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STRUCTURAL CLAY PRODUCTS

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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.

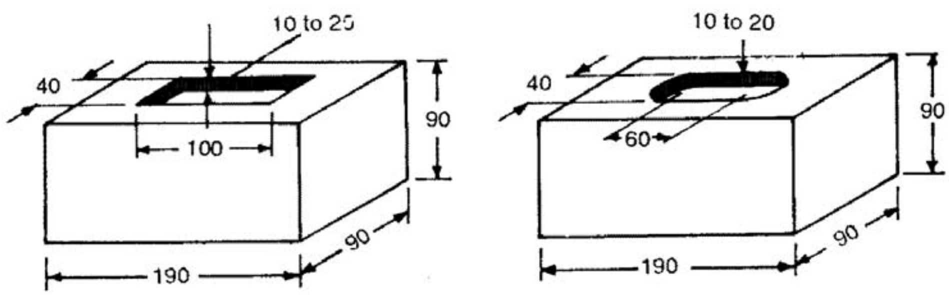


Fig. 2.1 Bricks with Frog

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.

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.

2.8 HARMFUL SUBSTANCES IN BRICK EARTH

Lime: When a desirable amount of lime is present in the clay, it results in good bricks, but if in excess, it changes the colour of the brick from red to yellow. When lime is present in lumps, it absorbs moisture, swells and causes disintegration of the bricks. Therefore, lime should be present in finely divided state and lumps, if any, should be removed in the beginning itself. Experience has shown, however, that when line particles smaller than 3 mm diameter hydrate they produce only small *pock mark* which, provided that there are not many of them, can usually be ignored. Particles larger than this might, if present in any quantity, cause unsightly blemishes or even severe cracking.

Pebbles, Gravels, Grits do not allow the clay to be mixed thoroughly and spoil the appearance of the brick. Bricks with pebbles and gravels may crack while working.

Iron Pyrites tend to oxidise and decompose the brick during burning. The brick may split into pieces. Pyrites discolourise the bricks.

Alkalis (Alkaline salts) forming less than 10 per cent of the raw clay, are of great value as fluxes, especially when combined with silicates of alumina. These are mainly in the form of soda or potash. However, when present in excess, alkali makes the clay unsuitable for bricks. They melt the clay on burning and make the bricks unsymmetrical. When bricks come in contact with moisture, water is absorbed and the alkalis crystallise. On drying, the moisture evaporates, leaving behind grey or white powder deposits on the brick which spoil the appearance. This phenomenon is called *efflorescence*. Efflorescence should always be dry brushed away before rendering or plastering a wall; wetting it will carry the salts back into the wall to reappear later.

If bricks become saturated before the work is completed, the probability of subsequent efflorescence is increased, brick stacks should, therefore be protected from rain at all times. During laying, the bricks should be moistened only to the extent that is found absolutely essential to obtain adequate bond between bricks and mortar; newly built brickwork should be protected from rain.

Organic Matter: On burning green bricks, the organic matter gets charred and leave pores making the bricks porous; the water absorption is increased and the strength is reduced.

Carbonaceous Materials in the form of bituminous matter or carbon greatly affects the colour of raw clay. Unless proper precaution is taken to effect complete removal of such matter by oxidation, the brick is likely to have a black core.

Sulphur is usually found in clay as the sulphate of calcium, magnesium, sodium, potassium or iron, or as iron sulphide. Generally, the proportion is small. If, however, there is carbon in the clay and insufficient time is given during burning for proper oxidation of carbon and sulphur, the latter will cause the formation of a spongy, swollen structure in the brick and the brick will be decoloured by white blotches.

Water: A large proportion of free water generally causes clay to shrink considerably during drying, whereas combined water causes shrinkage during burning. The use of water containing small quantities of magnesium or calcium carbonates, together with a sulphurous fuel often causes similar effects as those by sulphur.

2.9 MANUFACTURING OF BRICKS

Additives in the Manufacture of Bricks

Certain additives such as fly ash, sandy loam, rice husk ash, basalt stone dust, etc. are often required not only to modify the shaping, drying and firing behaviour of clay mass, but also to help conserve agricultural land and utilise waste materials available in large quantities. These additives should, however, have a desirable level of physical and chemical characteristics so as to modify the behaviour of clay mass within the optimum range without any adverse effect on the performance and durability. Some of the basic physio-chemical requirements of conventional additives are as under:

Fly Ash: A waste material available in large quantities from thermal power plants can be added to alluvial, red, black, marine clays, etc. The fly ash contains amorphous glassy material, mullite, haematite, magnetite, etc. and shows a chemical composition similar to brick earths. These silicates also help towards strength development in clay bodies on firing, when mixed in optimum proportion depending on the physio-chemical and plastic properties of soils to be used for brick making. The proportion of fly ash mixed as an additive to the brick earth should be optimum to reduce drying shrinkage, check drying losses and to develop strength on firing without bloating or black coring in fired product. The crystallites present in the fly ash should comply with the resultant high temperature phases in the finished product.

The desirable characteristics of fly ash which could be used as an additive to the soil mass are given in Table 2.2.

Table 2.2 Desirable Characteristics of Fly Ash for Use as an Admixture with Brick Earths

S.No.	*Characteristics*	*Desired level*
1.	Texture	Fineness, 200 to
2.	Maximum coarse material	300 m^2/kg
	(+ 1 mm)	0.5%
3.	Maximum unburnt carbon	
	per cent by mass	15%
4.	Maximum water soluble	
	per cent by mass	0.1%

Sandy Loam: Addition of sandy loam is often found effective in controlling the drying behaviour of highly plastic soil mass containing expanding group of clay minerals. Sandy loam should preferably have a mechanical composition as specified below. The material should, however, meet the other requirement as well.

Clay	(< 2 micron)	8–10%
Silt	(2–20 micron)	30–50%
Sand	(> 20 micron)	40–60%

Rice Husk Ash: The ash should preferably have unburnt carbon content in the range of 3–5% and should be free from extraneous material. It can be used with plastic black red soils showing excessive shrinkage.

Basalt Stone Dust: Basalt stone occurs underneath the black cotton soil and its dust is a waste product available in large quantity from basalt stone crushing units. The finer fraction from basalt stone units is mixed with soil mass to modify the shaping, drying and firing behaviour of bricks. The dust recommended for use as an additive with brick earth should be fine (passing 1 mm sieve), free from coarse materials or mica flakes and should be of non-calcitic or dolomitic origin.

The operations involved in the manufacture of clay bricks are represented diagrammatically in Fig. 2.2.

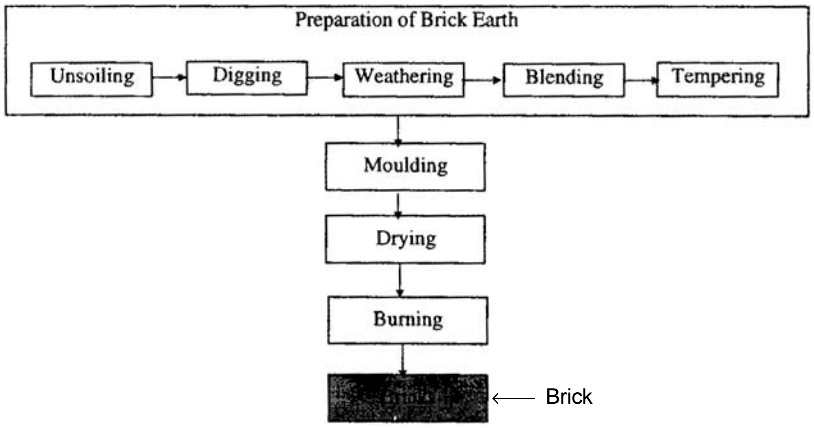


Fig. 2.2 Operations Involved in Manufacturing of Clay Bricks

Preparation of Brick Earth

It consists of the following operations.

Unsoiling: The soil used for making building bricks should be processed so as to be free of gravel, coarse sand (practical size more than 2 mm), lime and kankar particles, organic matter, etc. About 20 cm of the top layer of the earth, normally containing stones, pebbles, gravel, roots, etc., is removed after clearing the trees and vegetation.

Digging: After removing the top layer of the earth, proportions of additives such as fly ash, sandy loam, rice husk ash, stone dust, etc. should be spread over the plane ground surface on volume basis. The soil mass is then manually excavated, puddled, watered and left over for weathering and subsequent processing. The digging operation should be done before rains.

Weathering: Stones, gravels, pebbles, roots, etc. are removed from the dug earth and the soil is heaped on level ground in layers of 60–120 cm. The soil is left in heaps and exposed to weather for at least one month in cases where such weathering is considered necessary for the soil. This is done to develop homogeneity in the mass of soil, particularly if they are from different sources, and also to eliminate the impurities which get oxidized. Soluble salts in the clay would also be eroded by rain to some extent, which otherwise could have caused scumming at the time of burning of the bricks in the kiln. The soil should be turned over at least twice and it should be ensured that the entire soil is wet throughout the period of weathering. In order to keep it wet, water may be sprayed as often as necessary. The plasticity and strength of the clay are improved by exposing the clay to weather.

Blending: The earth is then mixed with sandy-earth and calcareous-earth in suitable proportions to modify the composition of soil. Moderate amount of water is mixed so as to obtain the right consistency for moulding. The mass is then mixed uniformly with spades. Addition of water to the soil at the dumps is necessary for the easy mixing and workability, but the addition of water should be controlled in such a way that it may not create a problem in moulding and drying. Excessive moisture content may effect the size and shape of the finished brick.

Tempering: Tempering consists of kneading the earth with feet so as to make the mass stiff and plastics (by plasticity, we mean the property which wet clay has of being permanently deformed without cracking). It should preferably be carried out by storing the soil in a cool place in layers of about 30 cm thickness for not less than 36 hours. This will ensure homogeneity in the mass of clay for subsequent processing. For manufacturing good brick, tempering is done in pug mills and the operation is called *pugging*.

Pug mill consists of a conical iron tube as shown in Fig. 2.3. The mill is sunk 60 cm into the earth. A vertical shaft, with a number of horizontal arms fitted with knives, is provided at the centre of the tube. This central shaft is rotated with the help of bullocks yoked at the end of long arms. However, steam, diesel or electric power may be used for this purpose. Blended earth along with required water, is fed into the pug mill from the top. The knives cut through the clay and break all the clods or lump-clays when the shaft rotates. The thoroughly pugged clay is then taken out from opening provided in the side near the bottom. The yield from a pug mill is about 1500 bricks.

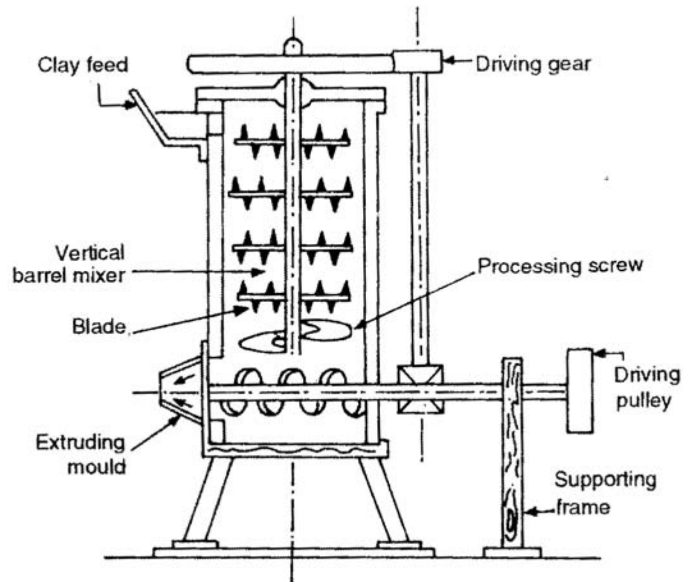


Fig. 2.3 Pug Mill

Moulding

It is a process of giving a required shape to the brick from the prepared brick earth. Moulding may be carried out by hand or by machines. The process of moulding of bricks may be the soft-mud (hand moulding), the stiff-mud (machine moulding) or the dry-press process (moulding using maximum 10 per cent water and forming bricks at higher pressures). Fire-brick is made by the soft mud process. Roofing, floor and wall tiles are made by dry-press method. However, the stiff-mud process is used for making all the structural clay products.

