CHAPTER - II

SCIENCE OF BRICKS: AN OVERVIEW

2.0 INTRODUCTION

Brick is a building material made usually from clay moulded as a rectangular block and backed or burned in a kiln. (McGraw Hill Encyclopedia 1982). In other words, brick is a small rectangular unit usually of burned clay, used in building construction. Laid in courses (layers) with mortar joints, bricks can provide many forms of construction, of massive or delicate proportion as required to carry loads, to screen, to protect against weather or resist penetration of heat (New Encyclopedia Britannica 1979).

Brick - a fat reddish earth, formed into rectangle shapes, four inches broad and eight or nine inches long, by means of a thin wooden mould baked or burnt in a kiln to serve as building material.

Bricks have been used as building materials for the last 10,000 years. Archaeologists at Ur of the Chaldees, the city of Abraham in Valley of the Euphrates, have discovered burned and unburned bricks in the great temples made over 5000 years ago. Primitive bricks were sun dried, but the brick kiln was invented at an early date; temples of the near East of the Third Millennium BC contained kiln-fired bricks. The Tower of Babel was probably a brick structure raised above the flat valley. The original bricks used in the Sixth century BC to build Nebuchadrezzer's City of Babylon were later taken from the ruins to build the towns of Ctesiphon and Baghdad. From Western Asia, the art of brick making appears to have spread westward toward Egypt and the Mediterranean and eastward to India and China (McKay, 1971).

Bricks were used in antiquity, until the fall of Roman Empire. Their use then declined, but was revived in Europe in the 12th and 13th Centuries. Bricks are of great antiquity. They are mentioned even in the sacred writings, tower and walls of Babylon. In the East, they backed their bricks in the sun; the Romans used them unburnt, only leaving them, to dry for four or five years in the air. The Greeks chiefly used three kinds of bricks: the first was called didoron (i.e) of two palms; the second, tetradoran, of four palms; the third, pentadoran, of five oalms. Pliny says that to make good bricks, they must not use any earth.
that is full of sand or gravel, not for such as is gritty or stony; but of a greyish marl; or whitish chalky clay of at least of a reddish earth (Dictionary of Arts and Science, 1945). Bricks vary according to their forms, dimensions, uses and method of making. An American Building brick measures about 2 1/4 x 3 3/4 x 8 in (57 x 45 x 203 mm); an English brick is about 2 5/8 x 4 3/8 x 9 in (67 x 111 x 222 mm). The red colour of brick is due to iron oxides in the finished product. Bricks may also be made of other materials. The clay may be mixed with sand or lime, the brick being pressed and steamed. Bricks are commonly fashioned as insulating materials, and refractory material, termed fire brick.

2.1 SCIENCE OF BRICK EARTH

Bricks are chiefly made from clay and shale and are moulded either by hand or machinery. The principal elements of clay suitable for brick-making are alumina and silica. Alumina renders the clay plastic, and thus facilitates the moulding process; if incorrectly proportioned, it will cause the bricks to crack, twist and shrink excessively when being burnt. The silica may be combined with the alumina or it may be free in the form of sand; if combined, it has a tendency to produce shrinking and warping, but if free, it counteracts this tendency and assists in the production of hard, durable and uniformly shaped bricks; brittle bricks will result, if the sand content is excessive.

Brick clays may also contain varying proportions of limestone, iron, magnesia, salts such as magnesium sulphate, sodium sulphate, potassium sulphate and calcium sulphate, in addition to organic matter and water, limestone or chalk has the effect of reducing shrinkage and acting as a flux during the burning process, causing melting and binding of the mass. It influences the colour of bricks. The limestone should be present only in a fine state of division, otherwise the pieces of quicklime will slake and expand if the bricks absorb moisture. Such expansion will crack or shatter the bricks. Fine grinding of the clay will prevent damage from this cause. An excess of chalk will produce mis-shaped bricks when being burnt.

Iron oxides and magnesia also influence the colour of bricks. Salts may cause efflorescence. Oragamic matter, if in excessive quantity, may contain
compounds which discolour plaster. Certain salts, particularly magnesium may cause the bricks to decay. Suitable clays for brick-making include "reds" "marls", "gaults", "loams", "knotts" and "plastics".

*Red Clays* are found in many parts of the country and are extensively used for producing high-class bricks. As is implied, the colour of these bricks is red in various shades, depending upon the proportion of iron oxide present.

*Marly or Limy or Calcareous Clays* have a large chalk or limestone content and are commonly used. Sand is sometimes added to such clays to prevent the bricks fusing during the burning process. Marly clays are converted into malm by the addition of chalk in correct proportion. The approximate analysis of marly includes 33.0 per cent silica 10.0 per cent alumina, 30.0 per cent chalk and 5.0 per cent oxide of iron.

*Gault Clays* are heavy, tough and of a bluish colour, but with sufficient chalk content to render the bricks a pale yellow or white colour when burnt. Bricks, called gaults, made from such clays are often perforated or have a large frog to reduce the weight; they are very satisfactory for general building purposes.

