5.8.20

# STONES

The engineering structures are composed of material. These materials are known as the engineering materials or building materials or materials of construction. It is necessary for an engineer to become conversant with the properties of such materials.

* Classification of Rocks:-

The building stones are obtained from the rocks which are classified in the following three ways:-

(i) Geological classification
(ii) Physical classification
(iii) Chemical classification

(1) Geological classification:-

According to this classification the rocks are of the following three types:

(i) Igneous rock
(ii) Sedimentary rocks, and
(iii) Metamorphic rocks.

(1) Igneous rocks:- The inside portion of the earth's surface has high temperature so as to cause fusion by heat at even ordinary pressure. The molten or pasty rocky material is known as the magma and this magma occasionally tries to come out to the earth's surface through cracks or weak portions. The rocks which are formed by the cooling of magma are known as the igneous rocks.
The igneous rocks are recognized in the following three classes:-

(a) <u>plutonic rocks</u> :- Such rocks are formed due to cooling of magma at a considerable depth from earth's surface. The cooling is slow and the rocks possess coarsely grained crystalline structure. The igneous rocks commonly used in building industry are of plutonic type. The granite is the leading example of this type of rocks.

(B) <u>Hypabyssal rocks</u> :- Such rocks are formed due to cooling of magma at a relatively shallow depth from the earth's surface. The cooling is quick and hence these rocks possess finely grained crystalline structure. The dolerite is an example of this type of rocks.

(C) <u>Volcanic rocks</u> :- Such rocks are formed due to pouring of magma at earth's surface. The cooling is very rapid as compared to the previous two cases. Hence these rocks are extremely fine grained in structure. They frequently contain some quantity of glass which is a non-crystalline material. The basalt is an example of this type of rock.

(ii) <u>Sedimentary rocks</u>:- These rocks are formed by the deposition of products of weathering on the pre-existing rocks. All the products of weathering are ultimately carried away from their place of origin by the agents of transport. Such agents are frost, rain, wind, flowing water, etc.

following four types of deposits occur.

(a) Residual deposits :- Some portion of the products of weathering remain at the site of origin. Such a deposit is known as a residual deposit.

(b) Sedimentary deposits :- The insoluble products of weathering [illegible] carried away in suspension and when such products are deposited, they give rise to the Sedimentary deposits.

(c) Chemical deposits :- Some material that is carried away in solution may be deposited by some physio-chemical processes such as evaporation, precipitation, etc. It gives rise to the chemical deposits.

(d) Organic deposits :- Some portion of the product of weathering gets deposited through the agency of organisms. Such deposits are known as the organic deposits.

The examples of Sedimentary rocks are gravel, sandstone, limestone, gypsum, lignite, etc.

(iii) Metamorphic rocks :- These rocks are formed by the change in character of the pre-existing rocks. The igneous as well as Sedimentary rocks are changed in character when they are subjects to great heat and pressure. The process of change is known as the metamorphism

following four types of metamorphism occur with various combinations of heat, uniform pressure and directed pressure

(a) Thermal metamorphism :- The heat is the predominant factor in this type of metamorphism

(b) Cataclastic Metamorphism :- At the surface of earth the temperatures are low and metamorphism is brought about by directed pressure only. Such metamorphism is known as the cataclastic metamorphism.

(c) Dynamo-thermal metamorphism :- There is a rise in temperature with increase in depth. Hence, the the heat in combination with stress, bring about the changes in rock. Such metamorphism is known as the dynamo-thermal metamorphism.

(d) Plutonic Metamorphism :- The stress is effective only upto a certain depth. This is due to the fact that rocks become plastic in nature at certain depths. At great depth, a stage is reached when stress cannot exist as it is converted into uniform pressure because of the plasticity of rocks. The metamorphic changes at great depths are therefore brought about by uniform pressure and heat. Such metamorphism is known as the plutonic metamorphism.

2) Physical Classification :- This classification is based on general structure of rock. According to this classification, the rocks are of the following three types :-

(i) Stratified rocks.
(ii) Unstratified rocks and
(iii) Foliated rocks.

(i) Stratified rocks :- These rocks possess planes of stratification or cleavage and such rocks can easily be split up along these planes. The sedimentary rocks are distinctly stratified rocks.

(ii) Unstratified rocks :- These rocks are unstratified. The structure may be crystalline granular or compact granular. The igneous rocks of volcanic agency and sedimentary rocks affected by movements of the earth are of this type of rocks.

(iii) Foliated rocks:- These rocks have a tendency to be split up in a definite direction only. The foliated structure is very common in case of metamorphic rocks.

3) Chemical Classification :-

This classification is known as the scientific or engineering classification and according to this classification, the rocks are of the following three types:-

(i) Silicious rocks:
(ii) Argillaceous rocks
(iii) Calcareous rocks.

(i) Silicious rocks:- In these rocks the silica predominates. The rocks are hard and durable. They are not easily affected by the weathering agencies. The silica however in combination with weaker minerals may disintegrate easily. It is therefore necessary that these rocks should contain maximum amount of free silica for making them hard and durable. The granites, quartzites, etc. are example of silicious rocks.

(ii) Argillaceous rocks:- In these rocks the argil or clay predominates. Such rocks may be dense and compact or they may be soft. These stones are hard and durable but brittle. The slates, laterites, etc. are examples of the silicious rocks.

(iii) Calcareous rocks:- In these rocks the calcium carbonate predominates. The durability of these rocks will depend upon the constituents present in the surrounding atmosphere. The limestones marbles, etc. are examples of calcareous rocks.

* ## Uses of Stones :-

The stones are used in the construction of building from the ancient times and most of the ancient temples and forts of our country were built with stones. The Taj Mahal at Agra and Red fort, Jama Masjid, Parliament House, Central Secretariat and Rashtrapati Bhavan at Delhi and various other prominent structures spread throughout the length and breadth of our country furnish us the splendid examples of contribution of stones as a building material. Even at present they form a basic material for cement concrete and bricks. following are the various uses to which stones are employed.

(i) Structure:- The stones are used for foundations, walls, columns, lintels, arches, roofs, floors, damp proof courses, etc.

(ii) Face-work:- The stones are adopted to give massive appearance to the structure. The walls are of bricks and facing is done in stones of desired shades. This is known as the composite masonry.

(iii) paving:- The stones are used to cover floor of buildings of various types such as residential, commercial, industrial, etc. They are also adopted to form paving of roads, footpaths, etc.

(iv) Basic material:- The stones are disintegrated and converted to form a basic material for cement concrete, murum of roads, calcareous cements, artificial stones, hollow blocks, etc.

(v) Miscellaneous:- In addition to above uses, the stones are also used as:

(i) ballast for railways

(ii) flux in blast furnaces.

(iii) blocks in the construction of bridges, piers, abutments, retaining walls, light houses, dams, etc.

* Natural Bed of Stones :-

(i) Definition :- The building stones are obtained from rocks. These rocks have a distinct plane of division along which stones can easily be split. This plane is known as the natural bed of stone and it thus indicates the plane or bed on which the sedimentary stone was originally deposited. The natural bed of stone need not necessarily be horizontal. for sedimentary rocks, it is easy to observe and locate the natural bed as it lies along the planes of stratification. for igneous rocks, the natural bed is of little significance or importance and it is also difficult to determine.

(ii) Importance :- In stone masonry, the general rule to be observed is that the direction of natural bed of all sedimentary stones should be perpendicular or nearly so to the direction of pressure. Such an arrangement gives maximum strength to the stonework.

The natural beds of stones can be detected by pouring water and examining the direction of layers. The magnifying glass may also be used for this purpose. An experienced worker can easily locate the direction of natural bed of stones from the resistance offered to the chisel. The stones break easily along their natural beds.

with respect to natural bed, the stones are placed in different situations as follows.

(i) Arches:- In stone arches, the stones are placed with their natural beds radial with such an arrangement, the thrust of arch acts normal to the direction of natural bed.

(ii) Cornices, string courses, etc:- The stones are partially unsupported in case of cornices, string courses, etc. Hence they should be placed with direction of natural beds as vertical. This principal will not hold good for corner stones. It would be desirable, in such cases, to adopt stone without natural beds.

(iii) Walls:- The stones should be placed in wall with the direction of their natural beds horizontal.

* Qualities of a good Building stone

Following are the qualities or characteristics or requirements of a good building stone:

(i) Crushing Strength:- For a good structural stone, the crushing strength should be greater than 100 N/mm². The approximate values of crushing strength of some of the stone are shown in table.

## Crushing Strength

| Rock | Stone | Crushing strength in N/mm² |
|---|---|---|
| Igneous | Basalt | 150 to 185 |
| | Diorite | 90 to 150 |
| | Granite | 75 to 127 |
| | Syenite | 90 to 150 |
| | Trap | 330 to 380 |
| Sedimentary | Laterite | 1.80 to 3.10 |
| | Limestone | 54 |
| | Sandstone | 64 |
| | Shale | 0.2 to 0.60 |
| Metamorphic | Gneiss | 206 to 370 |
| | Slate | 75 to 207 |

(ii) Appearance:- The Stones which are to be used for face works should be decent in appearance and they should be capable of preserving their colour uniformly for a long time. The colour of the Stones for face works should be chosen by keeping in mind the general get up of the surrounding area. It is desirable to prefer light coloured stones as compared to dark coloured Stones because there are chance of the latter variety to be attacked easily by weathering agents. A good building stone should be of uniform colour and free form clay holes, spots of other colour, bands. etc.

(iii) Durability:- A good building Stone should be durable. The various factors contributing to durability of a Stone are its chemical composition, texture, resistance to atmospheric and other influences, location in structure, etc.

following are the important atmospheric agencies which affect the durability of a stone

(i) alternate condition of heat and cold due to difference in temperature;

(ii) alternate conditions of wetness and dryness due to rain and scalling.

(iii) Chemical agencies such as dissolved gases in rain.

(iv) growth of trees and creepers in the joints between stones.

(v) wind with high velocity, etc.

for making durable, their natural bed should be carefully noted. Stones should be so arranged in a structure that the natural bed is perpendicular or nearly so to the direction of pressure.

(iv) Facility of dressing:- The stones should be such that they can be easily carved, moulded, cut and dressed. It is an important consideration from the economic point of view. However this property of stone is opposed to its strength, durability and hardness. Hence it is to be properly correlated with respect to the situation in which stone is to be used.

(v) fracture:- for a good building stone, its fracture should be sharp, even, bright and clear with grains well cemented together. A dull, chalky and earthy fracture of stone indicates signs of early future decay.

(vi) Hardness: The coefficient of hardness, as worked out in hardness test should be greater than 17 for a stone to be used in road work. if it is between 14 and 17, the stone is said is said to be of medium hardness. if it is less than 14, the stone is said to be of fair hardness and such stone should not be used in road work.

(vii) Percentage wear:- In attrition test, if wear is more than 3% the stone is not satisfactory. if it is equal to 3% the stone is just tolerable for a good building stone, the wear should be equal to or less than 3 per cent.

(viii) Resistance to fire:- The minerals composing stone should be such that shape of stone is preserved when a fire occurs. The failure of stone in case of a fire is due to various reasons such as rapid rise in temperature, sudden cooling, different coefficients of linear expansions of minerals, etc. The free quartz suddenly expands at a temperature lower than 600°C.

(ix) Seasoning:- The stones should be well seasoned before putting into use. The stones obtained fresh from a quarry contain some moisture which is known as the quarry sap. The presence of this moisture makes the stone soft. Hence the quarried freshly are easy to work it is therefore desirable to do dressing, carving, etc. when stones contain quarry sap. The stones should be dried or seasoned before they are used in structural work. A period of about 6 to 12 months is considered to be sufficient for proper seasoning.

(x) Specific gravity:- For a good building stone, its specific gravity should be greater than 2.7 ...
The heavy stones are more compact and less porous ... they can be used for various engineering applications such as dams, weirs, retaining walls, docks, harbours ... on the other hand, if stones are to be used for domes, roof coverings, etc., the lighter varieties of stones are preferred.

(xi) Texture:- A good building stone should have compact fine crystalline structure free from cavities, cracks or patches of soft or loose material. The stones with such texture are strong and durable.

(xii) Toughness index:- In impact test, if the value of toughness index comes below 13, the stone ... not tough. If it comes between 13 and 19, the the stone is ... to be moderately tough. If it exceeds 19, the toughness of stone is said to be high.

(xiii) water absorption:- All the stone are more or less porous but for stone, percentage absorption ... weight after 24 hour should not exceed 0.60 porous stones seriously affect the durability of stone. The rain water as it descends through the atmosphere absorbs some acidic gases forming light acids. Such rain water, if absorbed by porous stones, react with the constituents of stone causing them to crumble. Similarly, in cold regions, if porous stones are used, the water remaining in pores will disintegrate stones because of its increase in volume on freezing. Hence the porous stones should not be recommended for places subjected to frost rain or moisture.

