Program : **B.Tech**

Subject Name: **Construction Materials**

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Semester: **3rd**

UNIT-1
Construction Materials

Stones: Occurrence, varieties, Characteristics and their testing, uses, quarrying and dressing of stones. Timber : Important timbers, their engineering properties and uses, defects in timber, seasoning and treatment, need for wood substitutes, Alternate materials for shuttering doors/windows, Partitions and structural members etc. Brick and Tiles: Manufacturing, characteristics, Classification and uses, improved brick from inferior soils, Hand molding brick table, Clay-fly ash brick table, Flooring tiles and other tiles and their characteristics

OCCURRENCE

BUILDING STONES

In order to be able to decide what kind of stone to use under given conditions, knowledge of the different kinds employed in the various types of construction is essential. It is not necessary for a mason to determine the exact composition of a stone to be used in a structure, but his knowledge should be sufficient to help him in selecting or specifying the stone that is best for the type of structure.
The properties of a stone that determine its fitness for construction purposes are durability, strength, hardness, density, and appearance. The quality of a stone can easily and approximately be known by studying its origin and chemical composition and from the results of tests and experiments.

Definitions.
The term rock is commonly defined as a hard mass of mineral matter having, as a rule, no definite external form. In engineering construction, the word stone is applied indiscriminately to all classes of hard rocks.

Description of Classes.
Rocks are classified as follows:

- **According to geological origin- igneous, sedimentary and metamorphic**
- **According to the physical form- stratified, unratified and foliated.**
- **According to their chemical composition–siliceous, argillaceous and calcareous.**

GEOLOGICAL CLASSIFICATION

This is classification of rocks based on their origin and formation. On this basis, rocks are classified as igneous, sedimentary and metamorphic.

IGNEOUS ROCK

Igneous Rock, rock formed when molten or partially molten material, called magma, cools and solidifies. The inner layers of the earth are at a very high temperature causing the masses of silicates to melt. The melted masses of silicates is called magma, which forced up and released on the surface of the earth. This release is called volcanic eruption. The magma that is released cools and solidify into a crystalline rock.
Geologists classify igneous rocks according to the depth at which they formed in the earth's crust. Using this principle, they divide igneous rocks into two broad categories: those that formed beneath the earth's surface, and those that formed at the surface.
Rocks formed within the earth are called intrusive or plutonic rocks because the magma from which they form often intrudes into the neighboring rock. Rocks formed at the surface of the earth are called extrusive rocks. In extrusive rocks, the magma has extruded, or erupted, through a volcano or fissure.
Geologists can tell the difference between intrusive and extrusive rocks by the size of their crystals: crystals in intrusive rocks are larger than those in extrusive rocks. The crystals in intrusive rocks are larger because the magma that forms them is insulated by the surrounding rock and therefore cools slowly. This slow cooling gives the crystals time to grow larger. Extrusive rocks cool rapidly, so the crystals are very small. In some cases, the magma cools so rapidly that crystals have no time to form, and the magma hardens in an amorphous glass, such as obsidian.

SEDIMENTARY ROCKS.

Sedimentary rocks are formed by the consolidation of particles deposited in any of the three following ways:

· By the mechanical destruction and subsequent deposition of other rocks, usually by water, as in the case of sandstone or lime stone;

· By the action of animals and plants, as in the case of coral;

· By the chemical precipitation of mineral matter from water, as in the case of gypsum. The metamorphic rocks are formed by the transformation, of either igneous or sedimentary rocks through the influence of heat or chemical action. To this class belong marble, gneiss, and slate.

Most sedimentary rocks are characterized by parallel or discordant bedding that reflects variations in either the rate of deposition of the material or the nature of the matter that is deposited.

Sedimentary rocks are classified according to their manner of origin into mechanical or chemical sedimentary rocks.

· Mechanical rocks, or fragmental rocks, are composed of mineral particles produced by the mechanical disintegration of other rocks and transported, without chemical deterioration, by flowing water. They are carried into larger bodies of water, where they are deposited in layers. Shale, sandstone, and conglomerate are common sedimentary rocks of mechanical origin.

· The materials making up chemical sedimentary rocks may consist of the remains of microscopic marine organisms precipitated on the ocean floor, as in the case of limestone. They may also have been dissolved in water circulating through the parent rock formation and then deposited in a sea or lake by precipitation from the solution. Halite, gypsum, and anhydrite are formed by the evaporation of salt solutions and the consequent precipitation of the salts.

Due to the method of formation, sedimentary rocks are naturally soft and can be easily split up along the bedding. Their properties will vary depending on the nature of the sediment and type of bond.

METAMORPHIC ROCKS.

Metamorphic Rock is a type of rock formed when rocky material experiences intense heat and pressure in the crust of the earth.

Metamorphic rock forms when pre-existing rock undergoes mineralogical and structural changes resulting from high temperatures and pressures. These changes occur in the rock while it remains solid (without melting).

The changes can occur while the rock is still solid because each mineral is stable only over a specific range of temperature and pressure. If a mineral is heated or compressed beyond its stability range, it breaks down and forms another mineral. For example, quartz is stable at room temperature and at pressures up to 1.9 gigapascals (corresponding to the pressure found about 65 km [about 40 mi] underground). At pressures above

gigapascals, quartz breaks down and forms the mineral cohesive, in which the silicon and oxygen atoms are packed more closely together.

In the same way, combinations of minerals are stable over specific ranges of temperature and pressure. At temperatures and pressures outside the specific ranges, the minerals react to form different combinations of minerals. Such combinations of minerals are called mineral assemblages.

In a metamorphic rock, one mineral assemblage changes to another when its atoms move about in the solid state and recombine to form new minerals. This change from one mineral assemblage to another is called metamorphism. As temperature and pressure increase, the rock gains energy, which fuels the chemical reactions that cause metamorphism. As temperature and pressure decrease, the rock cools; often, it does not have enough energy to change back to a low-temperature and low-pressure mineral assemblage. In a sense, the rock is stuck in a state that is characteristic of its earlier high-temperature and high-pressure environment. The size, shape, and distribution of mineral grains in a rock are called the texture of the rock. Many metamorphic rocks are named for their main texture. Textures give important clues as to how the rock formed. As the pressure and temperature that form a metamorphic rock increase, the size of the mineral grains usually increases. When the pressure is equal in all directions, mineral grains form in random orientations and point in all directions. When the pressure is stronger in one direction than another, minerals tend to align themselves in particular directions. In particular, thin plate-shaped minerals, such as mica, align perpendicular to the direction of maximum pressure, giving rise to a layering in the rock that is known as foliation. Compositional layering, or bands of different minerals, can also occur and cause foliation. At low pressure, foliation forms fine, thin layers, as in the rock slate. At medium pressure, foliation becomes coarser, forming schist. At high pressure, foliation is very coarse, forming gneiss. Commonly, the layering is folded in complex, wavy patterns from the pressure.

<u>VARIETIES</u>

CLASSIFICATION BASED ON THE PHYSICAL FORM

Rocks are also classified as stratified and un-stratified, depending on their structure. Igneous and metamorphic rocks are un-stratified, that is, they are not arranged in any definite form in layers, or strata, but have the constituent parts mingled together.
The sedimentary rocks are stratified, or formed in a series of parallel layers, as they are deposited from water. The layers were originally horizontal, but in most cases they are found more or less inclined and curved on account of the action of disturbing forces. Sedimentary rocks are composed of grains bound together by a cementing medium, and their strength and durability depend on the nature of the cementing material.