*Loamy or Mild Clays* have a high silica content, and the addition of a flux, such as chalk, is often necessary. Shrinkage of these clays during burning is relatively small and they produce bricks of excellent quality. Compared with Marls, a loamy clay may consist of approximately 65.0 per cent silica, 27.0 per cent alumina, 0.5 percent chalk and 1.0 per cent iron.

*Knotts Clay* contains a relatively large proportion of finely distributed combustible matter, an economy in fuel for burning results. Fletton bricks are produced from this clay in enormous quantities. The approximate composition is 50.0 per cent, silica, 15.0 percent alumina, 10.0 per cent lime, 7.0 per cent iron, 5.0 per cent carbonaceous matter together with water and traces of magnesia, potash and soda.
Plastic or Strong Clays are composed chiefly of silica and alumina in combination, and chalk of a creamy consistency must be added to prevent distortion and excessive shrinkage in drying and burning.

Clay Shale, is a hard, laminated rock which is reduced to a plastic mass suitable for brick-making by weathering and the addition of water. It is found, often in the same quarry, with a varying content of oxides of iron, etc., and the careful blending of these shales produces bricks, used for faced work, of different shades. A typical shale may contain roughly 60.0 per cent silica, 25.0 per cent alumina, 0.6 per cent chalk, 7.0 per cent oxides of iron, 2.0 per cent magnesia and traces of alkalis (potash and soda), organic matter and water.

Fireclay contains a large proportion of silica (varying from 50.0 to 70.0 per cent) and a little, if any, lime and iron. Bricks made from such clay are highly resistant to high temperature and are therefore suitable for the lining of furnaces and fireplaces.

COMPOSITION OF BRICK EARTH: A good brick earth contains 20.0 per cent to 30.0 per cent of alumina, 50.0 to 60.0 per cent of silica, the remainder constituents being lime, magnesia, sodium, potassium, manganese and oxide of iron. Thus, the chief constituents of brick earth are alumina and silica, i.e. a mixture of clay and sand. Alumina is the principal constituent of all kinds of clay. In clay, silica is also present in combination with alumina. Thus, clay is a hydrated silicate of alumina derived from the decomposition of felspathic and silicious

CLASSIFICATION OF BRICK EARTH: Brick earths in natural state are (a) plastic or pure clay; (b) loam or sandy clay; and (c) marls, calcareous or chalky clay plastic or pure clay is also known as fat clay or foul clay. This clay contains chiefly silica and alumina with a small percentage of lime, magnesia and other salts. In making bricks, if pure clay alone is used, the bricks will shrink
and crack in drying and warp during burning. This clay becomes very hard when burnt. Sand and lime (to act as a flux) are added to this clay for manufacturing bricks. Loam or sandy clay is composed of free sand and clay. This belongs to the alluvial formation. This clay requires a flux (calcium carbonate) to fuse and bind the particles together. If flux is not used, the excess sand will remain in an uncombined state. The silica present in this clay prevents shrinking, cracking and warping of bricks. For manufacturing good bricks, plastic clay is added to this clay. Marl's containing large proportion of chalk make good bricks and are often used without addition of any other substances.

USEFUL AND HARMFUL INGREDIENTS IN BRICK EARTH: ALUMINA, the chief constituent of clay, gives the plasticity necessary for moulding into required shape. But, a brick containing too much of alumina and inadequate quantity of sand, shrinks, cracks, and warps in drying process and becomes too hard when burnt. Silica, present in adequate quantity in a brick, preserves the form of the brick at high temperatures and prevents shrinkage, warping and undue hardness during drying and burning. When in a brick, free silica is in excess, it destroys the property of cohesion and renders the brick brittle.

Limestone or chalk present in a brick, acts as a flux upon the silica during burning and causes the particles to unite together. Thus, it produces greater strength by diminishing contraction to some extent. If lime is in excess, it renders the clay too fusible and causes the bricks to melt and distort during burning. If in a brick earth, lime is present in form of limestone, it splits the brick when wetted, prevents adherence of mortar by absorbing the moisture from mortar and promotes disintegration. So, bricks, should be well soaked before use, so as to destroy the lime in bricks. Iron pyrite, if present in a brick, will oxidise, crystallise and split the brick into pieces. Magnesia, influences the colour of bricks and gives a yellow tint. Alkalies act as a flux, but cause the bricks to distort by melting when these are in excess.

Sulphate of lime causes the white discoloration called 'scum'. Magnesium sulphate causes surface scum or efflorescence. Oxide of iron acts as a flux and brings hardness and strength in bricks. This also colours
the bricks red on burning but makes the bricks dark blue, when in excess. *Carbonaceous matters* are harmful ingredients in a brick earth. When these are present in bricks, the interior of bricks has different colours from the exteriors and the bricks do not bear chipping. These also deface the plastering by discoloration.

*Sodium and potassium chlorides* are not wanted in a brick earth. They act as flux in burning and cause bricks to crack and warp. These salts cause efflorescence in damp situation and wet places. *Reh and kallar* consisting of sulphate of soda, carbonate of soda and common salt are harmful in a brick earth. These prevent bricks from proper burning. *Grits and pebbles* are harmful elements in a brick earth. These cause the bricks to crack. *Vegetable, matters, weeds, etc.*, should not be present in a brick earth. These make the bricks unsound.

