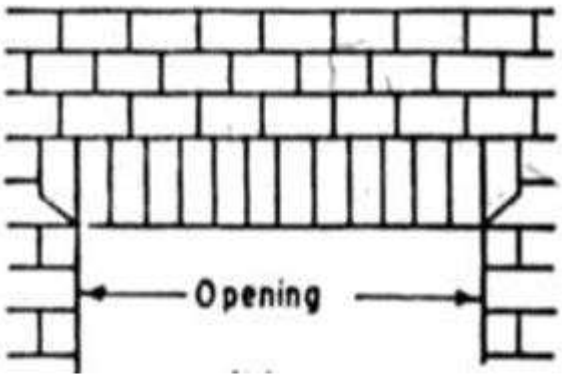
2.Stone Lintels

These are the most common types of lintels especially where stone is abundantly available. The thickness of these is most important factor of its design. These are also provided over the openings in brick walls. Stone lintels are provided in the form of either one single piece or more than one piece. The depth of this type is kept equal to 10 cm / meter of span, with a minimum value of 15 cm. They are used up to spans of 2 meters. In the structure is subjected to vibratory loads, cracks are formed in the stone lintel because of its weak tensile nature. Hence caution is needed.



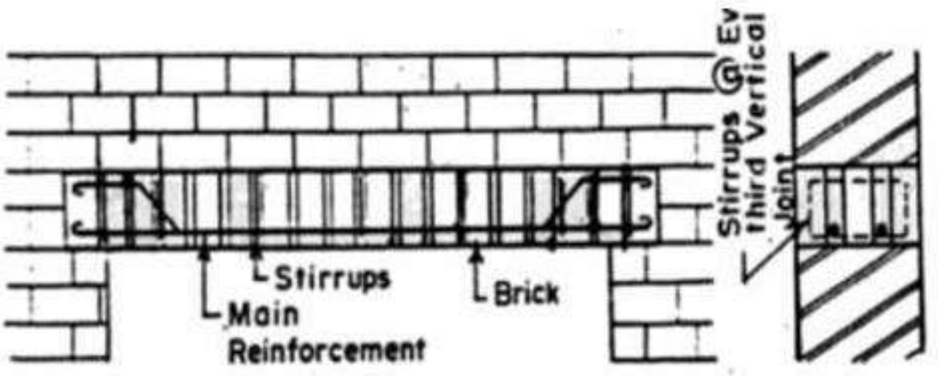
3.Brick Lintels

When the opening is less than 1m and lesser loads are acting, brick lintels are used. The depth of brick lintel varies from 10 cm to 20 cm, depending up on the span. Bricks with frogs are more suitable than normal bricks because frogs when filled with mortar gives more shear resistance of end joints. Such lintel is known as joggled brick lintel.



4.Reinforced Brick Lintels

If loads are heavy and span is greater than 1m, then reinforced brick lintels are useful. The depth of reinforced brick lintel should be equal to 10 cm or 15 cm or multiple of 10 cm. the bricks are so arranged that 2 to 3 cm wide space is left length wise between adjacent bricks for the insertion of mild steel bars as reinforcement. 1:3 cement mortars is used to fill up the gaps. Vertical stirrups of 6 mm diameter are provided in every 3rdvertical joint. Main reinforcement is provided at the bottom consists 8 to 10 mm diameter bars, which are cranked up at the ends.

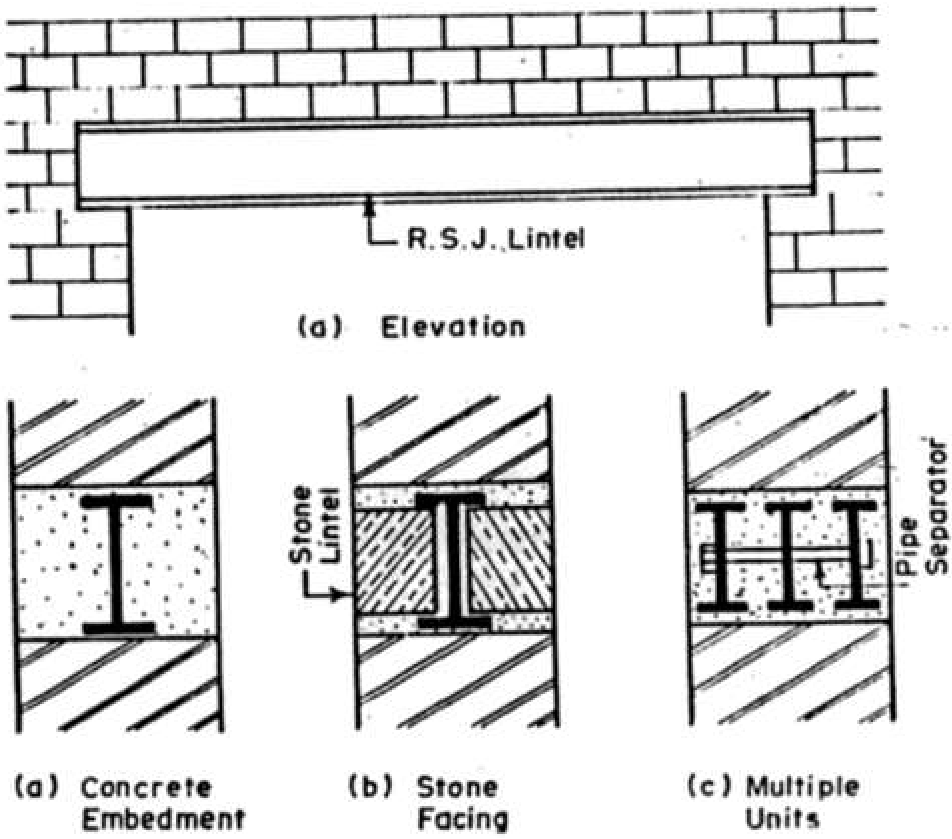


(a) LONGITUDINAL SECTION (b) CROSS SECTION

5. Steel Lintels

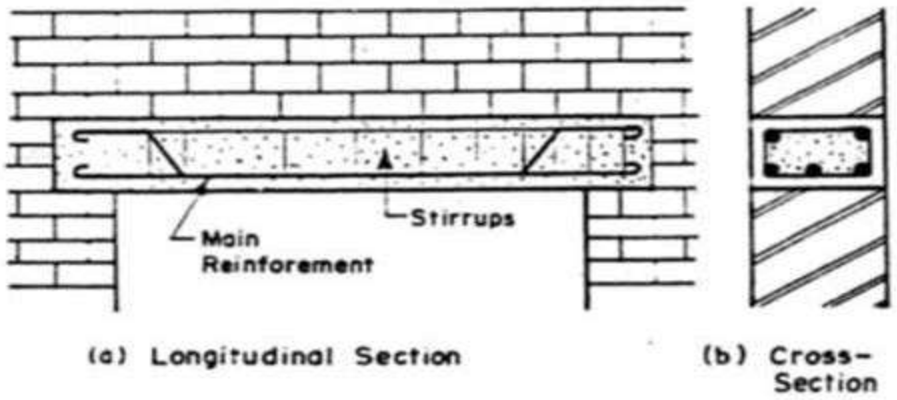
If the superimposed loads are heavy and openings are large then we can go for steel lintels. These lintels consist of channel sections or rolled steel joists. We can use one single section or in combinations depending up on the requirement.

When used singly, the steel joist is either embedded in concrete or cladded with stone facing to keep the width same as width of wall. When more than one unit are placed side by side, they are kept in position by tube separators.

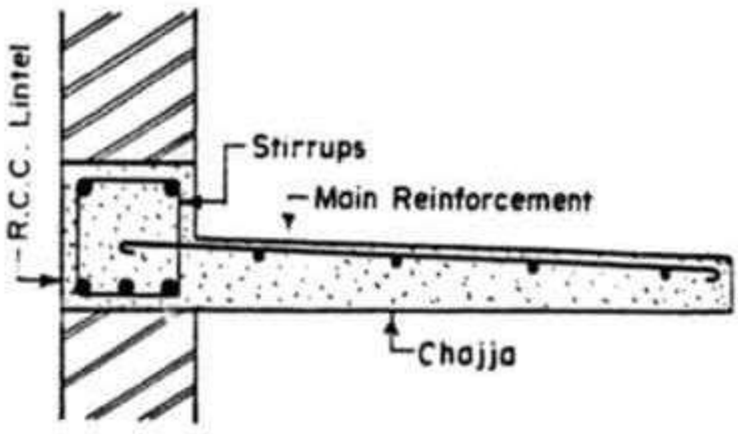


6. **Reinforced Cement Concrete Lintels**

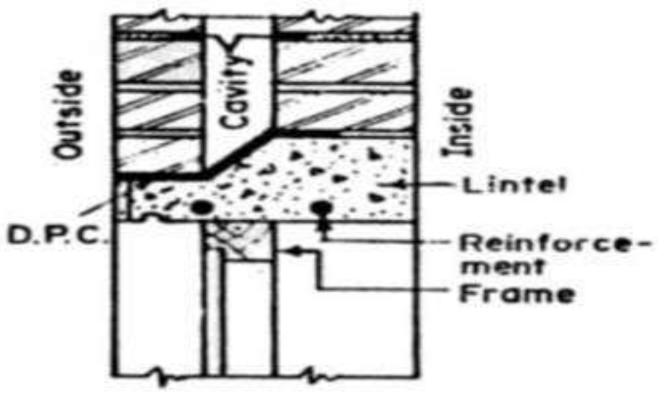
At present, the lintels of R.C.C are widely used to span the openings for doors, windows, etc. in a structure because of their strength, rigidity, fire resistance, economy and ease in construction. R.C.C lintels are suitable for all the loads and for any span. The width of lintel is equal to width of wall. Depth of lintel is dependent of length of span and magnitude of loading. Main reinforcement is provided at the bottom and half of these bars are cranked at the ends. Shear stirrups are provided to resist transverse shear as shown in fig.



