

# Building Materials

## (Unit-4)

### 4.1 Portland Cement: Composition:

Cement is a construction materials which posses adhesive and cohesive properties and used for binding the building blocks, bricks, stones etc. It is a mixture of silicates of calcium and aluminium.

**Chemical Composition of Portland cement:** Cement contains silica, lime and alumina. The proportion this continece in cements should be maintained to get good quality cement. A paste of cement with water on setting and hardening gave a hard mass whose color and hardness were similar to those of stones from Portland in England. Thus, it derived the name Portland cement. Portland cement is a mixture of silicates of calcium and aluminium. Major constituents of cement

1. Dicalcium silicates ( $2\text{CaO} \cdot \text{SiO}_2$ )- 28% [ $C_2S$ ]
2. Tricalcium silicates ( $3\text{CaO} \cdot \text{SiO}_2$ )-46%  $C_3S$
3. Tricalcium aluminates ( $3\text{CaO} \cdot \text{AL}_2\text{O}_3$ )-10% [ $C_3A$ ]
4. Tetra calcium aluminoferrite ( $4\text{CaO} \cdot \text{AL}_2\text{O}_3 \cdot \text{Fe}_2\text{O}_3$ )-9% [ $C_4AF$ ]
5. Small quantities of CaO and MgO- 7%

### Manufacture of cement by wet process

**Raw materials required:** 1. Calcareous materials – These materials supply lime. Examples: Limestone, chalk, marble

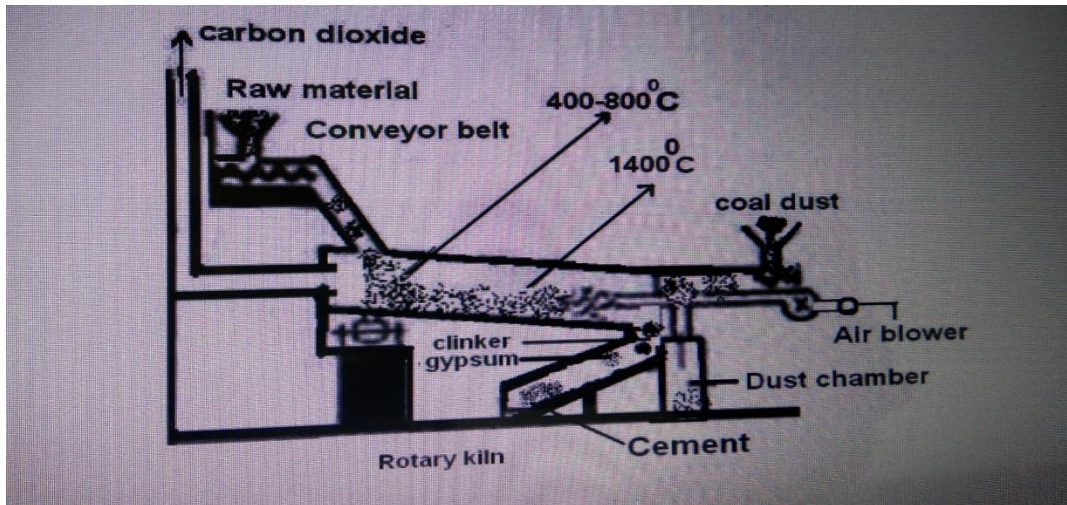
2. Argillaceous materials – These materials supply silica. Example: Clay

3. Powdered coal (fuel)

#### 4. Gypsum

**Process:** The cement is manufactured by wet process as follows.

1. The limestone is crushed and powdered well.
2. The clay is intimately mixed with water in wash mill.
3. The powdered limestone and wet clay are mixed and made into a paste in a grinding mill. This paste is known as slurry. The slurry contains 30 to 40% water.
4. The slurry is fed into the top of the rotary kiln. The rotary kiln is made of steel plates lined with fire bricks.
5. The kiln is heated by burning powdered coal which is injected at the lower end by an air blast.
6. In the upper part of the kiln (drying zone) where the temperature is  $400^{\circ}\text{C}$ , the slurry loses all its water.
7. When the charge enters the middle portion of the kiln (calcinations zone) where the temperature is about  $900 - 1000^{\circ}\text{C}$ , limestone decomposes to form  $\text{CaO}$  and  $\text{CO}_2$ .
8. Then the charge enters lower portion of the kiln (burning zone) where the temperature is about  $1400^{\circ}\text{C}$ . Lime and clay combines to form calcium silicates and aluminates called clinker.
9. The hot clinker is cooled and then grinded with 3 – 4% gypsum in a grinding mill. Gypsum retards the setting of cement. In the absence of gypsum, cement sets rapidly.
10. The cement coming out of the grinding mills is stored in concrete storage tanks and then packed in bags.