**PROPERTIES OF GOOD BRICK EARTH:** A good brick earth should be a proportionate mixture of clay and sand free from harmful ingredients mentioned above. With sufficient quantity of water, the brick earth can easily be moulded and dried without shrinking, cracking, and warping. It should have a small amount of finely divided lime to enable silica to melt and to unite the particles together during burning. It may contain a small quantity of oxide of iron to act as a flux and to bring the red colour on burning.

**ANALYSIS OF A FEW BRICK EARTHS:** The useful proportions of the ingredients present in a few brick earths are given below:

**TABLE : 2.1**

<table>
<thead>
<tr>
<th>Ingredients Present</th>
<th>Name of brick earth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plastic Clay</td>
</tr>
<tr>
<td>Alumina</td>
<td>34.5</td>
</tr>
<tr>
<td>Silica</td>
<td>49.5</td>
</tr>
<tr>
<td>Oxide of iron</td>
<td>7.5</td>
</tr>
<tr>
<td>Carbonate of lime</td>
<td>1.5</td>
</tr>
<tr>
<td>Carbonate of magnesia</td>
<td>5.0</td>
</tr>
<tr>
<td>Organic matter</td>
<td>2.0</td>
</tr>
<tr>
<td>Soda and Potash</td>
<td>-</td>
</tr>
</tbody>
</table>

*Source: Ghose, D.N.: Materials of Constructions (Tata McGraw Hill, New Delhi, 1989)*
Test of Brick Earth: By virtue of experience, one can easily assess the quality of a brick earth by visualising its colour, appearance and physical properties. GRITS, pebbles and vegetable matters present in a brick earth can easily be detected by fingers. Too much of stickiness to fingers indicates the necessity of adding, sand to it. On the other hand, if the prepared brick earth crumbles when rolled, it means excess sand is present in it. To find out the proportion of ingredients present in a brick earth, it is always advisable to analyse it chemically in a laboratory. The quality of brick earth can also be tested by making a few bricks out of it and by exposing them to sun and wind. If the bricks crack on drying, the brick earth is very plastic and if it breaks easily by dropping, the brick earth contains too much of sand.

**BRICK FIELD:** The brick field should be situated on a plain ground. The site should be selected such that good brick earth is readily available near the brick field. For easy conveyance of materials, it should not be far away from the communicating roads. There should be all sorts of facilities for the workmen.

**2.2. METHODS OF BRICK PRODUCTION**

The various methods of production are determined very largely by the nature of the clay or shale, and may be divided into (a) semi-dry or semi-plastic process, (b) stiff-plastic process; and (c) plastic process. (McKay, 1971).

Semi-dry or **Semi-plastic** process: The clay or shale is comparatively dry. It is ground to fine powder by heavy rollers, passed through a screen, mixed to a uniform consistency, pressed and re-pressed in moulds by very powerful machinery and burnt. Sometimes, the screened material is damped by sprayed water. Because of the dryness of the material the bricks are taken direct from the moulding machine to the kiln, the usual intermediate drying stage being omitted. The process is relatively cheap.
Stiff-plastic process: This process, which is being adopted to an increasing extent, is similar to the above, except that the water content of the material is increased and therefore less powerful machinery is required to mould the bricks. A separate drying plant is not always necessary. The process is usually applied to hard, dry clays, such as marls, and certain shales; it may also be applied to wetter clays, provided they have been partially dried before being crushed.

Plastic process: The clay suitable for this process contains a large proportion of moisture, and is used for making wire-cut and hand-made bricks. The bricks must be carefully dried before being burnt.

2.3 BRICKS MANUFACTURING PROCESS

The manufacture of bricks involves the following four major operations such as Preparation of brick earth; Moulding of bricks; Drying of moulded bricks; and Burning of bricks.

PREPARATION OF BRICK EARTH: First, the surface of the ground where from the earth is to be dug out stripped off its turf. The earth is dug out in clear weather and kept on the turf ground whether. Stones, girts, pebbles, vegetable matters, etc., are taken out from the earth manually. If these particles are in excess, the clay is to be washed and screened, which process is troublesome and expensive. If the earth dug out is full of lumps, this is to be ground into powder in the earth-crushing roller. This is hardly practised in a brick field. Actually, the earth after digging out is kept for a few weeks for weathering. It is found that 1.5 to 2.5 Cum of earth is required for moulding 1000 bricks depending upon the quality of earth. The clay is then tempered in pug-mills by being broken up, watered and thoroughly mixed up till it forms a homogeneous mass. The tempered clay is then covered up with mats for slow drying and for bringing the consistency for easy moulding. In brickfields where there is no pug-mill, the clay is kneaded well under foot till it becomes a homogeneous mass.
MOULDING OF BRICKS: When the brick earth is prepared, it is moulded either by hand or by machine.

Hand moulding: In ‘hand moulding’, bricks are moulded by hand, i.e., manually. Hand moulding is preferred where manpower is cheap and readily available or when bricks are manufactured on small scale. Hand moulding may be done either on ground or on table and accordingly these are termed as ‘ground moulding’ or ‘table moulding’. Again, hand moulding may be ‘slop moulding’ or ‘sand moulding’. To prevent bricks from sticking to the mould, the mould is either dipped in water or sprinkled over with sand each time it is used. In hand moulding, if water is used, the bricks are said to be slop-moulded and if sand is used, the bricks are called sand-moulded. Sand-moulded bricks are always preferred as they are sharper than slop moulded bricks.