R.C.C lintel over a window, along with chajja projection is displayed in below fig.



R.C.C boot lintels are provided over cavity walls. These will give good appearance and economical. A flexible D.P.C is provided above the lintel as shown in fig.

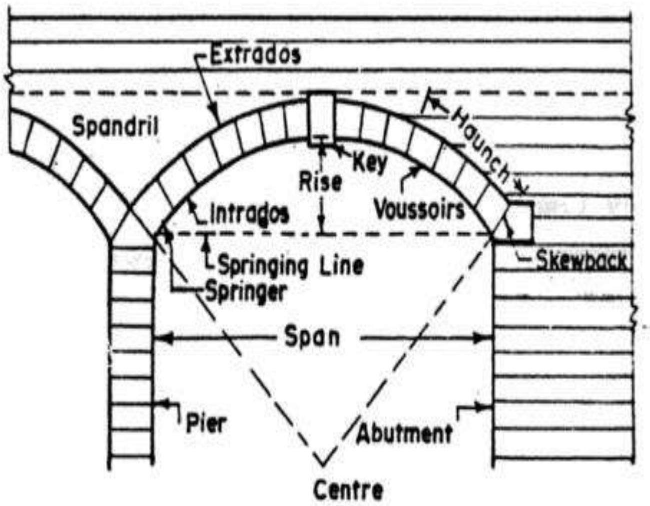


ARCHES:

An arch is a structure capable of spanning a spaces while supporting significant weight,e.g.,door way in stone or brick wall. Arches have been built with bricks and stones over the years especially for railway and road bridges.

An arch is a structure constructed of wedge-shaped units jointed togethere with mortar and spanning and opening to support the weight of the wall above it along with other super imposed loads.

The fig.shows various elements of an arch



Classification of arches:

Types of arches based on shape, material of construction, workmanship and number of centres are discussed here. An arch is constructed in curved shape due to which loads from above is distributed to supports (pier or abutment).

i) Types of Arches based on shape:

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

1.Flat Arch

For flat arch, the intrados is apparently flat and it acts as a base of equilateral triangle which was formed by the horizontal angle of 60^0 by skewbacks. Even though the intrados is flat but it is given that a slight rise of camber of about 10 to 15 mm per meter width of opening is allowed for small settlements. Extrados is also horizontal and flat. These flat arches are generally used for light loads, and for spans up to 1.5m.

2. Segmental Arch

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

3. Semi-Circular Arch

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

4. Horse Shoe Arch

Horse Shoe Arch is in the shape of horse shoe which curves more than semi-circle. This is generally considered for architectural provisions.

5. Pointed Arch

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

6. Venetian Arch

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

7. Florentine Arch

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

8. Relieving Arch

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

9. StiltedArch

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

10.Semi-Elliptical Arch

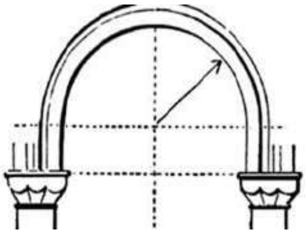
This is a type of arch of semi-ellipse shape and having three or five Centers.

ii)Types of Arches based on number of Centers

Based on number of centers the arches are classified as:

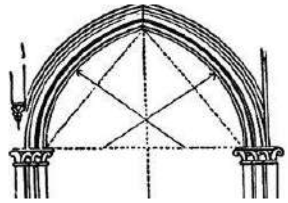
1. **One-centered Arches**

Segmental, semi-circular, flat, horse-shoe arches and stilted arches are one centred arches. In some cases, perfectly circular arch is provided for circular windows which are called as bull's eye arch is also come under this category.



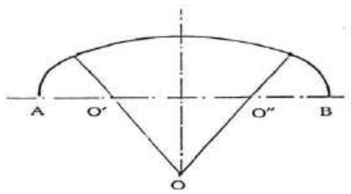
2. Two Centered Arches

Pointed or gothic or lancet arches are generally come under this type.



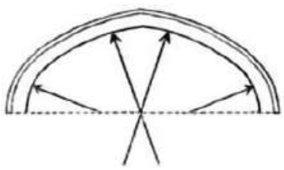
3. Three Centered Arches

Semi elliptical and Florentine arches are generally having three number of centers.



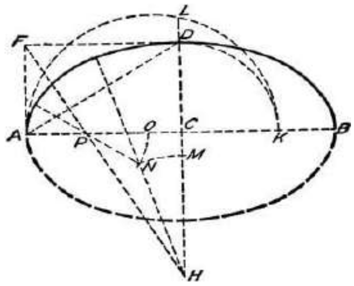
4.Four Centered Arches

Venetian arch is a typical example for four-centered arch. Tudor arch is also having four centers.



5.Five centered arches

A good semi-elliptical shape arch contains five centers.



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iii) Types of Arches based on Workmanship and Construction Materials

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

1. Stone Arches

Based on workmanship, these are sub divided into two types. They are **Rubble arches**: Rubble arches are very weak and used only for inferior work. These are used up to spans of 1m. These are made of rubble stones which are hammer dressed, roughly to shape and size and fixed in cement mortar. Sometimes these are also used as relieving arches up to a depth of 37.5cm, but these are constructed in one ring. If the depth is more, we can go for two rings in alternate course of headers and stretchers.

Ashlar arches:

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

2. Brick Arches

Brick arches are also subdivided into:

Rough brick arches:

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

Axed brick arches

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

Gauged brick arches

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

Purpose made brick arches

The bricks are manufactured, matching with the exact shape and size of voussoirs, to get a very fine workmanship.

3. Concrete Arches: Concrete arches are of two types:

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

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

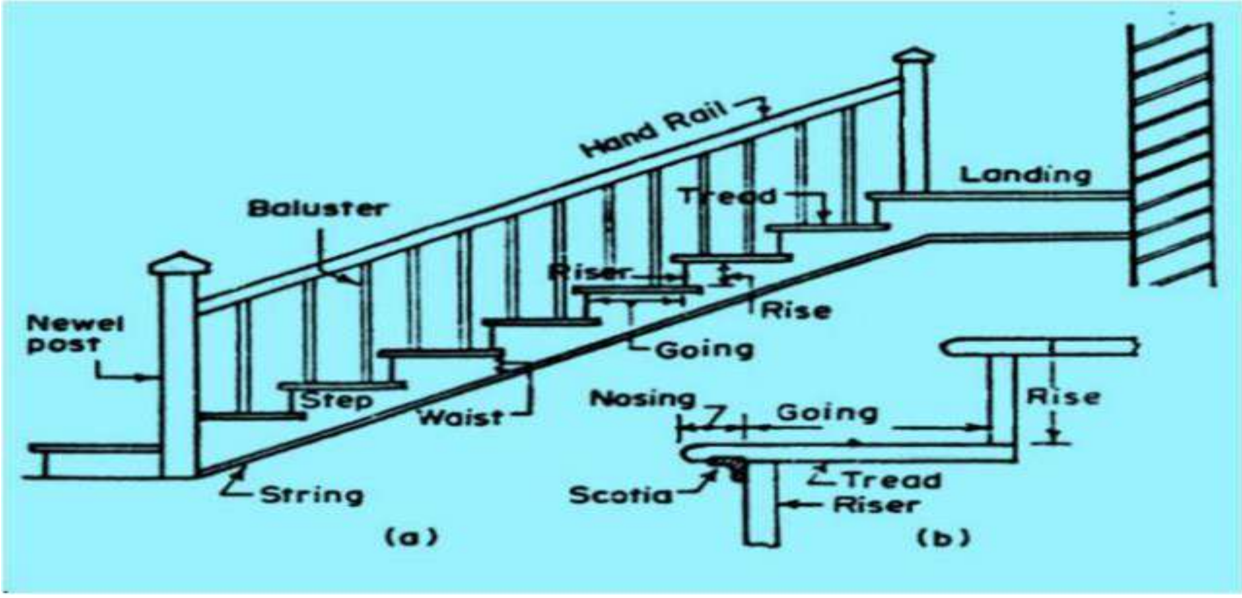
VAULTS:

Vault (French *voûte*, from Italian *volta*) is an architectural term for an arched form used to provide a space with a ceiling or roof. The parts of a vault exert lateral thrust that requires a counter resistance. When vaults are built underground, the ground gives all the resistance required. However, when the vault is built above ground, various replacements are employed to supply the needed resistance. An example is the thicker walls used in the case of barrel or continuous vaults. Buttresses are used to supply resistance when intersecting vaults are employed.