(xiv) weathering: A good building stone should possess better weathering qualities. It should be capable of withstanding adverse effects of various atmospheric and external agencies such as rain, frost, wind, etc. The best way to know the resisting power of a stone to the action of weather is to study the performance of buildings constructed with the similar stones in the locality at a place having more or less similar atmospheric conditions. The stone having excellent weathering qualities should mostly be used in the construction of important buildings.

It should however be remembered that one kind of stone is not suitable in all types of construction. For instance, the soft stones are required for carving, the light stones are required for arches and the hard stones are necessary to stand high pressure. It is therefore necessary to study carefully the situation in which stones are to be used before any recommendation is made. Other factors which affect the selection of stone are easy availability, nearness of quarry, facility of transport, reasonable price, climatic conditions of the construction site, etc.

* **Dressing of Stones:-**

The stones, after being quarried, are to be cut into suitable sizes and with suitable surfaces. The process is known as the dressing of stones and it is carried out for the following purposes.

(i) to get the desired appearance from stone work.
(ii) to make the transport from quarry easy and economical
(iii) to suit to the requirement of stone masonry.
(iv) to take advantage of local men near quarry who are trained for such types of work, etc.

With respect to the place of work, the dressing can be divided into two types namely, quarry dressing and site dressing. At the quarry place, the stones are roughly dressed to secure the following advantages:

(i) At quarry site, it is possible to get cheap labour for the process of dressing of stones.

(ii) It is possible to sort out stones for different works, if quarry dressing is practised.

(iii) The irregular and rough portions of the stones are removed which decreases the weight of stones and it also facilitates easy transportation of the stones.

(iv) The natural bed surface of stones can be made prominent during the quarry dressing.

(v) The stones when quarried freshly contain quarry sap and hence they are comparatively soft and can be easily dressed.

following are the varieties of finishes obtained by the dressing of stones.

(i) Axed finish:-

The surfaces of hard stones such as granite are dressed by mean of an axe. Such a finish is termed as an axed finish.

(ii) Boasted or droved finish:-

Boasted or droved finish

In this type of finish, the boaster is used to make non-continuous parallel marks on the stone surface as shown in figure. These marks may be horizontal inclined or vertical. A boaster is a chisel having an edge of width about 60 mm.

(iii) Chisel-draughted margins:-

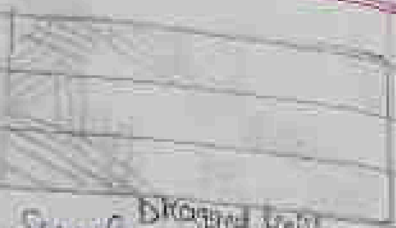
In order to obtain uniform joints in stone work, the margins are placed which may be either squared or pitched or chamfered.

(iv) Circular finish:-

In this type of finish the surface of stone is made round or circular as in case of a column.

(v) Dragged or combed finish:-

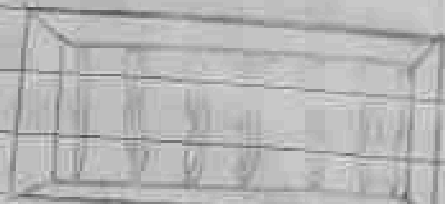
In this type of finish a drag or a comb which is a piece of steel with a number of teeth is rubbed on the surface


Dragged finish

in all direction and surface as shown in figure is obtained. This finish is suitable for soft stones only.

(vi) Furrowed finish

In this type of finish, a margin of about 20mm width is sunk on all the edges of stones and the central portion is made to project about 15 mm


Furrowed finish

A number of vertical or horizontal grooves about 10mm wide are formed in this projected portion as shown in figure. This finish is generally adopted to make the quoins prominent.

(vii) Moulded finish:-

The surface of stone can be moulded in any desired shape so as to improve the appearance of the work. The mouldings can be made either by hand or machine.

(viii) Hammer-dressed finish:-

In this type of finish, the stones are made roughly square or rectangular by means of a waller's


Hammer-dressed finish

hammer as show in figure. The hammer-dressed stones has no sharp or irregular corners and have comparatively even surface so as to fit well in masonry.

(ix) plain finish:-

In this type of finish the surface of the stone is made approximately smooth with a saw or with a chisel.

(x) polished finish:-

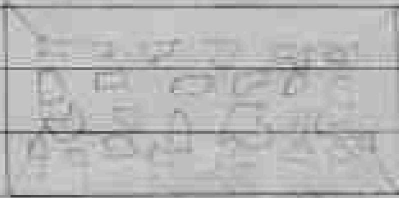
The surface of the stones such as marbles, granites, etc. can be polished either with hand or with machine.

(xi) punched machine:-

On the stone surface the depression are made by using a punch. The surface of the stone takes the form of a series of hollows and ridges.

(xii) Reticulated finish:-

This type of finish presents a net like apperance as shown in figure. A margin about 20mm wide is marked on the edge of stone and irregular sinking are made on the enclosed space. A margin about 10mm wide, is provided around the irregularly shaped sinking, having a depth of about 5mm. A pointed tool is used to pick the markers so the sunk surface so as to present a pock-marked appearance.



Reticulated finish

(xiii) Rubbed finish:-

This type of finish is obtained by rubbing a piece of stone with the surface or by rubbing the surface with the help of a suitable machine. The water and sand are freely used to accelerate the process of rubbing.

(xiv) Scabbing finish:-

In this type of finish the irregular projections are removed with a scabbling hammer and in this way the stones are roughly dressed.

(xv) Tooled finish:-

Tooled finish

The stone surface is finished by mean of a chisel and parallel continuous marks, either horizontal or inclined or vertical, are left on the surface as shown in figure.

(xvi) Self-faced or rock-faced or quarry-faced finish:-

Some stones, as obtained from the quarry posses smooth surface and they can be directly placed on the work. Such a stone surface is termed as the self-faced or rock-faced or quarry faced finish.

(xvii) Sunk finish:-

This finish is obtained by sinking the surface below the original level in the form of wide grooves, chamfers, inclined surfaces etc.

(xviii) Vermiculated finish:-

The finish is just similar to reticulated type except that the sinking are more curved. This finish presents a worm-eaten appearance.

Ch-2

28.8.20

# BRICKS

The bricks are obtained by moulding clay in rectangular blocks of uniform size and then by drying and burning these blocks. As bricks are of uniform size, they can be properly arranged and further, as they are light in weight, no lifting appliance is required for them. The brickwork can be carried out with the help of unskilled labourers. Thus, at places where stones are not easily available, but if there is plenty of clay suitable for the manufacture of bricks, the bricks replace stones.

The common brick is one of the oldest building material and it is extensively used at present as a leading material of construction because of its durability, strength, reliability, low cost, easy availability, etc.

The bricks seem to have been produced since the dawn of the civilization in the sun-dried form. The Great wall of China (210 B.C.) was built with both burnt and sun-dried bricks. The other examples of the use of bricks in early stage of civilization could be cited in Rome and other places.

The medieval cities were of wood and because of the disastrous fire potential of wood, the bricks replaced the wood over the years. For instance, the great fire of London in 1666 changed London from being a city of wood to one of brick. A number of country farm houses still exists in the Great Britain and profess to be the monuments of the excellent hand made bricks.

* Composition of Good Brick Earth:-

Following are the constituent of good brick earth

(i) Alumina:- It is the chief constituent of every kind of clay. A good brick earth should contain about 20% to 30% of alumina. This constituent imparts plasticity to the earth so that it can be moulded. If alumina is present in excess with inadequate quantity of sand, the raw bricks shrink and warp during drying and burning and become too hard when burnt.

(ii) Silica:- It exists in clay either as free or combined. As free sand, it is mechanically mixed with clay and in combined form, it exists in chemical composition with alumina. A good brick earth should contain about 50 percent to 60 percent of silica. The presence of this constituent prevents cracking, shrinking and warping of raw bricks. It thus imparts uniform shape to the bricks. The durability of bricks depends on the proper proportion of silica in brick earth. The excess of silica destroys the cohesion between particles and the bricks become brittle.

(iii) Lime:- A small quantity of lime not exceeding 5 percent is desirable in good brick earth. It should be present in a very finely powdered state because even small particles of the size of a pin-head cause flaking of the bricks. The lime prevents shrinkage of raw bricks. The sand alone is infusible. But it slightly fuses at kiln temperature in presence of lime. Such fused sand works as a hard cementing material for brick particles. The excess of lime causes the brick to melt and hence its shape is lost.

The lumps of lime are converted into quick lime after burning and this quick lime slakes and expands in presence of moisture. Such an action results in splitting of bricks into pieces.

(iv) Oxide of iron:- A small quantity of oxide of iron to the extent of about 5 to 6 percent is desirable in good brick earth. It helps as lime to fuse sand. It also imparts red colour to the bricks. the excess of oxide of iron makes the bricks dark blue or blackish. If, on the other hand, the quantity of iron oxide is comparatively less, the bricks. If, on the other hand, the quantity of iron oxide is comparatively less, the bricks will be yellowish in colour.

(v) Magnesia:- A small quantity of magnesia in brick earth imparts yellow tint to the bricks and decreases shrinkage. But excess of magnesia leads to the decay of bricks.

* MANUFACTURE OF BRICKS :-

Following considerations govern the selection of a brick field for the manufacture of bricks.

(i) It should be linked up with the communicating roads so that the materials can be conveyed easily.

(ii) It should be situated on a plain ground.

(iii) It should be so selected that the earth for manufacturing good quality bricks is readily and easily available.

(iv) It should offer all the facilities to the workers employed in the manufacturing process.

In the process of manufacturing bricks, the following four distinct operations are involved:

(i) Preparation of clay
(ii) Moulding
(iii) Drying
(iv) Burning.

Each of the above operation of manufacturing bricks will now be studied at length.

(1) Preparation of Clay:- The clay for bricks is prepared in the following order.

(i) Unsoiling (iv) Weathering
(ii) Digging (v) Blending
(iii) Cleaning (vi) Tempering.

(i) Unsoiling :-

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

(ii) Digging:- The clay is then dug out from the ground. It is spread on the levelled ground, just a little deeper than the general level of ground. The height of heaps of clay is about 600 mm to 1200mm.

(iii) Cleaning:-

The clay, as obtained in the process of digging should be cleaned of stones, pebbles, vegetable matter, etc. If these particles are in excess the clay is to be washed and screened. Such a process naturally will prove to be troublesome and expensive. The lumps of clay should be converted into powder form in the earth crushing roller.

(iv) Weathering:-

The clay is then exposed to atmosphere for softening or mellowing. The period of exposure varies from few weeks to full season. For a large project, the clay is dug out just before the monsoon and it is allowed to weather throughout the monsoon.

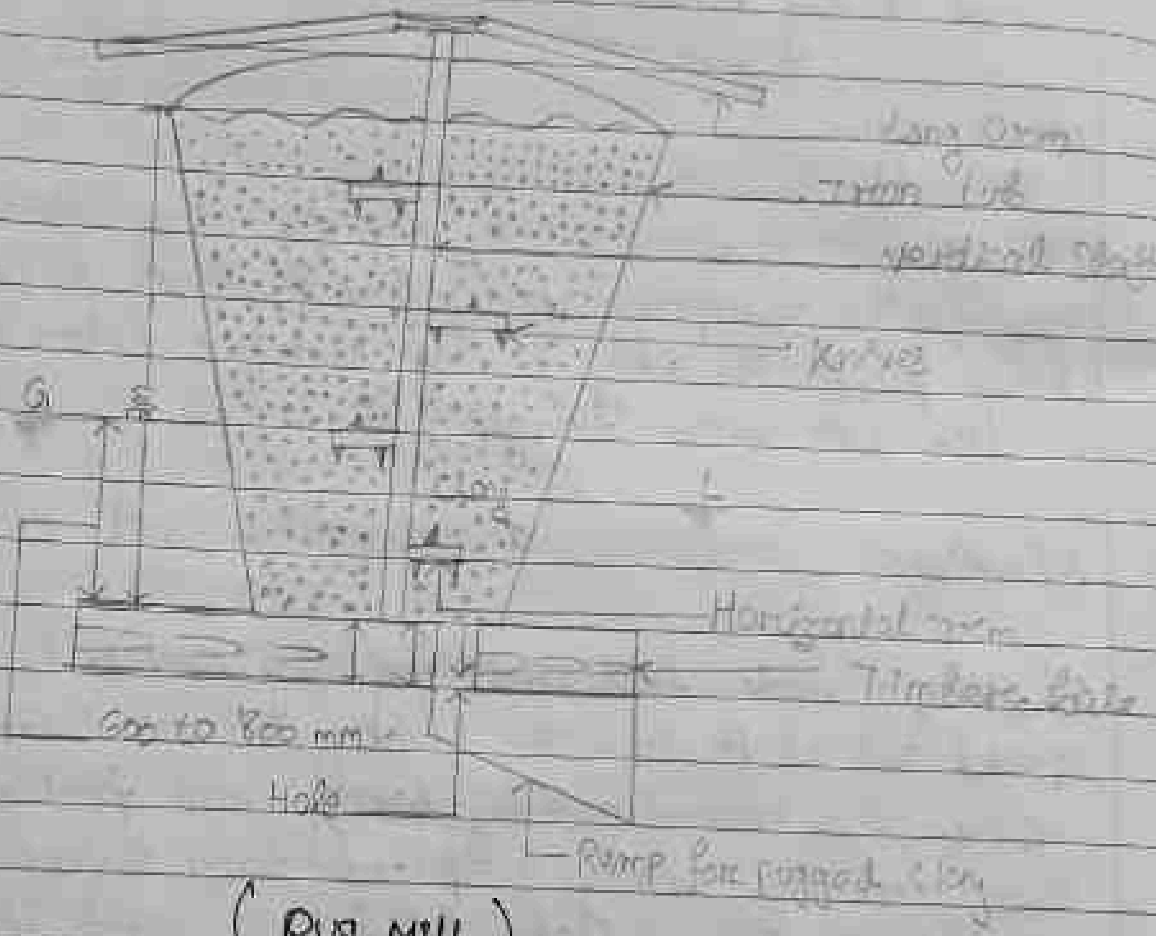
(v) Blending:-

The clay is made loose and any ingredient to be added to it, is spread out at its top. The blending indicates intimate or harmonious mixing. It is carried out by taking small portion of clay every time and by turning it up and down in vertical direction. The blending makes clay fit for the next stage of tempering.