CLASSIFICATION BASED ON THE CHEMICAL COMPOSITION.
Rocks may be further classified as siliceous, calcareous, and argillaceous, according to the chemical composition of the earth forming their main ingredients.

- In siliceous stones, silica is the principal earthy constituent;
- In calcareous stones, carbonate of lime is the predominating material;
- In argillaceous stones, alumina is the chief component.

QUARRYING OF STONES

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

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

Methods of Quarrying

Rocks suitable for the manufacture of stone materials are called useful minerals and the operations involved in obtaining minerals are called mining. In the process of mining, voids formed are called excavations, and the mined deposits are the quarries. The purpose of quarrying is to

Obtain stones for various engineering purposes. A knowledge of various quarrying methods is essential but does not make one very much more competent to choose or specify a stone for building work. Depending upon the nature and surface of rocks and the purpose for which stones are needed, quarrying is done by excavating, wedging, heating or blasting.

Excavating: Stones buried in earth or under loose overburden are excavated with pick axes, crow bars, chisels, hammers, etc.
Wedging: This method of quarrying is suitable for costly, soft and stratified rocks such as sandstone, limestone, laterite, marble and slate.

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

Heating is most suitable for quarrying small, thin and regular blocks of stones from rocks, such as granite and gneiss. A heap of fuel is piled and fired on the surface of rock in small area. The two consecutive layers of the rock separate because of uneven expansion of the two layers. The loosened rock portions are broken into

pieces of desired size and are removed with the help of pick-axes and crow-bars. Stone blocks so obtained are very suitable for coarse rubble masonry. Sometimes,
Intermediate layers are to be separated from the top and bottom layers. In such a case, the intermediate layer is heated electrically and the expansion separates it from the other two.

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

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

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

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

CHARACTERISTICS AND THEIR

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

1. **Blasting should not be carried out in late evening or early morning hours. The blasting hours should be made public and a siren should warn the workmen and nearby public timely to retire to a safe distance.**

2. **The danger zone, an area of about 200 m radius, should be marked with red flags.**

3. **First aid should be available.**

4. **The number of charges fired, the number of charges exploded and the misfires should be recorded.**
5. **Explosives should be stored and handled carefully.**

6. **Detonators and explosives should not be kept together.**

7. **Cartridges should be handled with rubber or polythene gloves.**

8. **A maximum of 10 bore holes are exploded at a time and that also successively and not simultaneously.**

Types of Dressing of Stones:
The different types of dressing of stones are,
1. Hammer Dressed or Quarry-faced Surface
2. Rough tooled surface
3. Tooled Surface
4. Cut stone Surface

5. Rubbed Surface
6. Polished Surface
The details of types of dressing of stones are as follows,

1. Hammer Dressed or Quarry-faced Surface:
This is the roughest form of surface finish. Stone as removed from the quarry has large projections which are knocked off with the quarry hammer and it is finally broken up into blocks of suitable size and shape such as khandki, quoin, or rectangular blocks, The faces of the blocks arc roughly planned and the stone is rendered suitable to be used in masonry. When used in a wall, the roughly finished surfaces arc further modified by forming a 2 cm. to 5 cm. wide margin about the edges of the exposed face.

2. Rough tooled surface:
In this type of surface finish, the projection of the stone block are removed by means of chisels and the surface is nearly dressed true. The corners and the edges are made accurate, chisel draughted margins sunk and the side and bed joints roughly treated to ensure proper bonding.

3. Tooled Surface:
In this type of surface finish continuous parallel chisel marks are produced throughout the width of the stone. The parallel corrugations or chisel marks are made at closer intervals rendering the surface truly planned. Different types of tooled finishes are obtained by use of different chisel and marking patterns.

4. Cut stone Surface:
In this type of surface finish the surface is dressed by using a, sharp chisel so that the chisel marks are practically imperceptible. It is considered superior to tooled surface.

5. Rubbed Surface:
This type of surface finish is obtained by grinding or rubbing a cut stone surface by hand or machine until it gets perfectly smooth.

6. Polished Surface:
The rubbed surfaces of granite, marble of lime stones are polished to enhance their texture. Polishing may be done by manual labor using sand and water, pumice stone etc. or by rubbing machine.

USES OF STONES
Use of stone as building material depends upon the nature of the work, type of the structural element in which it is to be used and its quality, availability and transportation cost. For structural purpose, granite, gneiss, trap, sandstone, limestone, marble, quartzite and slate are most useful.

On the basis of the method of manufacture, items and materials from natural stones are classified as Sawn— obtained either from massive rocks by stone-cutting and stone-splitting machines (large stones) or from semi-product
blocks by appropriate working (facing slabs, windows sill slabs, etc.); Split—obtained by splitting and finishing blocks (curb stones, paving blocks, etc.); Roughly split—manufactured by oriented splitting of blocks (bedded stone); Fractured—produced by blasting rocks and separating finer sizes (quarry stone); Crushed—produced by crushing and screening (crushed stone, artificial sand) and; Ground—obtained by grinding rocks (ground mineral powder, stone powder).

Foundation and Wall Items: Quarry, split and sawn stones from rocks are used to erect the substructure of buildings. Piece stones sawn and split from limestone, sandstone, dolomite and volcanic tuff are used for walls, piers, abutments, etc.

Facing and Architectural Items: Facing slabs and stones, stairs and landings, parapets, etc. are made of slabs sawn or split from semi-finished product blocks with glossy, dull, ground, sawn, pointed, fluted or rock finish. Facing slabs of granite, gabbro, basalt, marble, breccia, limestone, sandstone and volcanic tuff are generally used.

Building Items: Elements of stairs, landings, parapets and guard rails are manufactured from granite, marble, limestone, tuff, etc. Pedestal slabs and stones for farming doorways, cornices and window-sill slabs are made from the same material as the facing slabs.

Road Construction Items: Curb stones—intended to separate roadways from sidewalks; Paving blocks—used for pavements; Cobble stone—used to reinforce slopes of earth works and banks of water basins; Crushed stone—a mixture of jagged stone fragments (< 70 mm); Gravel—loose agglomeration of rock fragments (70 mm) and Sand—loose mass of mineral and rock particles (0.14–5 mm) obtained from natural stone are used in road construction.

Underground Structures and Bridges are built of slabs and stones from igneous and sedimentary rocks. Tunnels and above-water elements of bridges are built of granite, diorite, gabbro and basalt. Face stones and facing slabs for tunnels and bridges are given rock face, grooved or fluted finishes.

Heat and Chemically Resistant Items are manufactured from non-weathered rocks. For high temperature working conditions, they are made from chromite, basalt, andesite and tuffs. Building elements are protected against acid (except hydrofluoric acid and fluosilicic acids) by using slabs made of granite, syenite, and siliceous stones. Lime stones, dolomites, marble and magnesite show excellent resistance against alkalis. When high temperature and chemical attack is expected, crushed stone and sand for concrete and mortar are used.

CHARACTERISTICS OF GOOD BUILDING STONE

A good building stone should have the following qualities.

Appearance: For face work it should have fine, compact texture; light-colored stone is preferred as dark colors are likely to fade out in due course of time.

Structure: A broken stone should not be dull in appearance and should have uniform texture free from cavities, cracks, and patches of loose or soft material. Stratifications should not be visible to naked eye.

Strength: A stone should be strong and durable to withstand the disintegrating action of weather. Compressive strength of building stones in practice range between 60 to 200 N/mm^2.

Weight: It is an indication of the porosity and density. For stability of structures such as dams. Retaining walls, etc. heavier stones are required, whereas for arches, vaults, domes, etc. light stones may be the choice.