## Setting and hardening of cement:

### Setting and Hardening of Portland cement:

Cement is mixed with water to produce a plastic paste. The past is subjected to hydration and gelatin and finally crystalline products are formed.

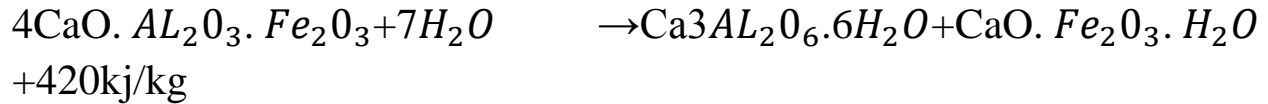
a) Initial setting of cement involves hydration of tricalcium aluminate.



b) Second step of the reaction involves gelatin in which tobermonite gel is formed. It also produces calcium hydroxide and hydrated tricalcium aluminate.



c) Crystallisation of tricalcium aluminate takes place, even though initial reaction involve the formation of tetracalcium aluminate. Hardening of tricalcium aluminate takes place finally through crystallization.



**Special cements:** Special cements are cements that serve some specific function such as altering the setting or hardening behavior of a concrete, producing different colors for architectural effects, imparting superior workability, imparting water retention and plasticity to mortars, resisting the penetration of water in walls or containment vessels or simply reducing the cost of the cementing agent.

#### Different Types Of Cement

- Ordinary Portland Cement (OPC) ...
- Portland Pozzolana Cement (PPC) ...
- Rapid Hardening Cement. ...
- Extra Rapid Hardening Cement. ...
- Low Heat Cement. ...
- Sulfates Resisting Cement. ...
- Quick Setting Cement. ...
- Blast Furnace Slag Cement.

**4.2 Glass: Definition:** Glass is an engineering material. It may be defined as an amorphous, rigid, brittle, hard, transparent super cooled liquid. It is resistant to heat. It is a transparent mixture of silicates of potassium or sodium. It is produced by the fusion of certain basic oxides and acidic oxides, with sand and other materials.

**Composition of Glass:** The composition of some common varieties of glass is as follows.

1. Soda lime glass  $\text{Na}_2\text{O} \cdot \text{CaO} \cdot 6\text{SiO}_2$ .
2. Potash lime Glass:  $\text{K}_2\text{O} \cdot \text{CaO} \cdot 6\text{SiO}_2$ .
3. Potash lead glass:  $\text{K}_2\text{O} \cdot \text{PbO} \cdot 6\text{SiO}_2$ .

**Raw material required for the manufacture of glass:** The raw materials for the manufacture of ordinary glass are of two kinds.

1. Acidic oxides: sand ( $\text{SiO}_2$ ). Boron oxides ( $\text{B}_2\text{O}_3$ ).

2. Basic oxides: Sodium-oxides ( $\text{Na}_2\text{O}$ ), potassium oxides ( $\text{K}_2\text{O}$ ), calcium oxides ( $\text{Ca}_2\text{O}$ ), Lead Oxide ( $\text{PbO}$ ), Zinc Oxide ( $\text{ZnO}$ ), Magnesium Oxide ( $\text{MgO}$ ) and Aluminum Oxide ( $\text{Al}_2\text{O}_3$ ).

**Manufacture of Glass: Raw materials are:**

1. Sand
2. Sodium carbonate
3. Calcium carbonate.

Mixing: The raw materials are powdered well and they are mixed homogeneously. With this some of the broken glass powders are also added to get an intimate mixture known as "Batch".

Fusion: The batch is then transferred to the tank or pot furnace. This batch is heated to  $1400\text{--}1500^\circ\text{C}$ . At this temperature the substances present in the batch react together forming a mixture of silicates. This mixture of silicates is known as glass.

Fining: The molten glass is kept at the highest temperature for some time to remove gas bubbles. This is called fining.  $\text{Na}_2\text{CO}_3$  is often added to lower the viscosity of the molten glass. The impurities rise to the top as scum and it is removed. Cullet, oxidizing agents, reducing agents and other materials are also added to the molten glass according to the requirements.

Fabrication: Coloring material may be added to the molten glass to get desired coloured glass. Molten glass is then moulded or fabricated into articles of desired shape by blowing, moulding, or pressing.