Ground moulding: In ‘ground moulding’, the brick moulder places the mould on a levelled ground and sprinkles over with sand, if the bricks are to be sand-moulded. He (moulder) then takes a lump of prepared clay and pushes it into the mould with hand pressure so as to fill all the corners of the mould. The superfluous clay is scrapped off from top of the mould with the help of a wooden or steel strike or a framed wire. The mould is then lifted up leaving the brick on the ground. Next, the mould is placed again close to the brick moulded and the second brick is moulded. Thus, the process goes on. A brick moulder can mould about 450 to 600 bricks per day in 8 hours working period.

Table moulding: In ‘table moulding’ the moulder stands behind a table and places the mould either on the table or on the stock board bearing the projection for the ‘frog’. The mould is filled up with clay, pressed, and the superfluous clay is removed from top. A pallet board is then placed over the mould and the mould with the pallet board is skillfully taken off and inverted. The mould is lifted up for its reuse and the brick lying on the pallet is carried and allowed to dry on edge. As the bricks require less space and they dry
quicker and better. Stock boards may also be used in ground moulding for providing frogs.

Machine moulding: Bricks are moulded in machine, when large numbers of bricks are to be manufactured in a short time. In plastic clay machines, the pugged clay in plastic condition is forced through an opening of bricks size (length x breadth) and the clay blocks so formed are cut with wires fixed in frames, at regular interval accordingly as the required thickness of the brick. These bricks are called 'wire cut bricks”

In dry clay machines, the mould is fed with powdered clay which takes the shape of the brick when subjected to a very high pressure. The consolidation becomes perfect and the bricks become hard and well-shaped, if the powdered clay is in moist condition. These bricks are called “pressed bricks”.

Machine-moulded bricks are heavier and stronger than hand-moulded bricks. Moreover, these bricks have regular shape and size, sharp edges and corners, smooth surface, distinct frogs, clean and dense impervious texture.

DRYING OF BRICKS: Prior to burning, the bricks are dried under the sun or under the shed. In ground moulding, when the bricks become sufficiently hard, they are placed on their edges for further drying. If the brick are not properly dried before they are burnt, they may get cracked and distorted during the burning process. The hack or the drying ground should be raised to drain out the rain water. After a day or two of sun-drying when the bricks become a little harder for safe handling, they are stacked on hacks in an open order with spaces in between them for free air circulation. The best form of stack is of width equal to two bricks placed longitudinally with gaps between the bricks, the alternate layers being laid along and across the stack, all on edge. About eight to ten layers of bricks on edge with spaces of 1 m, between them may safely be built up in each stack. If all the stacks are made of the
same length and height, it facilitates in counting the number of raw bricks kept in stacks for drying. The bricks are allowed to dry for three days after which they may be restacked diagonally (skintled) which is not usually done to save the labour cost and to avoid breakage of raw bricks. To protect bricks from unpredictable storms and rains, the stacks should be made under a shed. (Ghose, 1989),

Burning of Bricks

The burning of dry bricks is done either in a clamp or in a flame kiln. In India, both clamp and kiln burning are practiced. Clamp burning is adopted when bricks are manufactured on small scale; and for large scale manufacture of bricks, kiln burning is preferred.

Clamp burning: In clamp burning, both bricks and fuels are placed alternatively in layers. The shape and internal arrangement of clamp vary from place to place. The plan of the clamp is usually trapezoidal and it is built with one side nearly vertical. The floor is 30 m long with 10 m and 20 m wide ends and it is inclined at an angle of 15° with the horizontal. The smaller end is a little dug out and the larger is a little raised above the ground. The first layer is a fuel of 0.8 m thickness and the second layer is a course of four to five bricks set on edge with small spaces between them. The second layer is 15 cm less in thickness than the first layer of fuel under it. The proportion of fuel of bricks is gradually reduced towards the top of the clamp. The fuel used is dried cow dung, grass, litter, rice husk, coal dusts, wood chippings, and sometimes cheap quality wood. When one-third of the intended quantity of bricks and fuel is loaded, the clamp is fired at the lower end. When the fire burns gently, loading goes on. On setting the clamp to its desired shape and height, the surfaces are plastered over with mud to keep in the heat for its circulation from the smaller end to the larger end. During burning of its own, any violent flame coming out may be choked by throwing earth or rubbish on the spot. The clamp is not liable to injury from high wind or rainfall. This type of clamp is used for burning 30,000 (a small clamp) to 3,00,000 bricks (a large one). The time taken in loading a clamp vanes from 2 to 3 months for
1,00,000 bricks. A large clamp takes 6 moths to burn and to cool. Once the clamp starts burning the fire cannot be regulated and the bricks are liable to uneven burn. When tamarind wood is used as fuel, the clamp burns slowly and bricks are not liable to be attacked with saltpeter.