Hand Moulding: A typical mould is shown in Fig. 2.4. Hand moulding is further classified as ground moulding and table moulding.

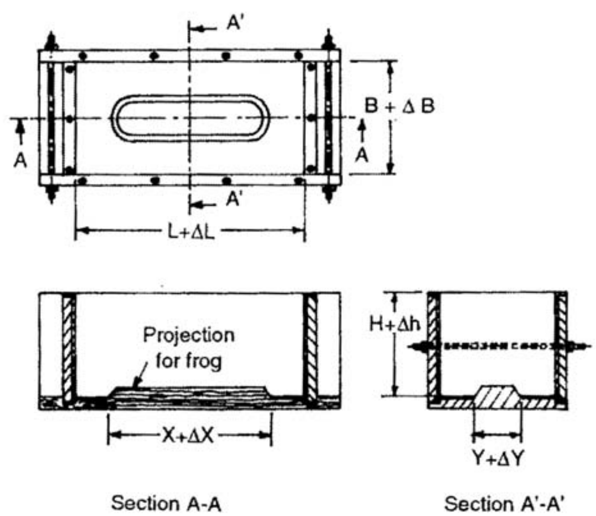


Fig. 2.4 Details of Mould

Ground Moulding: In this process, the ground is levelled and sand is sprinkled on it. The moulded bricks are left on the ground for drying. Such bricks do not have frog and the lower brick surface becomes too rough. To overcome these defects, moulding blocks or boards are used at the base of the mould. The process consists of shaping in hands a lump of well pugged earth, slightly more than that of the brick volume. It is then rolled into the sand and with a jerk it is dashed into the mould. The moulder then gives blows with his fists and presses the earth properly in the corners of the mould with his thumb. The surplus clay on the top surface is removed with a sharp edge metal plate called *strike* (Fig. 2.5) or with a thin wire stretched over the mould. After this the mould is given a gentle slope and is lifted leaving the brick on the ground to dry.

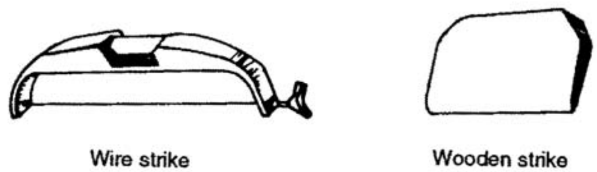


Fig. 2.5 Strikes

Notes: **(i) This method is adopted when a large and level land is available.**

(ii) To prevent the moulded bricks from sticking to the side of the mould, sand is sprinkled on the inner sides of the mould, or the mould may be dipped in water every time before moulding is done. The bricks so produced are respectively called sand moulded and slop moulded bricks, the former being better since they provide sufficient rough surface necessary for achieving a good bond between bricks and mortar.

Table Moulding: The bricks are moulded on stock boards nailed on the moulding table (Fig. 2.6). Stock boards have the projection for forming the frog. The process of filling clay in the mould is the same as explained above. After this, a thin board called *pallet* is placed over the mould. The mould containing the brick is then smartly lifted off the stock board and inverted so that the moulded clay along with the mould rests on the pallet. The mould is then removed as explained before and the brick is carried to the drying site.

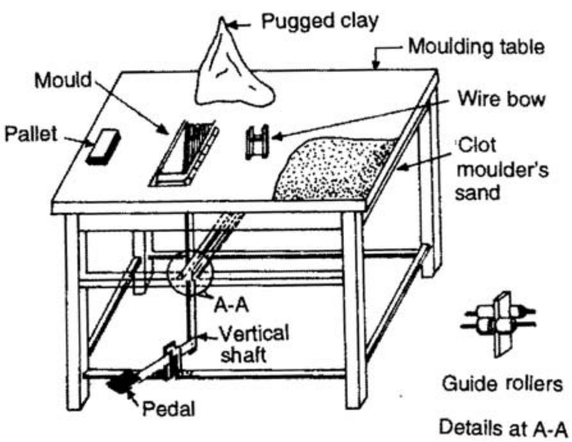


Fig. 2.6(a) Brick Moulding Table

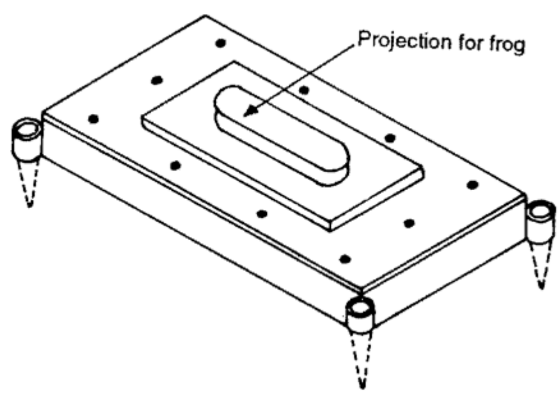


Fig. 2.6(b) Stock Board

Machine Moulding can be done by either of the following processes:

Plastic Method: The pugged, stiffer clay is forced through a rectangular opening of brick size by means of an auger. Clay comes out of the opening in the form of a bar. The bricks are cut from the bar by a frame consisting of several wires at a distance of brick size as shown in Fig. 2.7. This is a quick and economical process.

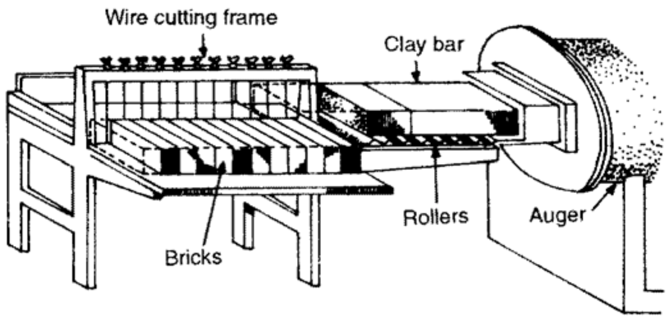


Fig. 2.7 Plastic Moulding

Dry-press Method: The moist, powdered clay is fed into the mould on a mechanically operated press, where it is subjected to high pressure and the clay in the mould takes the shape of bricks. Such pressed bricks are more dense, smooth and uniform than ordinary bricks. These are burnt carefully as they are likely to crack.

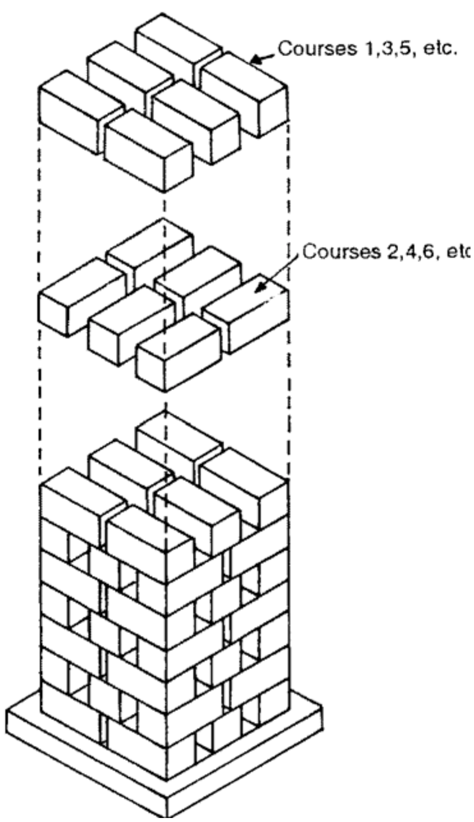


Fig. 2.8 Method of Drying Bricks

Drying

Green bricks contain about 7–30% moisture depending upon the method of manufacture. The object of drying is to remove the moistre to control the shrinkage and save fuel and time during burning. The drying shrinkage is dependent upon pore spaces within the clay and the mixing water. The addition of sand or ground burnt clay reduces shrinkage, increases porosity and facilities drying. The moisture content is brought down to about 3 per cent under exposed conditions within three to four days. Thus, the strength of the green bricks is increased and the bricks can be handled safely.

Clay products can be dried in open air driers or in artificial driers. The artificial driers are of two types, the hot floor drier and the tunnel drier. In the former, heat is applied by a furnance placed at one end of the drier or by exhaust steam from the engine used to furnish power and is used for fire bricks, clay pipes and terracotta. Tunnel driers are heated by fuels underneath, by steam pipes, or by hot air from cooling kilns. They are more economical than floor driers. In artificial driers, temperature rarely exceeds 120°C. The time varies from one to three days. In developing countries, bricks are normally dried in natural open air driers (Fig. 2.8). They are stacked on raised ground and are protected from bad weather and direct sunlight. A gap of about 1.0 m is left in the adjacent layers of the stacks so as to allow free movement for the workers.

Burning

The burning of clay may be divided into three main stages.

Dehydration (400–650°C): This is also known as water smoking stage. During dehydration, (1) the water which has been retained in the pores of the clay after drying is driven off and the clay loses its plasticity, (2) some of the carbonaceous matter is burnt, (3) a portion of sulphur is distilled from pyrites. (4) hydrous minerals like ferric hydroxide are dehydrated, and (5) the carbonate minerals are more or less decarbonated. Too rapid heating causes cracking or bursting of the bricks. On the other hand, if alkali is contained in the clay or sulphur is present in large amount in the coal, too slow heating of clay produces a scum on the surface of the bricks.

Oxidation Period (650–900°C): During the oxidation period, (1) remainder of carbon is eliminated and, (2) the ferrous iron is oxidized to the ferric form. The removal of sulphur is completed only after the carbon has been eliminated. Sulphur on account of its affinity for oxygen, also holds back the oxidation of iron. Consequently, in order to avoid black or spongy cores, oxidation must proceed at such a rate which will allow these changes to occur before the heat becomes sufficient to soften the clay and close its pore. Sand is often added to the raw clay to produce a more open structure and thus provide escape of gases generated in burning.

Vitrification—To convert the mass into glass like substance — the temperature ranges from 900–1100°C for low melting clay and 1000–1250°C for high melting clay. Great care is required in cooling the bricks below the cherry red heat in order to avoid checking and cracking. Vitrification period may further be divided into (a) incipient vitrification, at which the clay has softened sufficiently to cause adherence but not enough to close the pores or cause loss of space—on cooling the material cannot be scratched by the knife; (b) complete vitrification, more or less well-marked by maximum shrinkage; (c) viscous vitrification, produced by a further increase in temperature which results in a soft molten mass, a gradual loss in shape, and a glassy structure after cooling. Generally, clay products are vitrified to the point of viscosity. However, paving bricks are burnt to the stage of complete vitrification to achieve maximum hardness as well as toughness.

Burning of bricks is done in a clamp or kiln. A clamp is a temporary structure whereas kiln is a permanent one.

Burning in Clamp or Pazawah: A typical clamp is shown in Fig. 2.9. The bricks and fuel are placed in alternate layers. The amount of fuel is reduced successively in the top layers. Each brick tier consists of 4–5 layers of bricks. Some space is left between bricks for free circulation of hot gasses. After 30 per cent loading of the clamp, the fuel in the lowest layer is fired and the remaining loading of bricks and fuel is carried out hurriedly. The top and sides of the clamp are plastered with mud. Then a coat of cowdung is given, which prevents the escape of heat. The production of bricks is 2–3 lacs and the process is completed in six months. This process yields about 60 per cent first class bricks.

Kiln Burning: The kiln used for burning bricks may be underground, e.g. Bull's trench kiln or overground, e.g. Hoffman's kiln. These may be rectangular, circular or oval in shape. When the process of burning bricks is continuous, the kiln is known as continuous kiln, e.g. Bull's trench and Hoffman's kilns. On the other hand if the process of burning bricks is discontinuous, the kiln is known as intermittent kiln.

