2

STRUCTURAL CLAY PRODUCTS

- Introduction
- Clay and Its Classifications
- Physical Properties of Clay
- Bricks
- Classification of Bricks
- Characteristics of Good Brick
- Ingredients of Good Brick Earth
- Harmful Substances in Brick Earth
- Manufacturing of Bricks
- Different Forms of Bricks
- Testing of Bricks
- Defects of Bricks
- Heavy Duty Burnt Clay Bricks
- Burnt Clay Perforated Bricks
- Burnt Clay Paving Bricks
- Burnt Clay Soling Bricks
- Burnt Clay Hollow Blocks
- Burnt Clay Jallis
- Clay Tiles
- Fire-clay or Refractory Clay
- Fire-clay Bricks or Refractory Bricks
- Terracotta
- Porcelain
- Stoneware
- Earthenware
- Majolica
- Glazing
- Applications of clay Products
- Exercises
- Objective Type Questions

2.1 INTRODUCTION

Clay products are one of the most important classes of structural materials. The raw materials used in their manufacture are clay blended with quartz, sand, chamatte (refractory clay burned at 1000–1400°C and crushed), slag, sawdust and pulverized coal. Structural clay products or building ceramics* are basically fabricated by moulding, drying and burning a clay mass. Higher the bulk specific gravity, the stronger is the clay product. This rule does not hold good for vitrified products since the specific gravity of clay decreases as vitrification advances.

Bulk specific gravity of clay brick ranges from 1.6 to 2.5.

According to the method of manufacture and structure, bricks, tiles, pipes, terracotta, earthenwares, stonewares, porcelain, and majolica are well recognized and employed in building

---

* Polycrystalline materials and products formed by baking natural clays and mineral admixtures at a high temperature and also by sintering the oxides of various metals and other high melting-point inorganic substances.

construction. Clay bricks have pleasing appearance, strength and durability whereas clay tiles used for light-weight partition walls and floors possess high strength and resistance to fire. Clay pipes on account of their durability, strength, lightness and cheapness are successfully used in sewers, drains and conduits.

2.2 CLAY AND ITS CLASSIFICATIONS

Clay is the most important raw material used for making bricks. It is an earthen mineral mass or fragmentary rock capable of mixing with water and forming a plastic viscous mass which has a property of retaining its shape when moulded and dried. When such masses are heated to redness, they acquire hardness and strength. This is a result of micro-structural changes in clay and as such is a chemical property. Purest clays consist mainly of kaolinite ($2SiO_2.Al_2O_3.2H_2O$) with small quantities of minerals such as quartz, mica, felspar, calcite, magnesite, etc. By their origin, clays are subdivided as residual and transported clays. Residual clays, known as Kaolin or China clay, are formed from the decay of underlying rocks and are used for making pottery. The transported or sedimentary clays result from the action of weathering agencies. These are more disperse, contain impurities, and free from large particles of mother rocks.

On the basis of resistance to high temperatures (more than 1580°C), clays are classified as refractory, high melting and low melting clays. The refractory clays are highly disperse and very plastic. These have high content of alumina and low content of impurities, such as Fe_2O_3, tending to lower the refractoriness. High melting clays have high refractoriness (1350–1580°C) and contain small amount of impurities such as quartz, felspar, mica, calcium carbonate and magnesium carbonate. These are used for manufacturing facing bricks, floor tiles, sewer pipes, etc. Low melting clays have refractoriness less than 1350°C and have varying compositions. These are used to manufacture bricks, blocks, tiles, etc.

Admixtures are added to clay to improve its properties, if desired. Highly plastic clays which require mixing water up to 28 per cent, give high drying and burning shrinkage, call for addition of lean admixtures or non-plastic substances such as quartz sand, chamottee, ash, etc. Items of lower bulk density and high porosity are obtained by addition of admixture that burn out. The examples of burning out admixtures are sawdust, coal fines, pulverized coal. etc. Acid resistance items and facing tiles are manufactured from clay by addition of water-glass or alkalis.

Burning temperature of clay items can be reduced by blending clay with fluxes such as felspar, iron bearing ores, etc. Plasticity of moulding mass may be increased by adding surfactants such as sulphite-sodium vinasse (0.1–0.3%).

2.3 PHYSICAL PROPERTIES OF CLAYS

Plasticity, tensile strength, texture, shrinkage, porosity, fusibility and colour after burning are the physical properties which are the most important in determining the value of clay. Knowledge of these properties is of more benefit in judging the quality of the raw material than a chemical analysis.