Kiln Burning: For the purpose of burning bricks, bricks kilns or flamed kilns constructed are rectangular, circular or oval buildings-over ground or under ground, open to sky, with very thick side walls and wide doorways for taking in and out the bricks. The side walls are built of old bricks set in clay, by keeping opening for fire holes. The fire holes are built in fire brick and clay opposite to one another. The doorways are built up with some dried bricks set in clay while the kiln starts burning. A temporary roof or covering may be placed over the kiln to protect the raw bricks from rain while stacking. The covering or the roof should be removed when the kiln is fired. The flame kiln may be intermittent or continuous and over ground or under ground as mentioned earlier.

2.4 SCIENTIFIC PROPERTIES OF BRICK

Colour of bricks: There is a wide range of colours of bricks, such as white, grey, brown, red, purple, blue and black, with intermediate shades. Bricks of varying shades, called multi-coloured, have within recent years been in big demand for faced work. Some bricks are uniform in colour, whilst others are mottled or irregularly shaded. The colour is influenced by: (a) chemical constitution of the clay; (b) temperature during burning; (c) atmospheric condition of kiln; (d) sand-moulding; and (e) staining

Chemical constitution of clay or shale: Iron oxides affect the colour considerably. Thus, clays which produce white bricks have little or no iron present, whilst blue bricks contain at least 7.0 percent, oxide of iron. Careful blending of the clays and shale is responsible for the production of many beautifully coloured bricks, and such colours are permanent.
Temperature during burning: Light coloured bricks are often the result of the temperature of the gases in the kiln being too low, or the duration of the maximum temperature being too short, whilst, at the other end of the scale. Blue bricks require a temperature which may reach 1200° C.

Atmospheric condition of kiln: Certain white bricks can only be produced if they are protected in the kiln from smoke, whilst dark brown and purple coloured bricks are made by creating a smoky atmosphere in the kiln.

Sand-moulding: Sand-moulded hand-made bricks and pressed bricks which have sand sprinkled over their oiled surfaces whilst being moulded are richly coloured during the burning process. The nature of the sand used for this purpose depends upon that of the clay or shale, and a good deal of experimental work with different coloured sands is often necessary before the desired colour of the facing bricks is obtained.

Staining: Surface colours may be obtained by adding certain metallic oxides (such as manganese for browns, chromium for pinks, antimony for yellows, copper for greens, cobalt for blues, cobalt and manganese for blacks, etc.) which are crushed very finely and added to the sand sprinkled on the bricks prior to burning. Sometimes water is added to the oxides and brushed on the surfaces. Such colours, unlike those produced by blending are rarely permanent.

**White bricks** contain not more than a trace of iron and generally a large proportion of lime.

**Cream bricks** contain traces of iron and a small proportion of chalk.

**Grey bricks** are either commons which have been discoloured by scumming or facing, such as silver-greys, which have been stained on the surface.

**Yellow bricks** contain magnesia or sulphur.
Brown and purple bricks may have a similar iron content to reds, but the difference in the colour is due to smoking and special firing.

Black bricks contain a similar amount of iron to the blue clay, in addition to certain manganese oxides.

Multi-coloured bricks are generally produced in a downdraught kiln, the temperature and smoking are best controlled in this type.

Texture of bricks: There is considerable variation in the texture (or surface finish) of bricks. Thus, machine-made commons and certain facings have smooth faces, whilst hand-made facings cannot be equaled for the richness of their texture; many machine-made bricks are characterized by roughened surfaces which have been purposely exaggerated. The pleasing texture of hand-made bricks is produced during the moulding operation, the hand-pressing of the clay or shale into the mould and the sand from the sides of the mould, which is stamped into the material, giving an irregular creasing or unevenness to the side and end surfaces. The fine colouring of a mass of brickwork constructed of such bricks, particularly after it has weathered for some time, is enhanced by the light and shade effect produced by the uneven surfaces. Such bricks are expensive, and therefore attempts have been made to imitate this texture and apply it to mechanically-made bricks. Some of these attempts have been quite successful, even if the resulting texture is of less quality (chiefly because of the uniformity which results then the depressions or roughness are similar on every brick) than that of hand-made bricks.

Strength of bricks: The strength of a brick depends upon: (a) composition of brick earth; (b) preparation of clay for moulding; (c) nature of moulding adopted; (d) drying of green bricks; and (e) burning and cooling processes. Thus, it is obvious that bricks of different brick fields will have different strengths. Even in a brickfield, bricks of the same batch may have different strengths. The crushing strength and tensile strength of hand-moulded bricks
(on an average) are 6000 tonnes/sq. m and 200 tonnes/ sq. m, respectively. The shearing strength of bricks is about 1/10th of their crushing strength. In practice, bricks are not subjected to tensile stresses.

Sizes and weights of bricks: Bricks are made of different sizes according to the custom of the country, requirement of the consumer, and the fancy of the manufacturer. The size of the bricks should be such that they can be easily lifted and placed with one hand and they can be properly burnt to the core. The breadth of the brick should be 3 mm less than half the length of the brick so that the two breadths joined by a 6 mm thick mortar will make the length of the brick. This means one stretcher along the wall will cover two headers placed across it with a joint between them.