**Colouring Materials:**

1. Cobalt oxides            -Blue
2. Cuprous salt            -Red
3. Chromium oxide        -Green
4. Ferric iron            - yellow
5. Potassium dichromate -Green

**Types: Annealing of Glass:** The method of slow cooling of glass is called annealing. If the manufactured hot glass articles are cooled suddenly, it will easily break. To avoid this glass is cooled very slowly by passing them through several hot chambers. The temperature of the hot chamber is in the decreasing order gradually. This process of slow cooling of glass is called as annealing. The annealing temperature varies for different types of glasses.

**Photo chromatic glass:** Photo chromic lenses are lenses that darken on exposure to specific types of light, most commonly ultraviolet radiation. Once the light source is removed, the lenses will gradually return to their clear state. Photo

chromic lenses may be made of glass, polycarbonate, or another plastic. Traditional photo chromic eyeglasses are generally alkali Boro-alumino -silicates with 0.01 to 0.1 percent silver halide and a small amount of copper. Upon absorption of light, the silver ion reduces to metallic silver, which nucleates to form colloids about 120 angstroms in size. This is small enough to keep the glass transparent, but the colloids are dense enough to make the glass look gray or black.

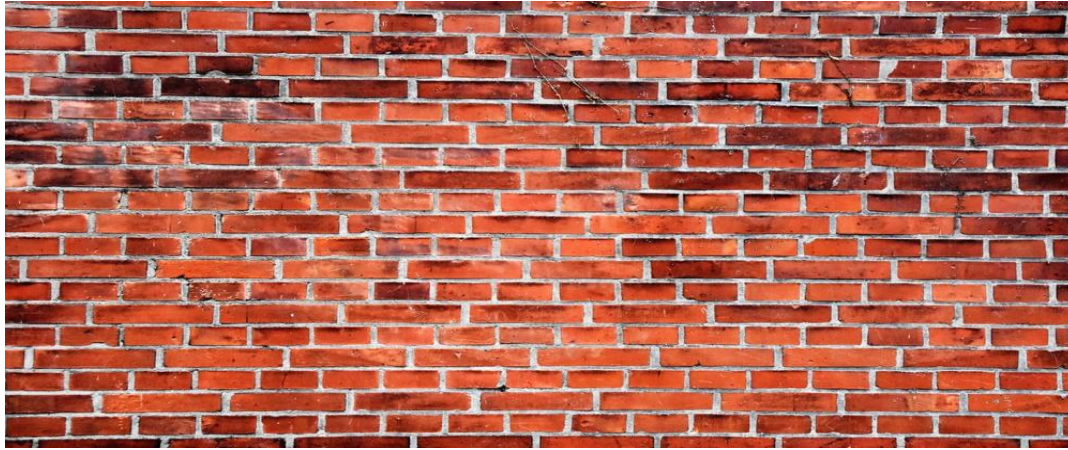
**Windshield glass:** A framed pane of usually curved glass or other transparent shielding located in front of the occupants of a vehicle to protect them from the wind. A shield placed to protect an object from the wind. Modern windshields are generally made of laminated safety glass, a type of treated glass, which consists of two (typically) curved sheets of glass with a plastic layer laminated between them for safety, and are bonded into the window frame. Motorbike windshields are often made of high-impact acrylic plastic.

**Laminated glass** is produced by permanently bonding two pieces of glass together with a tough Glass plastic interlayer (polyvinyl butyral, PVB) under heat and pressure. Once bonded together, the glass and which acts as a single unit and generally appears very similar to standard clear glass. The inter layer is virtually invisible when viewed in transmission with glass on either side.

Windshields protect the vehicle's occupants from wind and flying debris such as dust, insects, and rocks, and provide an aerodynamically formed window towards the front.

**Optical glass: (Crown glass)** Optical glass is a type of optical glass used in lenses and other optical components. It has relatively low refractive index ( $\approx 1.52$ ) and low dispersion Crown glass is produced from alkali-lime (RCH) silicates containing approximately 10% potassium oxide and is one of the earliest low dispersion glasses.