By plasticity is meant the property which wetted clay has of being permanently deformed without cracking. The amount of water required by different clays to produce the most plastic condition varies from 15 to 35 per cent. Although plasticity is the most important physical property of clay, yet there are no methods of measuring it which are entirely satisfactory. The simplest and the most used test is afforded by feeling of the wetted clay with the fingers. Personal equation necessarily plays a large part in such determination.

Since clay ware is subjected to considerable stress in moulding, handling and drying, a high tensile strength is desirable. The test is made by determining the stregth of specimens which have been moulded into briquette form and very carefully dried.

The texture of clay is measured by the fineness of its grains. In rough work the per cent passing a No. 100 sieve is determined. No numerical limit to the grain size or desired relation between sizes has been established. Very fine grained clays free from sand are more plastic and shrink more than those containing coarser material.

Knowledge of shrinkage both in drying and in burning is required in order to produce a product of required size. Also the amount of shrinkage forms an index of the degree of burning. The shrinkage in drying is dependent upon pore space within the clay and upon the amount of mixing water. The addition of sand or ground burnt clay lowers shrinkage, increases the porosity and facilitates drying. Fire shrinkage is dependent upon the proportion of volatile elements, upon texture and the way that clay burns.

By porosity of clay is meant the ratio if the volume of pore space to the dry volume. Since porosity affects the proportion of water required to make clay plastic, it will indirectly influence air shrinkage. Large pores allow the water to evaporate more easily and consequently permit a higher rate of drying than do small pores. In as much as the rate at which the clay may be safely dried is of great importance in manufacturing clay products, the effect of porosity on the rate of drying should be considered.

The temperature at which clay fuses is determined by the proportion of fluxes, texture, homogeneity of the material, character of the flame and its mineral constitution. Owing to non-uniformity in composition, parts of the clay body melt at different rates so that the softening period extends over a considerable range both of time and temperature. This period is divided into incipient vitrification and viscous vitrification.

Experiments roughly indicate that the higher the proportion of fluxes the lower the melting point. Fine textured clays fuse more easily than those of coarser texture and the same mineral composition. The uniformity of the clay mass determines very largely the influence of various elements; the carbonate of lime in large lumps may cause popping when present in small percentages, but when finely ground 15 per cent of it may be allowed in making brick or tile. Lime combined with silicate of alumina (feldspar) forms a desirable flux. Iron in the ferrous form, found in carbonates and in magnetite, fuses more easily than when present as ferric iron. If the kiln atmosphere is insufficiently oxidizing in character during the early stages of burning, the removal of carbon and sulphur will be prevented until the mass has shrunk to such an extent as to prevent their expulsion and the oxidation of iron. When this happens, a product with a discoloured core or swollen body is likely to result.

A determination of the fusibility of a clay is of much importance both in judging of the cost of burning it and in estimating its refractoriness.

2.4 BRICKS

One of the oldest building material brick continues to be a most popular and leading construction material because of being cheap, durable and easy to handle and work with. Clay bricks are used for building-up exterior and interior walls, partitions, piers, footings and other load bearing structures.

A brick is rectangular in shape and of size that can be conveniently handled with one hand. Brick may be made of burnt clay or mixture of sand and lime or of Portland cement concrete. Clay bricks are commonly used since these are economical and easily available. The length, width and height of a brick are interrelated as below:

Length of brick = 2 × width of brick + thickness of mortar

Height of brick = width of brick

Size of a standard brick (also known as modular brick) should be 19 × 9 × 9 cm and 19 × 9 × 4 cm. When placed in masonry the 19 × 9 × 9 cm brick with mortar becomes 20 × 10 × 10 cm. However, the bricks available in most part of the country still are 9" × $4\frac{1}{2}$" × 3" and are known as field bricks. Weight of such a brick is 3.0 kg. An indent called frog, 1–2 cm deep, as shown in Fig. 2.1, is provided for 9 cm high bricks. The size of frog should be 10 × 4 × 1 cm. The purpose of providing frog is to form a key for holding the mortar and therefore, the bricks are laid with frogs on top. Frog is not provided in 4 cm high bricks and extruded bricks.