STAIRCASES:

Staircases provide means of movement from one floor to another in a structure. Staircases consist of a number of steps with landings at suitable intervals to provide comfort and safety for the users. These include straight-flight stairs, quarter-turn stairs, half-turn stairs, branching stairs, and geometrical stairs. A stair is a series of steps arranged in such a manner as to connect different floors of a building. Stairs are designed to provide an easy and quick access to the different floors.

A staircase is an enclosure which contains the complete stairway.



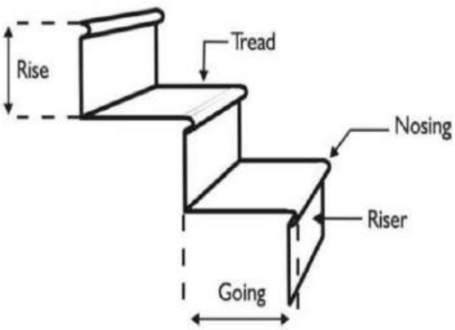
Components of Stairs

1. STEP: This is a portion of stair which permits ascending or descending from one floor to another. It is composed of a tread and a riser. A stair is composed of a set of steps.

2. TREAD: It is the upper horizontal portion of a step upon which the foot is placed while ascending or descending a stairway.

3. RISER: It is the vertical portion of a step providing a support to the tread.

4. RISE: It is the vertical distance between two successive tread faces.



5. FLIGHT: It is a series of steps without any platform or landing or break in their direction.

6. LANDING: This is a platform provided between two flights. A landing extending to full width of staircase is known as half spaced landing and the space extending only half across a staircase is called a quarter space landing. A landing facilitates change of direction and provides an opportunity for taking rest during the use of the stair.

7. GOING: It is the horizontal distance between two successive riser faces.

8. NOSING: This is the outer projecting edge of a tread. This is generally made rounded to give more pleasing appearance and makes the staircase easy to navigate.

9. WINDERS: They are tapering steps used for changing the direction of a stair.

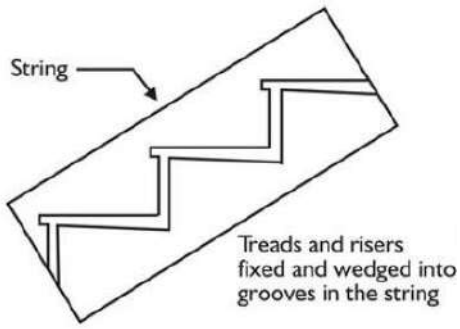
10. SCOTIA: It is a moulding provided under the nosing to improve the elevation of the step, and to provide strength to nosing.

11. SOFFIT: It is the underside of a stair.

12. LINE OF NOSING: It is an imaginary line parallel to the strings and tangential to the nosings. It is useful in the construction of hand rails, giving the line with which the under surface of the hand rail should coincide.

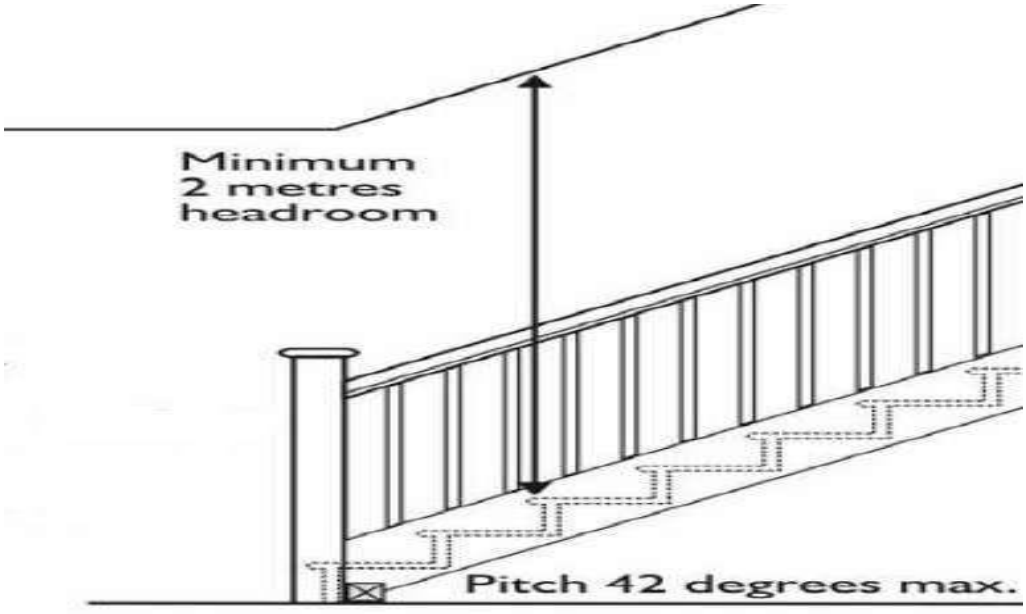
13. PITCH OR SLOPE: It is angle which the line of nosing of the stair makes with the horizontal.

14. STRINGS OR STRINGERS: These are the sloping members which support the steps in a stair. They run along the slope of the stair.



15. NEWEL POST: Newel post is a vertical member which is placed at the ends of flights to connect the ends of strings and hand rail.

16. BALUSTER: It is a vertical member of wood or metal, supporting the hand rails.



17. BALUSTRADE: The combined framework of handrail and baluster is known as balustrade. This provides protection for the user of the stair.

18. HAND RAIL: It is a rounded or moulded member of wood or metal following generally the contour of the nosing line, and fixed on the top of balusters.

19. HEAD ROOM: It is the minimum clear vertical distance between the tread and overhead structure (i.e. ceiling etc)

20. RUN: It is the total length of stair in a horizontal plane, including landings.

21. HEADER: It is the horizontal structural member supporting stair stringers or landings.

<u>TYPES OF STAIRS:</u>

Types of Stairs – Classification of stairs:

1. Straight stairs 2. Turning stairs 3. Continuous stairs

1. Straight stairs: Generally for small houses, available width is very retractable. So, this type of straight stairs are used in such conditions which runs straight between two floors. This stair may consists of either one single flight or more than one flight with a landing.

2. Turning stairs:

Turning stairs are sub classified as:

a) Quarter turn stairs

b) Half turn stairs (dog legged stairs)

c) Three – quarter turn stairs

d) Bifurcated stairs

a) Quarter turn stairs: A quarter turn stair is the one which changes its direction either to the right or to the left but where the turn being affected either by introducing a quarter space landing or by providing winders. In these type of stairs the flight of stair turns 90 degrees art landing as it rises to connect two different levels. So it is also called as L-stair. Again these quarter turn stairs are two types.

i. Newel quarter turn stairs: These type of stairs have clearly visible newel posts at the beginning of flight as well as at the end. At the quarter turn, there may either be quarter space landing or there may be winders.

ii. Geometrical quarter turn stairs: In geometrical stairs, the stringer as well as the hand rail is continuous without any newel post at the landing area.

b) Half turn stairs:

In case of half turn stairs its direction reversed, or changed for 180°. Such stairs are quite common. Again these are three types.

i. Dog-legged stairs: Because of its appearance in sectional elevation this name is given. It comes under the category of newel stairs in which newel posts are provided at the beginning and end of each flight.

ii. Open newel half turn stair: In this type of open newel half turn stairs, stair has a space or well between the outer strings. This is the only aspect in which it differs from the doglegged stair.

iii. Geometrical half turn stairs: In case of geometrical half turn stairs the stringers and the hand rails are continuous, without any intervening newel post. These stairs may contains either with half space landing or without landing.

c) Three quarter turn stairs: The direction of stairs changed three times with its upper flight crossing the bottom one in the case of three quarter turn stairs. These stairs are may either be newel or open newel type. This type stairs are generally used when the vertical distance between two floors is more and as well as length of the stair room is limited.

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

3. Continuous stairs: This type of stairs neither have any landing nor any intermediate newel post. They are geometric in shape. These are may be of following types.

- Circular stairs

- Spiral stairs
- Helical stairs

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

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

DIFFERENT TYPES OF FLOORS:

CONCRETE FLOORING:

Cement concrete flooring is one of the most common types of flooring provided in houses. This type of flooring is quite durable, easy to construct and maintain besides being economical as compared to tile, marble and other such type of floorings.

MOSAIC FLOORING:

For the construction of a mosaic flooring, a concrete base is prepared and over it lime surkhi mortar is spread to a depth of 5 to 8 cm and leveled. The area over which this is spread is restricted to a suitable working period so that the mortar may not get dried before the floor is finished.

Mosaic flooring consists of:
1. Concrete layer 2. A layer of cementing material of about 3mm thick (consisting 2 : 1 : 1 ratio of lime and marble and pozzolana material). 3. After 4 hours, the laying of marble pieces or tiles is started.
After starting marble pieces a stone roller about 30 cm dia, 45 to 6 cm long is passed over the surface gently, water being sprinkled over now and then to work up the cement between the marble pieces.
The surface thus prepared is allowed to set for 24 hours and is rubbed with a pumice stone 20 cm x 25 cm x 7 cm fitted to a long wooden handle. The object is to polish the surface and to make it smooth and level. The floor is dried for about two weeks before use.

