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Bricks, Tiles, Terracota and Other Materials

1·1. Bricks have been used for all types of construction from olden days. Production of bricks in India is more than 5000 million. Usefulness of brick has not been reduced even though better materials like cement, steel and other things have already come into use. It is known that bricks are made from soil and hence the properties of bricks will depend upon the property of soil. Therefore, at the outset it is necessary to study the property of soil thoroughly. Good quality bricks cannot be made from all types of soils. Analysis of soil to be used for the manufacture of bricks can be divided into three parts.

1. Chemical analysis
2. Mineralogical analysis
3. Physical analysis.

1·1·1. Chemical analysis. Chemical composition of soil is found out by chemical analysis. Percentage of Alumina, Silica, Iron oxide, Calcium oxide, Manganese oxide, TiO_2 and Alkali etc. is found out. Besides this, proportion of soluble salts (for example Sulphate, Chloride, Carbonate, Nitrate etc.) and insoluble salt in the soil is also found. There are many chemicals which are harmful for bricks. For example, alkali is very harmful for brick. It acts as flux in the kiln. Consequently the brick swells, fuses and warps. If there is presence of nodular *kankar* in the soil, then it becomes quick lime after burning. As soon as it comes in contact with water, its volume increases and bricks break into pieces. If there is little amount of iron oxide in sand, then the colour of bricks improve. Magnesium oxide gives yellowishness to brick. The cost of chemical analysis is high. Hence it is not done in case of ordinary bricks but in case of fire-bricks it is essential.

1·1·2. Mineralogical analysis. Researches have shown that the property of a soil depends upon the clay mineral present in it. The diameter of clay minerals is less than 0·002 mm. Kaolinite, ilite and montmorolinite mineral are often found in soil. Different types of minerals impart different properties to the brick. The apparatus required for mineralogical analysis is very costly and hence the testing cost becomes prohibitive in ordinary brick.

1·1·3. Physical analysis. Physical analysis of soil can be done very easily. At the same it is not costly. Percentage of sand, silt and clay can be found by physical analysis. Plasticity index, liquid limit and plastic limit of soil is also found in the laboratory. Very good bricks can be produced if the soil possesses following properties :

Clay	20 to 30 per cent
Clay and silt	40 to 65 per cent
Liquid limit	25 to 38 per cent
Plasticity index	7 to 16 per cent
Volumetric shrinkage	15 to 25 per cent.

If it is not possible to test the soil in the laboratory ; then such soil should be selected in which percentage of alumina is 20 to 25 per cent. Due to presence of alumina the soil becomes plastic and it can be moulded easily. If the percentage of alumina is high ; then shrinkage of brick increases. Amount of silica in the form of sand should be between 50 and 75 per cent. Due to this, volumetric shrinkage decreases. At the same time the edges of the bricks become firm. High percentage of sand gives the property of brittleness to the brick. Besides alumina and silica ; there should be calcareous and other materials in the soil.

1·2. Rough test while selecting the site for the manufacture of brick. There can be many probable sites for the manufactue of bricks. The properties of soil of different sites will be different. It is necessary to select a site whose soil will produce good quality bricks. If it is not possible to test the soil in the laboratory, then following rough tests can be done easily :

1. Soil and its mixing
2. Moulding property of the soil
3. Shrinkage test of soil
4. Determination of strength and quality of bricks.

1·2·1. Soil and its mixing. Soil samples should be collected from different places. Sample should be collected after removing top layer of soil (at least 30 cm). 15 litres of soil is normally collected for this purpose.

This test is very essential because quantity of sand and water to be added for the proper plasticity can be found out. If the amount of sand and water required per litre of soil is known, then total quantity can be found easily.

(*a*) Firstly remove all the gravels and stones from the soil sample and grind the soil to a fine powder. After that pour water slowly in the soil and go on mixing it so that the soil becomes plastic. The consistency should be such that it can be moulded easily. Amount of water should not be excess ; otherwise moulding will be difficult.

(*b*) Take a handful of mixed soil and make a ball by pressing it. If necessary, little amount of water can be added to it while making the ball. Keep the ball in the sun for drying. When the ball has dried then see whether the ball has lost its shape or not. Also examine if there are some cracks on the surface. The ball which does not get deformed on drying and has very little cracks on its surface ; is most suitable for the manufacture of bricks. The ball which gets deformed on drying and becomes powder easily ; shows that the soil has more sand. Such soil is unsuitable for brick making. If some soil containing less sand is available in that area then good bricks can be made by mixing this soil with previous soil which contains more sand. But it is easier to add sand to the soil which contains less amount of sand than to mix two types of soils for this purpose. The ball which after drying has become very hard and has wide cracks ; shows deficiency of sand in soil. Such soil can be used for the manufacture of bricks by adding requisite amount of sand. The easiest method for this is to add small quantity of sand slowly in the soil and then prepare the balls in each case. Balls made with all proportions of sand may be allowed to dry. After drying inspect the balls. The ball which has least amount of cracks ; gives the most suitable proportion of sand.

1·2·2. **Moulding property of soil.** (*a*) The soil whose ball does not get deformed after drying and has least amount of crack is suitable for brick making. For this test some soil should be used and proportion of water and sand should also be the same. Soil, mixture should be kneaded thoroughly. It is possible to make thick cylindrical threads from well kneaded soil.

(*b*) Put this well kneaded soil into the mould and make a brick. Examine the brick to see whether it has been properly moulded or not. If the corners and edges of the moulded brick are not well formed then the mixture contains less quantity of water. Hence add some more water in such case and make another brick. Repeat this process till you get well formed bricks.

(*c*) Leave all moulded bricks for drying.

1·2·3. **Shrinkage test of soil.** The extent of deformation and shrinkage of a brick after burning can be determined from this test.

(*a*) Burn the sample brick in Potter kiln for three days and four nights. Bricks should be burnt upto red heat. Actually the time for burning of the bricks depends upon the size and shape of kiln but normally it is twice the time taken for baking in an earthen pot.

(*b*) Bricks should be kept in the kiln in such a way that some space is left between them. This is essential for proper burning. Sample bricks of different proportions should be kept at different places so that bricks made from some proportion may not get over-burnt.

(*c*) After burning of the bricks ; allow all the bricks to cool. After remove them from the kiln and examine them for shrink-age and deformation. Sort out the bricks which have lost their shape. Those bricks which have shrunk evenly and have not lost shape should be selected for further test.

1·2·4. Determination of strength and quality of bricks.

(*a*) Strike the flat surface of two bricks. If the sound produced is a metallic one ; then the bricks are of good quality. If the sound produced is dull then the bricks are not of good quality.

(*b*) Strength of bricks can be found by soaking the same in water. Soak the brick in water for 24 hours. Bricks of good quality do not absorb water more than 1/8th to 1/6th of their own weight.

(*c*) Compressive strength of a good brick should not be less than 35 kg/sq. cm.

The soil which gives such test result should be used for the manufacture of bricks.

1·3. Selection of site for manufacture of bricks. Site for the manufacture of bricks should be selected in such a place where suitable quality of soil is available. Such sites are normally found near river banks, valleys or plains. If good quality of soil is not available near the site ; then cost of transportation of soil will be very high. Water and sand is also essential for brick making. Therefore, it is imperative that water and sand is also available near the site. Besides this wood and coal is required for burning bricks. If all these things are available at the site ; cost of production of bricks will be very low. Site for the manufacture of bricks must be levelled. In case of uneven ground there is a danger of the shape of bricks being defective. If there is a danger of rain or flood ; then mud wall must be constructed around the site. Vegetation, plant or trees should not be near the site. If they are there ; these should be removed.

1·4. Manufacture of bricks. There are four processes in the manufacture of bricks. 1. Preparation of soil. 2. Moulding of bricks. 3. Drying of bricks. 4. Burning of bricks.