The old Indian bricks (30 cm X 15 cm X 6 cm) and old Bengal bricks (25 cm X 12.5 cm X 7.5 cm) were too large and heavy to be handled by the brick layers with one hand. It was also difficult to burn these large size bricks properly. The standard sizes of bricks are: 19 cm X 9 cm X 4 cm or 19 cm X 9 cm X 9 cm. The specific gravity of bricks is about 2; one eft weights 112 lbs. The number of bricks required for 100 eft of brickwork is 1100 including breakage and wastage. Smaller bricks (10 cm X 7.5 cm X 2.5 cm) are easy to burn, but they require more mortar and labour. So, brickwork with small size bricks becomes more expensive.

2.5 CHARACTERISTICS OF BRICKS

Good bricks should be thoroughly burnt, as most well-burnt bricks are durable and capable of withstanding relatively heavy loads. As adequate firing in the kiln tends to eliminate any soluble salts in bricks, it follows that hard-fired bricks are relatively free from defects such as efflorescence and cryptoflorescence. Conversely, underburnt bricks (usually denoted by an abnormal light colour and dull sound when struck together) are comparatively soft, easily broken, are neither durable nor pressure-resistant and are liable to defects produced by salts. Good bricks should be free from the defects
enumerated above and, if used as facings, should conform to one or other of the colours and texture.

Permeability: Bricks for external use must be capable of preventing rainwater from passing through them to the inside of walls of reasonable thickness. In this connection, the practice of specifying the maximum amount of water a brick shall absorb (usually "one-seventh of its own weight of water after twenty-four hours immersion") is not now considered desirable, for it does not follow that a brick is impermeable if it has a relatively small absorption. Much depends upon the character of the pores.

Strength: It is only necessary to specify the strength of bricks when they are required for the construction of walls, piers etc., which have to support heavy concentrated loads. The reason for this is that the comprehensive strength of brickwork constructed of relatively inferior bricks will be quite adequate to resist the normal weight which it will be required to support. The average crushing strength of bricks serves as an approximate index only of the compressive strength of brickwork, as much depends upon workmanship, height in relation to thickness, etc. A rough approximation of the strength of brickwork built in cement mortar (1 : 3) and good hydraulic lime mortar (1 :3) is respectively one-third and one-fifth that of the individual bricks.

Frost Action: External walls constructed of porous under burnt bricks are particularly vulnerable to damage by the action of frost. Such damage is due to the absorbed water expanding (to about one-eleventh of its volume) as it freezes and exerting pressure on the pore walls which the comparatively soft material is unable to resist. Disintegration thus results, and when this is repeated during severe winters, disfigurement due to pitting and cracking of the surface and damage arises may become very pronounced. Brickwork of poor quality bricks with overhand struck joints, that below the ground level, and copings are particularly subject to damage by frost. It does not affect brickwork of sound, hard-burnt bricks.
2.6 FACTORS AFFECTING THE QUALITY OF BRICKS AND TESTS FOR GOOD BRICKS

The quality of a good brick depends upon: chemical composition of clay, blending of ingredients and preparation of clay; site conditions and the environs; care taken in moulding, drying and stacking; type of kiln used; kind of fuel used and its way of feeding; uniformity in burning and degree of temperature maintained in the kiln; during burning with the control of fire; and care taken in cooling and unloading.

The tests to be carried out to know the quality of good bricks are regularity of form; uniformity in size; uniformity in colour; texture and soundness; hardness; absorptive power; and strength of bricks.

2.7 CLASSIFICATION OF BRICKS ACCORDING TO THE QUALITY

Clay bricks may be divided into ordinary bricks and fire bricks. Ordinary bricks which are rectangular parallelepipeds are again classified into four classes according to their qualities, such as, First class, Second class, Third class and Zhama bricks.

First class bricks: These are well-burnt and sound bricks of proper rectangular shape and size with sharp, well-defined edges. The surface should be clean and smooth and free from cracks and flaws. A first class brick should not absorb more water than one-sixth of its weight when kept immersed for 16 hours. No mark can be made on it with finger nails. This should not break into pieces when dropped on ground from a height of 1 m. This should produce a metallic ringing sound when struck against another brick. It should show a uniform compact texture when fractured. The colour of the brick should be uniform and bright.

Second class bricks: The qualities of these bricks are almost same as those as first class bricks. But, these bricks are irregular in shape and size with spots on the surface. They may have fine hair cracks and the edges may not be sharp and uniform.
Third class bricks: These are usually the under-burnt bricks, which are soft and light in colour. They produce a dull sound when struck against each other.

Zhanna bricks: These are over burnt bricks having deformed shape and size. During the process of burning, if the temperature is not maintained accordingly, the bricks melt and sometimes these are converted into porous irregular masses having no definite shape and size.

First class and second class bricks are used for all sorts of sound work, especially of permanent nature. These are extensively used in construction of buildings, dams, bridge piers and abutments, roads, sewers, tunnels, lining and pitching works and water structures. First class bricks are specified for architectural compositions and face work of structures, where the bricks are kept exposed for beauty. The masonry work with second class bricks is usually plastered in order to hide the irregular shape and size of bricks. In using second class bricks more mortar is required. Third class and sun-dried bricks are used in constructions of temporary character. These bricks should not be used, in damp situations and in places subjected to heavy rains. Zhama bricks are used as road metal and as aggregates in foundation concrete.