(vi) Tempering:-

In the process of tempering the clay is brought to a proper degree of hardness and it is made fit for the next operation: moulding. The water in required quantity is added to clay and the whole mass is kneaded or pressed under the feet of men or cattle. The tempering should be done exhaustively to obtain homogeneous mass of clay of uniform character.

For manufacturing good bricks on a large scale, the tempering is usually done in a pug mill. A typical pug mill capable of tempering sufficient earth for a daily output of about 15000 to 20000 bricks is shown in figure. The process of grinding clay with water and making it plastic is known as the pugging.




(pug mill)

A pug mill consists of a conical iron tub with cover at its top. It is fixed on a timber base which is made by fixing two wooden planks at right angles to each other. The bottom of tub is covered except for the hole to take out pugged earth for the hole to take out pugged earth. The diameter of pug mill at bottom is about 800 mm and that at top is about one metre.

The provision is made in top cover to place clay inside the pug mill. A vertical shaft with horizontal arms is provided at the centre of iron tub. The small wedge-shaped knives of steel are fixed on horizontal arms.

The long arms are fixed at the top of vertical shaft to attach a pair of bullocks. The ramp is provided to collect the pugged clay. The heigh of pug mill is about 2m. its depth below ground is about 600mm to 800mm to lessen the rise of the barrow run and to throw out the tempered clay conveniently.

In the beginning, the hole for pugged clay is closed and with water is placed in pug mill from the top. When the vertical shaft is rotated or turned by a pair of bullocks, the clay is thoroughly mixed up by the actions of horizontal arms and knives and a homogeneous mass is formed.

The rotation of vertical shaft can also be achived by using steam, diesel or electric power. When clay has been sufficiently pugged, the hole at the bottom of tub, is opened out and the pugged earth is taken out from ramp by barrow that is a small cart with two wheels for the next operation of moulding. The pug mill is then kept moving and feeding of clay from top and taking out of pugged clay from bottom are done simultaneously.

If tempering is properly carried out, the good brick earth can then be rolled without breaking in small threads of 3mm diameter.

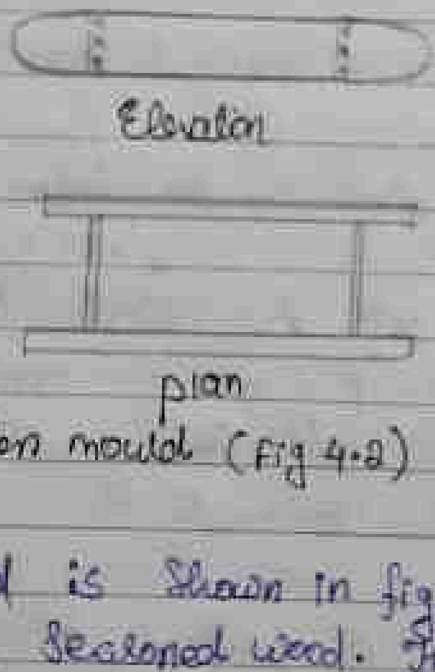
2) Moulding :-

The clay which is prepared as above is then sent for the next operation of moulding. following are the two ways of moulding:

(I) Hand moulding
(II) Machine moulding

(I) Hand moulding:-

In hand moulding the bricks are moulded by hand that is manually. it is adopted where manpower is cheap and is readily available for the manufacturing process of bricks on a small scale. The moulds are rectangular boxes which are open at top and bottom. They may be of wood or steel.




wooden mould (fig 4.2)

A typical wooden mould is shown in fig (4.2). it should be prepared from well seasoned wood. The longer sides are kept slightly projecting to serve as handles. The strips of brass or steel are sometimes fixed on the edges of wooden moulds to make the more durable.

Elevation

plan

Steel mould (Fig 4-3)

A typical steel mould is shown in fig (4-3). It is prepared from the combination of steel plates and channels. It may even be prepared from steel angles and plates. The thickness of steel mould is generally 6mm. They are used for manufacturing bricks on a large scale. The steel mould are more durable than wooden moulds and they turn out bricks of uniform size. The bricks shrink during drying and burning. Hence the mould are to be made larger than the size of fully burnt bricks. The moulds are therefore made longer by about 8 to 12 per cent in all directions. The exact percentage of increase in dimensions of mould is determined by actual experiment on clay to be used for preparing bricks.

The bricks prepared by hand moulding are of two type

(a) Ground - moulded bricks
(b) Table - moulded bricks.

(a) Ground-moulded bricks:-

The ground is first made level and fine sand is sprinkled over it. The mould is dipped in water and placed over the ground. The lump of tempered clay is taken and it is dashed in the mould. The clay is pressed or forced in the mould in such a way that it fills all the corners of mould. The extra or surplus clay is removed either by wooden strike or metal strike or frame with wire. A strike is a piece of wood or metal with a sharp edge. It is to be dipped in water every time.

The mould is then lifted up and raw brick is left on the ground. The mould is dipped in water and it is placed just near the previous brick to prepare another brick. The process is repeated till the ground is covered with raw bricks.

A brick moulder can mould about 750 bricks per day with working period of 8 hour. When such bricks become sufficiently dry, they are carried and placed in the drying sheds.

The bricks prepared by dipping mould water every time are known as the slop-moulded bricks. The fine sand or ash may be sprinkled on the inside surface of mould instead of dipping mould in water. Such bricks are known as the sand moulded bricks and they have sharp and straight edges.

The lower faces of ground moulded bricks are rough and it is not possible of place frog on such bricks. A frog is a mark of depth about 10mm to 20 mm which is placed on raw brick during moulding. It serves two purpose:

(i) It indicates the trade name of the manufacturer.
(ii) In brickwork, the bricks are laid with frog uppermost. It thus affords a key for mortar when the next brick is placed over it.

The 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. A pallet is a piece of thin wood. The block is bigger than mould and it has a projection of about 6 mm height on its surface. The dimensions of projection correspond to the internal dimensions of mould. The design of impression of frog is made on this block. This wooden block is also known as the moulding block or stock board.

The mould is placed to fit in the projection of wooden block and clay is then dashed inside the mould. A pallet is placed on the top and the whole thing is then turned upside down. The mould is taken out and another pallet is placed over the raw brick and it is conveyed to the drying sheds. The bricks are placed to stand on their longer sides in drying sheds and pallet boards are brought back for using them again. As the bricks are laid on edge, they occupy less space and they dry quicker and better.

(b) Table-moulded bricks:-

The process of moulding these bricks is just similar as above. But in this case, the moulder stands near a table of size about 2m x 1m. The clay mould, water pots, stock board strikes and pallet boards are placed on this table. The bricks are moulded on the table and sent for the further process of drying. However the efficiency of moulder decreases gradually because of standing at the same place for long duration. The cost of brick moulding also increases when table moulding is adopted.

(ii) Machine moulding :-

The moulding may also be achieved by machines it proves to be economical when bricks in large quantity are to be manufactured at the same spot in a short time. It is also helpful for moulding hard and strong clay. These machines are broadly classified in two categories.

(a) plastic clay machines.
(b) Dry clay machines.

(a) plastic clay machines:-

Such machines contain a rectangular opening of size equal to length and width of a brick. The 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. The arrangement is made in such a way that strips of thickness equal to that of the brick are obtained. As the bricks are cut by wire, they are also known as the wire cut bricks.

(b) Dry clay machines:-

In these machines, the strong clay is first converted into powder form. A small quantity of water is then 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 known as the pressed bricks and they do not practically require drying. They can be sent directly for the process of burning.

The wire cut and pressed bricks have regular shape, sharp edges and corners. They have smooth external surfaces. They are heavier and stronger than ordinary hand-moulded bricks. They carry distinct frogs and exhibit uniform dense texture.

3) Drying:-

The damp bricks, if burnt, are likely to be cracked and distorted. Hence the moulded bricks are dried before they are taken for the next operation of burning. For drying the are laid longitudinally in stacks of width equal to two bricks. A stack consists of eight or ten tiers. The bricks are laid along and across the stack in alternate layers. All bricks are placed on edge. The bricks should be allowed to dry till they become leather hard or bone-dry with moisture content of about 2 percent or so.

The important facts to be remembered in connection with the drying of bricks are as follows.

(i) Artificial drying:-

The bricks are generally dried by natural process. But when bricks are to be rapidly dried on a large scale, the artificial drying may be adopted. In such a case, the moulded bricks are allowed to pass through special dryers which are in the form of tunnels or hot channels or floors. Such dryers are heated with the help of special furnaces or by hot flue gases. The tunnel dryers are more economical than hot floor dryers and they may be either periodic or continuous.

In the formere case, the bricks are filled, dried and emptied in rotation. In the latter case the loading of bricks is done at one end and they are taken out at the other end. The temperature is usually less than 120°C and the process of drying of bricks takes about 1 to 3 days depending upon the temperature maintained in the dryer, quality of clay product etc. 4)

(ii) Circulation of air:-

The bricks in stacks should be arranged in such a way that sufficient air space is left between them for free circulation of air.

(iii) Drying yard:-

For the drying purpose special drying yards should be prepared. It should be slightly on a higher level and it is desirable to cover it with sand. Such an arrangement would prevent the accumulation of rain water.

(iv) Period for drying:-

The time required by moulded bricks to dry depends on prevailing weather conditions. Usually it takes about 3 to 10 days for bricks to become dry.

(v) Screens:-

It is to be seen that bricks are not directly exposed to the wind or sun for drying. Suitable screens, if necessary may be provided to avoid such situations.

4) Burning:-

This is a very important operation in the manufacture of bricks. It imparts hardness and strength to the bricks and makes them dense and durable. The bricks should be burnt properly. If bricks are over burnt, they will be brittle and hence break easily. If they are under burnt, they will be soft and hence cannot carry loads.

When the temperature of dull red heat, about 650c, is attained the organic matter contained in the brick is oxidized and also the water of crystallization is driven away. But heating of bricks is done beyond this limit for the following purposes.

(i) If bricks are cooled after attaining the temperature of about 650c, the bricks formed will absorb moisture from the air and get rehydrated.

(ii) The reactions between the mineral constituents of clay are achieved at higher temperature and these reactions are necessary to give new properties such as strength, hardness, less moisture absorption, etc. to the bricks.

When the temperature of about 1100c is reached the particles of two important constituents of bricks clay, namely, alumina and sand bind themselves together resulting in the increase of strength and density of bricks. Further heating is not desirable and if the temperature is raised beyond 1100c, a great amount of fusible glassy mass is formed and the bricks are said to be vitrified. The bricks begin to loose their shape beyond a certain limit of vitrification

The burning of bricks is done either in clamps or in Kilns. The clamps are temporary structures and they are adopted to manufacture bricks on a small scale to serve a local demand or a specific purpose. The Kilns are permanent structures and they are adopted to manufacture bricks on a large scale.

* Qualities of good Bricks:-

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

(i) The bricks should be table-moulded, well-burnt in Kilns, copper-coloured, free from cracks and with sharp and square edges. The colour should be uniform and bright.

(ii) The bricks should be uniform in shape and should be of standard size.

(iii) The bricks should give a clear metallic ringing sound when struck with each other.

(iv) The bricks when broken or fractured should a bright homogeneous and uniform compact structure free from voids.