1·4·1. Preparation of soil for brick-making. After the selection of site, grass, roots of trees etc. should be removed from that place. If there are stones and boulder ; these should also be thrown away. In fact 10 to 15 cm of layer should be completely scrapped. After that soil is dug by means of spade or anything else. If large quantity of brick is to be made, then digging of earth is done before monsoon and during monsoon it is left. After digging ; the clods of earth are broken into small pieces. The loose earth is spread out in heaps 1 to 1·5 metre high for weathering. If weathering of soil takes place for whole of monsoon ; it is good for brick manufacture. Care should be taken to see that no stone pieces are left in the earth. Two cubic metre of soil is required for 1000 ($20 \times 10 \times 10$ cm) bricks. After monsoon, again the earth is dug out from heaps. Due to weathering of soil ; possibility of warping of bricks is reduced. If small quantity of brick is to be made ; then weathering is done for about two weeks.

If necessary, sand is also mixed in the powdered natural soil. After that they are thoroughly mixed. This process is known as *blending*.

After blending requisite amount of water should be added in soil and the same is kneaded by feet of man or animal. This process is known as *tempering*. Amount of water to be mixed with the soil is determined by test. Quantity of water should not be in excess otherwise the shape will be deformed after drying. Tempering must be done very carefully so that the soil becomes plastic and mixing is uniform. If large quantity of brick is to be made ; then pug mill is used for kneading. It consists of a conical upright cylinder of steel whose height is 1·5 to 2 metres. Cylinder is normally tapered and 60 to 75 cm of its length remains buried in the

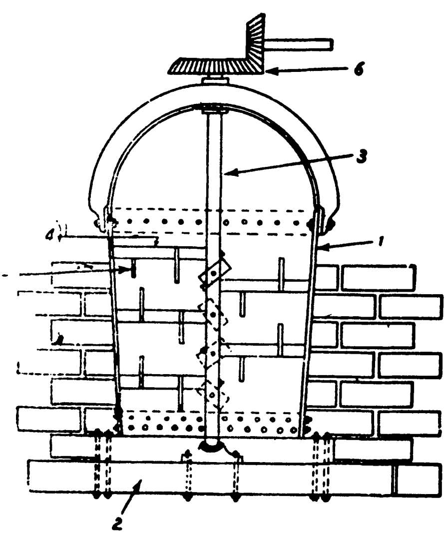


Fig. 1·1. Pug mill.

ground. There is a vertical shaft in its centre which can rotate. Horizontal blades are fixed to the shaft. There are many wedge shaped knives in the horizontal blade which are made of steel. Sketch of a pug mill has been shown in Fig. 1·1.

Following things have been shown : 1. Steel cylinder 2. Bottom supporting plank 3. Shaft 4. Horizontal arm 5. Knives 6. Bevel gear.

Clay and water are fed in the pug mill from top and shaft is turned either by bullock or by mechanical power. Due to churning action soil goes inside the blades where it is kneaded by knives. Finally well kneaded soil comes out from the bottom portion of the pug mill through an aperture. Pug mill works continuously. Kneaded soil is carried for moulding to other place.

1·4·2. Moulding of bricks. Moulding of bricks is done by means of mould. Mould is a rectangular box in which top and bottom portion remains open (Fig. 1·2). Mould is made from strong wood and iron plates are fitted at the edges so that wear and tear of mould is very little. Sometimes moulds are also made from steel or brass. Metallic moulds are superior to wooden moulds.

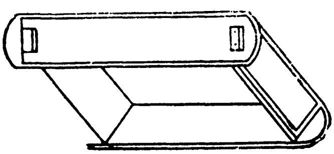


Fig. 1·2

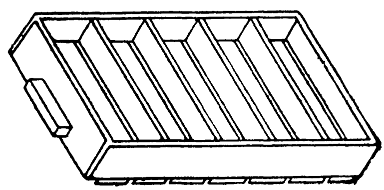


Fig. 1·3

Mainly mould is made for one brick but now-a-days a new type of mould has also come in practice. By means of this mould five bricks (Fig. 1·3) can be moulded at one time. Size of mould depends upon the size of the brick but size of mould in all directions should be larger by 8 to 10 per cent as compared to the size of the brick so that effect of shrinkage due to drying and burning can be compensated.

There are two methods of moulding :

1. Hand moulding ;
2. Machine moulding.

1. Hand moulding. This can also be sub-divided into two part—(*i*) ground moulding (*ii*) Table moulding.

(*i*) **Ground moulding.** Firstly a portion of ground is levelled carefully. It is rammed after sprinkling some water. After that fine sand or ashes is sprinkled on the ground. Moulding is started from one end of the ground. A lump of tempered clay is pushed into the mould with a jerk after keeping the mould on the ground. The volume of lump should be little more than that of the brick. Clay is pressed by hand nicely so that all corners of mould are filled with earth. Superfluous clay is scrapped by means of a wooden straight edge which is called *strike*. The length of strike is 30 cm, width 7·8 cm and thickness 1·5 cm. Normally wooden strikes are used for metallic as well as wooden mould. Sometimes wire is also used for removing superfluous clay. If the edge of strike is damaged then it should be corrected off and on. Mould must be dipped into water before clay is forced into it so that soil particles do not stick to it. Such type of moulding is known as *slope moulding*. Sometimes instead of dipping the mould into water; fine sand or ashes are sprinkled on the mould. Soil particles do not stick to the mould due to this also. Such type of moulding is known as *sand moulding*. Good quality bricks can be made by this method. Mould is lifted after clay has been filled into it with the help of the handle which is attached to it. Wet brick is allowed to dry on the ground. In this way the process of moulding of bricks continues till whole area is filled with brick. When bricks get partially dried then their faces are changed so that lower faces also get dried nicely. The face of the brick which remains in contact with ground, becomes rough in this case. Normally kneading of soil in this case is not done by pug mill. Instead it is done manually. Bricks of ordinary quality can be produced by ground moulding. The moulder moulds the brick in sitting position in this case.

(*ii*) **Table moulding**. Table moulding should be done under an experienced supervisor. The moulder stands behind (Fig. 1·4) the table while moulding. Both the ends of the table are kept either on a brick wall or anything else. A 'stock board' is fixed on the ground whose size is equal to the size of the mould. It has also a fillet for the impression or frog. Frog is and impression on one face of the brick on which initial of brick manufacturer is written. (For example A.B.S. or P.W.D. etc.) Frog has specific importance because frog acts as a key for mortar. A peg is kept just beneath

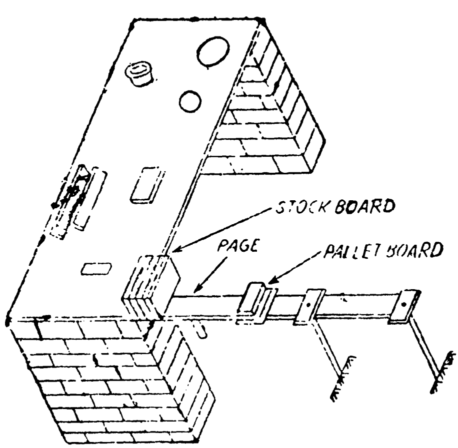


Fig. 1·4. Brick moulding table

the table which withstands the thrust while forcing the clay into the mould. The moulder sprinkles sand or ashes after keeping the mould on the stock board. The helper of the moulder gives a lump of kneaded clay in his hand. The moulder forces the soil into the mould and presses it so that all corners are filled. Superfluous soil is scrapped by means of strike. After that the moulder lifts the mould and turns it upside down. A pallet is kept over it and then wet brick is carried to another place where it is to be dried. After keeping the wet brick on the mould the pallet is brought back and is re-used.

In case of table moulding so many things are necessary. For example table, stock board, pallet etc. Besides this proper supervision is also essential. . Consequently cost of moulding increases. In this method wet bricks are carried from one place to another place so there is every likelihood that bricks may get deformed. Bricks are kept on edge for drying and that is why sometimes bricks lose their shape due to the pressure of its own weight. To overcome all these defects ; moulding of bricks can also be done in box mould. Essentially box mould is also a mould but there is a plate in its lower portion. The moulder goes near the kneaded clay and moulds the bricks in the usual way. Superfluous clay is scrapped and the mould is turned upside down where it is to be dried. After keeping the wet brick again the moulder makes another brick. If moulding is done in this fashion, then the shape of bricks is not lost.