TERRAZZO FLOORS:

Terrazzo flooring has a long and rich history that dates back over 1500 years. The word Terrazzo originated from the Italian word for "terraces." It was created purely by chance by Venetian marble workers. During the Fifteenth century workers discovered a new use for discarded chips from slab marble. They began setting odd size marble pieces from paying jobs in clay to surface the terraces around their own homes. The results were amazing. Throughout time, the process evolved and we now use glass, granite and quartz along with marble chips.

The combination of beauty, durability and low maintenance has led to a renaissance in the use of terrazzo over the past decade. Today, terrazzo flooring continues to provide the ultimate in durability and low maintenance, typically lasting the life of the building. Choosing carpeting over terrazzo flooring may be a cheaper choice now but over time it becomes just as expensive as a terrazzo floor if not more. Carpeting doesn't last forever, while a terrazzo floor technically does.

PITCHED ROOFS:

Pitched roofs are seen on a variety of structures, but most typically they are seen on residential homes. These roofs offer a few advantages that flat roofs do not. Perhaps the most significant benefit to installing pitched roofs on your home is the increased drainage capacity. With severe Texas thunderstorms, it is important to have a roof that is able to handle large amounts of rain. In addition to the increased drainage that pitched roofs offer, they also afford you the opportunity to create more space inside your home. With a pitched roof you can design loft or attic space in your home. This gives you a space for your home office, playroom or simply additional storage if needed. Not only is the additional space that comes with a pitched roof advantageous in terms of convenience, extra space also increases the property value of your home.

One of the disadvantages to installing pitched roofs is the increased cost. A pitched roof is more expensive due to additional building materials, intricate design and the extra hours roofing contractors must spend constructing the roof. Pitched roofs also place more stress on a home's foundation than flat roofs.

FLAT ROOFS:

Generally, flat roofs are cheaper to install at the time of construction than pitched roofs. Additionally, flat roofs are significantly easier to walk on for maintenance and inspections. Though you should always exercise caution, whether walking on pitched roofs or flat roofs, flat roofs tend to offer more stability than pitched roofs. Flat roofs also provide homeowners an option to save energy and be environmentally friendly as well. Green roofs are becoming increasingly common and are a way to reduce surface temperature. The International Green Roof Association notes that "even though it is possible to build pitched green roofs with a slope of 45 degrees it is not recommended to exceed 30 degrees due to significant limited accessibility for upkeep and maintenance."

Flat roofs do come with a few disadvantages. One of which is their ability to bear weight. Texas weather can leave your roof having to handle copious amounts of rain. Flat roofs are more likely to collapse as a result of a severe storm than pitched roofs. The larger a flat roof is, the less stable it becomes. While a flat roof on a residential property is likely to be small enough to not cause problems, knowing that the interior must make up for this structural weakness is worth noting.

CURVED ROOFS:

There have been many curved roof styles throughout history made using all manner of different techniques and materials. While curved roofs can also be constructed using tiles and shingles, modern curved roofs most commonly take advantage of the flexibility of metal roofing materials. Metal sheeting can be bent in such a way that it allows for curved surfaces, curved peaks and gently tapered roof edges. Curved roofs take many different forms, and can incorporate a variety of different concaved and convexed elements as required.

LEAN-TO-ROOF:

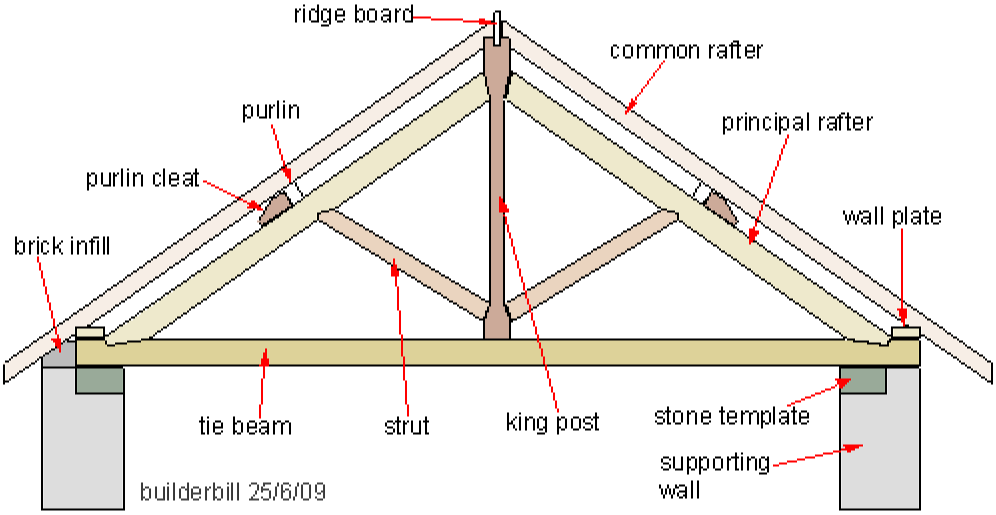
This is the simplest type of sloping roof n which rafters slope to one side only it is also known as pent roof or aisle roof. The wall to one side of the room is taken higher than the wall to the other side. Usual slope is 300. The common rafters are nailed to wooden wall plate at their upper end and notched and nailed to the wooden past plate at their lower end. Sometimes iron knee straps and bolts are used to connect rafters to the post plate. These are provided for sheds, out-houses attached to main building, verandas etc. it is suitable for maximum span of 2.5m

COUPLED ROOFS:

A 'coupled' roof is a conventional roof that is constructed on-site. It uses ceiling joists, hanging beams, strutting beams, struts, under purlins, collar ties, rafters and ridge boards.

KING POST TRUSS:

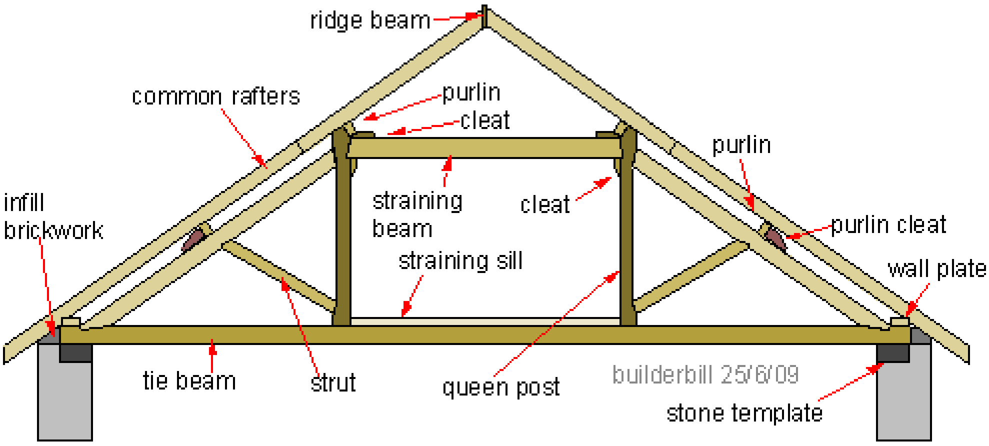
A **king post** (or **king-post** or **kingpost**) is a central vertical**post** used in architectural or bridge designs, working in tension to support a beam below from a **truss** apex above (whereas a crown **post** visually similar, supports items above from the beam below).



Traditional King Post Roof Truss

QUEEN POST TRUSS:

A **queen post** is a tension member in a truss that can span longer openings than a king post truss. A king post uses one central supporting post, whereas the queen post truss uses two. Even though it is a tension member, rather than a compression member, they are commonly still called a post. A queen post is often confused with a queen strut, one of two compression members in roof framing which do not form a truss in the engineering sense.



Traditional Queen Post Roof Truss

R.C.C. ROOFS:

R.C.C. roofs exposed to weather are susceptible to developing cracks due to shrinkage, variation of temperature and various other reasons, which provide easy passage to rain water in the form of leakage causing not only inconvenience to the inmates but also damaging the structure by ushering corrosion of the reinforcing bars and the concrete itself. Further, the slabs are comparatively thin and get heated quickly and transmit heat below to the inconvenience of the inmates. To overcome these effects, the R.C.C. roofs are provided with waterproofing course. R.C.C. slab of minimum 100 mm thickness should itself be waterproof. But a waterproof course is required as, due to bad workmanship, some defects occur through which the ingress of moisture starts and, ultimately, the structure is damaged.

MADRAS TERRACE ROOFS:

This is a traditional flooring technique found particularly practiced in south India. It involves the use of wood and " aachikal " (a locally termed material which is a small brick)and lime plaster. Commonly used for small spans. Wooden beams are used to cover the span. Over this wooden beams are laid at intervals of less than 45cms from each other. The gaps between is filled with bricks on edge with lime plaster. Upon this "aactchikal brick "is laid on edge across in diagonal fashion plastered with lime.

SHELL ROOFS:

Thin-**shell** structures are also called plate and **shell** structures. They are lightweight constructions using **shell** elements. These elements, typically curved, are assembled to make large structures. Typical applications include aircraft fuselages, boat hulls, and the **roofs** of large buildings.