(v) The brick should not absorb water more than 20 per cent by weight for first class bricks and 22 per cent by weight for second class bricks, when soaked in cold water for a period of 24 hours.

(vi) No brick should have the crushing strength below 5.50 N/m

(vii) The bricks should be sufficiently hard. No impression should be left on bricks surface when it is scratched with finger nail.

(viii) The bricks should not break into piece when dropped flat on hard ground from a height of about one metre.

(ix) The bricks should have low thermal conductivity and they should be sound-proof.

(x) The bricks, when soaked in water for 24 hours should not show deposits of white salts when allowed to dry in shade.

* <u>Classification of bricks:-</u>

The bricks can broadly be divided into two categories as follows:-

(i) unburnt or sun-dried bricks and
(ii) burnt bricks

The unburnt or sun-dried bricks are dried with the help of heat received from sun after the process of moulding. These bricks can only be used in the construction of temporary and cheap structures. Such bricks should not be used at places exposed to heavy rains.

The bricks used in construction works are burnt bricks and they are classified into the following four categories:-

(i) First class bricks
(ii) Second class bricks
(iii) Third class bricks
(iv) Fourth class bricks

i) First class bricks:-

These bricks are table-moulded and of standard shape and they are burnt in kilns. The surfaces and edges of the bricks are sharp, square, smooth and straight. They comply with all the qualities of good bricks which are mentioned earlier. These bricks are used for superior work of permanent nature.

(ii) Second class bricks:-

These bricks are ground-moulded and they are burnt in kilns. The surface of these bricks is somewhat rough and shape is also slightly irregular. These bricks may have hair cracks and their edges may not be sharp and uniform. These bricks are commonly used at places where brickwork is to be provided with a coat of plaster.

iii) Third class bricks:-

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

iv) Fourth class bricks:-

These are overburnt bricks with irregular shape and dark colour. These bricks are used as aggregate for foundation, floors, roads, etc. because of the fact that the overburnt bricks have a compact structure and hence they are sometimes found to be stronger than even the first class bricks.

It is thus seen that the above classification of bricks is based on the method of manufacturing or preparing bricks.

*) <u>Size and weight of bricks:-</u>

The bricks are prepared in various sizes. The custom in the locality is the governing factor for deciding the size of a brick. Such bricks which are not standardized are known as the traditional bricks.

If bricks are large, it is difficult to burn them properly and they become too heavy to be placed with a single hand. On the other hand, if bricks are small, more quantity of mortar is required.

For India, a brick of standard size 190mm x 90mm x 90mm is recommended by the BIS. with mortar thickness, the size of such a brick becomes 200mm x 100mm x 100mm and it is known as the nominal size of the modular bricks. Thus the nominal size of brick includes the mortar thickness.

It is found that the weight of 1 $m^3$ of brick earth is about 18 kN. Hence the average weight of a brick will be about 30 to 35 N.

# CEMENT MORTAR AND CONCRETE

The natural cement is obtained by burning and crushing the stones containing clays carbonate of lime and some amount of carbonate of magnesia. The clay content in such stones is about 20 to 40 percent. The natural cement is brown in colour and its best variety is known as the roman cement.

The natural cement resembles very closely eminent hydraulic lime. It sets very quickly after addition of water. It is not so strong as artifical cement and hence it has limited use in practice.

It was in the eighteenth century that the most important advances in the development of cement were made which finally led to the invention of portland cement. In 1756, John Smeaton showed that hydraulic lime, which can resist the action of water, can be obtained not only from hard limestone but from a limestone which contained substantial proportion of clay.

In 1796, Joseph Parker found that nodules of argillaceous limestone made an excellent hydraulic cement when burned in the usual manner. After burning, the product was reduced to a powder. The fused materials, if any, were picked out and thrown away as useless. This started the natural cement industry. Several experiments with artifical mixtures of limestone and argillaceous rock were soon began and the properties of the product could be kept under more uniform and proper control by using varying lime and clay proportions.

The artifical cement is obtained by burning at a very high temperature a mixture of calcareous and argillaceous materials. The mixture of ingredients should be intimate and they

Should be in correct proportion. The calcined Product is known as the clinker. A Small quantity of gypsum is added to the clinker and it is then pulverised into very fine powder which is known as the cement.

The Common Variety of artificial cement is known as the normal setting Cement or ordinary cement. This Cement was invented by a mason Joseph Aspdin of Leeds in England in 1824. He took out a patent for this Cement and called it Portland Cement because it had resemblance in its colour after setting, to a variety of sandstone which is found in abundance in portland in england. Though his patent made no mention of the necessity of using high temperature, it is felt that he was the first to realise the Same and if so, then the invention of modern portland cement must be attributed to him.

In this Chapter the items related to this important engineering material will be discussed.

application on the top of it, the government has set up consumer courts all over India in cities and towns where the Consumers can lodge their Complaints if any and get the justice.

* Properties of Cement:-

following are the physical, mechanical and chemical properties of Cement:-

(1) Physical properties of Cement:-

Following are the important physical properties of a good Cement which Primarily depend upon its Chemical Composition, thoroughness of burning and fineness of grinding.

(i) It gives strength to the masonry.

(ii) It is an excellent binding material

(iii) It is easily workable.

(iv) It offers good resistance to the moisture.

(v) It possesses a good plasticity

(vi) It stiffens or hardens early.

(vii) A thin paste of cement with water should feel sticky between the fingers.

(viii) A cement thrown in water should sink and should not float on the surface.

(ix) The particles should have uniformity of fineness. To get an idea of fineness, specific surface area of cement particles is calculated. The specific surface area is a measure of the frequency of particles of average size, which should not be less than 2250 cm²/g

(x) The consistency of cement should be checked with Vicat apparatus. If the settlement of plunger is between 5mm to 7mm from the bottom of mould, the water added is correct otherwise repeat the process with different percentage of water till the desired penetration is achieved.

(xi) The initial setting time for ordinary cement is about 30 minutes. The initial setting time is the interval between the addition of water to cement and the stage when the square needle of Vicat apparatus ceases to penetrate completely.

(xii)

(xiii)

(xii) The final setting time for ordinary cement is about 10 hours. The final setting time is the difference between the time at which water was added to cement and time required for needle with annular collar of vicat apparatus ceases to make an impression on test block.

(xiii) The cement should be tested for soundness using Le Chatelier apparatus. This test is to detect the presence of uncombined lime in cement. The expansion of cement after heating and cooling the mould should not exceed 10 mm.

2) Mechanical properties of cement:-

(i) The compressive strength at the end of 3 days should not be less than 11.5 N/mm² and that at the end of 7 days should not be less than 17.5 N/mm².

(ii) The tensile strength at the end of 3 days should not be less than 2 N/mm² and that at the end of 7 days should not be less than 2.50 N/mm².

3) Chemical properties of cement:-

(i) The ratio of percentage of alumina to iron oxide should not be less than 0.66.

(ii) The ratio of percentage of lime to alumina, iron oxide and silica, known as lime saturation factor (LSF) should not be less than 0.66 and should not be more than 1.02.

(iii) Total loss on ignition should not be more than 4 percent.

(iv) Total Sulphur content should not be more than 2%

(v) Weight of insoluble residue should not be more than 1.5%

(vi) weight of magnesia should not exceed 5 percent.

(iii)

x **Varieties of Cement:-**

In addition to ordinary cement the following are the other important varieties of cement.

(i) Acid - resistant cement
(ii) Blast furnace cement
(iii) Coloured cement
(iv) Expanding Cement
(v) High alumina cement
(vi) Hydrophobic Cement
(vii) Low heat Cement
(viii) Pozzolana cement
(ix) Quick setting Cement
(x) Rapid hardening cement
(xi) extra rapid hardening cement
(xii) Sulphate resisting Cement
(xiii) White Cement.

## (i) Acid - resistant Cement:-

An acid - resistant cement is composed of the following

(i) acid - resistant aggregates such as quartz, quartzites, etc

(ii) additives such as sodium fluosilicate $Na_2SiF_6$ and

(iii) aqueous solution of sodium silicate or soluble glass

The addition of additive sodium fluosilicate accelerates the hardening process of soluble glass and it also increases the resistance of cement to acid and water.

The binding material of acid - resistant cement is soluble glass which is a water solution of sodium silicate $Na_2O\ nSiO_2$ or potassium silicate, $K_2O\ nSiO_2$ where n is the glass modulus.

The term glass modulus is used to indicate the ratio of the number of silica molecules to that of alkali oxide molecules and its value in soluble glass varies from 2.50 to 3.50

The acid-resistance cement is used for acid - resistant and heat - resistant coatings of installations of chemical industry. It is not water - resistant and it fails when attacked by water or weak acids. By adding 0.50 per cent of linseed oil or 2 per cent of ceresit, its resistance to the water is increased and it is then known as the acid and water resistant cement.

(ii) Blast furnace Cement:-

For this cement, the slag as obtained from blast furnace is used. The slag is a waste product in the manufacturing process of pig-iron and it contains the basic elements of cement namely, alumina, lime and silica. The clinkers of cement are ground with about 60 to 65 per cent of slag.

The properties of this Cement are more or less the Same as those of ordinary Cement. Its strength in early days is less and hence it requires longer curing period. It proves to be economical as slag, which is a waste product, is used in its manufacture. This cement is durable but not suitable for use in dry arid zones.

(viii) Coloured Cement:-

The Cement of desired colour may be obtained by intimately mixing mineral pigments with ordinary Cement. The amount of colouring material may vary from 5 to 10 per cent. If this percentage exceeds 10 per cent, the strength of cement is affected.

The Chromium oxide gives green colour. The Cobalt imparts blue Colour. The iron oxide in different proportion gives brown, red or yellow colour. The manganese dioxide is used to produce black or brown coloured Cement.

The Coloured cements are widely used for finishing of floors, external surface, artificial marble, window sill Slabs, textured panel faces, stair treads, etc.

(ix) Expanding Cement:-

This type of Cement is produced by adding an expanding medium like sulpho-aluminate and a stabilising agent to the ordinary Cement. Hence, this cement expands where other cements shrink.

The expanding cement is used for the construction of water retaining structures and also for repairing the damaged concrete surface.

(v) High alumina cement (IS : 6452 - 1989)

This cement is produced by grinding clinkers formed by calcining bauxite and lime. The bauxite is an aluminium ore. It is specified that total alumina content should not be less than 32 per cent and the ratio by weight of alumina to the lime should be between 0.85 and 1.30

This cement is known by the trade names of cement fondu in England and lumnite in America.

Following are the advantages of high alumina cement:

(i) The initial setting time of this cement is more than 3 1/2 hours. The final setting time is about 5 hours. It therefore allows more time for mixing and placing operations.

(ii) It can stand high temperatures.

(iii) It evolves great heat during setting. It is therefore not affected by frost.

(iv) It resists the action of acids in a better way

(v) It sets quickly and attains higher ultimate strength in a short period. Its strength after 1 day is about 40 N/mm² and that after 3 days it about 50 N/mm².

(vi) Its setting action mainly depends on the chemical reaction and hence it is not necessary to grind it to fine powder. (vii)

Following are the disadvantages of high alumina cement:

(i) The extreme care is to be taken to see that it does not come in contact with even traces of lime or ordinary cement.

(ii) It cannot be used in mass construction as it evolves great heat and as it sets soon.

(iii) It is costly.

(Vi) Hydrophobic cement :(IS 8043 - 1991) :-

This type of cement contains admixtures which decrease the wetting ability of cement grains. The usual hydrophobic admixtures are acidol, naphthene soap, oxidized petrolatum, etc. These substances form a thin film around cement grains.

When water is added to hydrophobic cement, the absorption films are torn off the surface and they do not in any way prevent the normal hardening of cement. However, in initial stage, the gain in strength is less as hydrophobic films on cement grains prevent the interaction with water. However its strength after 28 days is equal to that of ordinary portland cement.

When hydrophobic cement is used, the fine pores in concrete are uniformly distributed and thus the frost resistance and the water resistance of such concrete are considerably increased.

(VII) Low heat Cement (IS: 12600-1989) :-

The considerable heat is produced during the setting action of Cement. In order to reduce the amount of heat, this type of Cement is used. It contains lower percentage of tricalcium aluminate $C_3A$ of about 5% and higher percentage of dicalcium silicate $C_2S$ of above 46%.

The cement possesses less compressive strength. The initial setting time is about one hour and final setting time is about 10 hours. It is mainly used for mass concrete work.

(VIII) Pozzolana cement (IS: 1489-1991) :-

The pozzolana is a volcanic powder. It is found in Italy near Vesuvius. It resembles surkhi which is prepared by burning bricks made from ordinary soils. It can also be processed from shales and certain types of clays. The percentage of pozzolana material should be between 10 to 30.

Following are the advantages of pozzolana cement

(i) It attains compressive strength with age.