Intermittent Kiln: The example of this type of an over ground, rectangular kiln is shown in Fig. 2.10. After loading the kiln, it is fired, cooled and unloaded and then the next loading is done. Since the walls and sides get cooled during reloading and are to be heated again during next firing, there is wastage of fuel.

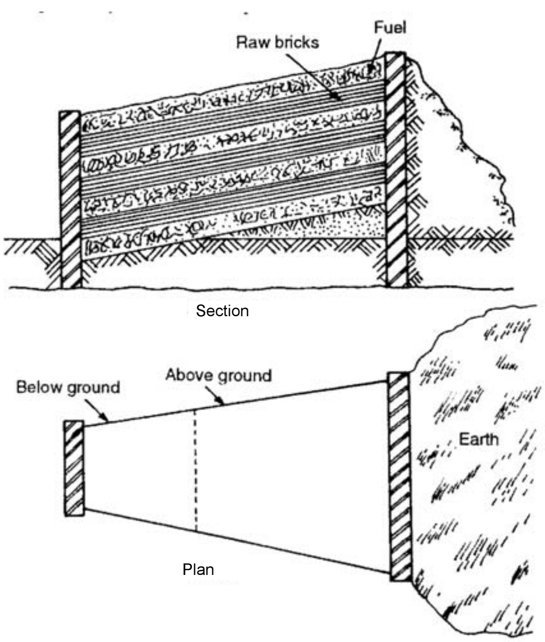


Fig. 2.9 Clamp or Pazawah

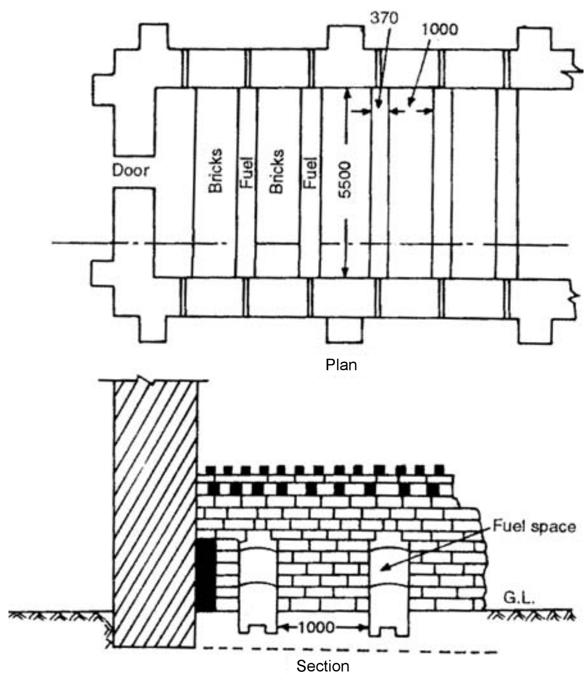


Fig. 2.10 Intermittent Kiln

Continuous Kiln: The examples of continuous kiln are Hoffman's kiln (Fig. 2.11) and Bull's trench kiln (Fig. 2.12). In a continuous kiln, bricks are stacked in various chambers wherein the bricks undergo different treatments at the same time. When the bricks in one of the chambers is fired, the bricks in the next set of chambers are dried and preheated while bricks in the other set of chambers are loaded and in the last are cooled.

Note: **In the areas where black cotton soil occur, a more elaborate method of processing is followed. The clay, which may be black or a mixture of black and yellow, is first washed free of the lime kankar in the 'GHOL' tanks. The slurry is then run off to the setting tanks. After 3–4 days when the clay has settled down, the supernatant water is bucketed off. Opening material like powdered grog of fine coal ash (passing 2.00 mm sieve), which opens up the texture of clay mass, is then added in predetermined proportions. This is usually 30 to 40 per cent of the mass of clay. A solution of 0.5 per cent sodium chloride may also be added at this stage to prevent lime bursting. The clay is then thoroughly mixed with the opening materials added and allowed to dry further for a period of 3–4**

days till the mix attains the correct moulding consistency. Grog is prepared by lightly calcining lumps of black cotton soil (about 10 to 15 cm dia.) in a clamp at about 700° to 750°C. Coal ash, fire wood, brambles, etc. may be used as fuel. The fuel and clay lumps are arranged in alternate layers in the clamp. After calcination the clay is pulverized in a machine, such as disintegrator, a hammer mill or a pan-mill to a fineness of less than 2.0 mm.

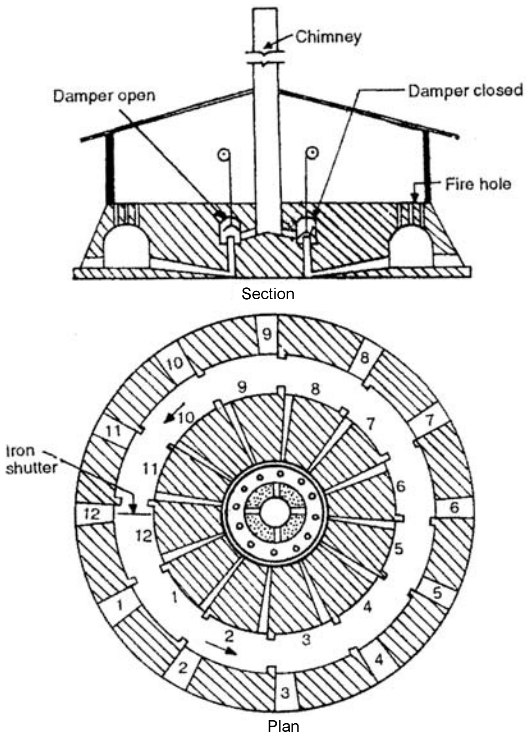


Fig. 2.11 Hoffman's Continuous Kiln

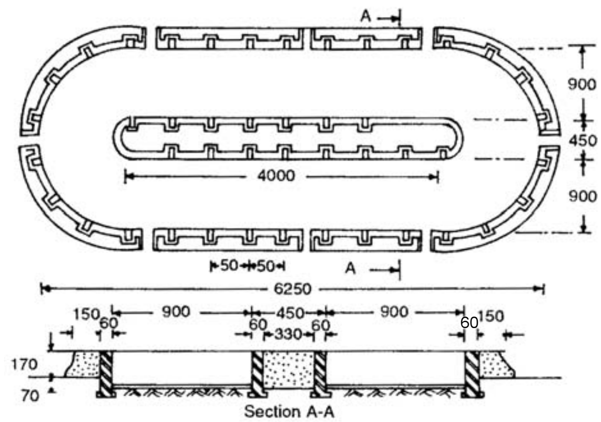


Fig. 2.12 Bull's Trench Kiln

2.10 DIFFERENT FORMS OF BRICKS

Some of the common type of bricks, depending upon the places of use, are shown in Fig. 2.13. Round ended and bull nosed bricks (Fig. 2.13 (a, f)) are used to construct open drains. For door and window jambs, cant brick, also called splay brick, shown in Fig. 2.13 (b, c), are most suitable. The double cant brick shown in Fig. 2.13 (c) is used for octagonal pillars. Cornice brick shown in Fig. 2.13 (d) is used from architectural point of view. Figure 2.13 (e) shows a compass brick—tapering in both directions along its length—used to construct furnaces. Perforated brick (Fig. 2.13 (g)) is well burned brick, but is not sound proof. Figure 2.13 (h) shows hollow bricks. These are about l/3rd the weight of normal bricks and are sound and heat proof, but are not suitable where concentrated loads are expected. Top most bricks course of parapets is made with coping bricks shown in Fig. 2.13 (i). These drain off the water from the parapets. Brick shown in Fig. 2.13 (j) is used at plinth level and for door and window jambs. Split bricks are shown in Fig. 2.13 (k, 1). When the brick is cut along the length, it is called queen closer and when cut at one end by half header and half stretcher, it is known as king closer.

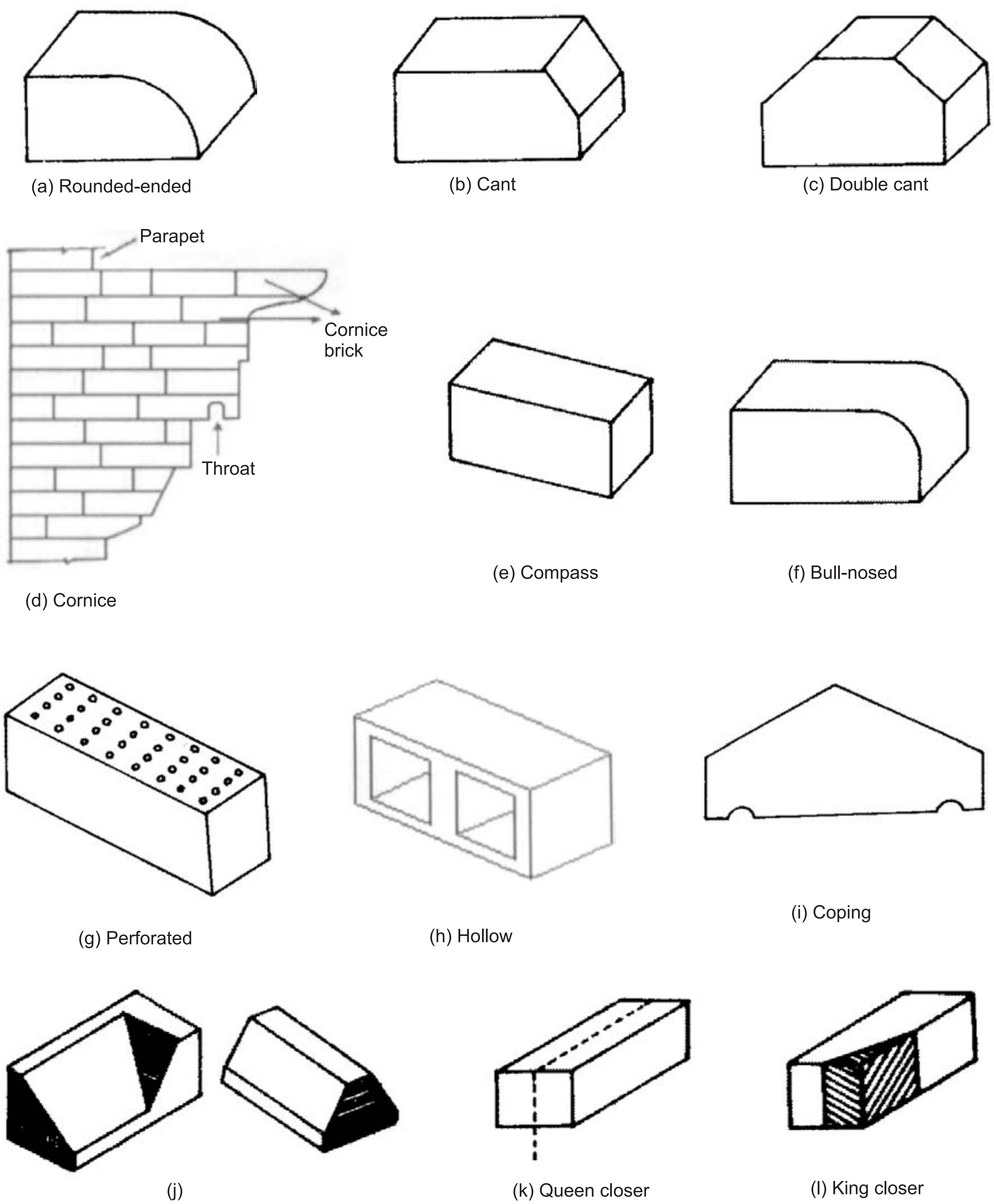


Fig. 2.13 Forms of Bricks

2.11 TESTING OF BRICKS

About fifty pieces of bricks are taken at random from different parts of the stack to perform various tests. For the purpose of sampling, a lot should contain maximum of 50,000 bricks. The number of bricks selected for forming a sample are as per Table 2.3, (IS: 5454). The scale of sampling for physical characteristics is given in Table 2.4.