Assignment-Cum-Tutorial Questions

A. Questions testing the remembering / understanding level of students

I) Objective Questions

1) The type of roof suitable in plains where rainfall is merge and temperature is high--------------
2) Pitched roofs and sloping roofs are suitable for-----------------regions
3) The type of roof which slopes in two directions with a break in the slope on each side is known as-----------
4) Couple close roof is suitable for maximum span of-----------
5) The function of a king-post in a king post roof truss is-----------------
6) The maximum number of steps in a flight should generally be restricted to-----------
7) Minimum width of landing should be----------

II) Descriptive Questions

1. What are the components of a truss?

2. Write the advantage of flat roof

3. Discuss about madras terrace roof and say the advantages.

4. What is lintel beam and its use?

5. Discuss the advantages of flat roof over sloped roof.

6. Write about classification of stairs.

7. Write classification of arches.

8. Write about madras terrace/shell roofs.

9. Write the technical terms which are used in stairs.

10. How to construct concrete flooring.

B. Question testing the ability of students in applying the concepts.

I) Multiple Choice Questions

1. The type of flooring suitable for use in churches, theatres and other places where noiseless floor covering is desired as

   (a) Cork flooring (b) glass flooring(c) wooden flooring (d) linoleum flooring

2. The vertical distance between the springing line and highest point of the inner curve of an arch as known as

   (a)intrados (b) rise (c) span drill (d) extrados

3. depth or height of the arch is the

   (a) Perpendicular distance between intra-dos and extra-dos (b) vertical distance between springing line and intrados(c) perpendicular distance between springing line and extra-dos (d) distance

4. The triangular space formed between the extrados and the horizontal line draw through the crown of an arch is known as

   (a) Haunch (b) span drill (c) voussiors (d) skewbacks

5. The lintels are preferred to arches because

   a)Arches require more headroom to span openings like doors, windows e.t.c (b) arches require strong abutments to withstand arch thrust (c) arches are difficult in construction (d) all the above

6. In the construction of arches, sand box method is used for

   (a) centering (b) actual laying of arch work (c) striking of centering (d) centering and levelling

II) Descriptive Questions

1. Give sketches of King post truss and Queen post truss. Compare the two. What are the requirements of staircase? Detail any five.

2. What are the types of Arches? Explain the construction of different Arches.

3. What are tread and riser?

4. Define a lintel and mention the materials which are commonly used to construct it.

5. Describe briefly the construction of RCC lintel.

6. What is difference between mosaic and terrazzo floor

BUILDING MATERIALS AND CONSTRUCTION

UNIT -5

Objectives:

1. Enumerate various types of building components, finishings and water-proofing methods.
2. To familiarize the importance of formwork and scaffolding.

Syllabus: Finishings

Damp proofing and Water proofing- materials used; Plastering, Pointing, White washing and Distempering; Painting – Constituents of paint – Types of paints; Painting of new/old Wood – Varnish – Form work and scaffolding.

Learning Outcomes:

Student will be able to

- explain various damp and water proofing materials and methods.
- enumerate the methods of plastering, pointing, white washing and distempering.
- explain the constituents of paints and varnishes.
- explain the procedures of painting old and new surfaces.
- illustrate the importance and types of formwork and scaffolding.

Learning Material

Damp Proofing:

Damp prevention is a chief requirement to ensure safety of building against dampness. One of the basic requirements in all the buildings is that structure should be dry as far as possible. If this is not satisfied it is likely that building may become inhabitable and unsafe from structural point of view. In order to prevent entry of damp into a building the courses known as damp proofing courses are provided at various levels of entry of damp into a building. Presently all buildings are given DPC(Damp Proof Course) treatment So DPC prevent entry of moisture from walls floors and basements of a buildings The treatment given to roofs of buildings for same cause is called water proofing.

Cause of Dampness

Responsible causes are one or more of the followings

1. Faulty design of structure
2. Faulty construction / poor workmanship
3. Using of poor quality materials in construction

These causes give rise to an easy access to moisture to enter the building from different points, such as rain penetration through walls, roof and floor etc. The moisture entering into the buildings from foundation and roofs travels in different directions farther under the effect of capillary action and gravity respectively. The entry of water and its movement in different parts of the buildings are positively due to one or more of the causes listed above

(1) Rising of moisture from the ground

The subsoil or ground on which the building is constructed may be made of soils which easily give an access to water to create dampness in building. Generally the foundation dampness is caused when the building structures are constructed on low lying water logged areas where a sub soil of clay or peat is commonly found through which dampness will easily rise under capillary action unless properly treated. This dampness further finds its way to the floors, walls etc. through the plinth.

(2) Action of Rain Water

Whenever the faces of walls are not suitably protected from the exposer to heavy shower of rains, they become the sources of dampness in a structure. Similarly the poor mortar joints in walls and cracked roofs also allow dampness to enter the building structure. Sometimes due to faulty eave courses and eave gutters, the rain water may percolate through the roof coverings.

(3) Rain penetration from top of the wall

All parapet walls and compound walls of the buildings which have not been protected from rain penetration by using dam proof courses or by such measures on their exposed tops are subjected to dampness. This dampness in the buildings is of serious nature and may results in unhealthy living condition or even in structurally unsafe conditions.

(4) Condensation due to atmospheric moisture

Whenever the warm air in the atmosphere is cooled it gives rise to process of condensation. On account of condensation the moisture is deposited on the whole area of walls, floors, and ceilings. However the sources of dampness is prevalent only in certain places in India, where very cold climate exist.

(5) Miscellaneous sources or causes

The various other sources responsible for dampness in buildings are mentioned below:-

(a) Poor Drainage of site
(b) Imperfect Orientation
(c) Constructional Dampness
(d) Dampness Due To Defective Construction

Effect of Dampness:

The various effects (indirect defects), caused due to dampness in buildings are mentioned below
All effects mainly result in poor functional performance, ugly appearance and structural weakness of the buildings.

(a) A damp building creates unhealthy living and working conditions for occupants.
(b) Presence of damp conditions causes efflorescence on building surface, which ultimately may result in the dis-integration of bricks, stones, tiles etc. and hence in the reduction of strength.
(c) It may cause bleaching and flaking of the paint which results in the formation of coloured patches on the wall surfaces and ceilings.
(d) It may result in corrosion of metals used in the construction of buildings.
(e) The material used as floor coverings, such as tiles, are damaged because they lose adhesion with the floor base.
(f) Timber, when in contact with damp conditions, gets deteriorated due to the effects of warping, buckling and rolling of timber.
(g) All electrical fittings get deteriorated, causing leakage of electric current with the potential danger of a short circuit.
(h) Dampness promotes the growth of termites and hence creates unhygienic conditions in buildings.

(i) Dampness when accompanied by the warmth and darkness, breeds the germs of tuberculosis, neuralgia, acute and chronic rheumatism etc., which sometimes result in fatal diseases.

Prevention of dampness:

Damp proofing courses or membranes:

These are the layers or membranes of water repellent material such as bituminous felts, mastic asphalts, plastic sheets, cement concrete, mortar, metal sheets which are interposed in the building structure at all location wherever water entry is anticipated. These damp proof courses of suitable materials should be provided at appropriate location for their effective use. Basically D.P.C is provided to prevent the water rising from the sub soil and getting into the different part of the buildings. The best location for D.P.C in case of buildings without basement lies at the plinth level or in case of structure without plinth should be laid at least 15 cm above the ground. These damp proof courses may be provide horizontally or vertically in floors, walls etc. in case of basement laying of D.P.C is known as tanking.

While providing damp-proof courses in buildings, the following general principles should be observed in practice.

The DPC should cover the full thickness of the walls excluding rendering, in order to act as an effective barrier to moisture under all conditions.

• The mortar bed upon which the DPC is laid should be level, even and free from any projections.

• The DPC course should be placed in correct relation with other DPC courses so as to provide a complete course should be placed in correct relation with other DPC courses so as to provide a complete and continuous barrier to the passage of moisture from below, top or sides. Therefore, the junctions and corners, formed by walls, or walls and floors, should be laid continuous.

• Where a vertical DPC is to be laid continuous with a horizontal DPC(i.e., forming angle projection), a fillet 75mm in radius should be provided. The DPC should not be exposed on the wall surface, otherwise it is likely to be damaged by carpenters, tile layers etc.

Waterproof surface treatment

The surface treatment consists in filling of the pores of the material exposed to moisture by providing a thin film of water repellent material over the surface. These surface treatments can be either external or internal, the external treatment is effective in preventing dampness where as internal one only reduces it to a certain extent.

Many surface treatments like pointing, plastering. Painting, distempering, are given to the exposed surfaces and also to the internal surfaces. Most commonly used treatments, to protect the walls against dampness, is lime cement plaster of mix (one cement : one lime : six sand) proportions. A thin film of water proofing can be materials, generally employed as waterproofing agent in surface treatments are : sodium or potassium silicates, aluminium or zinc sulphates, barium hydroxide and magnesium sulphate in alternate applications, soft soap and alum also in alternate applications, lime and linseed oil, coal tar, bitumen, waxes and fats, resins, and gum, etc.

Some of the above mentioned materials, like the waxes and fats, are unsuitable in the tropics as they melt with rise in temperature, resins and gums and also not lasting materials are coal tar and bitumen disfigure the original surface.