### **4.3 Bricks: Classification and preparation**



## BRICKS

- Brick is obtained by moulding good clay into a block, which is dried and then burnt.
- It is the oldest building block to replace stone.
- Manufacture of brick started with hand moulding, sun drying and burning in clamps.
- A considerable amount of technological development has taken place with better knowledge about to properties of raw materials, better machineries and improved techniques of moulding drying and burning.
- Nowadays, bricks are made from specially selected & matured brick-earth consisting chiefly of **silica (35-70%) and alumina (10-20%)**.
- Too much silica makes the brick brittle & too much alumina makes the brick distort (twist) & crack on burning.
- It is desirable to **add lime, magnesia & iron oxide**, which act as colouring agent & flux (fluctuation) to assist fusion during burning of brick earth.
- Clay when heated to **low temperatures**, it loses moisture & only physical changes occur.
- Such half-burnt clay crumbles when placed in water.
- However, when clay is heated to **high temperatures**, its constituents fuse, & chemical changes takes place.

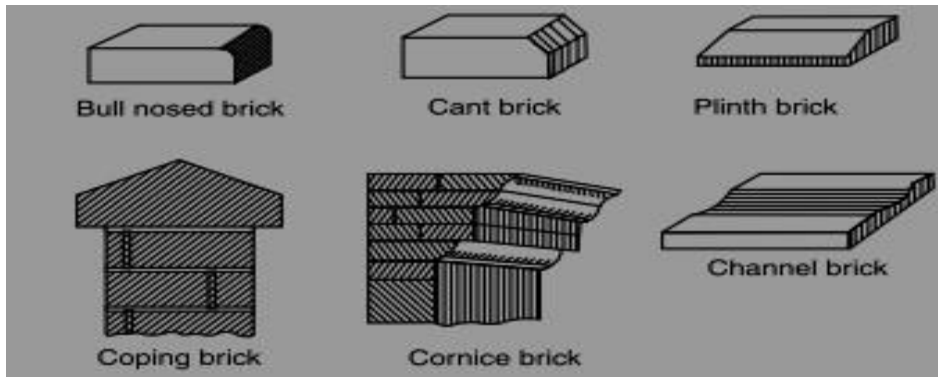
- Size of the bricks: 19 cm × 9 cm × 9 cm.
- With mortar joints, size of bricks: 20 cm × 10 cm × 10 cm.

## **Types of Bricks**

- Bricks may be broadly classified as:
  - **Building** bricks: These bricks are used for construction of walls.
  - **Paving** bricks: These are vitrified bricks & are used as pavers.
  - **Fire** bricks: These bricks are specially made to withstand furnace temperature. **Silica bricks** belong to this category.
  - **Special** bricks: These bricks are different from the commonly used building bricks with respect to their shape and the purpose for which they are made.
- Specially shaped bricks
- Facing bricks
- Perforated building bricks
- Burnt clay hollow bricks
- Sewer bricks
- Acid resistant bricks
- Fireclay Bricks
- Silicon Carbide bricks

### **1) Specially Shaped Bricks:**

Bricks of special shapes are manufactured to meet the requirements of different situations.



**2) Facing Bricks:** These bricks are used in the **outer face of masonry**. Once these bricks are provided, plastering is not required. Standard sizes:  $190 \times 90 \times 90$  mm or  $190 \times 90 \times 40$  mm.

### 3) Perforated (Puncture) Building Bricks:

- These are manufactured with area of perforation of 30-45%. Area of each perforation not  $> 500$  mm<sup>2</sup>. Perforation should be uniformly distributed over the surface. Size:  $190 \times 190 \times 90$  mm and  $290 \times 90 \times 90$  mm.

### 4) Burnt Clay Hollow Bricks:

- They are **light in weight**.
- They are used for the **construction of partition walls**.
- They provide **good thermal insulation** to buildings.
- They are manufactured in sizes  $190 \times 190 \times 90$  mm,  $290 \times 90 \times 90$  mm and  $290 \times 140 \times 90$  mm.



- Thickness of any shell should not be less than 11 mm and that of any web not less than 8 mm.

#### 5) Sewer Bricks:

- These are used for **construction of sewage lines**.
- They are manufactured from surface clay, fire clay shale or with the combination of these.
- They are manufactured in sizes 190×90×90 mm & 190 × 90 × 40 mm.
- Average strength of these bricks should be a minimum of 17.5 N/mm<sup>2</sup>.
- Water absorption not > 10%.

#### 6) Acid Resistant Bricks:

- Used for floorings likely to be subjected to acid attacks, lining of chambers in chemical plants, lining of sewers carrying industrial wastes etc.
- Made of clay or shale of suitable composition with low lime and iron content, flint or sand and vitrified at high temperature in a ceramic kiln.