2. Machine moulding. If production of large quantity of brick is essential at a particular place then moulding of brick is done by machine. Central Building Research Institute, Roorkee has invented such a machine which can be operated manually and whose initial cost is also low. This machine is quite strong and can work continuously. Two bricks can be moulded at a time by this machine. Four labourers are essential for operating the machine. Two labourers operate the handle of the machine ; one labourer fills the clay in the mould and one labourer carries the moulded brick to the drying place. 1500 bricks can be moulded in one day by this machine.

Another machine for moulding is also used which is known as 'Block master'. On an average 2000 bricks can be moulded per day with the help of this machine but five labourers operate this machine. A metallic box acts as a mould. The mould is filled with well kneaded clay. When handle is pressed downward it exerts a presure of 20,000 kg. per sq. cm on the brick. Different types of mould can be used in this machine. The weight of the machine is 200 to 220 kg. and can be transported easily from one place to another place.

Soil blocks can also be made from these machines. Soil blocks, prepared from these machines under pressure can also be used for construction without burning.

If the clay is very hard ; then special type of machine is used which is known as *Plastic clay machine*. This machine does the work of grinding, mixing and moulding. Lumps of raw clay is fed in the hopper of the machine. The soil passes between two crushing rollers which turns it into powder. Crushed clay goes into horizontal pug mill where it is mixed with water thoroughly. The pugged clay is then sent to moulding box and is forced from the box by a reciprocating piston in a continuous rectangular band. The band is cut into bricks by means of wires at fixed distance. These bricks are sometimes also called *Wire cut bricks*. Due to reciprocating piston, the pressure on the bricks is uniform and hence the size and density of brick remain uniform.

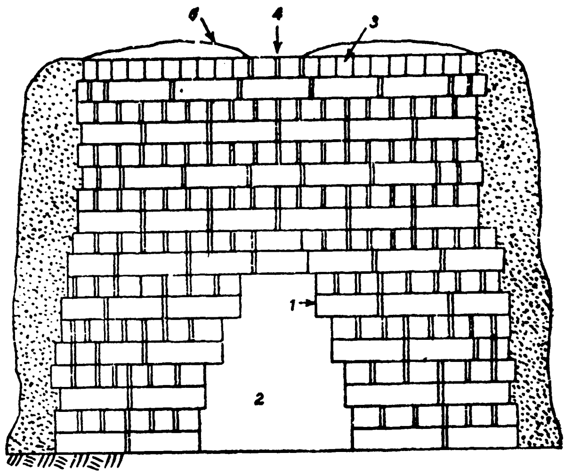
In dry clay machine the soil is first ground to powder and mixed with little amount of water to make stiff plastic paste. This paste is fed into a power driven press which makes the brick. The bricks made by this process does not need drying and can directly be sent to kiln for burning.

1·4·3. **Drying of bricks**. Bricks are dried in the sun after moulding. Bricks after moulding, when dry enough to be handled safely, are carried to the drying yard. Drying yard must be situated at higher elevation so that rain water may not accumulate. Bricks are stacked in the yard. Stacking is done by keeping the bricks on their edges. There are 8 to 10 bricks in each row. There should be enough space between the rows to that proper circulation of air may take place. Bricks must be protected from direct blast of air, otherwise there is a possibility that bricks may crack heavily. Sometimes roof is also made over the drying yard so that bricks are not destroyed due to rains. It takes about eight days for drying bricks. Sometimes bricks are dried artificially by hot gases from kiln. But there is a chance of warping of bricks in case of artificial drying. It is better to dry the bricks in a natural way. Bricks are sent for burning after drying. One should see carefully that bricks have dried fully otherwise moisture from wet brick may spoil the surfaces of other bricks while burning.

1·4·4. **Burning of bricks**. Burning of bricks must be done carefully because underburnt bricks remain soft and over-burnt bricks become *Jhama* after melting. Bricks are burnt in kilns. Mainly they are of three types : 1. Pajawa or clamp or open kiln, 2. Semi-continuous kiln, 3. Continuous kiln.

(*i*) **Clamp**. Clamps are of different types and they are made in different ways in different provinces. A temporary clamp has been shown in Fig. 1·5 by means of which 1800 bricks can be burnt.

Bricks are arranged in clamp in a specified manner. If the bricks are arranged length-wise in one row then in the other they are kept on their edges. This order should be repeated in alternate rows. Bricks should be arranged in such a way that space for burning fire is left in the middle. Topmost brick should be kept very close to each other so that roof of the clamp is formed. Small holes must be left in the roof so that fire can burn and air may go out. The outside of the clamp should then be covered with a layer of soil 20 cm thick so that heat may not go waste. Dampness from the bricks is expelled after burning of fire due



1. Bricks to be burnt. 2. Place of fire. 3. Bricks for roof. 4. Air space between four bricks. 5. Layer of soil over the walls. 6. Layer of soil over the roof.
Fig. 1·5

to heat and consequently bricks shrink. When topmost brick has shrunk ; it means that the dampness of the bricks has been driven out. After that top portion of clamp should be covered with a layer of soil 2·5 cm thick so that heat does not go waste. It is essential to keep some holes in the roof for the proper burning.

It takes about ten days for burning the brick. After ten days the layer of soil may be scratched to see whether brick has burnt nicely or not. If the bricks have not burnt well then firing should be continued. Clamp is allowed to cool after firing. 15 to 20 per cent of bricks are wasted in such type of clamp.

Another type of clamp has been shown in Fig. 1·6 which is mostly used in Bengal. Firstly a layer of grass, dry cowdung and wood is spread over the ground whose thickness should be 70 to 75 cm. Four or five courses of bricks on edge are then laid over it. There must be some gap between the bricks. After that another layer of fuel is placed. The same process is continued ; that is alternate layer of brick and fuel is kept. Amount of fuel in the top layer is decreased slowly. When the clamp is thus filled upto 1/3rd of the full size ; it is fired at the lower end whereas loading of the kiln still continues. After the completion of loading the clamp is plastered with a layer of mud so that heat may not escape. Mostly tamarind trees are used as fuel but coal is used in Bihar and Bengal.

30,000 to 300,000 bricks can be burnt in such type of clamp. Twenty tonnes of coal is required for burning one lac of bricks.

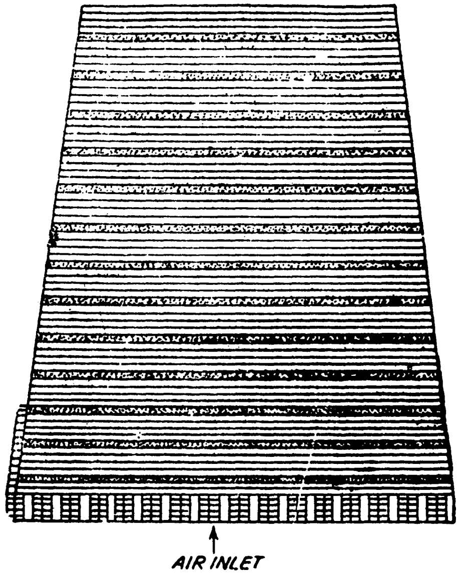


Fig. 1·6. Air inlet.

(*ii*) **Intermittent updraught clamp.** Such type of clamp is in the form of a rectangular house with thicks side walls. At each end there is a wide door. Bricks can be taken in or carried out through these doors. In case of necessity, temporary roof of lighter materials is also constructed so that bricks are not spoiled due to accidental rain. The roof is removed as soon as the clamp is fired.