Plastering:

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

The objectives of plastering are:

1. To conceal defective workmanship
2. To give smooth surface to avoid catching of dust
3. To give good appearance to structure
4. To protect the wall from rain water and other atmospheric agencies
5. To protect surfaces against vermit.

Requirement of good plaster are:

- It should adhere to the background easily.
- It should be hard and durable.
- It should prevent penetration by moisture.
- It should be cheap and economical.
- It should possess good workability.
- It should efficiently check entry or penetration of moisture from surface.

Materials for plastering:

Lime mortar is usually applied in 3 coats while cement mortar is applied in two or three coats for the stone and brick masonry. For concrete surfaces cement mortar may be applied in two or three coats. For concrete building blocks many times only one coat of cement mortar is applied. The first coat provides means of getting level surface. The final coat provides smooth surface. If three coats are used second coat is known as floating coat. The average thickness of first coat is 10 to 15 mm. Middle coat thickness is 6–8 mm. The final coat is just 2 to 3 mm thick. If single coat is used its thickness is kept between 6 to 12 mm. Such coats are used on concrete surfaces not exposed to rain. The mortar used for plastering work can be classified into three categories:

- **Lime mortar**: it consists of equal volume of lime and sand these two materials are carefully ground in mortar mill. Flat lime is recommended for plastering work.
- **Cement mortar**: the cement mortar consists of one part of cement to four part of clean, coarse and angular river sand. The materials are thoroughly mixed in dry condition before water is added to them. The mixing of materials is done on a watertight platform.
- **Water proof mortar**: This mortar is water proof and it is prepared by mixing one part of cement and two parts of sand and pulverized alum at the rate of 120 N per m^3 sand.

Method of Plastering:

The plastering could be done on the surfaces either in one, two and three coats. The plastering for two coats are as follows:

- The mortar joints are racked out to a depth of 20 mm and surface is cleaned and well watered. If it is found that the surface to be plastered is very rough and uneven, a primary coat is applied to fill up the hollows before the first coat of plaster is put on the surface.
- The first coat of plaster is now applied on the surface. The usual thickness of first coat for brick masonry is 9 mm to 10 mm. In order to maintain uniform thickness, the screeds are formed on the wall surface by fixing dots.
- The cement mortar is placed between successive screeds and surface is properly finished. The second coat is applied after six hours and thickness of second coat is 3 mm to 2 mm. The completed work is allowed to rest for 24 hours and then, the surface is kept well watered for rest of week.

For plastering in three coats are similar to two coats. The thickness of first coat (rendering coat) 9 to 10 mm, second coat (rendering coat) 9 to 10 mm, and third coat (setting coat) thickness around 3 mm.

Pointing:

The term pointing is used to denote finishing of mortar joints of either stone masonry or brick masonry. The joints are raked out to a depth of about 20 mm and then, these spaces are filled up by suitable mortar in the desired shape.

It is desirable to avoid pointing as far as possible. This is due to the fact that pointing involves raking out of joints which are constructed with good mortar and filling the joints with mortar which, in many cases, is not sufficiently watered. For this reason, the pointing work of new structure should follow the masonry work in progress. The joints are thus raked out when the mortar has not set.

Mortar for pointing: The pointing is generally adopted for the finishing of exposed external walls of a structure. It is cheap in the first coat, but it requires frequent replacement. The pointing may be carried out either in lime or in cement mortar. The lime mortar consist of equal volumes of lime and sand. These two materials are carefully mound in a mortar mill. The sand to be used for preparing lime mortar should be clean, fine and free from any organic impurities.

The cement mortar consists of equal volume of cement and sand. The cement should comply with standard requirements and sand should be clean, fine and free from organic impurities. The materials are thoroughly mixed in dry condition before water is added to them. The mixing of materials is done on watertight platform and mortar of one cement bag only is prepared at a time and this quantity of mortar is consumed within 30 minutes after adding water.

Method of Pointing: The pointing is carried out as follows:

- The mortar of masonry joints to be covered by pointing is raker out at least to a depth of 20 mm.
- The dust from the masonry joints is removed by the brushes.
- The surface is then washed within clean water and it is kept wet for a few hours.
- The mortar is then carefully placed in desired shapes in these prep are joints.
- The mortar is placed by a small towel and it is slightly pressed to bring into close contact with the old interior mortar of the joint.
- The finished surface is well-watered for a period of at least 3 days, It lime mortar is used and 10 days, if cement mortar is used.

Types of pointing:

- Beaded pointing
- Flush pointing
- Recessed pointing
- Rubbed or Keyed or grooved pointing
- Struck pointing
- Tuck pointing
- Vee-pointing

White Washing:

The complete process of white washing can be carried out under the following operations.

1. Preparation of white wash
2. Preparation of surface
3. Application of white wash

Step-1 Preparation of white wash

1. The white wash is prepared from fresh burnt shell lime or pure stone lime mixed with water. Shell lime is preferred to pure lime as it is whiter and slakes more perfectly to a smoother paste.
2. To prepare white wash, fresh lime is slaked at site of work and is dissolved in a tub with sufficient quantity of water.
3. After slaking, it is allowed to remain in the tub of water for two days and then stirred up with a pole until it attains the consistency of thin cream.
4. The mixture is then strained or screened through a clean coarse cloth.
5. Clean gum dissolved in hot water is then added at the rate of 2 kg/m^3 of lime (or 4 kg/m^3 of thin cream or white wash water) to the white wash water. The solution so formed is called as **white wash**.
6. To prevent the glare effect due to white wash, sometimes, the copper sulphate at the rate of 4 kg/m^3 of thin cream is added. In order to have better adhesive properties, alum or common salt may be added in the same proportion as gum.

Step-2 Preparation of surface

1. Before applying white wash to new wall surface, it is essential that surface should be cleaned, brushed and made free from loose materials and any other foreign matter.
2. If the surface to be coated is extra smooth or over smooth, then coats will not stick to it. In such a case, the surface should be rubbed with sand paper to ensure proper adhesion of white was.
3. In case of re white washing, all loose material and scales should be scrapped off. The old loose white wash is removed by rubbing with sand paper. All holes in wall, irregularities of surface, minor repairs, etc. are corrected in advance by filling with lime putty.
4. All greasy spots should be given a coat of a mixture of rice water and sand so that the finishing wash may stick to the surface. If old white wash is discoloured by smoke or other reasons as in kitchens, factories, restaurants, etc. then in such cases, the surfaces should be given a wash of a mixture of wood ashes and water or yellow earth, before the application of white wash.
5. Cement plastered walls should be washed with a weak solution of soap and dried before applying white wash.

Step-3 Application of white wash

The white wash is applied to a specified number of coats with a jute brush. Usually, three coats are required for new works and for scrapped surfaces, while one or two coats are considered sufficient for old work.

1. For each coat, one stroke is given from the top downwards and the other from the bottom upwards over the first stroke, and similarly one stoke from the right and another from the left over the first brush before it dries. Each coat should be allowed to dry before applying the next coat.
2. The finished dry wash surface should not show any signs of cracking or peeling and should also not come off readily on finger when rubbed.

Paint:

Paint is a liquid surface coating. On drying it forms a thin film on the painted surface. Paints are classified as oil paints, water paints, cement paints, bituminous paints and special paints such as fire proof paints, luminous paints, chlorinated rubber paints (for protecting objects against acid fumes), etc. The paintings are the coating of fluid materials

The functions of the paints are:

• To protect the coated surface against possible stresses mechanical or chemical; deterioration—physical or environmental;

• Decorate the structure by giving smooth and colourful finish; check penetration of water through R.C.C;
• check the formation of bacteria and fungus, which are unhygienic and give ugly look to the walls;
• check the corrosion of the metal structures;
• Check the decay of woodwork and to varnish the surface to display it to better advantage

Constituents of Paint

The essential constituents of paints are:

1. Base
2. Vehicle
3. Pigment
4. Drier and
5. Thinner.

1. Bases: It is a principal constituent of paint. It also possesses the binding properties. It forms an opaque coating. Commonly used bases for paints are white lead, red lead, zinc oxide, iron oxide, titanium white, aluminium powder and lithophone. A lead paint is suitable for painting iron and steel works, as it sticks to them well. However it is affected by atmosphere action and hence should not be used as final coat. While zinc forms good base but is costly. Lithophone, which is a mixture of zinc sulphate and barytes, is cheap. It gives good appearance but is affected by day light. Hence it is used for interior works only.

2. Vehicles: The vehicles are the liquid substances which hold the ingredients of a paint in liquid suspension and allow them to be applied on the surface to be painted. Linseed oil, Tung oil and Nut oil are used as vehicles in paints. Of the above four oils, linseed oil is very commonly used vehicles. Boiling makes the oil thicker and darker. Linseed oil reacts with oxygen and hardens by forming a thin film.

3. Pigment: Pigments give required colour for paints. They are fine particles and have a reinforcing effect on thin film of the paint. The common pigments for different colours are:

Black—Lamp black, suit and charcoal black.
Red—venedian red, red lead and Indian red.
Brown—burned timber, raw and burned sienna
Green—chrome green, copper sulphate.
Blue—Prussian blue and ultra-marine
Yellow—ochre and chrome yellow.

4. Drier: These are the compounds of metal like lead, manganese, cobalt. The function of a drier is to absorb oxygen from the air and supply it to the vehicle for hardening. The drier should not be added until the paint is about to be used. The excess drier is harmful because it destroys elasticity and causes flaking.