(ii) It can resist action of sulphates.

(iii) It evolves less heat during setting.

(iv) It imparts higher degree of watertightness.

(v). It imparts plasticity and workability to the mortar and concrete prepared from it.

(vi) It is cheap

(vii) It offers great resistance to the expansion

(viii) It possesses higher tensile strength

Following are the disadvantages of pozzolana cement:

(i) Its compressive strength in early days is less.

(ii) It possesses less resistance to the erosion and weathering action.

This cement is used to prepare mass concrete of barrages and for marine structures. It is also used in sewage works and for laying concrete under water.

(ix) Quick setting cement:-

This cement is produced by adding a small percentage of aluminium sulphate and by finely grinding the cement. The percentage of gypsum or retarder for setting action is also greatly reduced. The addition of aluminium sulphate and fineness of grinding are responsible for accelerating the setting action of cement. The setting action of cement starts within five minutes after addition of water and it becomes hard like stone in less than 30 minutes or so.

The extreme care is to be taken when this cement is used as mixing and placing of concrete are to be complete in a very short period. This cement is used to lay concrete under static water or running water.

(x) Rapid hardening cement (IS 8041 - 1990):-

The initial and final setting times of this cement are the same as those of ordinary cement. But it attains high strength in early days. It contains high percentage of tricalcium silicate $C_3S$ to the extent of about 56%. This is due to the following facts:

(i) Burning at high temperature

(ii) Increase lime content in cement composition.

(iii) Very fine grinding

This cement is slightly costlier than ordinary cement but it offers the following advantages:-

(i) As it sets rapidly, the construction work may be carried out speedily.

(ii) The formwork of concrete can be removed earlier and it can therefore be used frequently.

(iii) It is light in weight.

(iv) It is not damaged easily.

(v) This cement requires short period of curing

(vi) The structural members constructed with this cement may be loaded earlier.

(vii) The use of this cement allows higher permissible stress in the design. It therefore results in economic design.

(viii) It obtains strength in a short period. The compressive strength at the end of one day is about 11.50 N/mm² and that at the end of 3 days is about 21 N/mm². Similarly the tensile strength at the end of one day is about 2 N/mm² and that at the end of 3 days is about 3 N/mm².

(xi) Extra Rapid hardening Cement:-

This type of cement accelerates the setting and hardening process. It imparts strength of about 25% higher than that of rapid hardening cement at one or two days about 10% and 20% higher at 7 days. The gain of strength disappears with the age and at 90 days, the strength of extra rapid hardening cement is not merely same as that of Ordinary portland cement. Extra Rapid hardening cement is obtained by inter-grinding calcium chloride with rapid hardening portland cement. The normal addition of calcium chloride should not exceed 2% by the weight of rapid hardening cement. The specific varies between 5000 to 6000 cm² per gram and the size of the particles is less than 3 microns. This type of cement should be transported, placed, compacted and finished within 20 minutes after mixing.

(xii) Sulphate resisting Cement :- (IS : 12330 - 1998) :

Ordinary portland cement is susceptible to the attack of sulphates. Free calcium hydroxide and hydrate of calcium aluminum present in the set cement react with sulphate and form calcium sulphate and calcium aluminate respectively. The

Product formed by reaction within framework of hydrated cement paste results in expansion and subsequently disruption of the set concrete occurs.

The remedy of sulphate attack is sulphate resisting cement. It is a cement with low $C_3A$ content and comparatively lower $C_4AF$ content. The percentage of $C_3A$ (tricalcium aluminate) is kept below 5 per cent and it results in the increase in resisting power against sulphate attack.

Sulphate resisting cement is used the following conditions:

(i) For the structures which are likely to be damaged by severe alkaline conditions such as canal linings culverts, siphons, etc.

(ii) In construction of sewage treatment works.

(iii) In foundations and basements where soil contains sulphat

(iv) In marine construction

(v) In pile fabrication which are likely to be buried in marshy region or sulphate bearing soils.

(xiii) <u>White Cement</u> :- (IS : 8042 - 1989):

The first white cement factory was set up in Kottayam, Kerala by Travancore Cement Limited (TCL) in 1956 and the cement was sold under the brand name Vembanad Cement. Few more plants have now been put up for the manufacture of white cement in our country.

This is just a variety of ordinary cement and it is prepared from such raw materials which are practically free from colouring oxides of iron, manganese or chromium. For burning of this cement, the oil fuel is used instead of coal. It is white in colour and it is used for floor finish, plaster works, ornamental works, etc. It should not set earlier than 30 minutes. It should be carefully transported and stored in closed containers only. It is more costly than ordinary cement because of specific requirements imposed upon the raw materials and the manufacturing process.

The white cement is the wonder material of the century and it has quickly established itself as absolutely indispensable for the housing and construction industry. It is quick drying, possesses high strength and has superior aesthetic values. The miscellaneous application of white cement are in swimming pools where it replaces the use of glazed tiles with coloured shades usable under water, for moulding sculptures and statues, for painting garden usable under water, for moulding sculptures and statues, for painting garden furniture, etc. It is also used for ready mixed concrete and precast concrete blocks and also for fixing marble and glazed tiles.

## MORTAR:-

The term mortar is used to indicate a paste prepared by adding required quantity of water to a mixture of binding material like cement or lime and fine aggregate like Sand.

The above two components of mortar, namely the binding material and fine aggregate are sometimes referred to as the matrix and adulterant respectively. The matrix binds the particles of the adulterant and as such, the durability, quality and strength of mortar will mainly depend on the quantity and quality of the matrix. The combined effect of the two components of mortar is that the mass is able to bind the bricks or stones firmly.

In this chapter, the topic of mortar will be briefly describ

* Sand:-

we have studied about cement and lime in the previous chapters. The Sand forms an important ingredient of mortar. Its different aspects will now therefore be briefly discussed.

* Natural Sources of Sand:-

The Sand particles consist of small grains of silica ($SiO_2$). It is formed by decomposition of Sandstones due to various effects of weather. According to the natural sources from which the Sand is obtained, It is of the following three types (i) pit Sand (ii) River Sand (iii) Sea Sand

(i) Pit Sand:-

This Sand is found as deposits in soil and it is obtained by forming pits into soils. It is excavated from a depth of about 1 m to 2m from ground level. The pit sand consists of sharp angular grains which are free from salts and it proves to be excellent material for mortar or concrete work. for making mortar, the clean pit sand free from organic matter and clay should only be used. When rubbed between the fingers, the fine pit sand should not leave any stain on the fingers. If there is any stain it indicates the coating of oxide of iron over the sand grains.

(ii) River Sand:-

This Sand is obtained from banks or beds of rivers. The river sand consists of fine rounded grains probably due to mutual attrition under the action of water current. The colour of river sand is almost white. As river sand is usually available in clean condition, it is widely used for all purposes.

(iii) Sea Sand:-

This Sand is obtained from sea shores. The sea sand, like river sand, consists of fine rounded grains. The colour sea sand is light brown. The sea sand contains salts. These salts attract moisture from the atmosphere. Such absorption causes dampness, efflorescence and disintegration of work. The sea sand also retards the setting action of cement. Due to all such reasons, it is the general rule to avoid the use of sea sand for engineering purposes except for filling of basement etc. it can however be used as a local material after being thoroughly washed to remove the salt.

* Classification of Sand:-

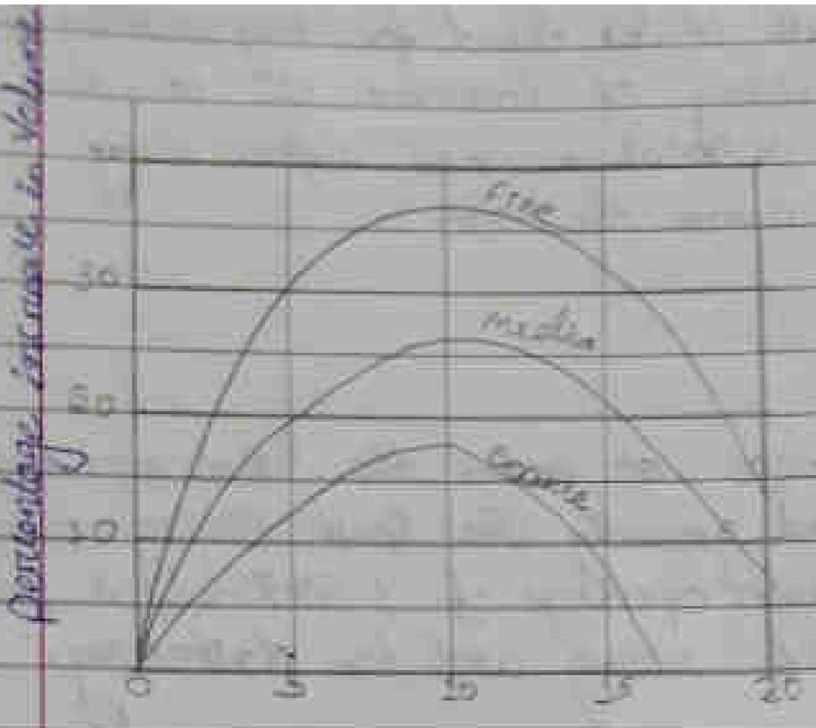
According to the size of grains, the sand is classified as fine, coarse and gravelly. The sand passing through a screen with clear openings of 1.5875 mm is known as the fine sand. It is mainly used for plastering.

The sand passing through a screen with clear openings of 3.175 mm is known as the coarse sand. It is generally used for masonry work.

The sand passing through a screen with clear openings of 7.62 mm is known as the gravelly sand. It is generally used for concrete work.

* Bulking of Sand:-

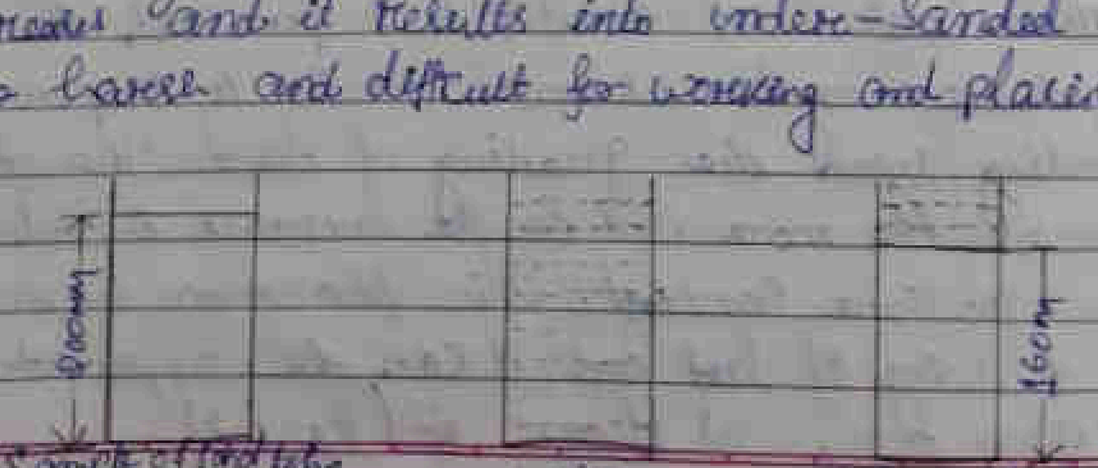
The presence of moisture in sand increase the volume of sand. This is due to the fact that moisture causes film of water around sand particles which results in the increase of volume of sand. For a moisture content of about 5 to 8 per cent, this increase of volume may be as much as 20 to 40 per cent, depending upon the grading of sand. The finer the material, the more will be the increase in volume for a given moisture content. This phenomena is know as the bulking of sand and it can be expressed in a graphical way as shown in (fig 7.1)




Percentage by weight of moisture
Chart Showing bulking of Sand
(Fig 7.1)

When moisture content is increased by adding more water the Sand particles pack near each other and the amount of bulking of Sand is decreased. Thus the dry Sand and the Sand Completely flooded with water have practically the Same volume.

The bulking of Sand affects the Volumetric proportions of Sand to a large extent. It is more with fine Sand and less with Coarse Sand. If proper allowance is not made for the bulking of Sand the Cost of Concrete and mortar increases and it results into under-Sanded mixes which are harsh and difficult for working and placing.




(Bulking of Sand)

A very simple test, as shown in (Fig 7.2) may be carried out to decide the percentage of bulking of sand. following procedure is adopted

(i) A container is taken and it is filled two-third with the sample of sand to be tested.

(ii) The height is measured, say it 200mm.

(iii) The sand is taken out of container. care should be taken to see that there is no loss of sand during this transaction

(iv) The container is filled with water.