Hardness: This property is important for floors, pavements, aprons of bridges, etc. The hardness is determined by the Mohr scale

Toughness: The measure of impact that a stone can withstand is defined as toughness. The stone used should be tough when vibratory or moving loads are anticipated.

Porosity and Absorption: Porosity depends on the mineral constituents, cooling time and structural formation. A porous stone disintegrates as the absorbed rain water freezes, expands, and causes cracking.

TESTING

Building stones are to be tested for their properties. Following are the tests conducted on stones:

1. Acid Test:

Here, a sample of stone weighing about 50 to 100 gm is taken. It is placed in a solution of hydrophobic acid having strength of one percent and is kept there for seven days. Solution is agitated at intervals. A good building stone maintains its sharp edges and keeps its surface free from powder at the end of this period. If the edges are broken and powder is formed on the surface, it indicates the presence of calcium carbonate and such a stone will have poor weathering quality. This test is usually carried out on sandstones.

1. **Attrition Test:**

This test is done to find out the rate of wear of stones, which are used in road construction. The results of the test indicates the resisting power of stones against the grinding action under traffic.

The following procedure is adopted:

i. Samples of stones is broken into pieces about 60mm size.

ii. Such pieces, weighing 5kg are put in both the cylinders of Devil's attrition test machine. Diameter and length of cylinder are respectively 20cm and 34 cm.

iii. Cylinders are closed. Their axes make an angle of 30 degree with the horizontal.

iv. Cylinders are rotated about the horizontal axis for 5 hours at the rate of 30 rpm.

v. After this period, the contents are taken out from the cylinders and they are passed through a sieve of 1.5mm mesh.

vi. Quality of material which is retained on the sieve is weighed.

vii. Percentage wear worked out as follows:

Percentage wear = $\frac{\text{Loss in weight}}{\text{Initial weight}} \times 100$

1. **Crushing Test:**

Samples of stone is cut into cubes of size 40x40x40 mm. sizes of cubes are finely dressed and finished. Maximum number of specimen to be tested is three. Such specimen should be placed in water for about 72 hours prior to test and therefore tested in saturated condition.

Load bearing surface is then covered with plaster of Paris of about 5mm thick plywood. Load is applied axially on the cube in a crushing test machine. Rate of loading is 140 kg/sq.cm per minute. Crushing strength of the stone per unit area is the maximum load at which the sample crushes or fails divided by the area of the bearing face of the specimen.

1. **Crystalline Test:**

At least four cubes of stone with side as 40mm are taken. They are dried for 72 hrs. And weighed. They are then immersed in 14% solution of Na_2SO_4 for 2 hours. They are dried at 100 degree C and weighed. Difference in weight is noted. This procedure of drying, weighing, immersion and reweighing is repeated at least 5 times. Each time, change in weight is noted and it is expressed as a percentage of original weight.

Crystallization of $CaSO_4$ in pores of stone causes decay of stone due to weathering. But as $CaSO_4$ has low solubility in water, it is not adopted in this test.

1. **Freezing and thawing test:**

Stone specimen is kept immersed in water for 24 hours. It is then placed in a freezing machine at -12 dig for 24 hours. Then it is thawed or warmed at atmospheric temperature. This should be done in shade to prevent any effect due to wind, sun rays, rain etc. this procedure is repeated several times and the behavior of stone is carefully observed.

1. Hardness Test:

For determining the hardness of a stone, the test is carried out as follows:

i. A cylinder of diameter 25mm and height 25mm is taken out from the sample of stone.
ii. It is weighed.
iii. The sample is placed in Dorry's testing machine and it is subjected to a pressure of 1250 gm.
iv. Annular steel disc machine is then rotated at a speed of 28 rpm.
v. During the rotation of the disc, coarse sand of standard specification is sprinkled on the top of disc.
vi. After 1000 revolutions, specimen is taken out and weighed.
vii. The coefficient of hardness is found out from the following equation:

Coefficient of hardness = $20 - \dfrac{\text{Loss of weight in gm}}{3}$

1. Impact Test:

For determining the toughness of stone, it is subjected to impact test in a Page Impact Test Machine as followed:

i. A cylinder of diameter 25mm and height 25mm is taken out from the sample of stones.
ii. It is then placed on cast iron anvil of machine.
iii. A steel hammer of weight 2kg is allowed to fall axially in a vertical direction over the specimen.
iv. Height of first blow is 1 cm that of second blow is 2cm that of third blow is 3 cm and so on.
v. Blow at which specimen breaks is noted. If it is nth blow, 'n' represents the toughness index of stone.

1. Microscopic Test:

The sample of the test is subjected to microscopic examination. The sections of stones are taken and placed under the microscope to study the various properties such as

i. Average grain size
ii. Existence of pores, fissures, veins and shakes
iii. Mineral constituents
iv. Nature of cementing material
v. Presence of any harmful substance
vi. Texture of stones etc.

1. Smith's Test:

This test is performed to find out the presence of soluble matter in a sample of stone. Few chips or pieces of stone are taken and they are placed in a glass tube. The tube is then filled with clear water. After about an hour, the tube is vigorously stirred or shaken. Presence of earthy matter will convert the clear water into dirty water. If water remains clear, stone will be durable and free from any soluble matter.

1. Water Absorption Test:

The test is carried out as follows:

i. From the sample of stone, a cube weighing about 50gm is prepared. Its actual weight is recorded as W_1 gm.
ii. Cube is then immersed in distilled water for a period of 24 hrs.
iii. Cube is taken out of water and surface water is wiped off with a damp cloth.
iv. It is weighed again. Let the weight be W_2 gm.
v. Cube is suspended freely in water and its weight is recorded. Let this be W_3 gm.
vi. Water is boiled and cube is kept in boiling water for 5 hours.
vii. Cube is removed and surface water is wiped off with a damp cloth. Its weight is recorded. Let it be W_4 gm.

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

Percentage absorption by weight after 24 hours = $\dfrac{W_2 - W_1}{W_1} \times 100$

Percentage absorption by volume after 24 hours = $\dfrac{W_2 - W_1}{W_2 - W_3} \times 100$

Volume of displaced water = $W_2 - W_3$

Percentage porosity by volume = $\frac{W_4 - W_1}{W_2 - W_3} \times 100$

Density = $\frac{W_1}{W_2 - W_3} kg/m^3$

Specific Gravity = $\frac{W_1}{W_2 - W_3}$

Saturation Coefficient = $\frac{\text{Water absorption}}{\text{Total porosity}} = \frac{W_2 - W_1}{W_4 - W_1}$

BRICKS

Manufacturing of bricks:-

Manufacturing of bricks is carried out in four distinct operation:-

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

1) *Preparation of clay*:-Preparation of clay is carried out in following distinct operations:-
    1) Unsoiling
    2) Digging
    3) Cleaning
    4) Weathering
    5) Blending
    6) Tempering

1) Unsoiling:-It is the process in which top 200 mm of the soil is removed as it is practically not possible to carry out the cleaning of this soil.