5. Thinner: It is known as solvent also. It makes paint thinner and hence increases the coverage. It helps in spreading paint uniformly over the surface Turpentine and naphtha are commonly used thinners. After paint applied, thinner evaporates and paint dries.

Properties of an Ideal Paint

1. It should be possible to apply easily and freely.
2. It should dry in reasonable time.
3. It should form hard and durable surface.
4. It should not be harmful to the health of workers.
5. It should not be easily affected by atmosphere.
6. It should possess attractive and pleasing appearance.
7. It should form a thin film of uniform nature i.e., it should not crack.
8. It should possess good spreading power.

9. It should be cheap.

Types of Paints

Depending upon their constituents there are various types of paints. A brief description of some of them which are commonly used are given below:

1. Oil Paint: These paints are applied in three coats-primer, undercoat and finishing coat. The presence of dampness while applying the primer adversely affect the life of oil paint. This paint is cheap and easy to apply.

2. Enamel Paint: It contains white lead, oil, petroleum spirit and resinous material. The surface provided by it resists acids, alkalies and water very well. It is desirable to apply a coat of titanium white before the coat of enamel is applied. It can be used both for external and internal walls.

3. Emulsion Paint: It contains binding materials such as polyvinyl acetate, synthetic resins etc. It dries in 1 1/2 to 2 hours and it is easy to apply. It is more durable and can be cleaned with water. For plastered surfaces, first a coat of cement paint should be applied and then the emulsion point. Emulsion paint needs sound surfaces.

4. Cement Paint: It is available in powder form. It consists of white cement, pigment and other additives. It is durable and exhibits excellent decorative appearance. It should be applied on rough surfaces rather than on smooth surfaces. It is applied in two coats. First coat is applied on wet surface but free from excess water and allowed to dry for 24 hours. The second coat is then applied which gives good appearance.

5. Bituminous Paints: This type of paint is manufactured by dissolving asphalt or vegetable bitumen in oil or petroleum. It is black in colour. It is used for painting iron works under water.

6. Synthetic Rubber Paint: This paint is prepared from resins. It dries quickly and is little affected by weather and sunlight. It resists chemical attack well. This paint may be applied even on fresh concrete. Its cost is moderate and it can be applied easily.

7. Aluminium Paint: It contains finely ground aluminium in spirit or oil varnish. It is visible in darkness also. The surfaces of iron and steel are protected well with this paint. It is widely used for painting gas tanks, water pipes and oil tanks.

8. Anti- corrosive Paint: It consists essentially of oil, a strong die, lead or zinc chrome and finely ground sand. It is cheap and resists corrosion well. It is black in colour.

Painting of various surfaces:

A. Painting of new woodwork

Painting of woodwork should be done with great care. Normally 3–4 coats are sufficient for wood work.

• **Surface preparation:** The wood should be well seasoned, dried, cleaned and the surface made smooth with an emery paper. Nails, if any, should be driven down the surface by at least 3 mm.

• **Knotting:** Knots in the wood create lot of problems. These excrete resin which causes defects such as cracking, peeling and brown discolouration. Knotting is done so that resin cannot exude from the knots. Any of the following methods may be used suitably.

Ordinary knotting: This is also known as size knotting. The knot is treated with a coat of hot red lead ground with a strong glue size in water. Then a coat of red lead ground in boiled linseed oil is applied.

Lime knotting: The knot is covered with hot lime for 24 hours after which it is scrapped off. Thereafter, the process described in ordinary knotting is followed.

Patent knotting: Two coats of varnish or shelac are applied.

• **Priming coat:** The main function of priming coat or primer is to form the base for subsequent ones. After knotting priming coat is applied over the entire surface to fill all the pores. A second priming coat is applied after first has dried. In general the ingredients are same as those of the subsequent coats but with a difference in proportion.

• **Stopping:** After the priming coat putty is applied to fill the pores of the surface. Then it is rubbed smooth. Colouring pigment is also added to it to match the shade of the finished coat. On drying, the selected paint is applied with brushes to bring smoothness and uniformity in colour. After painting the surface in one direction, the brush is worked in the perpendicular direction to eliminate brush marks. This is known as crossing. All the successive coats are applied after drying and slight rubbing of previous coats for proper bond.

B. Painting of old woodwork:

The old paint is removed with a sharp glass piece, sand paper, paint remover or with a blow lamp. Any smoky or greasy substance should be washed with lime and subsequently rubbed with pumice stone. The surface is then washed with soap and water and dried completely. Then two coats of paints are applied in a way similar to that described in painting new surfaces.

Distempers:

Distempers are the cheaper variety of paints in which chalk is used as base and water is used as a carrier.

The emulsifying agent which is commonly used is glue or casein. Distempers are available in powder form or in the form of paste. They are to be mixed with hot water before use.

The surface to be distempered should be thoroughly rubbed and cleaned. The cracks, if any should be filled by lime putty. The surface should be kept dry for about two months before applying distemper. Thus a primary coat is applied and is allowed to dry. Distemper is usually applied in two coats.

Properties of Distemper:

1. They are generally light in colour.
2. The coatings are generally thick.
3. They give reflective coating.
4. They are less durable than oil paints but are cheaper.

Varnishes:

Varnish is the solution of resins or resinous substances like amber, copal, shellac, gum resin etc. in solvents like oil, turpentine, alcohol etc. Depending upon the solvents used varnishes are classified as, oil varnishes, turpentine varnishes, spirit varnishes and water varnishes.

The desirable characteristics of an ideal varnish are

1. It should give glossy surface.
2. Should be durable.
3. It should dry rapidly after application.
4. It should not develop cracks after drying.
5. It is commonly used on wooden surfaces.

Formwork(Centering):

Formwork in concrete construction is used as a mould for a structure in which fresh concrete is poured only to harden subsequently. Types of formwork for concrete construction depends on formwork material and type of structural element. Formworks can also be named based on the type of structural member construction such as slab formwork for use in slab, beam formwork, column formwork for use in beams and columns respectively etc.

The construction of formwork takes time and involves expenditure upto 20 to 25% of the cost of the structure or even more. Design of these temporary structures are made to economic expenditure. The operation of removing the formwork is known as stripping. Stripped formwork can be reused. Reusable forms are known as panel forms and non-usable are called stationary forms.
Timber is the most common material used for formwork. The disadvantage with timber formwork is that it will warp, swell and shrink. Application of water impermeable cost to the surface of wood mitigates these defects.

Requirements of good formwork:

1. It should be strong enough to withstand all types of dead and live loads.
2. It should be rigidly constructed and efficiently propped and braced both horizontally and vertically, so as to retain its shape.
3. The joints in the formwork should be tight against leakage of cement grout.
4. Construction of formwork should permit removal of various parts in desired sequences without damage to the concrete.
5. The material of the formwork should be cheap, easily available and should be suitable for reuse.
6. The formwork should be set accurately to the desired line and levels should have plane surface.
7. It should be as light as possible.
8. The material of the formwork should not warp or get distorted when exposed to the elements.
9. It should rest on firm base.

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

Types of Scaffolding used in Construction:

1. Single scaffolding
2. Double scaffolding
3. Cantilever scaffolding
4. Suspended scaffolding
5. Trestle scaffolding
6. Steel scaffolding

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

2.Double Scaffolding:
Double Scaffolding is generally used for stone masonry so, it is also called as mason's scaffolding. In stone walls, it is hard to make holes in the wall to support putlogs. So, two rows of scaffolding is constructed to make it strong. The first row is 20 – 30 cm away from the wall and the other one is 1m

away from the first row. Then putlogs are placed which are supported by the both frames. To make it more strong rakers and cross braces are provided. This is also called as independent scaffolding.

3.Cantilever Scaffolding:

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

4.Suspended Scaffolding:

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

5.Trestle Scaffolding:

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

6.Steel Scaffolding:

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

Assignment-Cum-Tutorial Questions

A. Questions testing the remembering / understanding level of students

I) *Objective Questions*

In fire proof paints, the main constituent is _______________

2. The quantity of drier in paints is limited to ________________

3. ___________ type of paints are used over newly plastered surfaces.

4. Varnish is a homogenous solution of resin in _______________

5. _______________ thinner is used in plastic paints.

6. The amount of water used for 1 kg of distemper is ______________

7. To give a brilliant finish, ___________ type of varnish is used.

8. For rapid construction of a constant thickness wall, ____________ shuttering is used.

9. The minimum thickness of bitumen to be applied for damp proofing course is ________.

10. The damp proof course suggested by CBRI, Roorkee comprises of a __________ layer over Cement mortar.

II) Descriptive Questions

1. What is meant by a Damp Proof Course (DPC)?
2. Write the advantages of distempers?
3. Discuss the method of application of a paint.
4. What is meant by formwork?
5. Define scaffolding.
6. What is meant by white washing?
7. Write the ideal characteristics of a paint.
8. Mention the desirable characteristics of a varnish.
9. Write the requirements of a good formwork.
10. Write a short note on pointing.
11. Write a detailed note on constituents of a paint.
12. Explain the difference between plastering and pointing.
13. Briefly explain the procedure of painting of new and old wood works.
14. Explain the importance and types of formwork used in constructions.
15. Discuss the various types of scaffoldings used in constructions.
16. Write the detailed procedure of white washing of a wall.
17. Mention the harmful effects caused by dampness in buildings.
18. Write a short note on water proofing treatment.
19. Explain various types of pointings with a neat sketch.
20. Mention the functions of various ingredients of a paint.