Table 2.3. Scale of Sampling and Permissible Number of Defectives for Visual and Dimensional Characteristics

No. of bricks in the lot	For characteristics specified for individual brick		*For dimensional characteristics specified for group of 20 bricks–No. of bricks to be selected*
	No. of bricks to be selected	Permissible No. of defectives in the sample	
2001 to 10000	20	1	40
10001 to 35000	32	2	60
35001 to 50000	50	3	80

Note: In case the lot contains 2000 or less bricks, the sampling shall be subject to agreement between the purchaser and supplier.

Table 2.4. Scale of Sampling for Physical Characteristics

Lot size	Sampling size for compressive strength, breaking load, transverse strength, bulk density, water absorption and efflorescence	Permissible No. of defectives for efflorescence	*Warpage*	
			Sample size	*Permissible No. of defectives*
2001 to 10000	5	0	10	0
10001 to 35000	10	0	20	1
35001 to 50000	15	1	30	2

Note: **In case the lot contains 2000 or less bricks, the sampling shall be subject to agreement between the purchaser and supplier.**

Dimension Test (IS: 1077): 20 pieces out of selected pieces (Table 2.3) are taken and are laid flat as shown in Fig. 2.14. The cumulative dimensions of the bricks should be as discussed in Sec. 2.5.

The tolerances (Section 2.5) on the sizes of bricks are fixed by giving maximum and minimum dimensions, not on individual bricks but on batches of 20 bricks chosen at random.

It follows from this method of measurement that batches are likely to contain, bricks outside the prescribed limit of tolerance. Such lots should be rejected to avoid complaints about the variation of perpends.

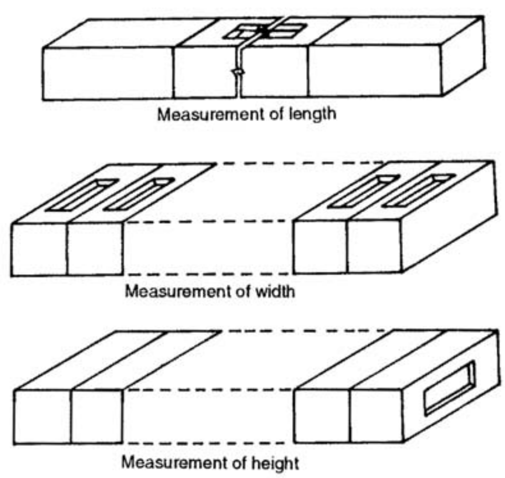


Fig. 2.14 Measurement of Tolerances of Common Building Bricks

Water Absorption Test (IS: 3495 (Part II)): The existence of minute pores confers marked capillary properties on brick ceramics. In particular all bricks absorb water by capillary action. The percentage of water absorption is a very valuable indication of the degree of burning. Vitrification, in the true sense, corresponds to such a dgree of compactness that the absorption of the brick is not over 3 per cent after 48 hours of immersion. It has been reported that for absorption less than 5 per cent danger from frost is negligible.

Water absorption does not necessarily indicate the behavior of a brick in weathering. Low absorption (< 7 %) usually indicates a high resistance to damage by freezing, although some type of bricks of much higher absorption may also be frost resistance. Since expansive force of water freezing in the pores of a clay product depends upon the proportion of pore space occupied, the ratio of the absorption after 24 hours submersion to the absorption after boiling for 5 hours (C_{24}/B_5) appears to be a better criterion of resistance to freezing than the percentage of absorption.

The durability of a brick may be tested by frost action, i.e., by alternate wetting and drying. The absorption test has long been considered a measure of durability, although the basis for this assumption is questionable. The suction rate of the brick at the time it is laid exercises a mark influence on the mortar bond. Too rapid withdrawal of water from the mortar by the brick produces a weak bond. The rate at which a brick absorbs water, frequently called its suction rate, maybe measured by immersing one face of the brick in water. The one minute water uptake (initial rate of absorprion) is taken as the suction rate. For long periods of immersion in theis test, the total wieght of water absorbed per unit area,

$$w = A\sqrt{t}$$

where, A is the water absorption coefficient
and t is the time elapsed in the test.

The standard methods of finding the absorption value of the bricks are discussed below. If absorption by volume is desired it can be obtained by multiplying the weight percentage by the apparent specific gravity.

24 Hours Immersion Cold Water Test: Dry bricks are put in an oven at a temperature of 105° to 115°C till these attain constant mass. The weight (W_1) of the bricks is recorded after cooling them to room temperature. The bricks are then immersed in water at a temperature of 27° ± 2°C for 24 hours. The specimens are then taken out of water and wiped with a damp cloth. Three minutes, thereafter it is weighed again and recorded as W_2.

$$\text{The water absorption in \%} = \frac{W_2 - W_1}{W_1} \times 100$$

The average water absorption shall not be more than 20 per cent by weight upto class 12.5 and 15 per cent by weight for higher classes.

Five Hours Boiling Water Test: The weight of the oven dried bricks (W_1) is recorded as above. Then the specimen is immersed in the water and boiled for five hours, followed by cooling down to 27° ± 2°C by natural loss of heat within 16–19 hours. The specimen is taken out of water and wiped with a damp cloth and the weight is recorded as W_3.

$$\text{The water absorption in \%} = \frac{W_3 - W_1}{W_1} \times 100$$

Compressive Strength Test (IS: 3495 (Part I)): The crushing affords a basis for comparing the quality of bricks but is of little value in determining the strength of a masonry wall, since the latter depends primarily on the strength of mortar. Six bricks are taken for the compressive strength test althought it may be found that an individual brick varies by 20% or more from the average, the permissible stresses allowed for load bearing walls take account of this, being based on an average strength of six bricks. It is, therefore, both unnecessary and uneconomical to insist that every bricks is above a certain strength. As a criterion of structural strength for brick, the transverse failure in a wall or pavement is likely to occur on account of improper bedment. For testing bricks for compressive strength from a sample the two bed faces of bricks are ground to provide smooth, even and parallel faces. The bricks are then immersed in water at room temperature for 24 hours. These are then taken out of water and surplus water on the surfaces is wiped off with cotton or a moist cloth. The frog of the brick is flushed level with cement mortar and the brick is stored under damp jute bags for 24 hours followed by its immersion in water at room temperature for three days. The specimen is placed in the compression testing machine with flat faces horizontal and mortar filled face being upwards. Load is applied at a uniform rate of 14 N/m^2 per minute till failure. The maximum load at failure divided by the average area of bed face gives the compressive strength.

$$\text{Compressive strength } (N/mm^2) = \frac{\text{Maximum load at failure (N)}}{\text{Average area of bed faces } (mm^2)}$$

The average of results shall be reported. The compressive strength of any individual brick tested in the sample should not fall below the minimum average compressive strength specified for the corresponding class of brick by more than 20 percent.

Warpage Test (IS:3495 (Part IV): Warpage of the brick is measured with the help of a flat steel or glass surface and measuring ruler graduated in 0.5 mm divisions or wedge of steel 60 × 15 × 15 mm (Fig. 2.15). For warpage test, the sample consists of 10 bricks from a lot.

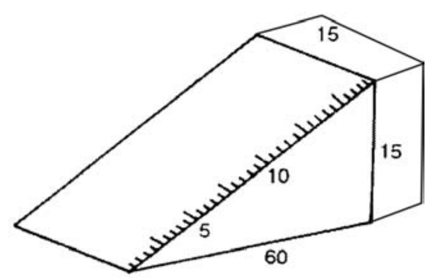


Fig. 2.15 Measuring Wedge

Concave Warpage: The flat surface of the brick is placed along the surface to be measured selecting the location that gives the greatest deviation from straightness. The greatest distance of brick surface from the edge of straightness is measured by a steel ruler or wedge.

Convex Warpage: The brick is place on the plane surface with the convex surface in contact with the flat surface and the distances of four corners of brick are measured from the flat surface. The largest distance is reported as warpage.

The higher of the distance measured in concave and convex warpage tests is reported as warpage.

Efflorescence Test (IS: 3495 (Part III)): The ends of the brick are kept in a 150 mm diameter porcelain or glass dish containing 25 mm depth of water at room temperature (20°–30°C) till the entire water is absorbed or evaporated. The water is again filled to 25 mm depth in the dish and allowed to be absorbed by the brick or evaporated. Presence of efflorescence is classified as below.

1. Nil — When the deposit of efflorescence is imperceptible.
2. Slight — When the deposit of efflorescence does not cover more than 10 per cent of the exposed area of the brick.
3. Moderate — When the deposit of efflorescence is more than 10 per cent but less than 50% of the exposed area of the brick.
4. Heavy — When the deposit of efflorescence is more than 50 per cent but the deposits do not powder or flake away the brick surface.
5. Serious — When the deposits are heavy and powder or flake away the brick surface.

The specifications limit the efflorescence to be not more than moderate (10–50%) up to class 12.5 and not more than slight (< 10 per cent) for higher classes.

2.12 DEFECTS OF BRICKS

Over-burning of Bricks: Bricks should be burned at temperatures at which incipient, complete and viscous vitrification occur. However, if the bricks are overburnt, a soft molten mass is produced and the bricks loose their shape. Such bricks are not used for construction works.

Under-burning of Bricks: When bricks are not burnt to cause complete vitrification, the clay is not softened because of insufficient heat and the pores are not closed. This results in higher degree of water absorption and less compressive strength. Such bricks are not recommended for construction works.

Bloating: This defect observed as spongy swollen mass over the surface of burned bricks is caused due to the presence of excess carbonaceous matter and sulphur in brick-clay.

Black Core: When brick-clay contains bituminous matter or carbon and they are not completely removed by oxidation, the brick results in black core mainly because of improper burning.

Efflorescence: This defect is caused because of alkalies present in bricks. When bricks come in contact with moisture, water is absorbed and the alkalis crystalise. On drying grey or white powder patches appear on the brick surface. This can be minimised by selecting proper clay materials for brick manufacturing, preventing moisture to come in contact with the masonry, by providing waterproof coping and by using water repellent materials in mortar and by providing damp proof course.

Chuffs: The deformation of the shape of bricks caused by the rain water falling on hot bricks is known as chuffs.

Checks or Cracks: This defect may be because of lumps of lime or excess of water. In case of the former, when bricks come in contact with water, the absorbed water reacts with lime nodules causing expansion and a consequent disintegration of bricks, whereas shrinkage and burning cracks result when excess of water is added during brick manufacturing.

Spots: Iron sulphide, if present in the brick clay, results in dark surface spots on the brick surfaces. Such bricks though not harmful are unsuitable for exposed masonry work.

Blisters: Broken blisters are generally caused on the surface of sewer pipes and drain tiles due to air imprisoned during their moulding.

Laminations: These are caused by the entrapped air in the voids of clay. Laminations produce thin lamina on the brick faces which weather out on exposure. Such bricks are weak in structure.

2.13 HEAVY DUTY BURNT CLAY BRICKS (IS: 2180)

These are similar to burnt clay bricks and of the same size but with high compressive strength.

Classification

Class 400: compressive strength not less than 40.0 N/mm^2 but less than 45.0 N/mm^2.

Class 450: compressive strength not less than 45.0 N/mm^2.

These are further subdivided as subclasses A and B based on tolerance.

Tolerance

Dimensions (cm)	Tolerances (mm)	
	Subclass A	Subclass B
9	± 3	± 7
19	± 6	± 15

Water absorption: should not be more than 10 per cent after 24 hours immersion in water.

Efflorescence: should be nil.

Bulk density: should be less than 2500 kg/m^3.

2.14 BURNT CLAY PERFORATED BRICKS (IS : 2222)

Perforated Bricks contain cylindrical holes throughout thier thickness, have high compressive strength and less water absorption. These bricks are light in weight, require less quantity of clay and drying and burning of these bricks is easy and economical. The direction of perforations can be vertical or horizontal. These are used in building walls and partitions. The area of perforations should not exceed 30 to 45% of the area of face. In case of rectangular perforations, larger dimensions should be parallel to longer side of the brick.

Dimensions

These are available in the following sizes.