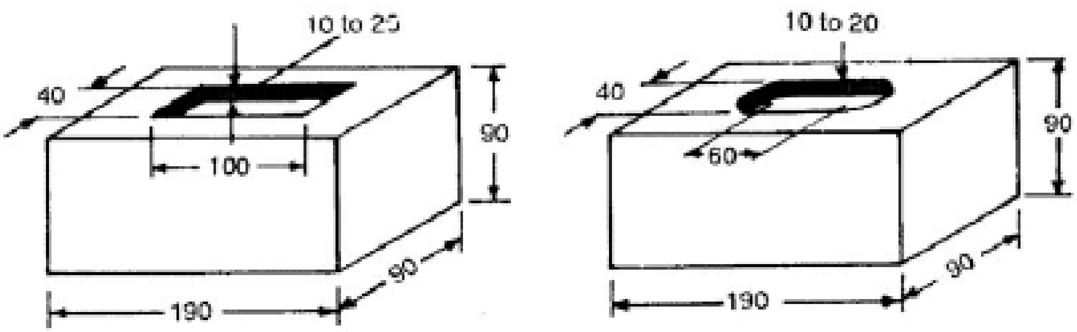


Fig. 2.1 Bricks with Frog

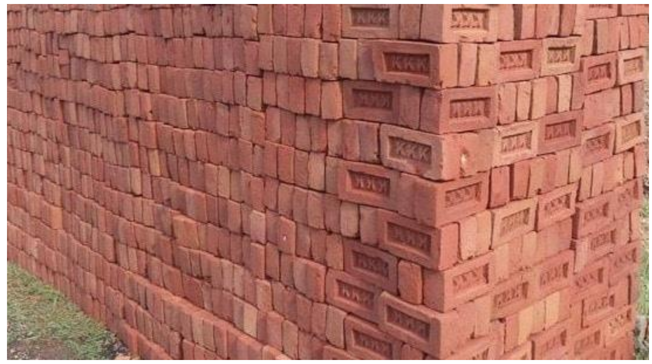
2.5 CLASSIFICATION OF BRICKS

On Field Practice

Clay bricks are classified as first class, second class, third class and fourth class based on their physical and mechanical properties.

First Class Bricks

1. These are thoroughly burnt and are of deep red, cherry or copper colour.
2. The surface should be smooth and rectangular, with parallel, sharp and straight edges and square corners.
3. These should be free from flaws, cracks and stones.
4. These should have uniform texture.
5. No impression should be left on the brick when a scratch is made by a finger nail.
6. The fractured surface of the brick should not show lumps of lime.
7. A metallic or ringing sound should come when two bricks are struck against each other.
8. Water absorption should be 12–15% of its dry weight when immersed in cold water for 24 hours.




PSI

9. The crushing strength of the brick should not be less than 10 N/mm^2. This limit varies with different Government organizations around the country.

Uses: First class bricks are recommended for pointing, exposed face work in masonry structures, flooring and reinforced brick work.

Second Class Bricks are supposed to have the same requirements as the first class ones except that

1. Small cracks and distortions are permitted.
2. A little higher water absorption of about 16–20% of its dry weight is allowed.
3. The crushing strength should not be less than 7.0 N/mm^2.

Uses: Second class bricks are recommended for all important or unimportant hidden masonry works and centering of reinforced brick and reinforced cement concrete (RCC) structures.

Third Class Bricks are underburnt. They are soft and light-coloured producing a dull sound when struck against each other. Water absorption is about 25 per cent of dry weight.

Uses : It is used for building temporary structures.

Fourth Class Bricks are overburnt and badly distorted in shape and size and are brittle in nature.

Uses: The ballast of such bricks is used for foundation and floors in lime concrete and road metal.

On Strength

The Bureau of Indian Standards (BIS) has classified the bricks on the basis of compressive strength and is as given in Table 2.1.

Table 2.1 Classification of Bricks based on Compressive Strength (IS: 1077)

Class	*Average compressive strength not less than (N/mm^2)*
35	35.0
30	30.0
25	25.0
20	20.0
17.5	17.5
15	15.0
12.5	12.5
10	10.0
7.5	7.5
5	5.0
3.5	3.5

Notes: 1. The burnt clay bricks having compressive strength more than 40.0 N/mm^2 are known as heavy duty bricks and are used for heavy duty structures such as bridges, foundations for industrial buildings, multistory buildings, etc. The water absorption of these bricks is limited to 5 per cent.

2. Each class of bricks as specified above is further divided into subclasses A and B based on tolerances and shape. Subclass-A bricks should have smooth rectangular faces with sharp corners and uniform colour. Subclass-B bricks may have slightly distorted and round edges.

	Subclass-A		*Subclass-B*	
	Dimension (cm)	*Tolerance (mm)*	*Dimension (cm)*	*Tolerance (mm)*
Length	380	± 12	380	± 30
Width	180	± 6	180	± 15
Height				
(i) 9 cm	180	± 6	180	± 15
(ii) 4 cm	80	± 3	80	± 6

On the Basis of Use

Common Brick is a general multi-purpose unit manufactured economically without special reference to appearance. These may vary greatly in strength and durability and are used for filling, backing and in walls where appearance is of no consequence.

Facing Bricks are made primarily with a view to have good appearance, either of colour or texture or both. These are durable under severe exposure and are used in fronts of building walls for which a pleasing appearance is desired.