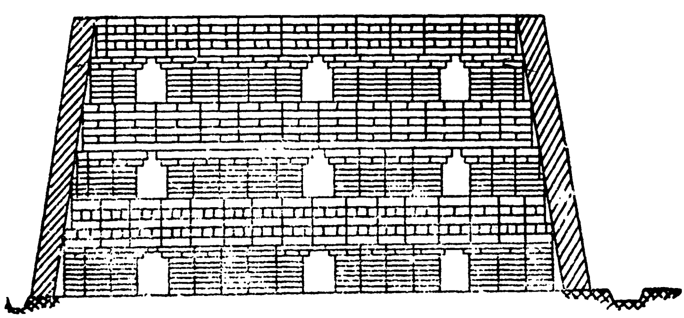


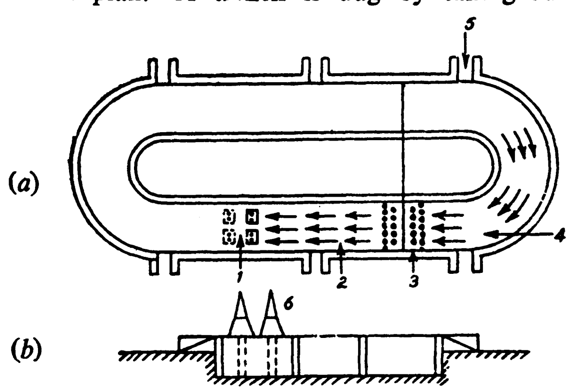
Fig. 1·7

The length, breadth and height of such type of clamp are approximately 1·5, 3·5 and 4·0 metres. Such type of clamp has been shown in Fig. 1·7. Horizontal flue paths have been shown there. Layers of bricks are arranged on both sides of the flue. Flue is situated at different heights as shown in the figure. One flue is on the ground and two on the upper part of the clamp. Thus there are nine flue paths in the clamp. Tamarind wood is normally used as fuel. For first three days and nights slow fire is given so that all the moisture has been driven out then white smoke will turn into black smoke. After that it is fired vigorously for 2 to 3 days so that the temperature rises up to 1000°C. All flue paths are closed after completion of the burning of the bricks and clamp is allowed to cool. 400 to 500 quintals of wood is required for burning one lac of bricks. Greatest defect of this clamp is that bricks near the fire get overburnt where as other bricks remain underburnt.

(*iii*) **Intermittent downdraught kiln.** Such type of kiln are either circular or rectangular. There is a permanent roof over the kiln and a good floor on the ground. Fire kilns remain separate but they are joined to a common chimney. Kiln and chimney are joined by flue paths made beneath the floor. Hot gas enters into the kiln above the floor and goes up to the roof through vertical flue paths. From there the gas is reflected below. Due to hot gas the bricks get burnt. At the end smoke goes out through chimney. Coal, oil or gas can be used in such type of kiln. From the point of view of fuel this kiln has proved better than updraught kiln.

(*iv*) **Continuous kiln.** They are of two types (*i*) Bull's trench kiln (*ii*) Hoffman's kiln. In case of large scale manufacture of bricks ; it is imperative to use these types of kilns. Bricks burn nicely in these kilns. There is economy in fuel also because of little loss of heat. That is why burning cost is greatly reduced. Bricks can be burnt continuously in these kilns and hence continuous supply of bricks can be made.

(*v*) **Bull's trench klin.** Bull's trench kiln is circular or elliptical in plan. A trench is dug by taking out soil from the



1. Damper. 2. Hot bricks 3. Trench for hot air.
4. Cool bricks. 5. Doorway. 6. Chimney.

Fig. 1·8

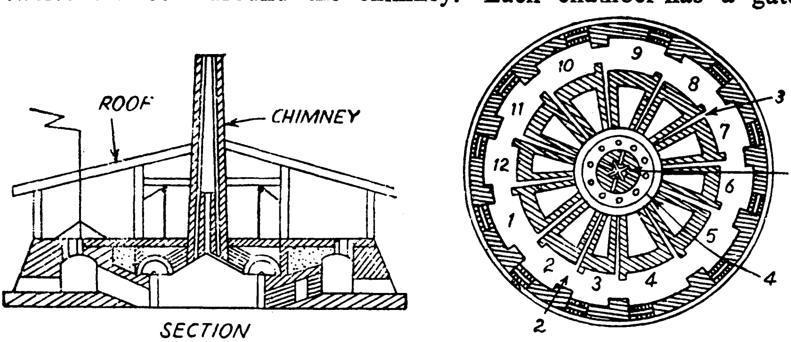
ground. The depth varies from 1·5 to 2·25 metres. Bricks are arranged in the kiln in such a way that some space is left between them. These spaces act as flue path in the lower portion. Fuel holes are provided over the flue at an interval of 90 cm through which fuel can be given. Bull's trench kiln has been shown in Fig. 1·8.

Bull's trench kiln is not loaded at one time but the kiln is loaded in sections. The length of one section is about 3·6 metres. A clear space of 15 cm is left between the sections over which chimney can be placed. After loading one section with brick ; it is covered with ashes and soil so that heat may not escape. When brick of one section is being burnt hot gases enter into the next section. In this way preheating of next section takes place. At the end smoke goes out in the atmosphere through chimney. This is the cause that chimney is placed well in advance of the section which is actually being burnt. Size of chimney depends upon the size of kiln but its height normally varies from 7·5 to 9 metres. Chimney is made from 4·5 mm steel sheet. Sometimes chimney is placed on four wheels so that it can be removed from one place to another place easily.

It takes about 24 hours in burning the brick completely. When one section has been burnt fully ; then fire is advanced to next section and the burnt section is allowed to cool. In this way process of burning preheating and cooling continues in different sections of the kiln. When the section is being burnt ; another section is being pre-heated and some other section is being cooled. After cooling the brick is transported to the construction site. Thus one gets continuous supply of brick from this kiln except in rainy season. This kiln cannot work in rainy season.

(*vi*) **Hoffman's kiln.** Hoffman's kiln is circular in plan. This kiln has been shown in Fig. 1·9.

Chimney is placed in the centre of the kiln and there are twelve chambers around the chimney. Each chamber has a gate



1. Place for chimney
2. Chambers 1 to 12
3. Hot air
4. Damper gate

Fig. 1·9

so that one can communicate from outside. This gate can be closed at will by means of brick walls and sand. Chamber is made from burnt bricks and lining of fire bricks is also provided in the interior portion. Every chamber has a flue which meets the chimney. Flue can be closed or opened at will. Bricks in two continuous chambers are burnt ; bricks in four chambers are heated ; bricks in four chambers are cooled ; cooled bricks are taken out from one chamber and raw bricks are placed in·one chamber. In this way work goes on cotinuously in all the chambers.

Air enters into the ring of chamber through two continuous doors. This air gets heated by the cooling bricks before it reaches the burning zone. It also helps the burning of the fuel which is fed through fire holes. The hot gases of combustion after burning of coal preheat the bricks of another chamber. Due to preheating consumption of fuel is reduced.

Normally the arrangement of chambers is like this :

Chamber 1—Loading.

Chambers 2 to 5—Drying and preheating.

Chambers 6 to 7—Burning

Chambers 8 to 11—Cooling.

Chambers 12—Unloading.

Cooling air enters through chamber 1 and 2 as their main doors are open. After crossing the cooling chambers 8 to 11 it enters the burning section in a heated condition. It then moves to chambers 2 to 5 to preheat the bricks. Damper of chamber 2 is in open condition and hence, it escapes into atmosphere through chimney. Regulation of heat inside the chamber is done through fuel holes.

Hoffman's kiln can work continuously and hence hot gas is always utilized. The length, breadth and height of Hoffman's kiln is 11, 4·5 and 2·5 metres. About 25,000 bricks can be burnt in one chamber. In this way three lac bricks can be burnt in 12 days. 80 to 90 lacs of bricks can be burnt per year in this kiln.

Advantages of Hoffman's kiln. *(i)* Considerable economy in fuel takes place due to preheating *(ii)* Burning of bricks is uniform and there is proper control over temperature *(iii)* Bricks can be sent at construction site in planned way *(iv)* Percentage of first class bricks is more.

Chiefly coal is used as fuel in Bull's trench kiln and Hoffman's kiln. Research work is in progress regarding use of oil as fuel. In certain areas coal is very costly but oil is found in abundance then oil can be used as fuel. Oil as a fuel has many advantages.

1. Burning of bricks is regular and uniform.
2. Complete control can be kept on temperatures in all stages.

3. Cost of labour is reduced because carrying coal is not necessary.
4. Less time is required in burning the brick.
5. Smoke, ash and all type of dirt is absent.
6. Area required for kiln is very small.