(i) 19 × 9 × 9 cm.

(ii) 29 × 9 × 9 cm.

Tolerance

Dimensions (cm)	Tolerances (mm)
9	± 4
19	± 7
29	± 10

Perforations

(i) Dimension of perforation parallel to short side should not be more than 20 mm in case of rectangular projection and 25 mm in case of circular projection.
(ii) Area of each perforation should not exceed 500 mm^2.

Compressive strength should not be less than 7.0 N/mm^2.

Water absorption should not be more than 15 per cent.

Efflorescence should not be more than slight.

Warpage should not exceed 3 per cent.

2.15 BURNT CLAY PAVING BRICKS (IS : 3583)

The iron content is more than that in the ordinary clay bricks. Excessive iron causes vitrification of bricks while burning at a low temperature, gives natural glaze to the brick, making it more resistant to abrasion. Paving bricks can be manufactured from surface clays, impure fire-clays or shale. However, shales are the best raw material for paving bricks. These are generally burned in continuous kiln for seven to ten days.

Dimensions: The available sizes are:
(i) 19.5 × 9.5 x 9 cm
(ii) 19.5 × 9.5 × 4 cm

Tolerances

Dimensions (cm)	Tolerances (mm)
19.5	± 6
9.5	± 3
9	± 3
4	± 1.5

Compressive strength should not be less than 40.0 N/mm^2.

Water absorption should not be more than 5 per cent by weight after immersion for about 24 hours.

2.16 BURNT CLAY SOLING BRICKS (IS : 5779)

These are used for soling of roads.

Dimensions

(i) 19 × 9 × 9 cm
(ii) 19 × 9 × 4 cm

Tolerances: Overall dimensions of 20 bricks (selected) should be within following limits.

Length	370–388 cm (380 ± 8 cm)
Width	176–184 cm (18 ± 4 cm)
Height	

For	9 cm bricks	176–184 cm
	4 cm bricks	76–84 cm

Compressive strength should not be less than 5.0 N/mm^2.

Water Absorption should not be more than 20 per cent by weight after immersion for about 24 hours in cold water.

Efflorescence: Rating should not be more than slight.

2.17 BURNT CLAY HOLLOW BLOCKS (IS : 3952)

Hollow blocks, also known as cellular or cavity blocks, are manufactured from a thoroughly ground, lump free, well mixed clay mass of medium plasticity to allow moulding. The process of manufacture is similar to that of stiff-mud bricks. These are used to reduce the dead weight of the masonry and for exterior as well as partition walls. They also reduce the transmission of heat, sound and dampness.

Types

Type A — Blocks with both faces keyed for plastering or rendering.

Type B — Blocks with both faces smooth for use without plastering or rendering on either side.

Type C — Blocks with one face keyed and one face smooth.

Dimensions

Length (cm)	Breadth (cm)	Height (cm)
19	19	9
29	9	9
29	14	9

Tolerances

Dimensions (cm)	9	14	19	29
Tolerances (mm)	± 4	± 5	± 7	± 10

Crushing Strength: Minimum average value should be 3.5 N/mm^2. Strength of individual block should not fall below the average value by more than 20 per cent.

Water absorption should not be more than 20 per cent.

2.18 BURNT CLAY JALLIS (IS: 7556)

These are normally used for providing a screen on verandah and construction of parapet or boundary walls. Total void area should not exceed 40 per cent. Keys for bonding with mortar should be 10 mm wide and 3 mm deep. These are generally hand moulded but superior qualities can be produced by machines.

Dimensions

19 × 19 × 10 cm, 19 × 19 × 5 cm, 19 × 14 × 10 cm, 19 × 14 × 5 cm,
14 × 14 × 10 cm, 14 × 14 × 5 cm, 14 × 9 × 5 cm, 9 × 9 × 5 cm.

Tolerances ± 3 per cent.

Breaking load average value should not be less than 1.2 N / mm^2 width.

Water absorption average value should not exceed 15 per cent.

Efflorescence rating should not be more than slight.

Warpage should not exceed 3 per cent.

2.19 CLAY TILES

Tiles are thin slabs of low melting clays used for various purposes in engineering constructions. These give a very pleasing appearance and good service properties. Roofing tiles, flooring tiles, wall tiles and partition tiles are some of the examples. Due to the considerable mass, labour-consuming manufacture, erection and drainage problems, and appreciable transportation charges, roofing tiles have lost their importance and are recommended locally. The various types of roofing tiles in common use are shown in Fig. 2.16. Floor tiles are extensively used in houses and industrial buildings. These are durable and impervious to water, resist abrasion well and wash easily. White burning and red burning clays, fire clays and shales are used in making tiles for floor surfaces. Tiles for surface of walls differ from floor tiles principally in design in degree of burning. Wall tiles are burned at a comparatively low temperature, glazed, and fired again in muffle kiln at a still lower temperature.