2.8 CLASSIFICATION OF BRICKS ACCORDINT TO THE USE

A conveniently broad division of bricks is in accordance with their use and suitability for (a) interior purposes, (b) exterior purposes, (c) pressure-resisting purposes and (d) fire-resisting purposes.

Bricks for interior purposes: Common bricks are invariably specified for internal walls, as neither strength, durability nor appearance is important.

Bricks for exterior purposes: The essential requirements of facing bricks are durability, colour, texture and freedom from defects. Colour and texture are not important if the walls are to be rough-coated or olastered. Good quality
commons being sufficient for this purpose. They should have sufficient suction capacity to ensure the thorough adhesion of the mortar. The crushing strength is not material unless heavy loads have to be supported, as any durable brick will safely support the load which has to be normally resisted. Bricks to be used below the horizontal damp proof course should be carefully selected, as these are subjected to the greatest frost action, and absorption of certain salts from the soil may cause deterioration, if the bricks are not durable.

Bricks for pressure-resisting purposes: These are required for the construction of piers, large-spanned arches, etc., where large stresses have to be resisted. Strength is, therefore, the chief requirement, and engineering bricks which are very strong and hard burnt are most suited for this purpose.

Bricks for fire-resisting purposes: Those best suited to resist high temperatures, as for lining furnaces, chimney stacks, boilers, etc., are fireclay, silica, ganister, bauxite and magnesite bricks.

2.9 SPECIAL SHAPES AND FORMS OF BRICKS

Special forms of bricks, also called purpose-made bricks, are required to serve special functions. These are desired and manufactured as per the requirement of specific jobs. The special bricks, are therefore, more costly than ordinary bricks. Most of these bricks are named after the position, where to be used and according to their shapes. Special care is needed in moulding and burning such bricks. Some of the special forms of bricks are:

- **Cant brick and bull nose bricks** are for use at corners of a brick work where sharp edges are liable to be damaged;
- **Plinth bricks** are used at the top layer of a plinth wall;
- **Cornice bricks** are ornamental 'bricks made in various patterns;
- **String course bricks** are made of various patterns, but those with a throat on a lower side are better;
Gutter bricks, Channel bricks and Drain bricks are used for draining water from sloped roofs, stables and pavement;

Jamb bricks are ornamental bricks used in door and window jambs;

Sill bricks are specially manufactured ornamental bricks for window sills;

Key bricks are used in arches;

Round bricks are used for circular pillars;

Muiiiion bricks are used for bay windows;

Perforated or Air bricks are made with circular or rectangular holes;

Copying bricks are manufactured in various ornamental pattern of differential sections to suit walls of different thickness;

Corbel bricks like cornic bricks or sill bricks are made in various patterns. These are used in railway platforms;

Chequered bricks are air paving bricks;

Tubular bricks are hallow bricks having large perforations running along their lengths. These bricks are tubular in shape;

Hourdi bricks are similar to the tabular bricks, but they are flat instead of round;

Culvert side wedge or Arch bricks are shaped as voussoirs of arches and they taper in thickness;

Squint bricks are used in the construction of acute and obtuse squint quoins;

Angle bricks are used at squint quoins, particularly of cavity walls;

Circular bricks are used for circular works as in the construction of bay windows;
*Pistol bricks* are used for forming circular or coved angles between walls or between a well and a floor;

*Compass bricks* of a circular forms, used in steyning of walls;

*Concave bricks*, on one side flate like a common brick, on the other hollowed and used for conveyance of water;

*Feather-edged bricks*, which are like common statute bricks, only thinner on one edge than the other are used for penning up the brick pandels in timber buildings;

*Cogging bricks* are used for making the indented works, the caping of wall built with great bricks;

*Caping bricks* are formed on purpose for caping of walls;

*Flemish bricks* are used to pave yard, stables and for soap boilers vaults and cisterns.

*Clinkers* such bricks as are glazed by the heat of the fire in making;

*Fame/bricks* are such as line outmost in kiln or clamp and consequently are soft and useless, as not being throughly burnt;

*Great bricks* are those twelve inches long, six inches broad and three inches thick, used to build fence wall;

*Buttress bricks* have a notch at one end, half the breadth of the birck; the use is to bind the work which is built of great bricks;

*Statute bricks or Small common bricks* are those bricks when burnt to be nine inches long, four and a quarter broad, and a half thick, They are commonly used in paving cellars, sinks, hearths etc.

*Fire bricks* are capable of resisting very high temperatures and are used for lining fire places, tall chimneys, furnaces, gas
retorts etc. They are made from fire clay; silica rocks; and silica rock together with ganister;

*Fire clay bricks* are associated with coal fields and are usually obtained by mining a distinct from quarrying. The clay contains 55.0 to 75.0 per cent silica and 22.0 to 35.0 per cent alumina.

Silica bricks contain 95.0 to 97.0 per cent of silica and 1.0 to 2.0 per cent lime.