Merits and demerits of clamp and kiln burning

Point of comparison	*Continuous or Semi-continuous Kiln*	*Clamp*
Initial cost	The initial cost of Bull's trench kiln or Hoffman's kiln is higher than that of other. Therefore, these kilns are used only when large scale manufacture of bricks is essential.	Initial cost is very low and hence it is suitable for burning small quantity of bricks.
Cost of fuel	Fuel consumption is very low in such type of kiln because heat is not wasted. Besides this pre-heating of raw bricks is done by hot gases.	Fuel consumption is very high because heat is lost from top as well as sides. Hot gases are not utilised in any way.
Control of fire	There is complete control on fire and even raw bricks (with very little moisture) can be burnt after preheating.	There is no control over fire. At some place temperature is high whereas at another place it is low. If bricks are not dry; then there is a possibility that they may be spoiled.
Number of labours	Supervision by skilled labourer is necessary.	Once it is fired no supervision is necessary.
Time for burning and cooling	It takes only 24 hours in burning the bricks and 12 days in cooling.	Time required is 2 to 6 months.
Percentage of first class brick	90% first class bricks can be had from such type of klin. The shape of bricks also do not get deformed.	Percentage of first class brick is low and it never exceeds 60%.
Qualities of brick	Quality of all the bricks is uniform. Warping does not take place.	Quality of brick is not uniform.

(*vii*) **Modern Hoffman's kiln.** The merits of Bull's trench kiln and Hoffman's kiln have been combined into a new design of kiln which is named as *modern Hoffman's kiln*. Uniform burning of bricks and low consumption of fuel are the special features of this kiln. Its shape is that of a Bull's trench kiln but chimney is permanent. In modern Hoffman's kiln there is a middle wall in the centre and there are trenches on both the sides. Kiln is divided into different compartment by means of permanent walls. The walls have parchment doors. Due to the burning of parchment fire enters from one chamber to another chamber. In this way when bricks in one chamber have burnt those in another chamber start burning. Sometimes kiln is also constructed on the ground for making the work load easy. Continuous supply of bricks can be maintained throughout the year by such kiln.

Temperature in any kiln should be between 800° to 1000°C.

(*viii*) **Tunnel kiln.** Continuous supply of brick, can also be had from tunnel kiln. It can be straight, circular or elliptical and its length may be up to 60 metres. At both ends the tunnel is provided with air locks. Fuel (coal powder) is fed to the kiln from the roof through flue hole. Bricks are carried from one place to another place on trolley. Preheating of raw bricks is done by hot gases. Complete control on temperature can be kept in this kiln.

1·5. Method for making good brick from black cotton soil. Black cotton soil is found in the central and western region of India and at other places. This soil has a special feature and that is why good bricks cannot be made. This soil becomes very hard after drying and wide cracks develop in it. Once water is mixed in the soil it becomes very plastic. The soil shrinks very much and contains lime nodules which expand on burning causing lime bursting in bricks. Black cotton soil swells heavily after it comes in contact with water. Black cotton soil possesses all these qualities due to the presence of a mineral in it known as montmoriolonite. Due to these qualities of black cotton soil ; it becomes difficult to mix and pug the soil. While moulding the bricks ; the soil sticks to the mould and cracks heavily after drying. Hence good bricks cannot be made from this soil by normal method.

Huge quantities of coal ash are available from Indian Railways, thermal power plants and other factories after burning coal. Bricks of good quality can be made from black cotton soil by utilising coal ash. First coal ash is ground nicely. It must be seen that unburnt carbon is absent in coal ash ; otherwise porosity of brick will increase. 40 to 50 per cent of coal ash should be mixed with black cotton soil nicely. Good bricks can be made from this mixed soil. Properties of black cotton soil change after mixing coal ash. Besides this compressive strength of brick also increases due to coal ash.

If coal ash is not available in sufficient quantity then following method may be adopted for getting good bricks from black cotton soil.

(*a*) Take out black cotton soil from any pit and spread it on the ground in a layer 5 cm thick. After two hours grind this soil in a grinding mill. Grinding should be done for about 40 minutes. After grinding soil should be screened.

(*b*) Take 1100 litres of screened soil and mix requisite quantity of water. Leave the soil for drying for one night. After that burn the lump in an ordinary potter's kiln for about 18 to 20 hours. Temperature of kiln should be 500°C to 800°C. Lump of soil should be kept in the kiln as long as the soil does not become red and when water is sprinkled on the soil they become soft. Remove the burnt soil from kiln and grind it again in the grinding mill. After grinding it should be again screened. Mix 25 to 30 per cent of burnt soil with unburnt black cotton soil and prepare brick. While mixing the soil care must be taken to mix them intimately.

(*c*) After this add sufficient quantity of water in dry soil and pug it by feet. Allow this mixture to remain for one night.

Sprinkle the burnt soil on the mould to make moulding easier. Burning of brick is done in the same way.

1·6. Colour of Bricks. Coloured bricks are used on a large scale in foreign countries. Bricks of different colours are found in England, America etc. for example blue, green, red, chocolate etc. The colour of brick depends upon the chemical composition of soil, type of salt (which can be added also), amount of moisture in brick, before burning, temperature of kiln and type of fuel. If iron is absent in soil ; then the colour is white. Bricks become red due to excess of iron. If there is some lime in the soil besides iron ; then the colour of bricks becomes that of cream. But due to excess of lime, bricks become grey. Bricks become black due to the presence of manganese in soil but if there is high percentage of alkali in soil then the colour of bricks become blue-green. If sodium chloride is added to the soil then yellow coloured bricks can be obtained.

Different types of colour can be given to the brick by artificial way. Different types of colours can be had by mixing different types of chemicals. However, only those chemicals are used which are cheap.

Coloured bricks can be obtained by clipping brick in coloured solution also. Paint is prepared by mixing suitable colouring agent in linseed oil or turpentine oil. Bricks, which are to be coloured are placed on an iron plate. The size of plate should be such that 40 to 50 bricks can be kept over it. After that bricks are heated to such a temperature so that these can be touched by hand. After heating bricks are dipped in paint solution and kept immersed for few seconds in it Brick is allowed to dry on a table. After drying it is washed by cold water. Normally paint solution penetrates into the brick by about 3 mm and bricks do not loose colour easily.

Sometimes instead of heating the bricks ; the paint solution itself is heated and painting of brick is done by brush. Different colours can be used for colouring bricks.

Modular Bricks. Indian Standards Institution has standardised the size of the bricks in metric system. These bricks are also called modular bricks. The value of its module is 10 cm. Advantages of modular bricks are given below :

(*i*) Cost of production of metric bricks is 20% less than other bricks.

(*ii*) Requirement of drying area is less in such bricks because its floor area is less.

(*iii*) There is saving in floor area by 3·5%. If other bricks make a floor of 4 m×4 m then metric bricks will make 4·07×4·07 =16·56 m^2 area.

(*iv*) Weight of metric brick is 87% of other bricks.

(*v*) Requirement of cement is less in such type of bricks.

(*vi*) Requirement of metric bricks for same surface area of a well is less by 13%.

Mainly bricks are rectangular in shape and their length, breadth and width in metric system are 190×90×90 mm. After useing mortar the size of bricks become 200×100×100 mm.

1·7. Different Types of Bricks. Different types of bricks are made for special work and their sizes are also different. Bull nosed brick is made to use these on (Fig. 1·10) corners. The length and breadth of queen closer (Fig. 1·11) remains the same but width is reduced by half as compared to ordinary brick. King closer has been shown in Fig. 1·12. A special type of brick known as plinth brick (Fig. 1·13) is used in plinth of the building. Hollow bricks are used for making hollow (Fig. 1·14) walls. Such type of walls are very cheap and light.