(v) The sand is then slowly dropped in the container and it is thoroughly stirred by means of a rod

(vi) The height of sand is measured say it is 160mm

Then, Bulking of Sand $= \frac{(200-160)}{160} = \frac{40}{160} = \frac{1}{4}$ or 25%

* Classification of Mortars:-

The mortars are classified on the basis of the following:

(1) Bulk density
(2) Kind of binding material
(3) Nature of application
(4) Special mortars.

(1) Bulk density :-

According to the bulk density of mortar in dry state, there are two type of mortars:

(i) Heavy mortars: The mortars having bulk density of 15 kN/m³ or more are known as the heavy mortars and they are prepared from heavy quartz or other sands.

(ii) Lightweight mortars: The mortars having bulk density less than 15 kN/m³ are known as the lightweight mortars and they are prepared from light porous sands from pumice and other fine aggregates.

(2) Kind of binding material :-

The kind of binding material for a mortar selected by keeping in mind several factors such as expected working conditions, hardening temperature, moisture conditions, etc. According to the kind of binding material the mortars are classified into the following five categories

(i) Lime mortar
(ii) Surkhi mortar
(iii) Cement mortar
(iv) Gauged mortar
(v) Gypsum mortar

(i) Lime mortar :- In this type of mortar, the lime is used as binding material. The lime may be fat lime or hydraulic lime.

The fat lime shrinks to a great extent and hence it requires about 2 to 3 times its volume of sand. The lime should be slaked before use. This mortar is unsuitable for water-logged areas or in damp situations.

For hydraulic lime, the proportion of lime to sand by volume is about 1:2 or so. This mortar should be consumed within one hour after mixing.

It possesses more strength and can be used in damp situations.

The lime mortar has a high plasticity and it can be placed easily. It possesses good cohesiveness with other surfaces and shrinks very little. It is sufficiently durable, but it hardens slowly. It is generally used for lightly loaded above-ground parts of buildings.

(ii) Surkhi mortar :- This type of mortar is prepared by using fully surkhi instead of sand or by replacing half of sand in case of fat lime mortar. The powder of surkhi should be fine enough to pass BIS No. 9 sieve and the residue should not be more than 10% by weight.

The surkhi mortar is used for ordinary masonry work of all kinds in foundation and superstructure. But it cannot be used for plastering or pointing since surkhi is likely to disintegrate after some time.

(iii) Cement mortar :- In this type of mortar the cement is used as binding material. Depending upon the strength required and importance of work, the proportion of Cement to Sand by Volume Varies from 1:2 to 1:6 or more. It Should the noted that Surkhi and cinder are not Chemically inert Substances and hence they Cannot be used as adulterants with matrix as Cement. Thus the Sand only Can be used to form Cement mortar.

The proportion of Cement with respect to Sand should be determined with due regard to the specified durability and working Conditions. The Cement mortar is used where a mortar of high Strength and water-resisting properties is required such as underground constructions, water Saturated Soils, etc.

(iv) Gauged mortar:- To improve the quality of lime mortar and to achieve early strength the cement is sometimes added to it. This process is known as the gauging. It makes lime mortar economical, strong and dense. The usual proportion of Cement to lime by Volume is about 1:6 to 1:8. It is also known as the Composite mortar or lime-Cement mortar and it Can be formed by the Combination of Cement and clay. This mortar may be used for bedding and for thick brick walls.

(v) Gypsum mortar:- These mortars are prepared from gypsum binding materials such as building gypsum and anhydrite binding materials.

# Cement Concrete

The Cement Concrete is a mixture of Cement, Sand, pebbles or Crushed rock and water, which when placed in the Skeleton of forms and allowed to cure, becomes hard like a Stone. The Cement concrete has attained the Status of a major building material in all branches of modern Construction because of the following reasons:

(i) It can be readily moulded into durable Structural items of Various Sizes and Shapes at practically no Considerable labour expenditure.

(ii) It is possible to Control the properties of Cement Concrete within a wide range by using appropriate ingredients and by applying Special processing techniques - mechanical, Chemical and physical.

(iii) It is possible to mechanise Completely its preparation and placing processes.

(iv) It possesses adequate plasticity for the mechanical working.

In this Chapter, the Salient features of this important engineering material will be briefly discussed.

* **Properties of Cement Concrete:-**

The cement concrete fulfills the following important properties:

(i) It has a high compressive strength

(ii) It is free from corrosion and there is no appreciable effect of atmospheric agents on it.

(iii) It hardens with age and the process of hardening continues for a long time after the concrete has attained sufficient strength. It is this property of cement concrete which gives it a distinct place among the building materials.

(iv) It is proved to be more economical than steel. This is due to the fact that sand and pebbles or crushed rock forming the bulk of cement concrete, to the extent of about 80 to 90% are usually available at moderate co. The formwork, which is of steel or timber, can be used over and over again or for other purposes after it is removed.

(v) It binds rapidly with steel and as it is weak in tension, the steel reinforcement is placed in cement concrete at suitable places to take up the tensile stresses. This is termed as the Reinforced Cement Concrete or simply R.C.C

(vi) Under the following two conditions, it has a tendency to shrink:

(a) There is initial shrinkage of cement concrete which is mainly due to the loss of water through forms absorption by surfaces of forms, etc.

(b) The shrinkage of cement concrete occurs as it hardens. This tendency of cement concrete can be minimized by proper curing of concrete.

(vii) It has a tendency to be porous. This is due to the presence of voids which are formed during and after its placing. The two precautions necessary to avoid this tendency are as follows:

(a) There should be proper grading and consolidating of the aggregates.

(b) The minimum water-cement ratio should be adopted.

(viii) It forms a hard surface, capable of resisting abrasion.

(ix) It should be remembered that apart from other materials the concrete comes to the site in the form of raw materials only. Its final strength and quality depend entirely on local conditions and persons handling it. However the materials of which concrete is composed may be subjected to rigid specifications.

* Compressive Strength for various water-cement ratio

| Net water-cement ratio by weight | Probable cube crushing strength in N/mm² 7 Days | 28 Days |
|---|---|---|
| 0.35 | 40 | 52.5 |
| 0.40 | 35 | 47 |
| 0.45 | 30 | 42 |
| 0.50 | 25 | 37 |
| 0.55 | 22 | 33 |
| 0.60 | 18 | 28 |
| 0.65 | 15.5 | 24.5 |
| 0.70 | 13.5 | 22 |
| 0.75 | 11.2 | 20 |
| 0.80 | 10.5 | 17.5 |

* Workability :-

The term workability is used to describe the ease or difficulty with which the concrete is handled, transported and placed between the forms with minimum loss of homogeneity. However this gives a very loose description of this vital property of concrete which also depends on the means of compaction available. For instance, the workability suitable for mass concrete is not necessarily sufficient for thin, inaccessible or heavily reinforced sections. The compaction is achieved either by ramming or by vibrati

The workability as a physical property of concrete al irrespective of a particular type of construction, can be defined as the amount of useful internal work necessa to produce full compaction.

If the concrete mixture is too wet, the coarse aggregates settle at the bottom of concrete mass and the resulting concrete becomes of non-uniform composition. On the other hand if the concrete mixture is too dry, it will be difficult to handle and place it in position. Both these conflicting conditions should be corrected by proportioning carefully various components of concrete mixture. The important facts in connection with workability are as follows:

(i) If more water is added to attain the required degree of workmanship it results into concrete of low strength and poor durability.

(ii) If the strength of concrete is not to be affected the degree of workability can be obtained:

(a) by slightly changing the proportions of fine and coarse aggregates, in case the concrete mixture is too wet; and

(b) by adding a small quantity of water cement paste in the proportion of original mix, in case the concrete mixture is too dry.

(iii) A concrete mixture for one work may prove to be too stiff or too wet for another work. For instance, the stiff concrete mixture will be required in case of vibrated concrete work while wet concrete mixture will be required for thin sections containing reinforcing bars.

(iv) The workability of concrete is affected mainly by water content, water cement ratio and aggregate-cement ratio.

(v) The workability of concrete is also affected by the grading, shape, texture and maximum size of the coarse aggregates to be used in the mixture.

In order to measure the workability of concrete mixture, the various tests are developed. The test such as flow test and compacting test are used in great extent in laboratory. The Slump test which is commonly used in the field, is briefly described below.

It should however be remembered that numerous attempts have been made to correlate workability with some easily determinable physical measurement. But none of these tests is fully satisfactory although they may provide useful information within a range of variation in workability. At the same time, the slump test does not measure the workability of concrete. It is simply useful in detecting variations in the uniformity of a mix of given nominal proportions.

* Mixing The materials of Concrete :-

The process of rolling, folding and spreading of particles is known as the mixing of concrete. The materials of concrete should be mixed thoroughly so that there is uniform distribution of materials in the mass of concrete. The thorough mixing also ensures that cement water paste completely covers the surface of aggregates. The mixing of materials of concrete can be done either with hand or with the help of a machine.

(a) Hand mixing:-

For hand mixing the materials are stacked on a water tight platform, which may be either of wood, brick or steel.

The materials should be thoroughly mixed at least three times, in dry condition before water is added. The prepared mix should be consumed in 30 minutes after adding water. The mixing by hand is allowed in case of small works or unimportant works where small quantity of concrete is required. For important works, if hand mixing is to be adopted, it is advisable to use 10 percent more cement than specified.

(b) Machine mixing:- For machine mixing all the materials of concrete including water are collected in a revolving drum and then the drum is rotated for a certain period. The resulting mix is then taken out of the drum. The features of machine mixing are as follows:

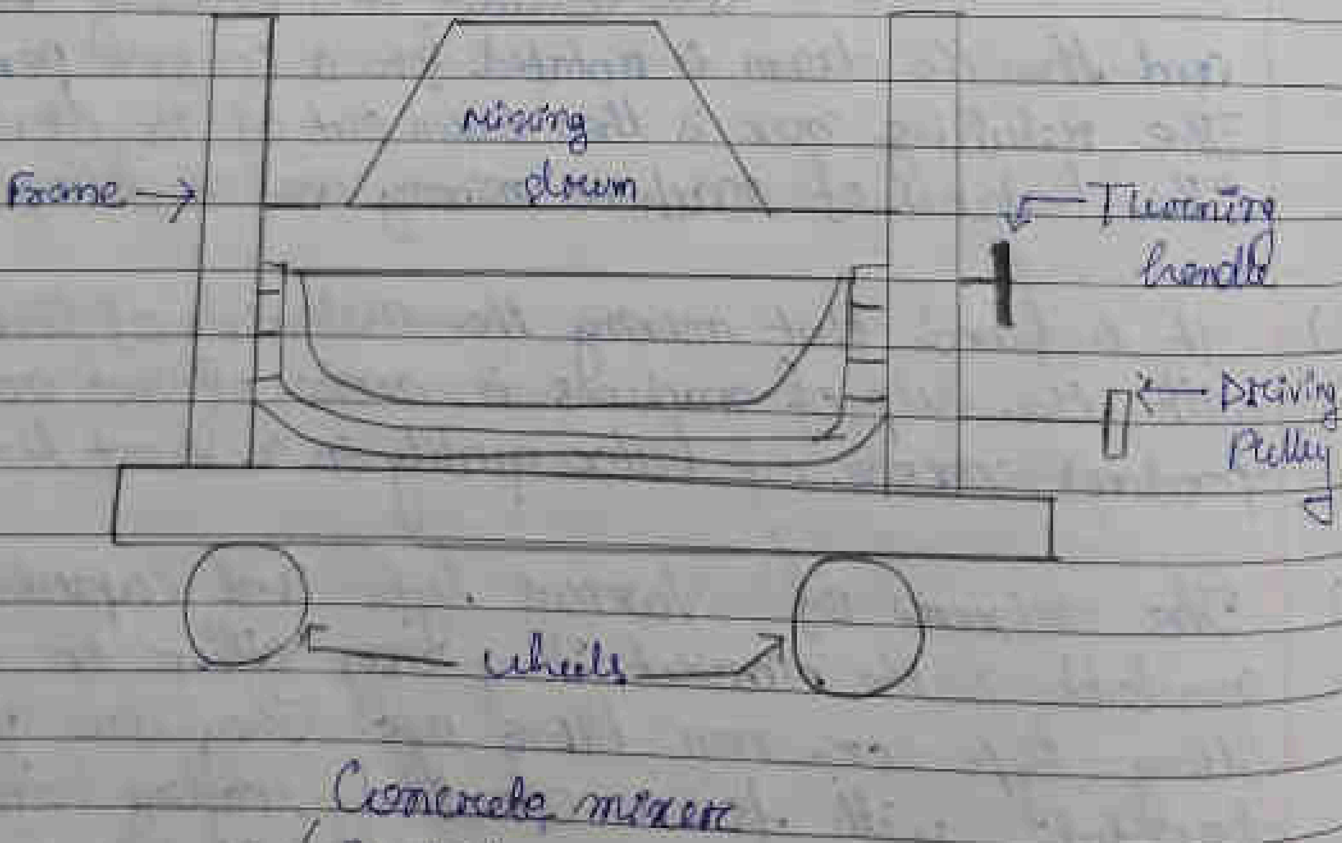
(i) It is found that mixing the materials of concrete with the help of machines is more efficient and it produces concrete of better quality in a short time.