B. Question testing the ability of students in applying the concepts.

I) Multiple Choice Questions

1. Linseed oil is used in paints as [ ]

A. thinner B. vehicle C. base D. drier.

2. Spirit varnish generally consists of [ ]

A. oil, wax and resin B. alcohol, wax and turpentine

C. pigment and synthetic resin D. spirit and shellac

3. Plastic asphalt is [ ]

A. used as a water proofing layer over roof B. a mixture of cement and asphalt

C. a natural asphalt D. a refinery product.

4. The material generally not used as extender in paints, is [ ]

A. powdered silica B. gypsum

C. talc D. zinc white.

5. The form work from the slabs excluding props, can be removed only after [ ]

A. 1 day B. 4 days C. 7 days D. 14 days

6. The local swelling of a finished plaster, is termed [ ]

A. cracking B. dubbing

C. blistering D. hacking.

7. The form work from the sides of beams can be removed only after [ ]

A. 1 day B. 4 days

C. 7 days D. 14 days.

8. The type of pointing in which upper side of mortar joints is kept about 12 mm inside the face of the masonry and bottom is kept flushed with face of wall, is [ ]

A. truck pointing B. recessed pointing

C. struck pointing D. grooved pointing.

9. An ordinary concrete may be made water proof by adding [ ]

A. pudlo B. impermo

C. snowcem D. cico

10. The type of pointing in which a V-shaped projection outside the wall surface, is provided, is called

A. recessed pointing B. weather pointing [ ]

C. V-pointing D. tuck pointing.

11. Assertion A : Paints with white lead base are not recommended for painting of iron works. [ ]

Reason R : Paints with white lead base do not check rusting of iron.

Select your answer according to the coding system given below:

a. Both A and R is true and, R is the correct explanation of A

b. Both A and R is true but R is not the correct explanation of A

c. A is true but R is false

d. A is false but R is true

12. Assertion A : Normally turpentine oil is recommended as thinner for indoor painting. [ ]

Reason R : Turpentine oil is costlier than other thinners.

Select your answer according to the coding system given below:

(A) Both A and R is true and R is the correct explanation of A

(B) Both A and R is true but R is not the correct explanation of A

(C) A is true but R is false

(D) A is false but R is true

C. Questions testing the analyzing/ evaluating ability of students.

1. What is the difference between a normal paint and an emulsion paint?

2. What is the difference between painting a new surface and old surface?

UNIT-VI

BUILDING MATERIALS &CONSTRUCTION

Course Objectives:

- To understand the knowledge of building components, finishings.

Syllabus:

Alternative materials

Properties and applications of Galvanized Iron, Fibre-reinforced plastics, Steel, Aluminium, Glass, Gypsum, ceramics, fly ash.

Learning Outcomes:

At the end of the unit the student will be able to

- evaluate importance and role of alternative materials.

LEARNING MATERIAL

INTRODUCTION:

Galvanized iron:

Galvanization or **galvanisation** (or **galvanizing** as it is most commonly called in that industry) is the process of applying a protective zinc coating to steel or iron, to prevent rusting. The most common method is hot-dip galvanizing, in which parts are submerged in a bath of molten zinc. Galvanizing protects in three ways:

- It forms a coating of zinc which, when intact, prevents corrosive substances from reaching the underlying steel or iron.
- The zinc serves as a sacrificial anode so that even if the coating is scratched, the exposed steel will still be protected by the remaining zinc.
- The zinc protects its base metal by corroding before iron. For better results, application of chromates over zinc is also seen as an industrial trend.

Fibre reinforced plastics

Fibre-reinforced plastic (**FRP**) (also fibre-reinforced polymer) is a composite material made of a polymer matrix reinforced with fibres. The fibres are usually glass, carbon, aramid, or basalt. Rarely, other fibres such as paper or wood or asbestos have been used. The polymer is usually an epoxy, vinyl ester or polyester thermosetting plastic; phenol formaldehyde resins are still in use.

FRPs are commonly used in the aerospace, automotive, marine, and construction industries. They are commonly found in ballistic armour as well.

Steel

Steel is an alloy of iron and other elements, primarily carbon, and is widely used in construction and other applications because of its high tensile strength and low cost. Steel's base metal is iron, which is able to take on two crystalline forms (allotropic forms), body centred cubic (BCC) and face centred cubic (FCC), depending on its temperature.

It is the interaction of those allotropes with the alloying elements, primarily carbon, that gives steel and cast iron their range of unique properties. In the body-centred cubic arrangement, there is an iron atom in the centre of each cube, and in the face-centred cubic, there is one at the centre of each of the six faces of the cube. Carbon, other elements, and inclusions within iron act as hardening agents that prevent the movement of dislocations that otherwise occur in the crystal lattices of iron atoms.

The carbon in typical steel alloys may contribute up to 2.1% of its weight. Varying the amount of alloying elements, their presence in the steel either as solute elements, or as precipitated phases, retards the movement of those dislocations that make iron comparatively ductile and weak, and thus controls its qualities such as the hardness, ductility, and tensile strength of the resulting steel. Steel's strength compared to pure iron is only possible at the expense of iron's ductility, of which iron has an excess.

Aluminium

Aluminium or **aluminum** (in North American English) is a chemical element in the boron group with symbol **Al** and atomic number 13. It is a silvery-white, soft, nonmagnetic, ductile metal. Aluminium is the third most abundant element in the Earth's crust (after oxygen and silicon) and its most abundant metal. Aluminium makes up about 8% of the crust by mass, though it is less common in the mantle below. Aluminium metal is so chemically reactive that native specimens are rare and limited to extreme reducing environments. Instead, it is found combined in over 270 different minerals. The chief ore of aluminium is bauxite.

Glass

Glass is a non-crystalline amorphous solid that is often transparent and has widespread practical, technological, and decorative usage in, for example, window panes, tableware, and optoelectronics. Scientifically, the term "glass" is often defined in a broader sense, encompassing every solid that possesses a non-crystalline (that is, amorphous) structure at the atomic scale and that exhibits a glass transition when heated towards the liquid state.

The most familiar, and historically the oldest, types of glass are "silicate glasses" based on the chemical compound silica (silicon dioxide, or quartz), the primary constituent of sand. The term *glass*, in popular usage, is often used to refer only to this type of material, which is familiar from use as window glass and in glass bottles. Of the many silica-based glasses that exist, ordinary glazing and container glass is formed from a specific type called soda-lime glass, composed of approximately 75% silicon dioxide (SiO_2), sodium oxide (Na_2O) from sodium carbonate (Na_2CO_3), calcium oxide, also called lime (CaO), and several minor additives.

Gypsum

Gypsum is a soft sulphate mineral composed of calcium sulphate dehydrate, with the chemical formula $CaSO_4 \cdot 2H_2O$. It is widely mined and is used as a fertilizer, and as the main constituent in many forms of plaster, blackboard chalk and wallboard. A massive fine-grained white or lightly tinted variety of gypsum, called alabaster, has been used for sculpture by many cultures including Ancient Egypt, Mesopotamia, Ancient Rome, Byzantine empire and the Nottingham alabasters of Medieval England. Mohs scale of mineral hardness, based on scratch Hardness comparison, defines hardness value as gypsum. It forms as an evaporate mineral and as a hydration product of anhydrite.

Ceramics:

A ceramic material is an inorganic, non-metallic, often crystalline oxide, nitride or carbide material. Some elements, such as carbon or silicon, may be considered ceramics. Ceramic materials are brittle, hard, strong in compression, weak in shearing and tension. They withstand chemical erosion that occurs in other materials subjected to acidic or caustic environments. Ceramics generally can withstand very high temperatures, such as temperatures that range from 1,000 °C to 1,600 °C (1,800 °F to 3,000 °F). Glass is often not considered a ceramic because of its amorphous (noncrystalline) character. However, glassmaking involves several steps of the ceramic process and its mechanical properties are similar to ceramic materials.

Traditional ceramic raw materials include clay minerals such as kaolinite, whereas more recent materials include aluminium oxide, more commonly known as alumina. The modern ceramic materials, which are classified as advanced ceramics, include silicon carbide and tungsten carbide. Both are valued for their abrasion resistance, and hence find use in applications such as the wear plates of crushing equipment in mining operations. Advanced ceramics are also used in the medicine, electrical, electronics industries and body armor.

Fly ash:

Fly ash, also known as "pulverised fuel ash" in the United Kingdom, is a coal combustion product that is composed of the particulates (fine particles of burned fuel) that are driven out of coal-fired boilers together with the flue gases. Ash that falls to the bottom of the boiler is called bottom ash. In modern coal-fired power plants, fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys. Together with bottom ash removed from the bottom of the boiler, it is known as **coal ash**. Depending upon the source and composition of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline), aluminium oxide (Al_2O_3) and calcium oxide (CaO), the main mineral compounds in coal-bearing rock strata.