#### 7) Fireclay Bricks:

- Made for lining in devices such as furnaces, ovens and other places which are exposed to high temperatures.
  - Also called as **refractory bricks**.
  - They are made from special clays called fireclay.
  - These bricks should be laid with fireclay mortar and not with cement mortar, when built as lining for chimneys.
  - They are available as acidic, basic & neutral bricks.

## 8) Silicon carbide bricks:

- Made of silicon and carbon.
- Used in electric resistance furnace.

## Preparation of Bricks:

Following are the steps for preparation of bricks:

- **Preparation of clay**
- **Moulding of Bricks**
- **Burning of Clay**
- After removal of vegetation, clay deposits are excavated in *steps* rather than in layers to ensure a better distribution of several constituents which vary in different proportions at different depths.
- Further processing depends on type of bricks to be made.
  - For ordinary bricks, only mixing by crushing is done.
  - For Ist class facing bricks, clay is allowed to weather by keeping it exposed to open air for a considerable time so that lumps of clay breakdown into smaller particles.
  - For very superior bricks, clay is washed & processed before moulding into bricks.
  - For Clay tiles, processed clay is used.
- Bricks are moulded in various ways depending on the quality of product to be made.
- They may be hand-moulded or machine- moulded or pressed by machines or in moulds.

## Burning of Clay

- It is carried out in temporary clamps or in permanent kilns.

- **In clamps**, one batch of green bricks is heaped along the firewood, coal, etc. & sealed with clay.
- It is then fired slowly to high intensity in many days.
- **Modern kilns** are permanent structures consisting of many chambers.
- They are intermittent & continuous kilns.
- Moulded clay is stacked in the chambers.
- They are then slowly dried & burned to high temperature & cooled.
- One cycle of loading, drying, burning, cooling & emptying may take atleast 2 weeks.
- These processes are carried out intermittently in intermittent kilns & in cyclic order in continuous kilns.
- Nowadays, kilns have almost replaced the clamps as heat can be controlled better in kilns & bricks produced in kilns are of uniform quality.
- Also it saves cost of fuel.

### **Properties of Bricks**

- **Colour:** Colour should be uniform & bright.
- **Shape:** Bricks should have plane faces. They should have sharp & true right angled corners.
- **Size:** Bricks should be of standard sizes as prescribed by codes.
- **Texture:** They should possess fine, dense & uniform texture. They should not possess fissures, cavities, loose grit & un-burnt lime.
- **Soundness:** When struck with hammer or with another brick, it should produce metallic sound.
- **Hardness:** Finger scratching should not produce any impression on the brick.

- **Strength:** Crushing strength of brick should not be  $< 3.5 \text{ N/mm}^2$ . A field test for strength is that when dropped from a height of 0.9 m to 1m on a hard ground, the brick should not break into pieces.
- **Water Absorption:** After immersing the brick in water for 24 hours, water absorption should not be  $> 20\%$  by weight. For class-I works this limit is 15%.
- **Efflorescence:** Bricks should not show white patches when soaked in water for 24 hours and then allowed to dry in shade. White patches are due to the presence of sulphate of calcium, magnesium and potassium. They keep the masonry permanently in damp and wet conditions.
- **Thermal Conductivity:** Bricks should have low thermal conductivity, so that buildings built with them are cool in summer and warm in winter.
- **Sound Insulation:** Heavier bricks are poor insulators of sound while light weight and hollow bricks provide good sound insulation.
- **Fire Resistance:** Fire resistance of bricks is usually good. In fact bricks are used to encase steel columns to protect them from fire.

### Tests on Bricks

- The following laboratory tests may be conducted on the bricks to find their suitability:
  - Crushing strength
  - Absorption
  - Shape and size
  - Efflorescence

### Crushing Strength

- Brick specimen is immersed in water for 24 hours.

- Frog of the brick is filled with 1:3 cement mortar and the specimen is stored in damp jute bag for 24 hours and then immersed in clean water for 24 hours.
- Specimen is placed in compression testing machine with 6 mm plywood on top and bottom of it to get uniform load on the specimen.
- Then load is applied axially at a uniform rate of 14 N/mm<sup>2</sup>.
- Crushing load is noted. Then the crushing strength is the ratio of crushing load to the area of brick loaded.
- Average of 5 specimens is taken as the crushing strength.
- Brick specimens are weighed dry. Then they are immersed in water for a period of 24 hours.
- Specimen are taken out and wiped with cloth.
- Weight of each specimen in wet condition is determined.
- Difference in weight indicates the water absorbed.
- Then the percentage absorption is the ratio of water absorbed to dry weight multiplied by 100. The averages of 5 specimens are taken.
- Value should not > 20%.
- Bricks should be of standard size and edges should be truly rectangular with sharp edges.
- To check it, 20 bricks are selected at random and they are stacked along the length, along the width and then along the height.
- For standard bricks of size 190 mm × 90 mm × 90 mm. IS code permits the following limits:
  - Lengthwise: 3680 to 3920mm
  - Widthwise: 1740 to 1860mm
  - Height wise: 1740 to 1860 mm.