(ii) The mixers of various type and capacities are available in the market. They may either be of tilting type or non-tilting type. They are generally provided with power operated loading hoppers. For small works, a mixer capable of producing concrete of one bag of cement, is used. For works such as roads, aerodromes, dams, etc, special types of of mixers are used. Fig 8.7 shows a typical concrete mixer.

(iii) The water should enter the mixer at the same time or before the other materials are placed. This ensures even distribution of water.

(iv) The concrete mixer should be thoroughly washed and cleaned after use. If this precaution is not taken the cakes of hardened concrete will be formed inside the mixer. These cakes are not only difficult to remove at a later stage but they considerably affect the efficiency of the mixer.

(v) The inside portion of the mixer should be inspected carefully at regular intervals. The damaged or broken blades should be replaced.




Concrete mixer
(Fig 8.7)

(vi) The time of mixing the materials in the mixer and the speed of the mixer are very important factors in deciding the strength of concrete which is formed. The mixing time should be related at a speed as recommended by the manufacture of the mixer.

(vii) The concrete discharged by the mixer should be consumed within 30 minutes.

* **Transporting and placing of concrete :-**

The concrete as it comes out of the mixer or as it is ready for use on the platform is to be transported and placed on the formwork. The type of equipment to be used for transport of concrete depends on the nature of work, height above ground level and distance between the points of preparation and placing of concrete.

For ordinary building works the human ladder is formed and concrete is conveyed in pans from hand to hand. For important works, the various mechanical device such as dumpers, truck mixers, buckets, chutes, belt conveyors, pumps, hoist etc may be used.

The two important precautions necessary in the transportation of concrete are as follows:

(i) The concrete should be transported in such a way that there is no segregation of the aggregates.

(ii) Under no circumstances, the water should be added to the concrete during its passage from mixer to the formwork.

The precautions to be taken during the placing of concrete are as follows:

(i) The formwork or the surface which is to receive the fresh concrete should be properly cleaned prepared and well-watered.

(ii) It is desirable to deposite concrete as near as practicable to its final position.

(iii) The large quantities of concrete should not be deposited at a time. otherwise the concrete will start to flow along the formwork and consequently the resulting concrete will not have uniform composition.

(iv) The concrete should be dropped vertically from a reasonable height. for vertical laying of concrete care should be taken to use stiff mix. otherwise the bleeding is used to mean the diffusion or running of concrete through formwork.

(v) The concrete should be deposited in horizontal layers of about 150 mm height. For mass concrete the layers may be of 400 mm to 500mm height. The accumulation of excess water in the upper layers is known as the laitance and it should be prevented by using shallow layers with stiff mix or by putting dry batches of concrete to absorb the excess water.

(vi) As far as possible the concrete should be placed in single thickness. In case of deep sections, the concrete should be placed in successive horizontal layers and proper care should be taken to develop enough bond between successive layers.

(vii) The concrete should be thoroughly worked around the reinforcement and tapped in such a way that no honeycomb is used to mean comb or mass of waxy cells formed by bees in which they store their honey. Hence, if this precaution is not taken, the concrete surface so formed would have a honeycomb like surface.

(viii) The concrete should be placed on the formwork as soon as possible. But in no case, it should be placed after 30 minutes of its preparation.

(ix) During placing, it should be seen that all edges and corners of concrete surface remain unbroken, sharp and straight in line.

(x) The placing of concrete should be carried out uninterrupted between predetermined construction joints.

22.2.21

Ch-4

# TIMBER

The word timber is derived from an old English word timbrian which means to build. The timber thus denotes wood which is suitable for building or carpentry or various other engineering purposes and it is applied to the trees measuring not less than 60cm in girth or circumference of the trunk.

Following three terms are to be noted in connection with the timber:

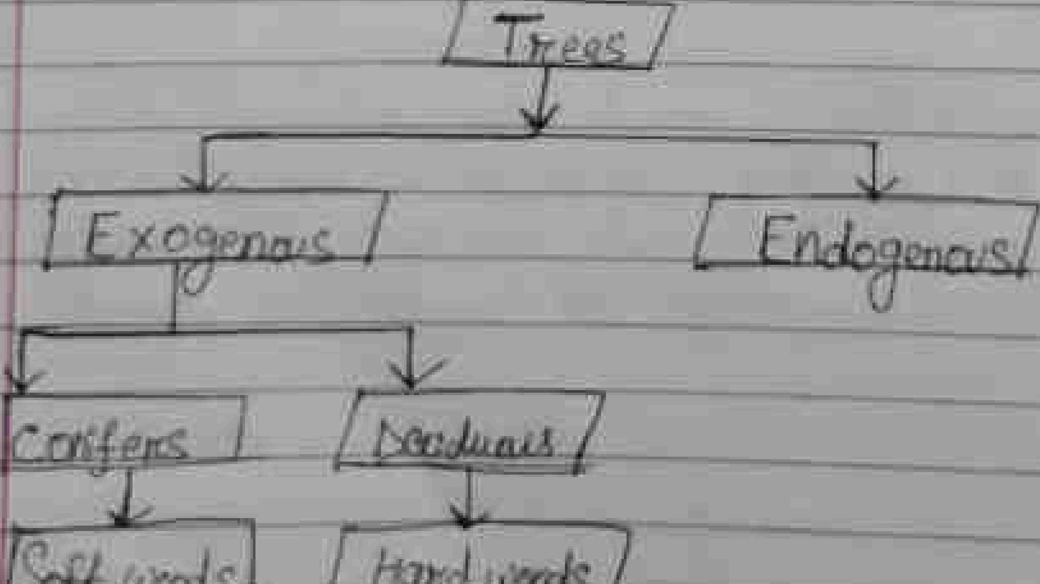
(i) Converted timber :- This indicates timber which is sawn and cut into suitable commercial sizes.

(ii) Rough timber :- This indicates timber which is obtained after felling a tree.

(iii) Standing timber :- This indicates timber contained in a living tree.

* CLASSIFICATION OF TREES :-

For the engineering purposes, the trees are classified according to their mode of growth. Following is the classification.



(i) Exogenous trees:- These trees increase in bulk by growing outwards and distinct consecutive rings are formed on the horizontal section of such a tree. These rings are known as the annual rings because one such ring is added every year and these rings are useful in predicting the age of tree. The timber which is mostly used for engineering purpose belongs to this category.

The exogenous trees are further subdivided into two groups:

(i) Conifers and (ii) deciduous.

(i)⇒ The conifers also known as the ever-green trees and leaves of these trees do not fall till new ones are grown. As these trees bear cone-shaped fruits, they are given the name conifers. These trees yield soft woods which are generally light coloured, resinous, light in weight and weak. They show distinct annual rings.

(ii)⇒ The deciduous trees are also known as the broad-leaf trees and leaves of these trees fall in autumn and new ones appear in spring season. The timber for engineering purposes is mostly derived from deciduous trees. These trees give hard woods which are usually close-grained, strong, heavy, dark coloured, durable and non-resinous. They do not show distinct annual rings.

* Soft woods and hard woods:-

The soft woods form a group of ever-green trees. The hard woods form a group of broad-leaf trees. It is to be noted that the terms soft woods and hard woods have commercial importance only. It is quite likely that some variety of soft-wood may prove to be stronger than some variety of hard wood. Table 9-1 is prepared to show points of difference between soft wood and hard woods.

* Structure of a tree:-

A tree basically consists of three parts, namely trunk, crown and roots. The function of the trunk is to support the crown and to supply water and nutrients from the roots to the leaves through branches and from the leaves to the roots. The roots are meant to implant the trees in the soil, to absorb moisture and the mineral substances it contains and to supply them to the trunk.

From the visibility aspect, the structure of a tree can be divided into two categories

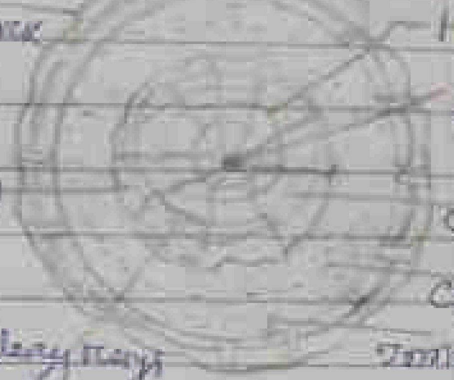
(i) macrostructure
(ii) microstructure.

(i) macrostructure:-

The structure of wood visible to the naked eye or at a small magnification is called the macrostructure. Fig 9-2 shows the transverse section of the trunk of an exogenous tree.

Following are its different components:-

(i) pith :- The innermost central portion of core of the tree is called the pith or medulla. It varies in size and shape for different types of trees. It consists entirely of cellular tissues and it nourishes the plant in its young age. When the plant becomes old, the pith dies up and decays and the sap is then transmitted by the woody fibres deposited round the pith. The pith of branches is nothing but merely a prolongation of the pith of stem.




Cross-Section of an exogenous tree (Fig - 9.1)

(ii) Heart wood :- The inner annual rings surrounding the pith constitute the heart wood. It is usually dark in colour. As a matter of fact, it indicates dead portion of tree and as such, it does not take active part in the growth of tree. But it imparts rigidity to the tree and hence it provides strong and durable timber for various engineering purpose.

(iii) Sapwood :- The outer annual rings between heart wood and cambium layer is known as the sapwood. It is usually light in colour and weight. It indicates recent growth and it contains sap. The annual rings of sapwood are less sharply defined than those of heart wood. It takes active part in the growth of tree and the sap moves in an upward direction through it. The sap wood is also known as the alburnum.

(iv) <u>Cambium layer</u>:- The thin layer of sap between sap wood and inner bark is known as the cambium layer. It indicates sap which has yet not been converted into sapwood. If the bark is removed for any reason, the cambium layer gets exposed and the cells cease to be active resulting in the death of tree.

(v) <u>Inner bark</u>:- The inner skin or layer covering the cambium layer is known as the inner bark. It gives protection to the cambium layer from any injury.

(vi) <u>Outer bark</u>:- The outer skin or cover of the tree is known as the outer bark. It is the outer protective layer and it sometimes contains cracks and fissures. It consists of cells of wood fibre and is also known as the cortex.

(vii) <u>Medullary rays</u>:- The thin radial fibres extending from pith to cambium layer are known as the medullary rays. The function of these rays is to hold together the annual rings of heart wood and sap wood. These rays are sometimes broken and in some varieties of trees, they are not very prominent.

* <u>Microstructure</u>:-

The structure of wood apparent only at great magnification is called the microstructure. When studied under a microscope, it becomes evident that wood consists of living and dead cells of various sizes and shapes

A living cell consist of four parts, namely, membrane, protoplasm, sap and core. The cell membrane consists mainly of cellular tissue and cellulose. The protoplasm is a granular, transparent, viscous vegetable protein composed of carbon, hydrogen, oxygen, nitrogen and sulphur. The core of cell differs from protoplasm mainly by the presence of phosphorus and it is generally oval.

The cells, according to the function they perform, are classified into the following three categories:-

(i) Conductive cells :- These cells serve mainly to transmit nutrients from roots to the branches and leaves.

(ii) Mechanical cells :- These cells are elongated, thick-walled and have tightly interconnected narrow interior cavities. These cells impart strength to the wood.

(iii) Storage cells :- These cells serve to store and transmit nutrients to the living cells in the horizontal direction and they are usually located in the medullary rays.

## * SEASONING OF TIMBER :-

(1) Meaning of Seasoning :-

When a tree is newly felled, it contains about 50 per cent or more of its own dry weight as water. This water is in the form of sap and moisture. The water is to be removed before the timber can be used for any engineering purpose

In other words, the timber is to be dried. This process of drying of timber is known as the seasoning of timber and the moisture should be extracted during seasoning under controlled conditions as nearly as possible at a uniform rate from all parts of the timber.

It should also be seen during seasoning that the remaining moisture, which cannot be extracted, is uniformly distributed throughout the mass. If the drying is irregular, the shrinkage of timber will also be irregular and it will set up external stresses between the fibres. When these stresses become excessive and are capable of overcoming the cohesion of fibres, the timber warps and the shakes are formed.

The wood is a hygroscopic material. The capacity of wood to absorb water vapours from air is called the hygroscopicity of wood. The dry wood absorbs the moisture from the surrounding air. Now the air humidity is not constant and hence the wood moisture content also varies accordingly. The fluctuations in wood moisture content from zero to the fibre saturation point cause corresponding volume changes in wood leading to cracking, warping, swelling and shrinkage of wood.