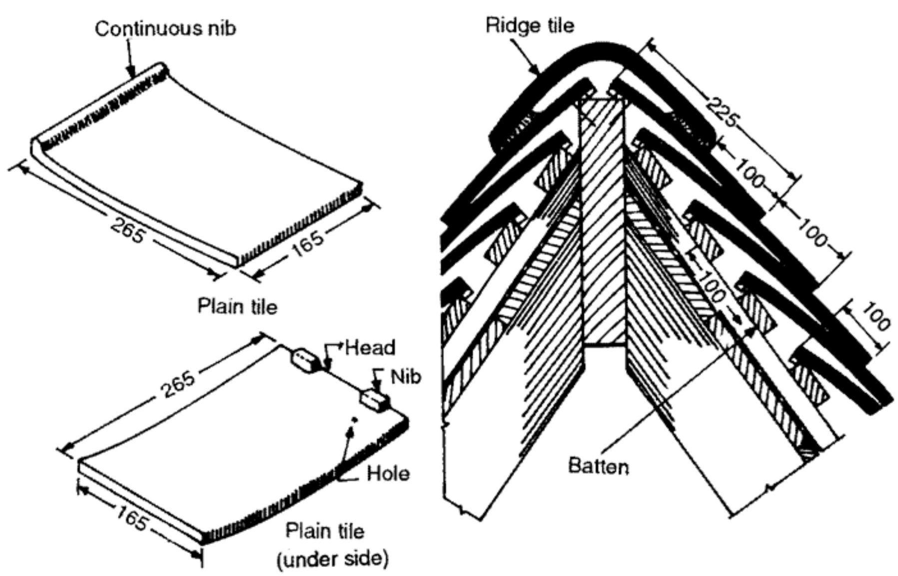


Fig 2.16 (a) Plain Tiling

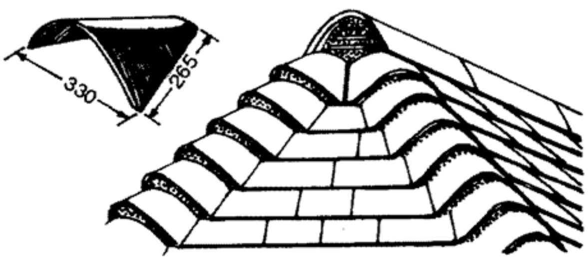


Fig. 2.16 (b) Hip Tiling

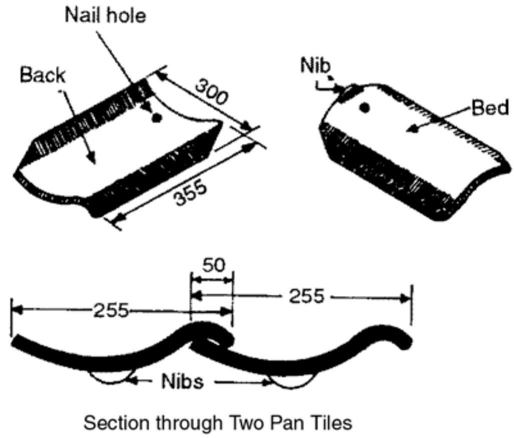


Fig. 2.16 (c) Pan Tiles

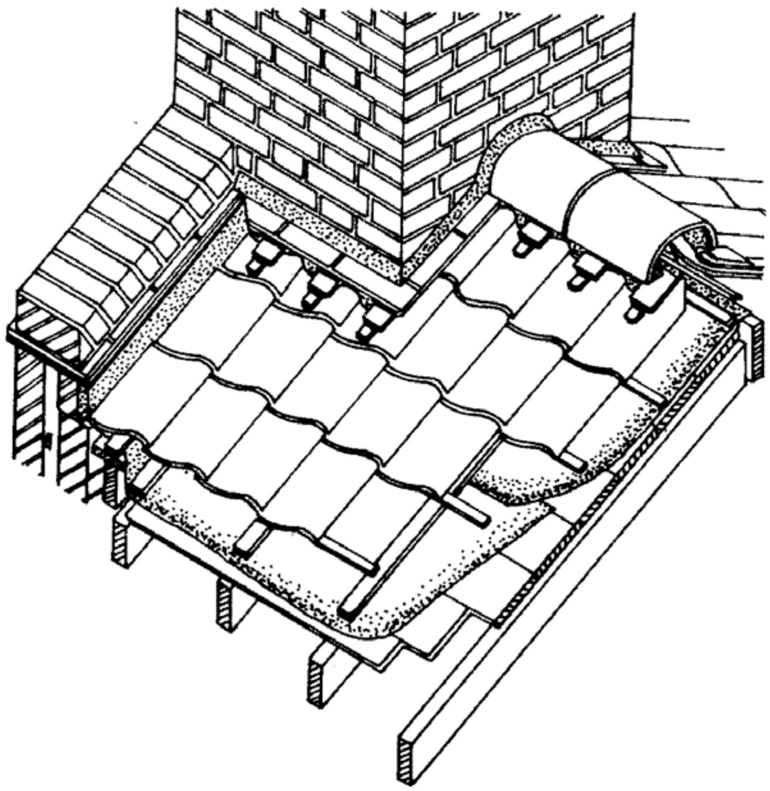


Fig. 2.16 (d) Pan Tiling

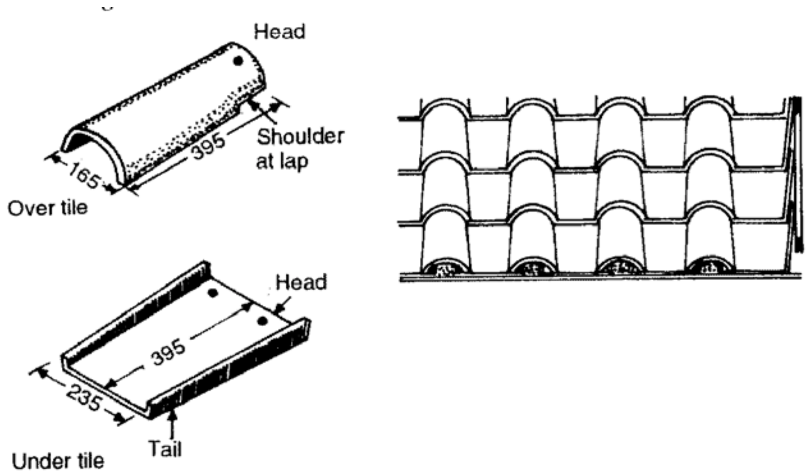


Fig. 2.16 (e) Spanish Tiling

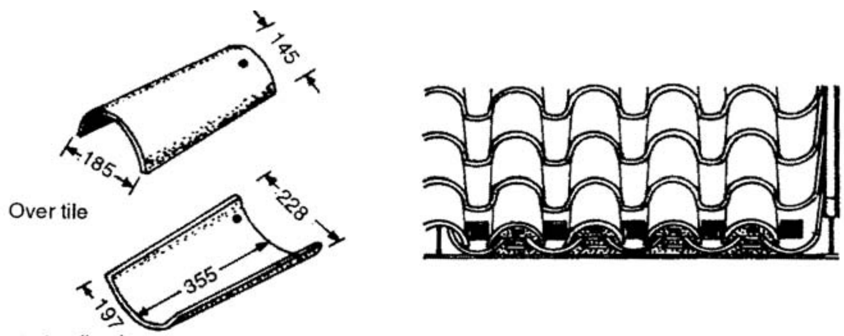


Fig. 2.16 (f) Italian Tiling

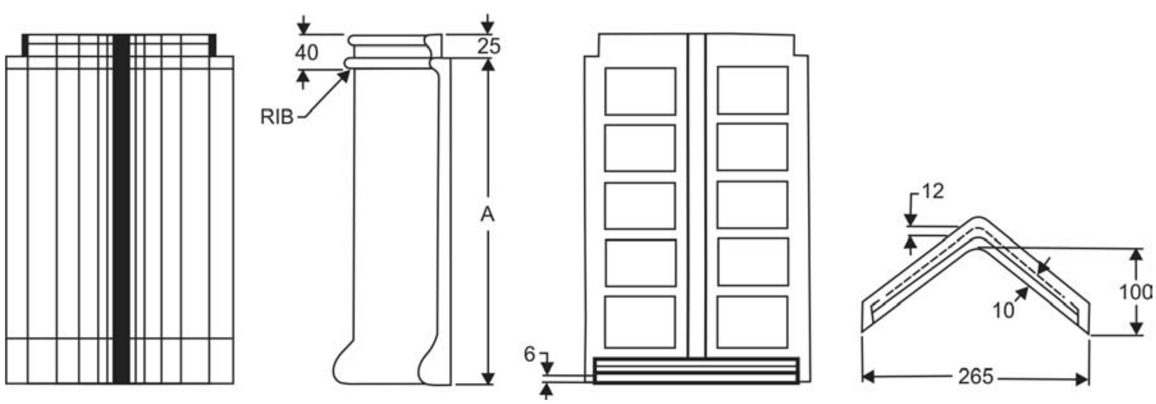
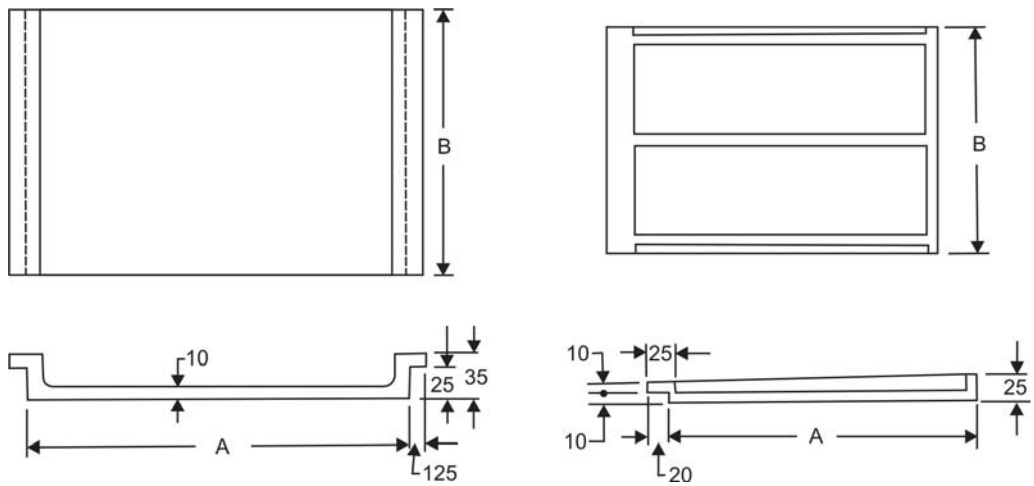


Fig. 2.17 (a) Ridge Tile



Double Lug Type
(Length of ceiling tile at the bottom)

Single Lug Type
(Width of ceiling tile at the bottom)

Fig. 2.17 (b) Ceiling Tile

Manufacturing

Tiles are made in the same manner as bricks, but are thinner and lighter, so require greater care. These are manufactured from a clay mass with or without admixtures of colouring impurities by moulding and subsequent burning until baked, up to about 1300 °C. The clay should be highly plastic with lean admixtures and fusing agents to lower the melting point. These are moulded in machines of the auger or plunger type and are commonly burned in continues kilns.

Specifications

Flat Terracing Tiles *(IS: 2690):* The flat terracing tiles may be hand moulded or machine moulded. Their specifications are given in Table 2.5. Hand moulded tile is marked with symbol H and the machine moulded tile with symbol M.

Table 2.5 Specifications for Flat Terracing Tiles

Characteristic/Dimensions	*Hand moulded*	*Machine moulded*
Length (mm)	250 to 150 in stages of 25	250 to 150 in stages of 25
Width (mm)	200 to 75 in stages of 25	200 to 100 in stages of 25
Thickness (mm)	25 to 50 in stages of 5	20 and 15
Tolerances	± 3%	± 2% for machine pressed ± 3% for machine extrudel
Warpage	$\not>$ 2 %of deminsion	$\not>$ 1% of diminsion
Water absorption	$\not>$ 20 %	$\not>$ 15%
Modulus of rupture (N/mm2)	$\not>$ 1.5	$\not>$ 2

Clay Ridge and Ceiling Tiles

The clay ridge and ceiling tiles (Fig. 2.17) are grouped as class AA and also A and should fulfil the following requirements.

	Class AA	Class A
1. Maximum water absorption (%)	18	20
2. Minimum breaking strength (kN)	0.015 (average) 0.0125 (individual)	0.011 (average) 0.0095 (individual)

The length of the ridge tile measured from face to face excluding the portion containing the catch should be 375, 400 and 435 mm with a tolerance of 15 mm. When a ridge tiles is placed on a horizontal plane (Fig. 2.17 (a)), the triangle formed in elevation by producing the inner faces of the tile should have a base of 265 mm and height of 100 mm with a tolerance of ± 5 mm. The tiles shold be not less than 100 mm thick throughout.
The ceiling tiles may be of single lug or double lug type as shown in Fig. 2.17(b).

Flooring Tiles

The flooring tiles are of three classes–class 1, class 2 and class 3. These are available in following sizes.

150 × 150 × 15mm, 150 × 150 × 20mm, 200 × 200 × 20mm
200 × 200 × 25mm, 250 × 250 × 30mm

The average dimensions should not vary by more than ± 5 mm and that for a given area and space the dimensions of individual tile should not vary by more than ± 2 %. For thickness these limits are ± 2 mm and ± 1 mm respectively.
The characteristics of these tiles are given in Table 2.6.

Table 2.6 Classification of Flooring Tiles

Sl. No.	*Characteristic*	*Requirements for*		
		Class 1	*Class 2*	*Class 3*
(i)	Water absorption per cent, ***Max:***	10	19	24
(ii)	Flexural strength, kg/cm width, ***Min:***			
	(a) Average	6	3.5	2.5
	(b) Individual	5	3.0	2.0
(iii)	Impact, maximum height in mm of drop of steel ball:			
	(a) 15 mm thick	25	20	15
	(b) 20 mm thick	60	50	40
	(c) 25 mm thick	75	65	50
	(d) 30 mm thick	80	70	60

Characteristics

A good roofing tile should have the following properties:

1. uniform texture.
2. accurate size and shape.
3. free from defects like flaws, cracks and nonuniform burning.

4. water absorption (less than 15 per cent).
5. resistant to atmosphere and dampness.
6. durability.

Uses

They are used as roofing material for low cost houses in big cities and also used to give a pleasing look from architectural point of view.

Testing of Tiles

The burnt, clay roofing tiles must comply with two tests—the transverse strength test and the water absorption test. The flooring tiles in addition to these tests must also be tested for impact. Ridge tiles are tested for water absorption and breaking strength.

Transverse Strength Test (IS: 2690) consists of applying the load along the centre line at right angles to the length of the tile (which has been immersed in water for twenty four hours) supported on the rounded edges of wood bearers. Six tiles are tested and the average breaking load should not be less than as specified in the code. The rate of loading is kept uniform and may vary in the range of 450-550 N / min.

$$\text{Flexural strength (N / mm}^2) = \frac{15\ WS}{bt^2}$$

where W = breaking load, S = span in mm (3/4 of tile), and b, t = width and thickness, respectively.

Water Absorption Test (IS: 2690): Six tiles are dried in oven at 105 ± 5°C and cooled at the room temperature. They are then immersed in water for twenty four hours. Thereafter wiped dry and weighed.

$$\text{Absorption in \%} = \frac{W_2 - W_1}{W_1} \times 100$$

where, W_1 and W_2 are the respective weights of dry and the immersed specimens.

Impact Test (IS: 1478): The apparatus for the impact test consists of an upright stand fixed to a heavy base. A steel ball 35 mm in diameter and 170 g in weight is held in jaws of a clamp fixed to the stand. Three specimen tiles are oven dried at a temperature of 100–110°C till they attain a constant weight and then allowed to cool at room temperature. The tile is placed horizontally with its face upwards over a 25 mm thick rubber sheet which in turn is placed over a rigid horizontal surface. The tile is so adjusted that the ball when released falls vertically on the centre of the tile. The steel ball is first released from a height of 75 mm. Then the height of release is raised in steps of 75 mm until the test specimen fractures. The maximum height of release of the test ball is reported.

Breaking Strength Test (IS: 1464): A sample of six tiles is used for the test. The tiles are soaked in water for 24 hours. The two longitudinal edges of the ridge tiles are kept, in the normal position, over two strips of 25 mm thick rubber sheet placed on the table of the testing machine. A 75 × 100 × 300 mm block is placed over the ridge of the tile and a load of 2.7 kN / min is applied on the block. The breaking load of individual tile is noted. It is divided by the length of tile. The results are reported in N / mm.

2.20 FIRE-CLAY OR REFRACTORY CLAY

Fire-clay is a term, loosely applied, to include those sedimentary or residual clays which vitrify at a very high temperature and which, when so burnt, possess great resistance to heat.

These are pure hydrated silicates of alumina and contain a large proportion of silica 55–75%, alumina 20–35%, iron oxide 2–5% with about 1 per cent of lime, magnesia and alkalis. The greater the percentage of alumina, the more refractory the clay will be. Fire clays are capable of resisting very high temperatures up to 1700°C without melting or softening and resist spalling. The presence of a small percentage of lime and magnesia and alkalis help to melt the clay particles more firmly, whereas a large percentage of lime and magnesia tend to melt the clay at low temperatures. Iron oxide or other alkalis reduce refractory qualities of fire clay. The fire clay is used for manufacturing fire bricks used in furnance linings, hollow tiles, and crucibles.

2.21 FIRE-CLAY BRICKS OR REFRACTORY BRICKS

Fire-clay bricks are made from fire-clay. The process of manufacturing is as of an ordinary brick, burnt at very high temperatures in special kilns (Hoffman's kiln). The raw materials used for the manufacture of fire bricks consist of flint clay and grog (burnt fire clay) as non-plastic materials and soft fire clay as plastic material. Fire clay mortar is used to clay rerfractory bricks.

Properties

1. The colour is whitish yellow or light brown.
2. The water absorption of fire-clay bricks varies from 4–10%
3. The minimum average compressive strength of the bricks should be 3.5 N / mm^2.

Uses These are used for lining blast furnances, ovens, kilns, boilers and chimneys.

The principal varieties of fire-clay bricks are as follows:

Acid Refractory Bricks consist of silica bricks (95–97% silica and 1–2% lime) and ganister bricks (ganister—a hard coloured sand stone containing 10 per cent clay and 2 per cent of lime), used in lining furnaces having siliceous and acidic slag, steel industry and coke oven. The softening temperature ranges from 1700° to 1800°C. Silica bricks are hard and also possess good refractoriness under load. But they have tendency to spall during rapid temperature change therefore, these can not be used for lining of furnaces which have to be cooled and reheated frequently.

Basic Refractory Bricks consist of magnesia bricks (magnesia minimum 85 per cent, calcium oxide maximum 25 per cent and silica maximum 5.5 per cent) and bauxite bricks (minimum 85 per cent aluminium oxide and maximum 20 per cent clay). These are highly resistant to corrosion and are used for lining furnances having basic slag. Due to high thermal expansion and consequent poor resistance to spalling the use of these bricks is retricted to copper metallurgy and basic open hearth.