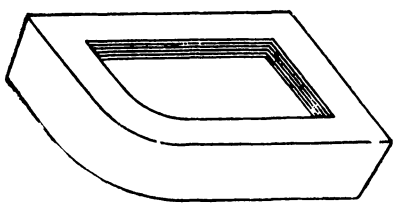


Fig. 1·10

(*i*) **Preforated brick.** Preforated brick has many advantages over solid brick. Perforated bricks are lighter and hence the cost of transportation from one place to another place is less. The compressive strength of a perforated brick is quite high. A nine storeysed building has been constructed in France by perforated bricks. In rainy season there is every likely that rain water may enter into

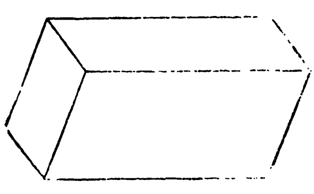


Fig. 1·11

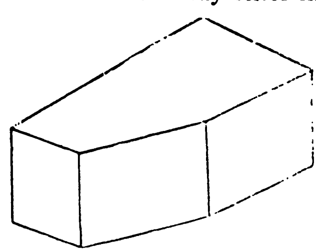


Fig. 1·12

the walls. Perforated bricks have proved to be better than solid brick from this point of view. Heat insulation capacity of thes

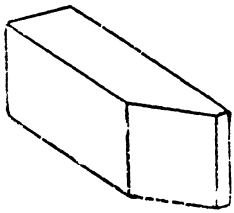


Fig. 1·13

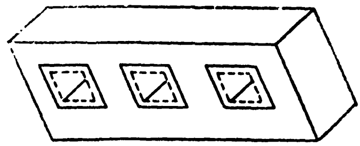


Fig. 1·14

bricks is very high but sound insulation capacity is low. Perforations in the brick can be done in vertical as well as horizontal direction. Direction of perforation has also appreciable effect on the property of brick. A type of perforated brick named B_{25} is produced in Switzerland (Fig. 1·15) which has perforations in vertical direction. In England also perforated brick named V_5 has been used successfully. The amount of void in this brick (Fig. 1·16) is about 58%. The size and weight of perforated brick should be such so that it can be handled with ease. Weight of such brick should not exceed 5·5 kilograms. According to the Indian Standards Institution the area of perforation in no case should be less than 30% and more than 45%. Size and compressive strength of brick

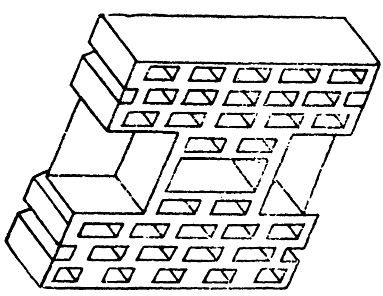


Fig. 1·15

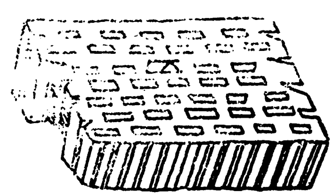


Fig. 1·16

should be equal to that of ordinary brick. Absorption of water should not exceed 15%.

(*ii*) **T-Brick and Channel brick.** T-bricks and channel bricks are being used these days in building constructions. Its shape is that of letter T and C. T-brick and channel brick have been shown in Figs. 1·17 and 1·18 There is a definite ratio between the lengths of each part in T-brick and channel brick. Both types of bricks can be used separately or, in combination with each other at construction site. Solid wall as well as hollow wall can be constructed from these bricks. Buildings made from these bricks are stronger and cheaper than ordinary bricks. Its heat insulation capacity is good.

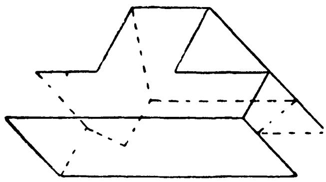


Fig. 1·17

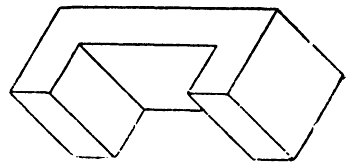


Fig. 1·18

It takes less time in drying and burning these bricks. These bricks can be sent to kiln for burning only after 48 hours of drying, whereas ordinary bricks must be dried for 100 to 120 hours before they are sent to kiln. Consumption of fuel is 40% less as compared to ordinary brick. Compressive strength of T-brick is more than ordinary brick. T-brick can also be cut into different sections like ordinary brick in case of necessity.

Construction of light partition wall has proved to be very beneficial. All types of walls, columns and other things can be constructed from these bricks. It is not necessary to use choukhats in doors and windows if T-bricks have been used. It is desirable to use such type of bricks in the construction of lintel, staircase and drain.

(*iii*) **Sand lime brick.** Sand lime brick is a special type of brick which is sometimes also called calcium silicate brick. Such bricks are widely used in Germany and U.S.S.R. 8600 million sand lime bricks were produced in U.S.S.R. in 1964 which shows its popularity in that country. In India the production of sand lime brick has started in Pallipuram in Kerala.

90% sand is used for manufacture of sand lime brick. Rock minerals, clay, calcium and other carbonates are also present in sand but the percentage of clay should not exceed 4%. If soluble salts are more in sand ; then it should not be used. Good quality lime can also be used for manufacture of brick instead of sand. There are three operations in the manufacture of sand lime bricks.

(*a*) Mixing of raw material

(*b*) Pressing

(*c*) Auteclaving.

88—92% sand, 8—12% calcium hydroxide and 3·5% water is used for the manufacture of sand lime brick. Firstly the raw materials are mixed nicely. After that it is given proper shape by pressing it on the table press in semi dry condition. Pressure of 315 to 630 kg/sq. cm is applied while pressing. Subsequently the brick is sent to autoclave for autoclaving. Saturated steam at a pressure of 8·5 to 16 kg/sq. cm is applied in the autoclave. The brick is kept in autoclave for 6 to 10 hours. Advatages of sand lime brick :

1. Size of brick is very uniform.
2. There is no efflorescence because soluble salt is absent.
3. The value of co-efficient of variation in strength is very low. Hence low factor of safety can be used.
4. There is no necessity of plaster.
5. Very little mortar is required for joining the bricks.
6. Sand is used which is a waste material.
7. Density of such bricks is more than other bricks. Its density varies from 1·68 to 2·08 gm/ c.c.
8. Thermal conductivity of sand lime brick is equal to that of dense concrete. Its value for about 12 cm thickness is about 9·3 gm-cal/cm^2/Hour/1°C/cm.
9. Fire resistance is more than other bricks.
10. Its reflecting quality is also very good and is used for sound insulation also.

Sand lime brick has low resistance against abrasion. Hence it should not be used for flooring or where there is continuous flow of water.

(*iv*) **Blue brick**. This brick is made by mixing 7 to 10% of iron oxide in clay and marl. Water cannot enter into the brick easily. Besides this it can withstand water pressure. It is used as an interior lining for sewage drain.

(*v*) **Paving brick**. Paving brick is made from clay and shale. Water is added to the soil after grinding it thoroughly. Pugging is done in a pug mill. Paving bricks are burnt in a kiln whose temperature is higher than the temperature which is required for ordinary brick. Such type of brick can withstand friction. Hence they are used for making floors in factories and roads. Roads made from these bricks do not get damaged due to wheel friction. Compressive strength of paving brick should not be less than 440 kilogram per sq. cm. Absorption of water should not be more than 5%.

1·8. Qualities of a good brick and their tests. Bricks of good quality should be used for construction. Tests are necessary to identify bricks. Tests can be divided into two groups :

1. Those tests which can be performed anywhere and special apparatus is not necessary.

2. Those tests which can be performed only in the laboratory.

Following things come under first group :

1. External appearance 2. Hammer test 3. Hardness test 4. Absorption test 5. Specific gravity 6. Efflorescence Tests for compressive strength and weathering tests are performed in the laboratory.

(*i*) **External appearance**. The shape of a good brick should be uniform and regular and their edges must be sharp. There should be no crack, air bubble, lime nodules or pebbles in the brick. The degree of burning of a brick, can be estimated from the colour of the brick although sometimes colour of bricks give misleading estimation. Surface of brick must be plane but neither it should be very rough nor very smooth. Degree of burning of brick should neither be less nor more. Overburnt bricks, known as Jhama bricks, become unless for construction work. In fact due to high temperature Jhama brick melts and hence it loses its shape.