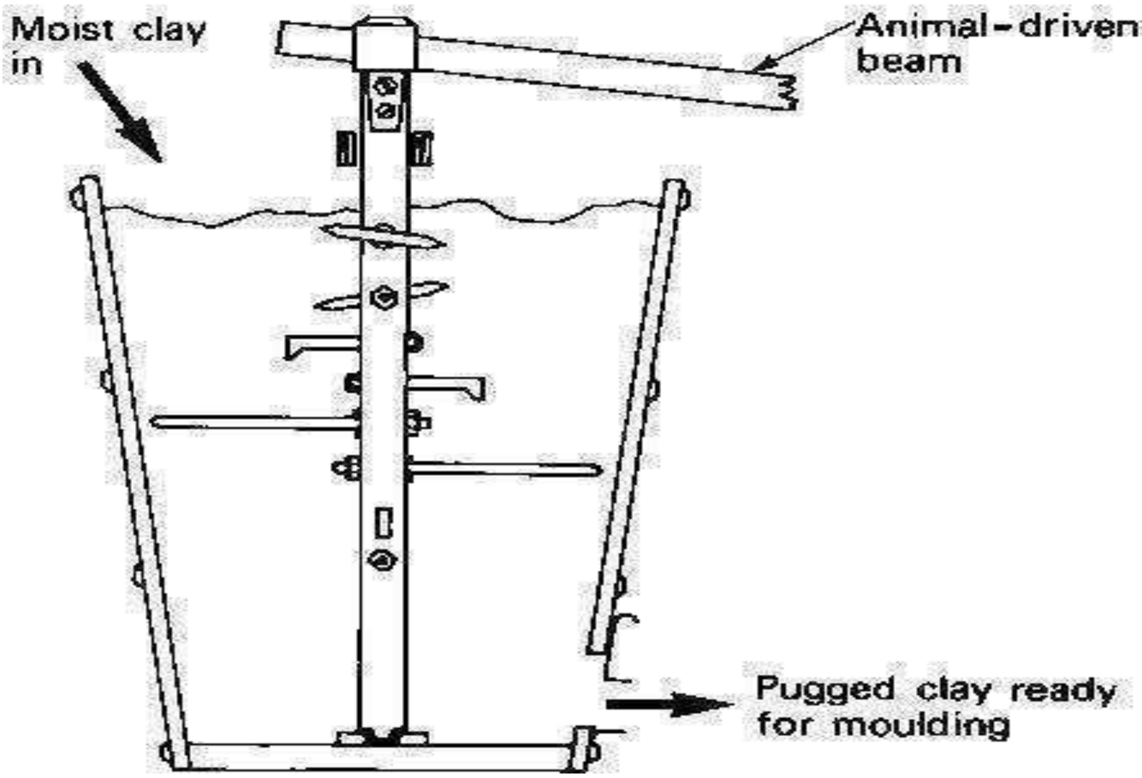
2) Digging: - The remaining soil is dug out and spread over the level field this process is referred as digging.

3) Cleaning:-It is the process of removal of impurities from the soil in which it is being cleaned for the presence of stones, pebbles, organic matter or vegetative matter.

4) Weathering:-It is the process in which clean soil is exposed to the atmosphere for few weeks to few months in order to carry out its softening, mellowing or ripening.

5) Blending:-It is the process in which clay is made loose and any ingredient of it is in deficiency spread over it.

6) Tempering:-It is the process in which water is added in the clay in order to bring it up to required plasticity as is required for the next operation of moulding. Tempering is generally carried out in pug mill.



2) *Moulding: -* It is the process of giving the required shape and size to the bricks. Moulding can be done either manually or mechanically. If moulding is done manually it is referred as hand moulding and if it is done mechanically it is referred as machine moulding. Moulding is done with the help of moulds which may be of steel or wood. The size of the mould is kept to be 8-12% greater than the actual size of brick in order to account for the shrinkage during drying and burning process. An indentation mark referred as Frog is left over the bricks during moulding that serves the following purposes:-

a) It is used to indicate the trade name of the manufacturer.

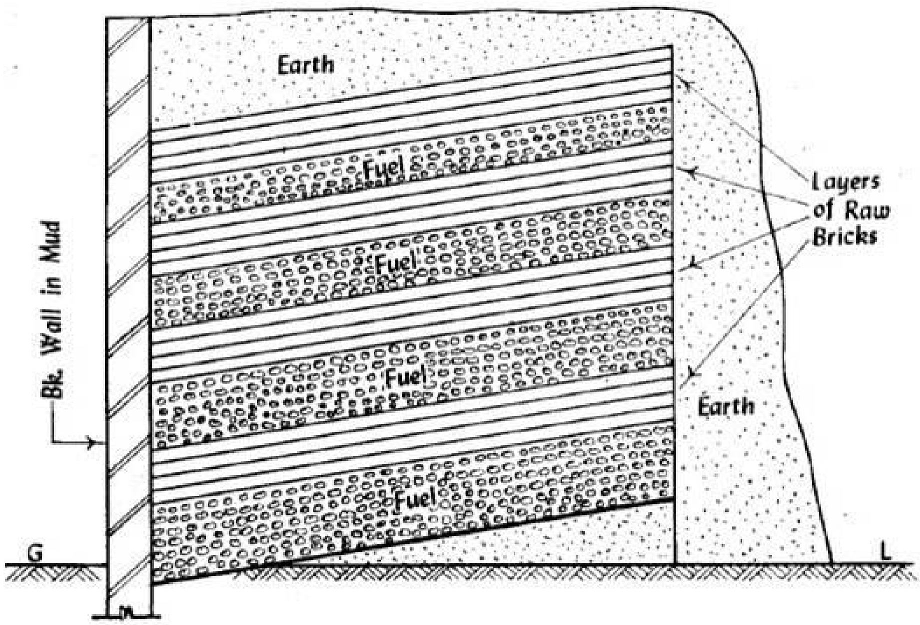
b) It acts as a key for motor it is used in between the bricks.
Increasing order of moulding is preferred as follows:-

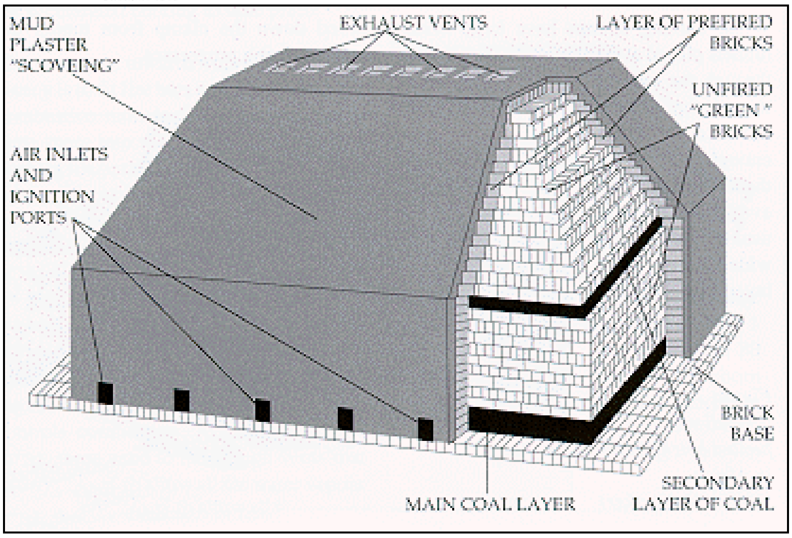
1) Dry Clay moulding
2) Plastic Clay moulding
3) Table moulding
4) Ground moulding

c) *Drying:* - Damp bricks if burnt directly are liable to crack and disintegrate, hence after moulding bricks are subjected to drying before subjecting it to the next operation of burning. Drying can be carried out other naturally or artificially in such a way that moisture content of bricks is reduced up to 2%.During drying which must be placed along the edge and not along the surface.