Ganister bricks are made with ganister - a dark coloured sand stone containing up to 10.0 per cent of clay;

Sand lime bricks are made from a mixture of sand and hydrated lime. The quality of lime to be used varies from 4.0 to 10.0 per cent of clean sand;

Cement sand bricks can be made from a mixture of cement and sand;

Cement - lime - sand bricks resemble sandstone;

Concrete bricks are produced from lime or cement and aggregates like stone chips, broken bricks, kankar etc;

Slag bricks are manufactured from the blast furnace slag;

Slag - concrete bricks are made of slag granules and unslaked lime in proportion 5.0 per cent slag to 5.0 per cent lime;

Glass bricks is the outline of a brick made of glass, the central portion being entirely open;

Magnesite bricks are made from the precipitated magnesia moulded under high pressure and burnt at high temperature;

Dolomite bricks are made from calcined dolomite magnesium carbonate and lime are powdered and mixed together with water. The bricks are moulded dried and burnt in the same way as for magnesite bricks;
Rubbers or cutters are soft red, white or buff coloured bricks consisting of washed loamy clay containing a large proportion of sand and are usually hand made in a box mould and backed in a kiln;

Glazed bricks are produced with fireclays or shales. As they are usually required to be built with joints not exceeding 3 mm thick, they must be true to shape with fine straight arrises. They are, therefore carefully pressed and sometimes re-pressed with the arrises hand trimmed with a strike. Glazed bricks are imprevious and are of two kinds namely salt-glazed and enamelled;

Engineering bricks are exceptionally strong and durable and are used perpieces, bridges, sewers and similar engineering purpose; and

Hollow bricks are made of clay formed with one or more cavities which reduce their weight and increase insulation against heat and moisture. Hollow bricks are used for construction of hollow walls.

2.10 DEFECTS IN BRICKS

The following are the principal defects to which bricks are subjected:

Black core or Hearting: This is fairly common in bricks made of red clays which have been heated too rapidly in the kiln, causing the surface to vitrify and the interior to remain black.

Bloating or Swelling: This is attributed to the presence in the clay of an excess of carbonaceous matter and to bad burning.

Burring or Clinkering: Clamp-burnt bricks, usually adjacent to the flues, which have been fused together by excessive heat are called burrs or clinkers.
Chuffs or Shuffs: These are badly cracked and mis-shapen bricks produced by rain falling on them when hot. They are useless.

Crazzling: It is a defect common in glazed bricks characterized by fine cracks. These are due to the glaze and the body (clay) not expanding and shrinking to the same extent.

**Crozzling:** Excessive heating in the kiln may produce mis-shapen bricks known as crozzles. If not too badly shaped, they may be used for brickwork below ground level, otherwise they are only suitable for aggregates.

Efflorescence: Bricks made from clay containing a relatively large proportion of soluble salts, particularly calcium sulphate, are liable to become discoloured by the formation of a whitish deposit. Whilst this efflorescence or salting is particularly common to new brickwork, it may also form on the faces of old external walls which are subjected to excessive dampness.

Grizzling: Common bricks, though of good shape, which are under burnt (indicated by a light colour and a dull sound when struck), and therefore weak, are called grizzles; only suitable for inferior internal partition walls when little strength is required.

Iron spots: These are surface dark spots, due to the presence of iron sulphide in the clay, which render the bricks unsuitable for facings.

Laminations: These are generally caused by the air in the voids between the particles of clay not being eliminated in the grinding, pugging, etc., processes, and producing the formation of thin laminae on the faces of bricks which may scale off on exposure to the weather.

Lime nodules: Bricks containing pieces of limestone left uncrushed in the clay during its preparation are quite unsuited for external walls or internal
walls which are to be plastered, as the lime will expand when water is absorbed, causing cracking or disintegration.

Scumming or Kiln-white: This is an unsightly discoloration of bricks, particularly those containing lime and iron sulphide, which have been fired in a continuous kiln. Several causes contribute to this condition, but it is chiefly due to the hot gases from the firing chambers (which contain sulphur) coming in contact with the damp bricks in the early drying chambers, and producing a thin brownish-white or grey film (usually sulphate of lime) on the surface.

Distortion

Distortion may be produced by over burning. Badly worn auger mouth-pieces and press moulds will cause the bricks to be badly shaped. Cracking may be caused by drying and cooling the bricks too quickly in the kiln. Careless handling of green bricks during manufacture will cause damage. Chipped, cracked and broken bricks, especially if underburnt, are common results of improper handling in course of transit.

2.11 SUMMARY

Brick is a value added product, manufactured with help of natural resources, where there is an involvement of science mechanism for producing bricks and management mechanism for making bricks. Scientific aspects of bricks include the chemical composition of soil, clay, sand, fuel etc., and management aspects side of bricks include the economics of brick industry which consists of production, material, labour, finance, energy, environment, marketing and risk management. In this chapter, the researcher has intensively brought out the scientific aspects of bricks, which pave the way for analysing the economics of brick units. It is a right place to mention here that most of the brick unit entrepreneurs, including chamber bricks entrepreneurs do not know and care about the science of bricks. However, science of brick is very important factor that determines the quality and quantity of bricks. Further, the knowledge of science of bricks can decide the production function (input-output relation) and cost function (cost-output relation) which decide the profitability of the brick industry.
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