(*ii*) **Hammer test**. When well burnt brick (having no cracks) is hit by a hammer then metallic ringing sound is produced. Such type of bricks are called first class brick. If two first class bricks are struck against each other; then they produce metallic ringing sound. A first class brick will not break if it is dropped from a height of 2 to 5 metres.

(*iii*) **Hardness test**. If the surface of a good brick is scratched by the nail of a finger ; no mark should be left over it. Estimation of hardness can also be done by breaking the brick with a hammer. Under burnt brick will break easily where first class brick will not break easily.

(*iv*) **Absorption test**. The amount of absorption of water is a good indication of the degree of burning of brick. The brick is immersed in water for 24 hours. Due to this the weight of brick increases. After weighing the wet brick the percentage of absorption (expressed in terms of its own weight) can be found out. If the percentage absorption of water is 16 then these can be used for construction. Percentage of water absorption of first class brick varies from 12 to 16%. If the brick is to be used for hydraulic work, then percentage of absorption should not be more than 6% High percentage of water absorption indicates insufficient burning. The permeability of brick is of extreme importance in the case of exterior walls. If the permeability is high then rain water will penetrate into the wall.

Rate of absorption of water by brick in a certain condition is known as suction rate. Bricks start absorbing water from the mortar after its application. If suction rate is very fast then the joint of brick will become weak because chemical reaction with cement will not take place in absence of sufficient moisture. Bricks should absorb 10 to 35 gm. of water per sq. cm. of surface in one minute. Bricks having suction rate higher than this ; are not considered to be good.

(*v*) **Specific gravity**. Other factors being constant, higher the specific gravity of the brick the stronger is the bricks. Unit weight of ordinary brick should be 1600 to 1920 kilogram per cubic metre.

(*vi*) **Efflorescence**. Main cause of decay of brick is the crystallisation of soluble salts. These salts remain present in the brick before hand or are absorbed by brick later on. Name of the salts are magnesium sulphate, calcium sulphate, sodium and potassium sulphate etc.

Being soluble in water these salts are deposited on the brick surface as efflorescence as a result of wetting and drying of the brick by rain and sun and by rise and fall of watertable. In fact salts come in the brick along with water from below and is deposited on the brick in a layer after evaporation. Due to this, decay of bricks begins. Efflorescence disappears in rainy season. Sometimes due to presence of these salts in mortar, bricks are affected by efflorescence. Hence before selecting sand and it must be seen that harmful salts are absent.

Following test is done for efflorescence—Take distilled water in a shallow vessel and dip one end of brick in water by about 2·5 cm. If there will be efflorescence then salt will be deposited on brick otherwise not. Test takes about 5—7 days.

Use of 'high lime' mortar is practised for reducing efflorescence. Sometimes damp proof course is also given. Clear water must be used for making mortar. If the efflorescence has occurred then the surface should be painted after removing the salt by wire brush.

(*vii*) **Compressive strength**. Durability of brick can be estimated from the result of compressive strength. Classification of brick is also done according to compressive strength.

(*viii*) **Weathering test**. Weathering test should also be done in the laboratory to see its effect on brick.

1·9. Classification of brick. In different parts of country bricks are termed at First Class, Second Class and Third Class but the quality of first class brick of one province, is not similar to the quality of first class brick of another province. Therefore, Indian Standards Institution has classified brick so that standard of whole of India is same. The classification is based on the value of compressive strength and other properties of brick, Class H_I and H_{II} is used for heavy duty work, F_I and F_{II} are used as facing brick. Class I and II is used for ordinary construction work. Class L_I and L_{II} is used for low quality work.

Name of Class	*Compressive strength in kilo-gram per sq. cm (Minimum)*	*Degree of absorp-tion of cold water in 24 hours (Minimum)*	*Efflorescence*	*Tolerance on dimensions per cent*	*Shape and other properties*
H_1	440	5	zero	±13	Smooth, rectangular, faces and edges must be sharp. Metallic ringing sound should be produced when two bricks are struck.
H_{11}	440	5	zero	±8	Slight deformation in shape. Edges may be curved. Metallic ringing sound should be produced when two bricks are struck.
F_1	175	12	Very little	±3	Smooth, rectangular, sharp edges, metallic ringing sound should be produced when two bricks are struck.
F_{11}	175	12	Little	±8	Slight deformation in shape. Edges may be curved to a slight extent. Metallic ringing sound should be produced when two bricks are struck.
I	70	20	Very little	±3	Smooth, rectangular, sharp edge. Metallic ringing sound should be produced when two bricks are struck.
II	70	20	Little	±8	Slight deformation in shape. Edges may be curved to a slight extent. When two bricks are struck metallic ringing sound may be produced or may not be produced.
L_1	35	25	Very little	±3	Rectangular, sharp edges. Metallic ringing sound may be or may not be.
L_{11}	35	25	Little	±8	Slight deformation in shape. Edges may be curved slightly. Metallic ringing sound may be or may not be.

Recently I.S.I. has changed the classification system of bricks (I.S. : 1077—1976). The new classification system is given below. In this system name of class has been abolished and class designation based on compressing strength has been given.

Table 1·1

Class Designation	*Average compressive strength*			
	Not less than		*Less than*	
	Kgf/cm²	*N/mm²*	*Kgf/cm²*	*N/mm²*
350	350	35	400	40
300	300	30	350	35
250	250	25	300	30
200	200	20	250	25
175	175	17·5	200	20
150	150	15	175	17·5
125	125	12·5	150	15
100	100	10	125	12·5
75	75	7·5	100	10
50	50	5	75	7·5
35	35	3·5	50	5

Each class of brick is further divided into two sub-classes A and B based on tolerances and shape. For example the brick of classification 35 has further sub-classifications of 35 A and 35 B.

Tables 1·2 and 1·3 show standard sizes of common building bricks and tolerances for A and B class respectively.

Table 1·2

Length in cm	*Width in cm*	*Height in cm*
19	9	9
19	9	4

Table 1·3

Tolerances per 20 bricks

Sub-Class A	(*a*) Length	368 to 392 cm	(380±12 cm)
	(*b*) Width	174 to 186 cm	(180±6 cm)
	(*c*) Height	174 to 186 cm	(180±6 cm)
Sub-Class B	(*a*) Length	350 to 410 cm	(380±30 cm)
	(*b*) Width	165 to 195 cm	(180±15 cm)
	(*c*) Height	165 to 86 cm	(180±15 cm)
		74 to 86 cm	(80±5 cm)

Heavy duty bricks (known as engineering bricks) are required in masonry in heavy engineering works such as bridge structures, industrial foundations and multi-storeyed buildings.

Investigations conducted by the Central Building Research Institute (CBIR), Roorkee have revealed the possibility of making heavy duty bricks from alluvial soils thereby reducing the problem of procurement of the raw materials. IS : 2180—1970 lays down the requirements regarding dimensions, general quality, and physical properties of heavy duty burnt clay building bricks.

The heavy duty bricks are classified in accordance with their compressive strength. The bricks of compressive strength of 400 kg/cm^2 are classified as '400'. Each class of brick is further divided into two sub-classes A and B based on tolerances and shape. The brick of class 400 is further sub-classified as 400 A and 400 B.

The heavy duty clay bricks have the sizes as given in Table 1·4.

Table 1·4

Length in cm	*Width in cm*	*Height in cm*
19	9	4
19	9	9

The maximum permissible tolerances in the dimensions are given in table 1·5.

Table 1·5

Dimension in cm	*Tolerances*	
	Sub-class A in mm	*Sub-class B in mm*
9	±3	±7
19	±6	±15

When burnt bricks can be conveniently manufactured economically at site, they form very good soling material IS : 5779—1970 specifies the requirements in regards to dimensions, general quality and physical properties for burnt clay bricks for use in soling of roads. Dimensions and tolerances for such bricks are given in Tables 1·6 and 1·7.