Following tests help in ascertaining good quality bricks:

- Uniformity in size
- Uniformity in colour
- Structure
- Hardness test
- Sound test
- Strength test.
- **Uniformity in Size:** A good brick should have rectangular plane surface and uniform in size. This check is made in the field by observation.
- **Uniformity in Colour:** A good brick will be having uniform colour throughout. This observation may be made before purchasing the brick.
- **Structure:** A few bricks may be broken in the field and their cross-section observed. The section should be homogeneous, compact and free from defects such as holes and lumps.

**Sound Test:** If 2 bricks are struck with each other they should produce clear ringing sound. The sound should not be dull.

- **Hardness Test:** For this a simple field test is scratch the brick with nail. If no impression is marked on the surface, the brick is sufficiently hard.
- Presence of alkalies in brick is not desirable because they form patches of gray powder by absorbing moisture.
- Hence to determine the presence of alkalies this test is performed as explained below:
- Place the brick specimen in a glass dish containing water to a depth of 25 mm in a well ventilated room.
- After all the water is absorbed or evaporated again add water for a depth of 25 mm.

- After second evaporation observe the bricks for white/grey patches.
- Observation is reported as „nil“, „slight“, „moderate“, „heavy“ or serious to mean
  1. **Nil:** No patches
  2. **Slight:** 10% of area covered with deposits
  3. **Moderate:** 10 to 50% area covered with deposit but unaccompanied by flaking of the surface.
  4. **Heavy:** More than 50% area covered with deposits but unaccompanied by flaking of the surface.
  5. **Serious:** Heavy deposits of salt accompanied by flaking of the surface.

## **Classification of Bricks**

**Bricks can be classified in 3 ways –**

- according to Use
- according to general physical requirement and
- according to strength & as in IS classification.

### **According to Use**

- Bricks are classified as
  - Common bricks
  - Engineering Bricks
  - Facing Bricks
  - Fire Bricks
  - Special Bricks

Bricks are classified as Class I, Class II & Class III according to general physical properties. Bricks of different classes differ in their water absorption property. A brick which disintegrates when immersed in water for a long period is not of good quality. This is due to lack of good burning.

|  | <b>Class I Bricks</b>  | <b>Class II Bricks</b>   | <b>Class III Bricks</b>   |
|--|--|--|---|
| <b>General Requirements</b>                                  | Shall have uniform colour, shall be thoroughly burnt, and shall have rectangular faces with parallel sides & sharp straight right angled edges. They shall have a compact & uniform texture. | Shall have a uniform colour, may be slightly overburnt, may be slightly distorted & round edges. They shall have a fine compact & uniform texture. | May be slightly underburnt or overburnt, may be distorted & have round edges. |
| <b>Water absorption after 24 hrs immersion in cold water</b> | Not > 20% by weight  | Not > 22% by weight  | Not > 25% by weight   |
| <b>Efflorescence</b>   | Slight   | Slight   | Moderate  |

- IS 3102-1971 “Classification of burnt clay solid bricks” classifies brick according to their strengths.

| <b>Class Designation</b> | <b>Compressive Strength Requirements (not less than)</b> | <b>Additional Requirements</b>   |
|--------------------------|--|--|
| 10                       | 10 N/mm <sup>2</sup>                                     | Dimensional Tolerance+/- 3%. Surface must be smooth, corners should be sharp, should give a ringing sound when struck. |
| 7.5                      | 7.5N/mm <sup>2</sup>                                     | Dimensional Tolerance+/- 5%. Permitted to have slight distortion but it should not cause difficulty in laying.         |
| 5                        | 5N/mm <sup>2</sup>                                       | Dimensional Tolerance+/- 8%. Permitted to have slight distortion but it should not cause difficulty in laying.         |

|     |                      |  |
|-----|----------------------|--|
| 3,5 | 3,5N/mm <sup>2</sup> | Dimensional Tolerance+/- 8%. Permitted to have slight distortion but it should not cause difficulty in laying. |
|-----|----------------------|--|