d) *Burning:*-It imparts strength and hardness to the brick and makes it more durable and dense Burning of bricks should be carried out properly as if bricks are over burnt, they become brittle and breaks easily, and if they are under burnt they remain soft and weak and are not able to carry the required load. Burning of the bricks takes place in the temperature range of 900 to 1200^{0}centigrade at which Alumina and silica fuse with each other thereby imparting strength to the bricks. Burning of the bricks can be carried out either in clamps or kilns

A) *Clamps:*-In order to prepare the clamps, a suitable piece of land is selected which is generally trapezoidal in plan. The shorter side is kept in excavation and the longer side is raised by an angle of 15 degree. A brick wall in mud is constructed along the shorter side and a layer of locally available fuel of thickness 700 mm to 800 mm is applied over the area. Which is further followed by the application of brick over it in the layer of approximately 5-6 courses is further followed by the application of fuel over it.Hence the entire clamp consists of alternate layer of fuel and bricks. The total height of Clamp is in the range of 3-4 Mt. and when 1/3rd of the clamp is constructed, fuel in the lower layer is burnt along with the subsequent construction of the clamp in upper layer. When the entire clamp is constructed it is covered with mud lining in order to avoid the escape of the heat through it.Bricks are allowed to burnt in it for the period of 2 to 4 weeks and further followed by the cooling of bricks for the same duration. As gradual burning and cooling of bricks is insured in this case bricks obtained from the clamps are comparatively stronger. More skilled supervision is required in this case and locally available fuel is used due to which this process is comparatively economical. Bricks obtained from the clamp are not of regular shape and size as there is no control over the burning in this case quality of brick obtained is not uniform. It is the time consuming process.





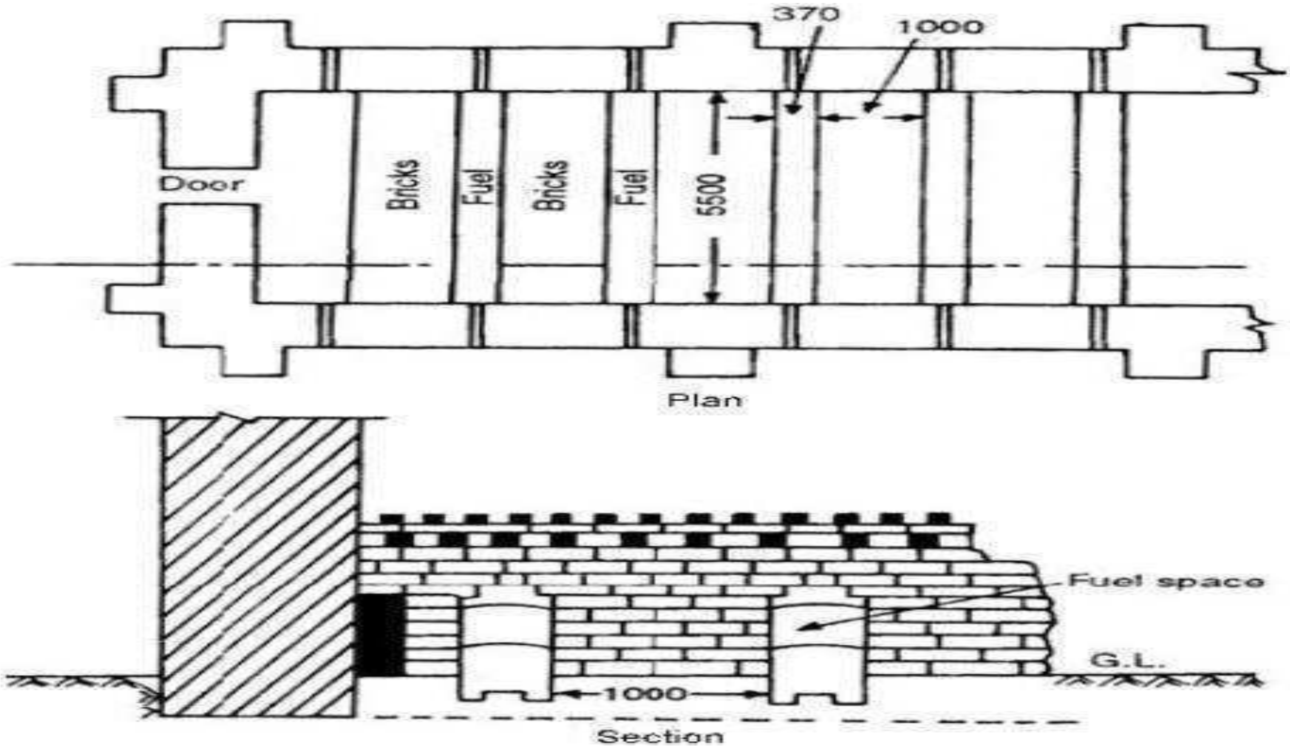
B) *Kilns:-*Kilns are larger ovens which are used for the burning of the bricks. Depending upon the supply of the brick obtained from this kilns they are classified into two:-

1) Intermittent kilns
2) Continuous kilns

1) ***Intermittent kiln:-*** These may be over ground or underground and they are classified into types:-

a) Intermittent up drought kiln
b) Intermittent down drought kiln

a) Intermittent up-drought kiln: - These kilns are in the form of rectangular structure with thick outside walls. Flues are provided to carry Flames of hot gases through the body of kiln. Top course is finished with flat bricks. Other courses or formed by placing bricks on edge. Strong fire is maintained for period of 48 to 60 hours.3



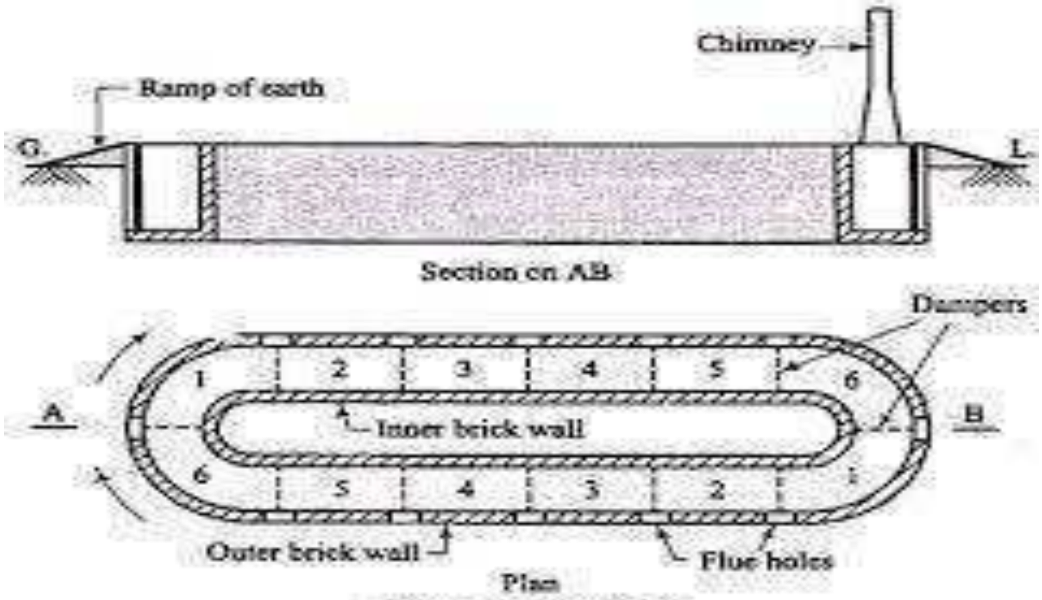
- Disadvantage:-
  1) The quality of burnt brick is not uniform. The brick near the bottom are over burnt and those near the top are under burnt.
  2) The supply of brick is not continuous.
  3) There is wastage of heat as kiln is to be cool down every time after burning

b) ***Intermittent down-drought kiln***:-These kilns are rectangular or circular in shape. They are provided with permanent walls and closed tight roof. The working of this is more or less similar to the up-drought kiln but it is so arranged in this kiln that hot gases are carried through vertical flues up to the level of roof and they are then released. These hot gases move downward by the chimney drought and in doing so, they burnt the bricks.