Neutral Refractory Bricks consist of chromite bricks (50 per cent chrome and iron ore containing 30 per cent iron oxide and bauxite containing 15 per cent aluminium and 5 per cent silica), chrome magnesite bricks (Cr_2O_3 18 per cent, MgO 30 per cent), spinel and forsterite bricks. The neutral refractory bricks are suitable at places where acidic and basic linings are to be separated, e.g. for lining copper reverberatory furnance.

2.22 TERRACOTTA

It is an Italian word, *Terra* means clay and *Cotta* means burnt. Terracotta is refractory clay product and is used in ornamental parts of buildings. The clay used for its manufacture should be of superior quality and should have sufficient iron and alkaline matters. By varying iron oxide in clay, desired colour can be obtained. The clay is mixed with powdered glasses, pottery and sand ground to fine powder and pugged several times till it gets uniform and soft for moulding. Terracotta is impervious, hard and cheap. When properly made the material weathers well and becuse of its glazed surface can be cleaned easily. The product is burnt in special kilns (Muffle furnance).

Preparation of Clay: The clay is mixed thoroughly with water in a tub. Powdered pottery, glass and white sand are added to it in sufficient proportions. It is then intimately mixed with spades. The intimate mix is then placed in wooden boxes with joints. This allows the surplus water to drain off. Thereafter the mix is passed several times through pug mills.

Moulding and Drying: Special porous moulds are made of Plaster of Paris or of zinc. The pugged clay is pressed into moulds. The dried articles are taken out of the moulds after a few days and then dried slowly.

Burning: Terracotta is burned with care to get uniform colour in muffle furnance between 1100–1200°C.

Composition

Dry clay 50–60%	Ground glass 8–10%
Crushed pottery 20%	Clean white sand 10–20%

Uses

1. Hollow blocks of terracotta are used for masonry.
2. Cornices and arches.
3. Statuettes.
4. Ornamental works.
5. Being fire proof, terracotta is most suitable as casing for steel columns and beams.
6. Porous terracotta is used for sound insulation.

Classification: Terracotta is of two types, the porous and the polished (Faience).

Porous Terracotta: It is manufactured by mixing sawdust or finely fragmented cork in the clay and has the following characteristics.

1. Light weight.
2. Resistant to weathering action.
3. Fire resistant.

4. Can be nailed and sawn to various shapes.
5. Sound proof.
6. Poor strength—used only for ornamental works.

Polished Terracotta is highly glazed architectural terracotta with relatively coarse body. These are made from refractory clays with addition of quartz sand and fusing agents such as chalk.The polished terracotta is also called *terracotta twice burnt*. The 1st burning is called *biscutting* and is done at 650°C. Then, this product is coaled with glazed solution which imparts texture and colour. Thereafter it is dried and fired at 1200°C. The material

1. is hard, strong and durable.
2. can be given different colours.
3. is leak proof (water absorption < 12 per cent) and can be easily cleaned.
4. is resistant to chemical action.
5. is resistant to weathering action of atmosphere.
6. is fire proof.

2.23 PORCELAIN

A high grade ceramic ware having white colour, zero water absorption and glazed surface which can be soft or hard, consists of finely dispersed clay, kaolin, quartz and felspar, baked at high temperature and covered with a coloured or transparent glaze. The glazing material is applied before firing. At high temperatures, the felspar particles fuse and bind the other constituents into a hard, dense, and vitreous mass. High temperature ensures non-porosity and a better product. Because of white colour, it is also called *whiteware* which is of two types:

Soft Porcelain is made from white clay to which flint is added.

Hard Porcelain is made form china clay or kaolin with quartz and felspar are added as filler.

Composition

China clay	50–60%
Ordinary clay	5%
Whiting	< 1%
Felspar	20%

Characteristics

1. Low (zero) water absorption.
2. Hard and glazed.
3. Good refractory material.
4. Good electric insulator.

Uses: Porcelain is used for manufacturing sanitary wares, containers and crucibles, reactor chambers and electric insulators.

Note: **A special type of porcelain known as Ziron Porcelain is used in automobile industry. Its composition is as follows:**

Iron	**60%**
Clay	**15–30%**

2.24 STONEWARE

A hard ceramic material resembling porcelain with a different colour, usually grey or brownish is made from refractory clay mixed with crushed pottery, stones and sand burned at high temperatures and cooled slowly. The clay used for making stoneware consists of about 75 per cent silica and 25 per cent alumina. Iron oxide is added to give colour.

Characteristics

1. Hard, compact, strong and durable material.
2. Gives ringing sound when struck.
3. Glazed stoneware becomes resistant to chemical and weathering action.
4. Gives good finish and appearance.

Uses

1. Light sanitary wares, e.g. wash basins, water closets, etc.
2. Drain pipes and fittings.
3. Road paving materials.
4. Flooring tiles and wall tiles in toilets and kitchens.

2.25 EARTHENWARE

These are made by burning the ordinary clay at low temperature and cooling slowly. To check shrinkage, sand and crushed pottery are mixed with clay. This also increases the toughness, hardness and strength of the ware.

Characteristics

1. Soft, porous and weak.
2. Glazed earthenware becomes resistant to weathering action.

Uses: Earthenware is used for manufacturing drain pipes, lavatory fittings and light weight partition walls.

2.26 MAJOLICA

It is Italian earthenware coated with an opaque white enamel, ornamented with metallic colour. It is manufactured from low-heat clays to which up to 20 per cent calcium carbonate is added in the form of chalk. Majolica has a microporous texture.

Uses: It is used in doorways, window casings, and facing tiles.

2.27 GLAZING

Bricks, tiles, earthenwares and stonewares are glazed by an impervious film to protect the surface from chemical attack and other weathering agencies. The different types of glazing in use are as to follow.

Transparent Glazing

There are many methods for imparting transparent glazing, but salt glazing is most commonly used, since this makes the items impermeable. It consists of throwing sodium chloride in the kiln when burning is at peak (1200°–1300°C). The heat of the kiln volatises the salt, which enters into the pores of the burning item and combines with the silica in clay to make soda silicate. The soda silicate so formed combines with alumina, lime and iron in the clay to form a permanent thin, transparent surface coating.

Lead Glazing

Clay items are burned thoroughly and then dipped in a solution of lead oxide and tin oxide. The particles of lead and tin adhere to the surface of clay items. After this, the articles are returned in potter's kiln where these adhered particles melt and form a thin transparent layer on the outer surface. This method of glazing is used for items of inferior clay which cannot withstand high temperature required for salt glazing.

Opaque Glazing

This is also known as *enamelling.* Borax, kaolin, chalk and colouring matter is fired with total or a part of felspar, flint, and lead oxide. The resulting molten glass is poured into water to give shattered frit. The frit is then ground with remaining materials and water and is made of the consistency of cream known as *slip.* Fully burnt earthenwares known as *biscuits* are dipped in the slip. The biscuits absorb water and form thin layer of glaze on the surfaces. After drying the products, these are once again fired to a lower temperature so as to fuse the glaze.

2.28 APPLICATION OF CLAY PRODUCTS

Universal availability of raw materials, comparative simplicity of manufacture and excellent durability of ceramic materials have put them in the forefront among other constructional materials. The high strength and durability of clay products underlie their wide use in the various elements of buildings, such as walls, wall and floor facing materials, lining materials for chemical industry apparatus, chimney, light porous aggregates for roofing, and sewer pipes. The various applications of clay products in the building industry are as follows.

1. *Wall materials.* The examples are common clay brick, perforated clay brick, porous and perforated stiff-mud brick, hollow clay dry-press brick. Perforated plastic moulded ceramic stones and light weight building brick. Clay brick accounts for half of the total output of wall materials. Structural properties of hollow clay products and low heat losses through air-filled voids (particularly at subzero temperatures) provide great possibilities for reducing the thickness and the weight of exterior walls. Ceramic facing tiles remain the chief finishing material for sanitary and many other purposes and are still in great use for external facing of buildings.
2. *Brick for special purposes.* The example are curved clay brick, stones for sewage installations (underground sewer pipes) brick for road surface (clinker).
3. *Hollow clay products for floors.* The examples are stones for close-ribbed floors (prefabricated or monolithic), stones for reinforced ceramic beams, sub flooring stones (fillers between beams).
4. *Facade decoration.* The examples are glazed or non-glazed varieties subdivided in to facing brick and ceramic stones, floor ceramics, small-size ceramic tiles, ceramic plates for facades and window-sill drip stones.

5. *Clay products for interior decoration.* The examples are tiles for facing walls, built-in parts, large floor tiles and mosaic floor tiles.
6. *Roof materials.* The examples are common clay roof tiles for covering slopes of roofs, ridge tiles for covering ridges and ribs, valley tiles for covering valleys, end tiles ("halves" and "jambs") for closing row of tiles, special tiles.
7. *Acid-resistant lining items.* The examples are common acid-resistant brick, acid-resistant and heat-and-acid-resistant ceramic shaped tiles for special purposes, ceramic acid-resistant pipes and companion shapes.
8. *Sanitary clay items.* Sanitary ware items are manufactured mainly form white-burning refractory clay, kaolins, quartz and feldspar. There are three groups of sanitary ceramics: faience, semi-porcelain and porcelain, which differ in degree of caking and, as a consequence, in porosity. Items from faience have a porous shell, and items from porcelain, a solid shell, while those from semi-porcelain are of intermediate densities. The various degrees of caking of faience, porcelain and semi-porcelain, made of the same raw materials, are due to the latter's different proportions in the working mass.

   Solid faience is used mainly to manufacture toilet bowls, wash basins, toilet tanks and bath tubs. Items are glazed, since unglazed faience is water permeable. Semi-porcelain items feature excellent hygienic and mechanical properties being intermediate between those of faience and porcelain. Porcelain outer shell is impervious to water and gases and possesses high mechanical strength and resistance to heat and chemical agent. Porcelain is used to manufacture insulators for power transmission lines, chemical laboratory vessels, etc.
9. *Aggregate for concrete.* Creamiste (manufactured from low-heat clay), a light weight porous material forms excellent aggregate for light weight concrete.

EXERCISES

1. (a) What are the requirements of soil suitable for burning bricks?
   (b) How can good bricks be made from black cotton soil?
   (c) What are the substances which harm the qualities of good bricks, in their manufacture and as finished product.
2. (a) Enumerate the chief characteristics of clay as material used for manufacture of bricks. Describe its behaviour under varying climatic conditions.
   (b) Describe the qualities of first class building bricks and indicate how are they influenced by the
      (1) nature of clay used
      (2) process of manufacture
      (3) manner of firing
3. (a) What are the properties of first class bricks?
   (b) Describe how bricks are classified?
   (c) What are the constituents of good brick-earth?
4. (a) Describe the common defects in bricks.
   (b) What are the factors to be considered while selecting a site for the manufacture of bricks?