Engineering Bricks are strong, impermeable, smooth, table moulded, hard and conform to defined limits of absorption and strength. These are used for all load bearing structures.

On the Basis of Finish

Sand-faced Brick has textured surface manufactured by sprinkling sand on the inner surfaces of the mould.

Rustic Brick has mechanically textured finish, varying in pattern.

On the Basis of Manufacture

Hand-made: These bricks are hand moulded.

Machine-made: Depending upon mechanical arrangement, bricks are known as wire-cut bricks—bricks cut from clay extruded in a column and cut off into brick sizes by wires; pressed-bricks—when bricks are manufactured from stiff plastic or semi-dry clay and pressed into moulds; moulded bricks—when bricks are moulded by machines imitating hand mixing.

On the Basis of Burning

Pale Bricks are underburnt bricks obtained from outer portion of the kiln.

Body Bricks are well burnt bricks occupying central portion of the kiln.

Arch Bricks are overburnt also known as clinker bricks obtained from inner portion of the kiln.

On the Basis of Types

Solid: Small holes not exceeding 25 per cent of the volume of the brick are permitted; alternatively, frogs not exceeding 20 per cent of the total volume are permitted.

Perforated: Small holes may exceed 25 per cent of the total volume of the brick.

Hollow: The total of holes, which need not be small, may exceed 25 per cent of the volume of the brick.

Cellular: Holes closed at one end exceed 20 per cent of the volume.

Note: **Small holes are less than 20 mm or less than 500 mm^2 in cross section.**

2.6 CHARACTERISTICS OF GOOD BRICK

The essential requirements for building bricks are sufficient strength in crushing, regularity in size, a proper suction rate, and a pleasing appearance when exposed to view.

Size and Shape: The bricks should have uniform size and plane, rectangular surfaces with parallel sides and sharp straight edges.

Colour: The brick should have a uniform deep red or cherry colour as indicative of uniformity in chemical composition and thoroughness in the burning of the brick.

Texture and Compactness: The surfaces should not be too smooth to cause slipping of mortar. The brick should have precompact and uniform texture. A fractured surface should not show fissures, holes grits or lumps of lime.

Hardness and Soundness: The brick should be so hard that when scratched by a finger nail no impression is made. When two bricks are struck together, a metallic sound should be produced.

Water Absorption should not exceed 20 per cent of its dry weight when kept immersed in water for 24 hours.

Crushing Strength should not be less than 10 N/mm^2.

Brick Earth should be free from stones, kankars, organic matter, saltpetre, etc.

2.7 INGREDIENTS OF GOOD BRICK EARTH

For the preparation of bricks, clay or other suitable earth is moulded to the desired shape after subjecting it to several processes. After drying, it should not shrink and no crack should develop. The clay used for brick making consists mainly of silica and alumina mixed in such a proportion that the clay becomes plastic when water is added to it. It also consists of small proportions of lime, iron, manganese, sulphur, etc. The proportions of various ingredients are as follows:

Silica	50–60%	
Alumina	20–30%	
Lime	10%	
Magnesia	< 1%	Less than 20%
Ferric oxide	< 7%	
Alkalis	< 10%	
Carbon dioxide		Very small percentage
Sulphur trioxide		
Water		

Functions of Various Ingredients

Silica: It enables the brick to retain its shape and imparts durability, prevents shrinkage and warping. Excess of silica makes the brick brittle and weak on burning. A large percentage of sand or uncombined silica in clay is undesirable. However, it is added to decrease shrinkage in burning and to increase the refractoriness of low alumina clays.

Alumina absorbs water and renders the clay plastic. If alumina is present in excess of the specified quantity, it produces cracks in brick on drying. Clays having exceedingly high alumina content are likely to be very refractory.

Lime normally constitutes less than 10 per cent of clay. Lime in brick clay has the following effects:

1. Reduces the shrinkage on drying.
2. Causes silica in clay to melt on burning and thus helps to bind it.
3. In carbonated form, lime lowers the fusion point.
4. Excess of lime causes the brick to melt and the brick looses its shape.
5. Red bricks are obtained on burning at considerably high temperature (more than 800°C) and buff-burning bricks are made by increasing the lime content.

Magnesia rarely exceeding 1 per cent, affects the colour and makes the brick yellow, in burning; it causes the clay to soften at slower rate than in most case is lime and reduces warping.

Iron Iron oxide constituting less than 7 per cent of clay, imparts the following properties:

1. Gives red colour on burning when excess of oxygen is available and dark brown or even black colour when oxygen available is insufficient, however, excess of ferric oxide makes the brick dark blue.
2. Improves impermeability and durability.
3. Tends to lower the fusion point of the clay, especially if present as ferrous oxide.
4. Gives strength and hardness.