- Advantages:-
  1) Brick are evenly burnt.
  2) The performance of this kiln is better than that of up-drought kiln.
  3) There is closed control of heat and hence such kilns are useful for burning structural clay tiles, Terracotta etc.

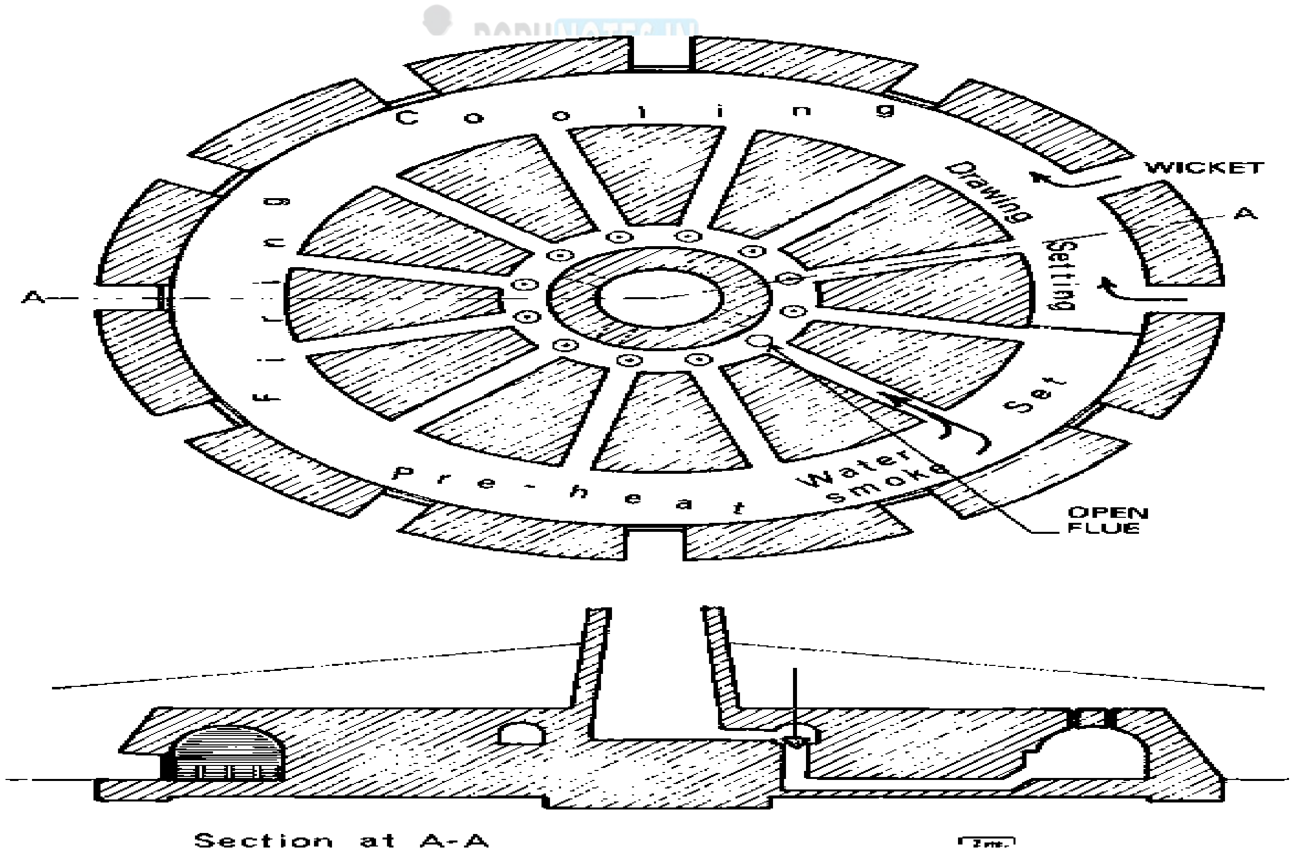
2) ***Continuous kilns:-***These are the type of kilns in which supply of the bricks is ensured to be continuous as all the operations of loading, burning, cooling and unloading are carried out simultaneously. These kilns are further of three types:-
   1) Bull Trench kiln
   2) Hoffman kiln
   3) Tunnel kiln

1) ***Bull Trench kiln***:-These kilns are either rectangular, circular, oval in plan and are constructed in excavation either partially or fully. In these kilns continuous supply of the bricks is ensured by carrying out all the operations of loading, burning, cooling and unloading simultaneously in different sections. It consists of two sets of movable chimneys which are placed one section ahead of the section in which burning is to be carried out which ensures preheating of the brick placed in the section over which Chimney is kept.

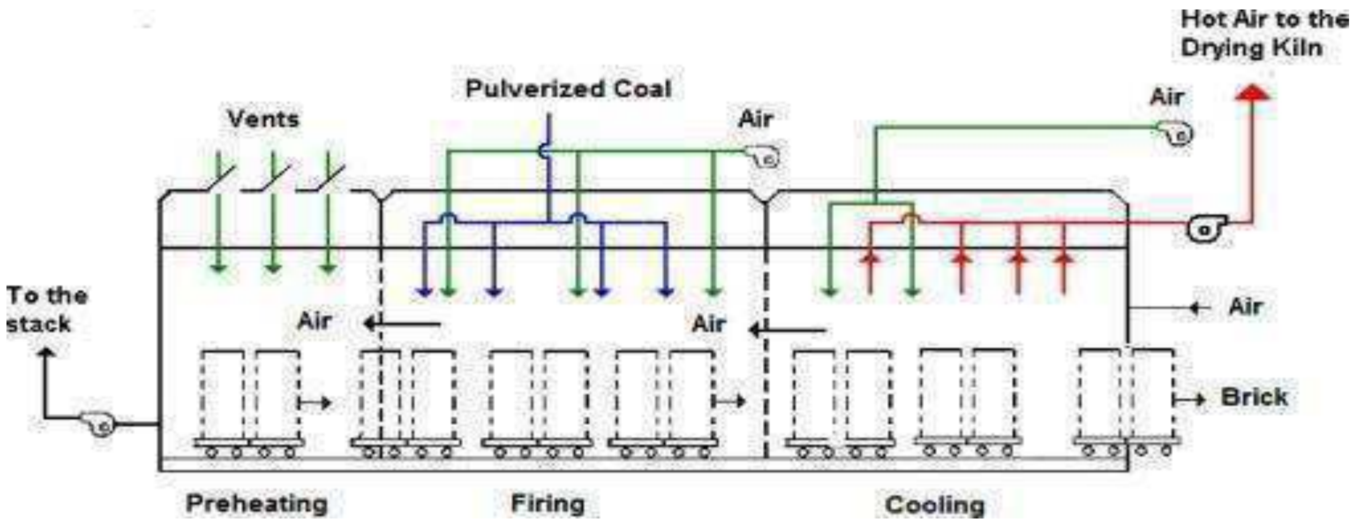


Bull's trench kiln
FIG. 4-6

2) ***Hoffman kiln:-***The Kilns are circular in plan constructed above the ground. In these kilns supply of the brick is ensure to be continuous by carrying out all the operations loading, burning, cooling and unloading simultaneously in different Chambers by effectively closing and opening different sets of Doors provided in a chamber the capacity of these kilns are comparatively greater than Bull Trench kiln.