5. (a) What constituents render brick-earth unsuitable for manufacturing bricks?
   (b) How does excess of each of the constituents of brick-earth affect the quality of bricks?
6. Differentiate between
   (a) Perforated and hollow bricks.
   (b) Acid refractory and basic refractory bricks.
   (c) Over-burnt and under-burnt bricks.
   (d) Earthenware and stoneware.
   (e) Slop-moulded and sand-moulded bricks.
7. (a) Describe the tests performed to check the quality of bricks.
   (b) What do you understand by glazing ? How is it done?
8. Write short notes on:
   (a) Clay Jallis (b) Defects in bricks
   (c) Clamp burning of bricks (d) Glazing
   (e) Efflorescence (f) Heavy duty bricks
9. (a) What is a frog? State its importance in clay bricks.
   (b) What are the characteristics of good bricks?
10. Describe briefly the tests to which bricks may be put before using them for engineering purposes.
11. What is efflorescence in bricks? What are its causes and remedies?
12. (a) What are fire clays? State there constituents and importance.
    (b) Describe the process of manufacturing clay tiles.
13. Write short notes on:
    (a) Refractory bricks (b) Earthenware
    (c) Majolica (d) Over-burnt bricks.
    (e) Ceiling tiles (f) Testing of tiles
14. Sketch and state the uses of:
    (a) Coping brick (b) Bull nose brick
    (c) Perforated brick (d) Cornice brick
    (e) Hollow brick (f) Queen closer
15. Write short notes on:
    (a) Paving bricks (b) Roofing tiles
    (c) Terracotta (d) Faience
    (e) Porcelain (f) Warpage test of bricks
    (g) Majolica (h) Testing of tiles

OBJECTIVE TYPE QUESTIONS

1. Consider the following statements:
   A good soil for making bricks should contain
   (1) about 30% alumina
   (2) about 10% lime nodules
   (3) a small quantity of iron oxides
   (4) about 15% magnesia
   Of these statements
   (a) 1 and 2 are correct (b) 1 and 3 are corect
   (c) 1, 3 and 4 are correct (d) 2, 3 and 4 are correct

2. If L is the length and B the width of the brick and t the thickness of mortar, the relation between these is
   (a) L = 2B (b) L = B + t
   (c) L = B + 2 t (d) L = 2B + t
3. The weight of a standard brick should be
   (a) 1000 g (b) 1500 g
   (c) 2500 g (d) 3000 g
4. Frog is provided in
   (i) 9 cm high bricks only
   (ii) 4 cm high bricks only
   (iii) extruded bricks only
   Of the above
   (a) only (i) is correct (b) only (ii) is correct
   (c) (i) and (iii) are correct (d) (i), (ii) and (iii) are correct
5. The most important purpose of frog in a brick is to
   (a) emboss manufacturer's name
   (b) reduce the weight of brick
   (c) form keyed joint between brick and mortar
   (d) improve insulation by providing 'hollows'
6. Consider the following statements :
   (1) About 25% of alumina in brick earth imparts the plasticity necessary for moulding bricks into required shape
   (2) Iron pyrite present in brick earth preserves the form of the bricks at high temperatures.
   (3) Presence of weeds in brick earth makes the bricks unsound.
   Which of these statements are correct?
   (a) 1 and 2 (b) 1 and 3
   (c) 2 and 3 (d) 1, 2 and 3
7. Water absorption for Ist class bricks should not be more than
   (a) 12% (b) 15%
   (c) 20% (d) 25%
8. For hidden masonry works the bricks used should be
   (a) Ist Class (b) IInd Class
   (c) IIIrd Class (d) for any of the above
9. For centring of R.C.C. structures the bricks used should be
   (a) Ist Class (b) IInd Class
   (c) IIIrd Class (d) IVth Class
10. Match List-I (Constituents of bricks) with List-II (Corresponding influence) and select the correct answer using the codes given below the lists :

List-I *(Constituents of bricks)*	*List-II* *(Corresponding influence)*
A. Alumina	1. Colour of brick
B. Silica	2. Plasticity recovery for moulding

C. Magnesia	3. Reacts with silica during burning and causes particles to unite together and development of strength
D. Limestone	4. Preserves the form of brick at high temperature and prevents shrinkage

Codes :

(a) A B C D
2 1 4 3

(b) A B C D
3 4 1 2

(c) A B C D
2 4 1 3

(b) A B C D
3 1 4 2

11. The IS classification of bricks is based on
    (i) compressive strength
    (ii) water absorption
    (iii) dimensional tolerance
    Of the above
    (a) only (i) is correct
    (b) (i) and (ii) are correct
    (c) (i) and (iii) are correct
    (d) (i), (ii) and (iii) are correct
12. Which of the following constituent in earth gives plasticity to mould bricks in suitable shape?
    (a) Silica
    (b) Lime
    (c) Alumina
    (d) Magnesia
13. The raw bricks shrink during drying and warp during burning because of
    (a) less lime in brick earth
    (b) less silica and excess magnesia in brick earth
    (c) excess of alumina and silica in brick earth
    (d) alkalis in brick earth
14. The moulded bricks are dried before burning to an approximate moisture content of
    (a) 3%
    (b) 6%
    (c) 10%
    (d) 20%
15. In the process of brick manufacturing the pug mill is used in which of the following operation?
    (a) Weathering
    (b) Blending
    (c) Tempering
    (d) Burning
16. Consider the following statements :
    For the manufacture of good quality bricks it is essential to
    (1) use a reverberatory kiln
    (2) blend the soil with clay or sand as deemed appropriate
    (3) knead the soil in a ghani
    (4) temper the soil in a pug mill
    Of these statements
    (a) 1 and 3 are correct
    (b) 2 and 4 are correct
    (c) 1, 3 and 4 are correct
    (d) 2, 3 and 4 are correct

17. Bricks are burnt at a temperature range of
    (a) 500° to 700° C (b) 700° to 900° C
    (c) 900° to 1200° C (d) 1200° to 1500° C
18. Match List-I with List-II and select the correct answer using the codes given below the lists :

List-I (Ingredients)	*List-II (%)*
(A) Silica	(1) 50 – 60%
(B) Lime	(2) 20 – 30%
(C) Alumina	(3) 10%
(D) Alkalis	(4) <10%

Codes :

	A	B	C	D
(a)	1	2	3	4
(b)	1	3	2	4
(c)	1	2	4	3
(b)	2	1	4	3

19. Match List-I with List-II and select the correct answer using the codes given below the lists :

List-I (Ingredients)	*List-II (Property)*
A. Silica	1. imparts durability, prevents shrinkage
B. Alumina	2. softens clay
C. Lime	3. renders clay plastic
D. Ferric Oxide	4. lowers fusing point

Codes :

	A	B	C	D
(a)	1	3	2	4
(b)	1	4	2	3
(c)	1	3	4	2
(b)	4	3	1	2

20. Excess of silica makes brick
    (a) brittle on burning (b) to melt on burning
    (c) to crack on drying (d) to warp
21. Which of the following is harmful in the clay used for making bricks?
    (a) Iron oxide (b) Iron pyrite
    (c) Alkali (d) Magnesia
22. When carbonaceous materials in the form of bituminous matter of carbon are present in the clay, the bricks will
    (a) be spongy (b) have black core
    (c) be porus (d) have cracks
23. Swollen structure and white blotches will be found in bricks when
    (a) carbon (b) bituminous matter
    (c) organic matter (d) sulphur
    is present in clay used for making bricks.

24. Consider the following properties
    1. Strength development during firing
    2. Drying shrinkage
    3. Shaping

    When flyash is used as an additive with clay in brick manufacturing the improved properties are
    (a) 1 only (b) 2 only
    (c) 1 and 2 (d) 1 and 3
25. Consider the following stages in the manufacturing of bricks :
    1. Weathering 2. Moulding
    3. Tempering

    The correct sequence of these stages in the manufacturing of the bricks, is
    (a) 1, 2, 3 (b) 2, 3, 1
    (c) 1, 3, 2 (d) 3, 2, 1
26. Consider the following operations of preparation of brick earth
    1. Digging 2. Weatherig
    3. Tempering 4. Blending
    5. Unsoiling

    The correct sequence of these operations are
    (a) 5, 1, 2, 4, 3 (b) 5, 1, 3, 2, 4
    (c) 1, 5, 2, 4, 3 (d) 5, 1, 4, 2, 3
27. In some brick masonry walls, patches of whitish crystals were found on the exposed surfaces, also chipping and spalling of bricks took place from the same walls. Which among the following are the causes of these defects?
    1. Settlement of foundation 2. Over-loading of the walls
    3. Sulphate attack 4. Efflorescence

    Codes :
    (a) 1 and 2 (b) 2 and 3
    (c) 2 and 4 (d) 3 and 4
28. Efflorescence of bricks is due to
    (a) soluble salts present in clay for making bricks
    (b) high porosity of bricks
    (c) high silt content in brick earth
    (d) excessive burning of bricks
29. What is efflorescence ?
    (a) Formation of white patches on the brick surface due to insoluble salts in the brick clay.
    (b) Swelling of brick due to presence of carbonaceous matter and gass
    (c) Deformation of brick due to exposure to rain
    (d) Impurities in the brick clay which show after burning
30. Consider the following with regards to burning of clay bricks.
    1. The clay loses its plasticity
    2. Carbonate minerals are decarbonated
    3. Some of the carbonaceous matter is burnt
    4. Clay mass is converted into glass like substance
    5. Ferrous iron is oxidized to ferric form

The changes that occur during dehydration period are :

(a) 1, 3, 5 (b) 1, 2, 4
(c) 1, 2, 3 (d) 2, 4, 5

31. When the deposits of efflorescence is more than 10 per cent but less than 50 per cent of the exposed areas of brick, the presence of efflorescence is classified as
(a) slight (b) moderate
(c) heavy (d) serious

32. A good brick when immersed in water bath for 24 hours, should not absorb water more than
(a) 20% of its dry weight (b) 15 % of its saturated weight
(c) 10% of its saturated weight (d) 20% of its saturated weight

33. Crushed pottery is used in the manufacture of
(a) fire bricks (b) stone bricks
(c) terracotta (d) clay tiles

34. Match List I with List II and select the correct answer used the codes given below the lists:

List - I	*List - II*
A. Acid Brick	1. Made from Quartzite
B. Silica Brick	2. Made from magnesite
C. Basic Brick	3. Made from fire clay
D. Neutral Brick	4. Made from chromite

Codes :

	A	B	C	D
(a)	3	1	2	4
(b)	3	2	1	4
(c)	4	1	2	3
(b)	1	2	3	4

35. The compressive strength of burnt clay bricks as per IS 1077 is
(a) 100 kg/cm^2 (b) 150 kg/cm^2
(c) 100 – 150 kg/cm^2 (d) 35 – 350 kg/cm^2

36. The deformation of the shape of bricks caused by the rain water falling on the hot bricks is known as
(a) spots (b) checks
(c) chuffs (d) blisters

37. The defect in clay products because of imprisoned air during their moulding is known as
(a) blister (b) lamination
(c) cracks (d) spots

38. Basic refractory bricks consist of
(a) silica bricks (b) ganister bricks
(c) magnesia bricks (d) chromite bricks

39. In steel industry the bricks used for lining furnaces should be
(a) acid refractory (b) basic refractory
(c) neutral refractory (d) heavy duty

40. Terracotta is burned in
(a) pug mill (b) reverberatory furnance
(c) muffle furnance (d) puddling furnance

41. Glazing of clay product is achieved by throwing sodium chloride in kiln at a temperature of
    (a) 600 – 800° C (b) 700 – 1000° C
    (c) 900 – 1100° C (d) 1200 – 1300° C
42. The bricks which are extensively used for basic refractories in furnaces are
    (a) chrome bricks (b) sillimanite bricks
    (c) magnesite bricks (d) fosterite bricks
43. Which one of the following procedure is applied to determine the soundness of bricks?
    (a) Immersing the bricks under water for 16 hrs and determining the quantity of water absorbed by the brick
    (b) Immersing the brick under water for 24 hrs and determining its expansion using Le Chatelier apparatus
    (c) Taking two bricks, hitting one against the other and observing whether they break or not and the type of sound produced while hitting
    (d) Scratching the brick by finger nail and noting whether any impression is made or not
44. The number of bricks required per cubic meter of brick masonry is
    (a) 400 (b) 450
    (c) 500 (d) 550

Answers Table

1. (a)	2. (d)	3. (d)	4. (a)	5. (c)	6. (b)	7. (b)	8. (b)	9. (b)	10. (c)
11. (c)	12. (c)	13. (c)	14. (a)	15. (c)	16. (b)	17. (c)	18. (b)	19. (c)	20. (a)
21. (b)	22. (b)	23. (d)	24. (c)	25. (c)	26. (a)	27. (d)	28. (a)	29. (a)	30. (c)
31. (b)	32. (a)	33. (c)	34. (a)	35. (d)	36. (c)	37. (b)	38. (c)	39. (a)	40. (c)
41. (d)	42. (c)	43. (a)	44. (c)						