The wood attains a level of equilibrium moisture content under the given climatic conditions of temperature and relative humidity. By the process of seasoning, the excess water of timber is extracted in such a way that the moisture content of seasoned timber corresponds to the required moisture content in timber for the environments in which it is to be used.

The relationship between the climatic conditions and moisture content in timber has been established from tests on various types of timber. It is to be noted that the seasoned timber should be protected from exposure to the rain and excessively high humidity.

2) Free moisture and bound moisture:-

The moisture in timber can be present either in the cell cavities or in the cell walls. The former is known as the free moisture or free water and major part of moisture in timber is present as free water. The latter is known as the bound moisture and it is closely associated with the body of timber.

When timber containing moisture is exposed to the atmospheric conditions, it starts losing its moisture content. The free water is evaporated first and the points at which the cell cavities no longer contain free water is known as the fibre saturation point. After the fibre saturation point has been reached, the tendency of timber to shrink appears and it is more or less proportional to the loss in bound moisture.

3) Determination of moisture content:-

The moisture content of timber is determined as follows:

$$P = \frac{W_1 - W_2}{W_2} \times 100$$

P = Percentage of moisture
$W_1$ = Original weight of timber
$W_2$ = oven-dry weight of timber.

The Samples of timber are taken in the form of piece having dimensions of 50mm x 50mm x 25mm. The test piece is taken and weighed fresh. It is then dried in an oven at a temperature of 103C ± 2C. The weight of test piece in the oven is regularly observed till the variation in last two consecutive observations does not exceed 0.002 gm. The test piece is then considered to be oven-dry and its weight is noted.

The oven-dry method of determining moisture content is a standard method. But for field observations, the electronic instruments are available for readily working out the moisture content of timber.

4) Objects of Seasoning:-

The Seasoning of timber is carried out to achieve the following objects:-

(i) To allow timber to burn readily, if used as fuel.

(ii) To decrease the weight of timber and thereby to lower the cost of transport and handling.

(iii) To impart hardness, Stiffness, Strength and better electrical resistance to timber.

(iv) To increase the resisting power of timber, as most of the causes of decay of timber are more or less related to the moisture.

(v) To Maintain the shape and Size of the Components of the timber articles which are expected to remain unchanged in form.

(vi) To make timber fit for receiving treatment of paints, preservatives, varnishes, etc.

(vii) To make timber easily workable and to facilitate operation during conversion.

(viii) To make timber safe from the attack of fungi and insects.

(ix) To make timber suitable for gluing i.e. effectively joining two members of timber with the aid of glue.

(x) To reduce the tendency of timber to crack, shrink and warp.

5) Methods of Seasoning :-

The Methods of Seasoning can broadly be divided into the following two Categories:-

(i) Natural Seasoning:- In this method, the Seasoning of timber is carried out by natural air and hence it is also Sometimes reffed to as air Seasoning. following procedure is adopted in the air Seasoning.

(a) The timber in log form is not usually fit for the process of Seasoning. Hence it is cut and sawn into Suitable section of planks or Scantlings.

b) The timber pieces can either be stacked horizontally or vertically, the former arrangement being very common. (Fig.) shows a typical horizontal stack for air seasoning.


Horizontal Stack for air Seasoning
(Fig 9-3)

(C) The ground, where stack is to be constructed, is cleared and it is levelled for good drainage.

(d) The platform of stack is made slightly higher, about 300 than the ground level. for this purpose, the rows of brick or concrete pillars are constructed. The pillars may also be made of creosoted wood or wood coated with coal tar. The tops of pillars should be in the same horizontal plane. The pillars should be durable.

(e) The timber pieces are sorted out according to length and thickness. They are then arranged in layers one above the other. The care should be taken to see that all members in a particular layer are of the same thickness. If this precaution is not taken, there are chances for timber to become warped or cracked.

(f) Each layer is separated by spacers of sound dry wood. The usual dimensions of spacers vary from 35 mm x 25 mm to 50 mm x 25 mm the largest dimension being the width. The spacers are to be carefully placed in correct vertical alignment.

(g) The distance between spacers depends on the sizes of timber members to be seasoned. It is less for thin sections and more for thick sections. It usually varies from 450 mm to 600 mm.

(h) The length of stack is equal to length of timber pieces. The width and height of stack are restricted to about 1500 mm and 3000 mm respectively. A distance of about 25 mm is kept between adjacent layers.

(i) The stack is to be protected from fast blowing wind, rain and extreme heat of sun. Hence the stack should preferably be covered by a roof of suitable material.

(j) Similar stacks may be constructed. The minimum distance between adjacent stacks should be at least 600 mm

## Advantages:-

(i) Depending upon the climatic condition, the moisture content of wood can be brought down to about 10 to 20 per cent

(ii) It does not require skilled supervision.

(iii) It is uneconomical to provide artificial seasoning to timber sections thicker than 100mm, as such sections dry very slowly. Hence, such thicker timber sections are usually seasoned by the process of air seasoning.

(iv) This method of seasoning timber is cheap and simple.

## Disadvantages:-

(i) As the process depends on the natural air, it sometimes becomes difficult to control it.

(ii) The drying of different surface may not be even and uniform.

(iii) If ends of thick sections of timber are not protected by suitable moisture-proof coating, there are chances for end splitting because the ends of such timber dry rapidly in comparison to the central portions.

(iv) If not properly attended, the fungi and insects may attack timber during the process of seasoning and may thereby damage it.

(v) The moisture content of wood may not be brought down to the desired level.

(vi) The space required for this process will be more as timber will have to be stacked or stored for a sufficiently long time.

(vii) The process of seasoning is very slow and it usually takes about 2 to 4 years to make timber fit for the work of carpenter.

(ii) Artificial Seasoning :-

Following are the reason for adopting the artificial seasoning to the natural seasoning:

(a) The defects such as shrinkage, cracking and warping are minimized.

(b) The drying is controlled and there are practically no chances for the attack of fungi and insects.

(c) The drying of different surfaces is even and uniform

(d) It considerably reduces the period of seasoning.

(e) There is better control of circulation of air, humidity and temperature.

(f) The wood becomes more suitable for painting, gluing etc.

(g)

(g) The wood with desired moisture content may be obtained by the artificial seasoning.

The various methods of artificial seasoning are as follows:-

(a) Boiling (d) Kiln Seasoning

(b) Chemical Seasoning (e) Water Seasoning

(c) Electrical Seasoning

(a) <u>Boiling:-</u> In this method of artificial seasoning the timber is immersed in water and water is then boiled. This is a very quick method. The timber is thus boiled with water for about three to four hours. It is then dried very slowly under a shed. The period of seasoning and shrinkage are reduced by this method, but it affects the elasticity and strength of wood. In place of boiling water, the timber may be exposed to the action of hot steam. This method of seasoning proves to be costly.

b) <u>Chemical Seasoning:-</u> This is also known as the salt seasoning. In this method, the timber is immersed in a solution of suitable salt. It is then taken out and seasoned in the ordinary way. The interior surface of timber dries in advance of exterior one and chances of formation of external cracks are reduced.

(c) Electrical Seasoning:- In this method the use is made of high frequency alternating current. The timber, when it is green offers less resistance of the flow of electric current. The resistance increase as the wood dries internally which also results on the production of heat. This is the most rapid method of Seasoning. But the initial and maintenance costs are so high that it becomes uneconomical to Season timber on commercial basis by this method.

(d) Kiln Seasoning:- In this method, the drying of timber is carried out inside an airtight chamber or oven. The process of seasoning is as follows.

(i) The timber is arranged inside the chamber such that spaces are left for free circulation of air.

(ii) The air which is fully saturated with moisture and which is heated to a temperature of about 35°C to 38°C is then forced inside the chamber by suitable arrangement.

(iii) This forced air is allow to circulate round the timber pieces. As air is fully saturated with moisture, the evaporation from the surface of timber pieces is prevented. The heat gradually reaches inside the timber pieces.

(iv) The relative humidity is now gradually reduced. 6)

(v) The temperature is then raised and maintained till the desired degree of moisture content is attained.

Depending upon the mode of construction and operation the kilns are of two types, namely, stationary kilns and progressive kilns. A stationary kiln is also known as a compartment kiln and in this kiln, the process of seasoning is carried out in a single compartment only.

(e) Water Seasoning:- In this method, the following procedure is adopted.

(i) The timber is cut into pieces of suitable sizes.

(ii) These pieces are immersed wholly in water, preferably in running water of a stream. The care should be taken to see that the timber is not partly immersed.

(iii) The thicker or longer end of timber is kept pointing on the upstream side.

(iv) The timber is taken out after a period of about two weeks. During this period, the sap contained in timber is washed away by water.

(v) The timber is then taken out of water and allowed to dry under a shed having free circulation of air. The water that has replaced sap from the timber dries out and the timber is seasoned.

6) Comparision between natural seasoning and artificial seasoning :-

| NO | Item | Natural Seasoning | Artifical Seasoning |
|---|---|---|---|
| 1 | Moisture content | It is difficult to reduce the moisture content below 15 to 18 %. | The moisture content can be reduced to any desired level |
| 2 | Nature | It is simple and economical | It is expensive and quite technical. |
| 3 | Quality of timber | The air seasoned timber is more liable to the attacks of insects and fungi | The kiln seasoned timber is less liable to the attacks of insects and fungi. |
| 4 | Space | It required more space for stacking | It required less space for stacking. |
| 5 | Speed | It is a slow process | It is a quick process |
| 6 | Strength | It gives stronger timber | It gives a little weaker timber. |

* Qualities of good Timber :-

In general, the quality of timber depends on the following factors:

1) Environmental condition of the locality.

2) maturity of the tree,
3) method of seasoning,
4) nature of the soil,
5) process of preservation and
6) time of felling.

1) Appearance :- A freshly cut surface of timber should exhibit hard and shining appearance.

2) Colour :- The colour of timber should preferably be dark. The light colour usually indicates timber with low strength.

3) Defects :- A good timber should be free from serious defects such as dead knots, flaws, shakes, etc.

4) Durability :- A good timber should be durable. It should be capable of resisting the actions of fungi insects, chemicals, physical agencies and mechanical agencies. If wood is exposed to the action of acids and alkalies for a prolonged period. It is seriously damaged. The weak alkali and acid solutions usually do not affect wood to a considerable extent.

5) Elasticity :- This is the property by which it returns to its original shape when load causing its deformation is removed. This property of timber would be essential when it is to be used for bows, carriage shafts, sport goods, etc.

6) Fibres:- The timber should have straight fibres.

7) Fire resistance:- The timber is a bad conductor of heat. A dense wood offers good resistance to the fire and it requires sufficient heat to cause a flame. The heat conductivity of wood is low and it depends on various factors such as porosity, moisture content, surrounding temperature, orientation of fibres, bulk density etc.

8) Hardness:- A good timber should be hard i.e, it should offer resistance when it is being penetrated by another body. The chemicals present in heart wood and density of wood impart hardness to the timber. The mere resistance offered to chisel or saw does not usually indicate hardness of timber.

9) Mechanical wear:- A good timber should not deteriorate easily due to mechanical wear or abrasion. This property of timber would be essential for places where timber would be subject to traffic e.g, wooden floors, pavements, etc.

10) Shape:- A good timber should be capable of retaining its shape during conversion or seasoning. It should not bow or warp or split.

11) Smell :- A good timber should have sweet smell. An unpleasant smell indicates decayed timber.

12) Sound:- A good timber should gives out a clear ringing sound when struck. A dull heavy sound when struck, indicates decayed timber. The velocity of sound in wood is 2 to 17 times greater than that in air and hence the wood may be considered high in sound transmission. The sound conductivity is taken along the fibres, is lower in the radial direction and is slowest along the chord of a cross-section.

13) Strength :- A good timber should be strong for working as structural member such as joist, beam, rafter, etc. It should be capable of taking loads slowly or suddenly. It should also possess enough strength in direct and transverse directions.

14) Structure:- It should be uniform. The fibres should be firmly added. The medullary rays should be hard and compact. The annual rings should be regular and they should be closely located.

15) Toughness:- A good timber should be tough i.e it should be capable of offering resistance to the shocks due to vibrations. This property of timber would be essential when it is to be used for tool handles, parts of motor cars and aeroplanes, etc.

16) Water permeability:- A good timber should have low water permeability which is measured by the quantity of water filtered through unit surface area of specimen of wood. The water permeability is greater along the fibres than in other directions and it depends on initial moisture content, character of cut, type of wood, width of annual rings, age of wood etc.

17) Weathering effects:- A good timber should be able to stand reasonably the weathering effects. when timber is exposed to weather, its colour normally fades and slowly turns grey. A good timber should show the least disintegration of the surface under adverse weather conditions such as drying and wetting, extreme heat and extreme cold, etc.

18) Weight:- The timber with heavy weight is considered to be sound and strong.

19) Working Conditions:- The timber should be easily workable. It should not clog the teeth of saw and should be capable of being easily planed or made smooth.