3) ***Tunnel kiln: -*** These kilns are in the form of tunnels which may other have straight, rectangular or circular plan. These kilns consists of number of stationary Zone In which all the operations of loading, burning, cooling and unloading is carried out simultaneously. Bricks are placed over the trolleys or conveyor belts and passed through different zones in order to obtain the continuous supply of bricks.These kilns are found to be more economical if burning is carried out on large scale.



CHARACTERISTIC OF GOOD BRICKS

1) The bricks should be at least table molded, free from cracks and should have uniform bright colour.
2) The brick should be of uniform shape and size (Dimension test). Standard or modular size of the brick is 19 CM x 19 CM x 9 CM.
3) Size of conventional brick is 23 CM X 11.4 CM X 7.60 CM
4) Weight of $1m^3$ of brick is approximately 1800 kilogram hence the weight of one brick is approximately 3-3.5 kilogram.
5) The bricks must produce clear ringing sound when struck with each other (soundness test)
6) The brick must have uniform structure across any section free from voids(structure test)
7) BRICKS must not absorb more than 20% of the water by weight when immersed in water for 24 hours. For 1st class brick and not more than 22 % for second class bricks(Absorption test)
8) The bricks must not show any sign of staining when immersed in water for 24 hours (alkali test)
9) The BRICKS must possess minimum compressive strength of 3.5 N/mm^2(strength test)
10) The brick must not break into pieces when dropped over the hard surface from the height of 1 M (toughness test).
11) The brick must not show any sign or indentation mark over its surface when is scratched with finger nail (hardness test).

Note:-

- With increase in percent of silica, resistance of the brick against the action of acids increases.
- With the increase in percentage of magnesia resistance of bricks against the action of bases increases.
- With the increase in percent of Alumina and chromite neutral bricks are formed.

Use:-Bricks are used for building, block paving and pavement. Bricks in the metallurgy and glass industries are often used for lining furnaces, in particular refractory bricks such as silica, magnesia, chamotte and neutral (chromo magnesite) refractory bricks. This type of brick must have good thermal shock resistance, refractoriness under load, high melting point, and satisfactory porosity. Engineering bricks are used where strength, low water porosity or acid (flue gas) resistance are needed.

IMPROVED BRICK FROM INFERIOR SOILS

1) ***Manufacture of bricks from alumina red mud:-***

Developed by the Central Building Research Institute (CBRI) Roorkee, India.

Alumina red mud as a raw material for the brick-manufacturing industry

Alumina red mud or bauxite reject is one of the important inorganic waste materials obtained in large quantities from aluminium production plants. For the production of aluminium, bauxite ore is digested with caustic soda when most of the aluminium passes into solution as aluminate. The red colour residue, consisting mainly of alumina, iron oxide and titania with small quantities of silica, calcium oxide and alkali is left over as a major reject of the process.

In countries where there are huge reserves of bauxite there is the possibility of a manifold expansion of the aluminium industry. Thus, alumina red mud is going to create similar problems, due to serious pollution and indiscriminate disposal, in the very near future to those which flyash is creating today.

The physical properties of red mud, such as the colloidal nature of particles, plasticity, water absorption, mouldability and chemical composition showing the presence of alumina, iron oxide and fluxes, indicate the suitability of red mud to be disposed of in large quantities and used in the brick-making industry (or for flooring tiles). The suitability of red mud, to be used for the brick-making industry, is proved by the fact that only a slight modification, by incorporating some siliceous materials in the composition of red mud, is required. The Central Building Research Institute (CBRI) has carried out laboratory and field trials for making building bricks out of red mud supplied from three different aluminium plants in India. The test results show that the physical properties of bricks made by hand-moulding or extrusion are similar to normal building bricks. In many cases a very high compressive strength is obtained due to better fluxing action that is produced by the red mud. The bricks can be made and dried in the usual way and fired in any type of traditional brick kilns.

2) Manufacture of bricks from red murrum soil:-Developed by the Central Building Research Institute (CBRI), Roorkee, India. Red murrum soils present difficulties in producing good quality bricks due to their coarse, highly siliceous and non-plastic nature, short vitrification range and lime-bursting. Generally, bricks produced out of red murrum soils are porous and of low strength (20-25 kg/cm^2). The Central Building Research Institute (CBRI) has been studying the murrum soil of Hyderabad for some time and has developed processes for making bricks of a compressive strength in the range of 100 kg/cm^2 from it.

CONCRETE

Concrete is a composite, manmade material and is most widely used building material in the construction industry. It is a mixture of binding material such as lime or cement, well graded coarse and fine aggregate, water and sometimes admixture. Basic requirements of good concrete is that it should be satisfactory in its hardened state and also in its fresh state while being transported from mixture and placed in formwork. In fresh state consistency of mix should be such that it can be compacted by Desire means without excessive effort and also the mix should be cohesive enough for the methods of transporting and placing used so as not to cause segregation. In hardened state satisfactory compressive strength and an adequate durability is required.

INGREDIENTS OF CONCRETE

Concrete is a mixture of cement, aggregate and water and the function of ingredients are as follows:-

a) *Cement:-*It imparts adhesive and cohesive property to concrete and binds various ingredients into a compact whole
b) *Aggregate:-*They form body of concrete and occupy 70 to 80% volume of concrete they further classified as fine and coarse aggregate
c) *Water:-*It causes hydration of cement for uniform strength of concrete.

GRADES OF CONCRETE

M5 - 1:5:10	M7.5 - 1:4:8
M10 - 1:3:6	M15 - 1:2:4
M20 - 1:1.5:3	M25 - 1:1:2

PRODUCTION OF CONCRETE

The various stages of concrete production are:-

1) Batching or measurement of materials
2) Mixing
3) Transporting
4) Placing

5) Compacting
6) Curing
7) Finishing

1) *Batching:-*Aggregates cement and water should be measured with an accuracy of ±3% of batch quantity and the admixture by 5% of the batch quantity. Two methods of batching of materials
   1) Volume batching
   2) Weight batching

   For important works weigh batching is preferred. Volume batching is used for small jobs only. Volume of 1 bag of cement is 0.035 M^3or (sometimes also said 35litre)

2) *Mixing*:-Mixing is done to obtain homogeneous and uniform colour concrete having desired strength. Mixing time depends on type and capacity of mixer but IS 456 suggest approximately mixing time as 2 minute. If mixing time is increased to 2 minutes the compressive strength of concrete produced is enhanced and beyond this time the improvement in compressive strength of concrete is insignificant and prolonged mixing may cause segregation as due to longer mixing period the water may get absorbed by the aggregates or evaporation resulting in loss of workability and strength. Mixing is done by hand or by machine mixing. Hand mixing is done for smaller jobs. Machine mixing is done for large work

3) *Transporting:-*Specifications states that process of mixing, transporting, placing and compacting of concrete should not take more than initial setting time of cement that is 30 minute if using OPC. It must also ensure that segregation not took place. The various methods of transporting of concrete are pans, wheelbarrows, power buggies, transit mixer, belt conveyor etc.

4) *Placing:-*Research has shown that delayed placing of concrete results in gain in ultimate compressive strength provided the concrete can be adequately compacted. For dry mixes in hot weather delay of half to one hour is allowed whereas for wet mixes in cold weather it may be several hours. for example:- Mass concreting:- when a concrete is laid in mass as for raft Foundation, Dam, Bridge, piers etc. concrete is placed in layers of 350 to 450 mm thickness.

5) *Compaction:-*The process of removal of entrapped air and of uniform placement of concrete to form a homogeneous dense mass is termed compaction. The density and consequently the strength and durability of concrete depends upon the quality of compaction. The presence of even 5% and 10% voids in hardened concrete left due to incomplete compaction may results in decrease in compressive strength by about 30% and 60% respectively.

   Compaction of concrete can be achieved by the following
   1) Hand rodding
   2) High pressure and shock
   3) Centrifugation or spinning
   4) Mechanical vibration

6) *Curing*:-Cement gains strength and hardness because of chemical reaction between cement and water. The water in a concrete mix takes one of the following three forms as a consequence of hydration:-
   1) *Combined water*:-Which is chemically combined with the products of hydration it is non evaporable.
   2) *Gel water: -* Which is held physically or absorbed on the surface area of the cement gel.
   3) *Capillary water: -* Which partially occupies the 'capillary pores' that constitute the space in the cement paste remaining after accounting for the volumes of cement gel and unhydrated cement. This water is easily evaporable.

Curing is name given to procedures that are employed for actively promoting the hydration of cement in a suitable environment during early stages of hardening of concrete. IS: 456 define curing as the process of preventing the loss of moisture from the concrete while maintaining a satisfactory temperature regime. Curing of freshly placed concrete is very important for optimum strength and durability. The major part of the strength in the initial period is contributed by the clinker compound C_3S and partly by C_2S and is completed in about 3 weeks. Curing must be done for at least three week and in no case for less than 10 days. Increase in strength of concrete is very rapid from 3 to 7 days and continues slowly for indefinite period. It has to be observed that moist cured concrete for 7 days is nearly 50% stronger than that which is exposed to dry air for entire period. If concrete is cured for 1 month strength is nearly double than that of concrete exposed to dry air.

Objective of curing:-

1) To keep capillary pores saturated, to ensure hydration of cement to increase durability and impermeability of concrete and reduce the shrinkage.
2) It improves wear resisting and weather resisting qualities.
3) To improve the loss of moisture from concrete due to evaporation or any other reason. Supply additional moisture or heat and moisture to accelerate the gain of strength.

Method of curing:-

1) Shading concrete work.
2) Covering concrete surface with wet hessian or gunny bags.
3) Sprinkling water on concrete surface
4) Ponding method: - it is best method and generally used in practice.
5) Steam curing: - recommended for precast concrete members.
6) Applying curing compound.

- As per IS: 456 concrete members shall be kept under curing of minimum period of 7 days. For OPC (7 to 14 days) at 90% humidity.
- Curing temperature: 5 ^{0}Cto 28^{0}C.

- NOTE: - Lower temperature reduces the rate of setting and higher temperature reduces ultimate strength.

Steam curing:-For concrete mixes with water cement ratio ranging from 0.3 to 0.7, the increased rate of strength development can be achieved by resorting to steam curing. This method of curing is also known as *accelerated curing* since an increased rate of strength development can be achieved. Concrete members are heated by and steam at 93^{0}C either at lower pressure or high pressure. By low pressure steam curing about 70% of 28 days compressive strength of concrete can be obtained in about 16 to 24 hours and high pressure steam curing is usually applied to precast concrete members and given 28 days compressive strength at 24 hours. It also results in increased resistance to sulphate action and to freezing and thawing. Mixes with low water cement ratio respond more favourable to steam curing than those with higher water cement ratio. Early rise in temperature at the time of setting of concrete may be detrimental because the green concrete may be too weak to resist the air pressure setup in the pores by the increased temperature. Rate of increase or decrease of temperature should not exceed 10 to 20 degree centigrade per hour to avoid thermal shock. Steam curing should be followed by water curing for a period of at least 7 days. This supplementary wet curing is found to increase the later age strength of steam cured concrete by 20 to 35%. Rapid gain of strength can be obtained with the help of infrared radiation then even with steam curing. Rapid initial rise of temperature does not affect the ultimate strength.

Effect of improper curing:-

1) Chances of ingress of chlorides and Chemicals are very high.
2) The cracks are formed due to plastic shrinkage.
3) The rate of carbonation increases.
4) The durability decreases due to high permeability.

7) *Finishing*: - Finishing is defined as the process of levelling and smoothing the top surface of freshly placed concrete to achieve the desired appearance.

SPECIAL CONCRETES

1) concrete Lightweight concrete

Lightweight concretes can either be lightweight aggregate concrete, foamed concrete or autoclaved aerated concrete (AAC). Lightweight concrete blocks are often used in house construction.

Lightweight aggregate

Lightweight aggregate concrete can be produced using a variety of lightweight aggregates. Lightweight aggregates originate from either:

- Natural materials, like volcanic pumice.
- The thermal treatment of natural raw materials like clay, slate or shale i.e. Leca.
- Manufacture from industrial by-products such as fly ash, i.e. Lytag.
- Processing of industrial by-products such as pelletised expanded slab, i.e. Pellite.

The required properties of the lightweight concrete will have a bearing on the best type of lightweight aggregate to use. If little structural requirement, but high thermal insulation properties, are needed then a light, weak aggregate can be used. This will result in relatively low strength concrete.

2) HIGH STRENGTH CONCRETE

The definition of high strength concretes is continually developing. In the 1950s a cube strength of 35MPa was considered high strength, and in the 1960s compressive strengths of up to 50MPa were being used commercially. More recently, compressive strengths approaching 140MPa have been used in cast-in-place buildings. Eurocode 2 allows for concrete strengths of up to 105MPa cube strength. There is no definition of high strength concrete in Eurocode 2, but the measures and formulae change when the concrete strength is greater than C50/60 so this seems a reasonable working definition.

3) High workability concrete

The workability of fresh concrete should be suitable for each specific application to ensure that the operations of handling, placing and compaction can be undertaken efficiently.

BS EN 206 and BS8500 the European and UK standards for concrete give guidance on workability for different uses. The handling and placing properties of concrete mixes can be improved considerably by the use of cement replacement materials such as fly ash. Furthermore, the use of admixtures such as water reducers and superplasticisers has beneficial effects on workability without compromising other concrete properties.

On site productivity can be greatly increased by utilising highly workable concretes. They are especially suitable in the following applications:

- Inaccessible locations
- Large flat areas
- Underwater applications
- Pumping concrete over long distances.

4) No-fines concrete

No-fines concrete is obtained by eliminating the fine material sand, from the normal concrete mix. The single-sized coarse aggregates are surrounded and held together by a thin layer of cement paste giving strength of concrete.

The advantages of this type of concrete are:

- Lower density.

- Lower cost due to lower cement content.
- Lower thermal conductivity relatively low drying shrinkage.
- No segregation and capillary movement of water.
- Better insulating characteristics than conventional concrete because of the presence of large voids.

No-fines concrete is not suitable for use in reinforced concrete.

5) Self-compacting concrete (SCC)

Self-compacting concrete (SCC) is a flowing concrete that does not require vibration and, indeed, should not be vibrated. It uses super plasticisers and stabilisers to significantly increase the ease and rate of flow. It achieves compaction into every part of the mould or formwork simply by means of its own weight without any segregation of the coarse aggregate.

The consistence of the concrete is specified and measured as a flow rate rather than the normal slump test. SCC offers:

- Health and safety benefits (as no vibration is required).
- Faster construction times.
- Increased workability and ease of flow around heavy reinforcement.
- Excellent durability.

Having no need for vibrating equipment spares workers from exposure to vibration. No vibration equipment also means quieter construction sites.