Table 1·6

Length in cm	*Width in cm*	*Height in cm*
19	9	4
19	9	9

Table 1·7

Tolerances of soling bricks (20 whole bricks)

Length	350 to 410 cm	(380±30 cm)
Width	165 to 195 cm	(180±15 cm)
Height	165 to 195 cm	(180±15 cm)
	74 to 86 cm	(80±6 cm)

1·11. Defects in Bricks

Overburning of bricks. Due to overburning, bricks loose their shapes. These bricks are called Jhama bricks. This is unsuitable for building construction.

Underburning of bricks. The compressive strength of under burnt bricks is less and the degree of absorption of water is more. Underburnt bricks should not be used.

Bloating. Swelling of bricks takes place due to the presence of excess of carbonaceous matter and gas forming material in the clay and due to bad burning or very rapid firing.

Black core. This defect occurs where clays are heated too rapidly in the kilns causing the surface to vitrify and the interior to remain black.

Efflorescence. Bricks containing a relatively large proportion of soluble salts are liable to become discoloured by the formation of a whitish deposit.

Lamination. Laminations are caused by air in the voids of clay. They produce thin lamina on the faces of bricks which scale off on exposure to weather.

Lime nodules. If particles of the lime stone are left uncrushed during preparation of clay, then they become lime nodules in brick. These lime nodules will expand when water is absorbed thus causing disintegration of bricks. Wide cracks in walls develop due to this.

Chuffs. If rain water falls on hot brick, then the shape of brick gets deformed badly.

Iron spots. These are surface dark spots due to the presence of iron sulphide in the clay. Bricks become unsuitable for exposed brick work due to this.

1·12. Fire brick, Silica brick, Refractory brick. There is great difference between ordinary brick and refractory brick. The main property of ordinary brick is its compressive strength so that it can withstand the structural load and may not be affected by wear and tear. Refractory bricks are used for the construction of furnaces and hence these must be capable to withstand high temperature. Therefore, fusion point of these bricks must be high. Besides this refractory brick should be able to withstand friction, pressure and impact. There is a chance of corrosion of refractory brick also because it comes in contact with molten metal and slag. Hence it must be able to resist corrosion.

Refractory bricks are made from Magnesite, Bauxite, Kaonite, Silimanite, Olivine, Carbon, Graphite, Chromite ore, Fireclay, Diaspor, Pyrofulite etc.

Refractory bricks can be divided into three divisions from the point of view of chemical rection.

1. Acid refractory. 2. Basic refractory. 3. Neutral refractory.

Acid refractory bricks. Fireclay brick is most important among acid bricks. Fireclay brick is made from fireclay. In this brick there is 44 to 25% of alumina and 50 to 72% silica. After grinding fireclay nicely ; it is sieved through a sieve. After that 'Grog' is mixed in it and brick is made. Brick is burnt in a kiln whose temperature varies from 1250 to 1350°C. Fireclay is used as mortar in such type of bricks. Choice of acid, basic or neutral bricks depend upon the type of furnace for it is going to be used.

Silica brick. Silica bricks contains 95 to 97% silica and 0·2 to 1·2%alumina. This is made from quartzite, calcined flint and ganister. These material contain large amount of silica. Silica brick is burnt in a kiln at a temperature of 1760°C. Silica brick can withstand very high temperature. Hence it is used in copper melting furnace and open hearth steel furnace. These bricks are used for lining.

Semi-silica brick. Semi-silica brick contain 72 to 80% of silica, and 25 to 18% of alumina and some amount of oxides. The fusion temperature of these bricks are low and hence these cannot withstand very high temperature like silica brick. Greatest merit of semi-silica brick is that it can withstand high pressure even at high temperature. Besides this, its coefficient of expansion is low.

Basic refractory brick. High alumina brick is very important among basic bricks. High alumina bricks contain 47·5 to 99% alumina. Sometimes these bricks are named according to the percentage of alumina present in them. For example 50%, 60% alualumina etc. The brick is mainly made from Bauxite, Diaspor, Aluminium silicate, Kaolinite, Andalucite etc. This is used in cement kiln and glass melting tanks as lining. High alumina brick can withstand corrosion It can withstand higher temperature as compared to fireclay brick. The fusion point of 99% alumina brick is 2050°C.

Magnesite brick. This brick is made from magnesite which normally contains 47·6% magnesia and 52·4% carbon dioxide. Before making brick magnesite is burnt. It is heated in a rotary kiln to such a temperature so that CO_2 and water is expelled out. After that it is heated in the same kiln from 1950°C after mixing some amount of iron oxide. The final product after burning magnesite is named as 'Perilax'. This is a crystalline material but is inactive and does not dissolve in water. Magnesite bricks are used in copper reverberatory furnaces and steel open hearth furnaces. Slag containing large amount of lime does not affect magnesite brick.

Dolomite brick. Dolomite brick is made from dolomite. Dolomite contains 30·4% lime, 21·7% magnesia and 47·9% carbon dioxide. This brick is also used lining in basic furnaces. Dolomite bricks are inferior to magnesite bricks.

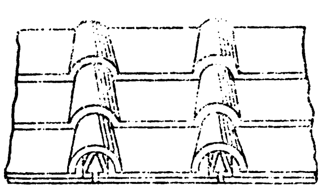
Neutral refractory brick. These bricks are used for separating the acid and basic linings of furnaces to prevent them reacting together. Forsterite brick is important among neutral refratory bricks. Pure forsterite contains 57·3% magnesia and 42·7% silica. Forsterite brick is made from olivine. Olivine, which is to be used for making brick, should contain less than 5% of iron oxide. This brick is used in copper reverberatory furnace because brick is not affected by slag.

Chromite brick. Chromite brick is made from chromite. It contains 30 to 35 chromic oxide 12 to 16% iron oxide, 14 to 20% magnesia, 13 to 30% alumina, 3 to 6% silica and 1% lime. Combined percentage of alumina and chromic oxide should in no case be less than 60%. Chromite brick is burnt in a kiln at 1450°C. The brick is used as lining in kiln.

Silimanite brick. Silimanite brick is made from silimanite, cyanite and andalusite. The brick in pure condition contains 62·9% alumina and 37·1% silica. These bricks are used in reheating furnaces, glass melting furnaces and roofs of electric arc furnaces. The stability of this brick is better then that of other bricks. The value of co-efficient of expansion is also low.

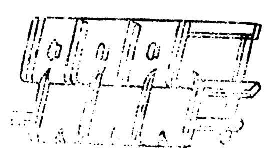
Carbon brick. Carbon brick is made from crushed coke bonded with tar. This brick is used as lining in blast furnace and electric furnace.

1·13. Tile. Tiles are not only used for roofing purpose but also for making floors and drains. Tiles, which are used for making



ALLAHABAD TILE

Fig. 1·19

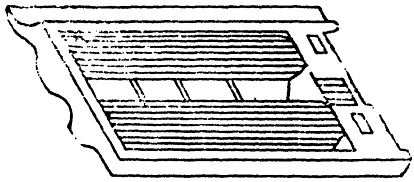


RANIGUNJ TILE

Fig. 1·20

floors are plain and they are of rectangular size. Sometimes tiles are made hexagonal also. Tiles for roofing purpose may be plain, curved or corrugated. Some tiles are patented product—such as Allahabad tiles (Fig. 1·19), Ranigunj tiles (Fig. 1·20), Mangolore tiles

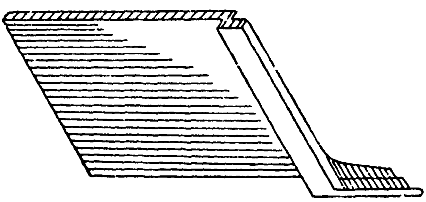
(Fig. (1·21), Sialkot tile, Quilon tiles etc. Weight of these tile varies from 2·25 to 2·50 kilograms. 125 tiles are required for covering nine square metre of roof.



MANGALORE TILE

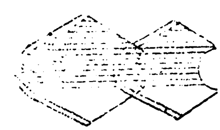
Fig. 1·21

1. **Allahabad and Mangalore tile**. Allahabad tile has been shown in Fig. 1·19. These tiles are made from best clay. Machines are used for moulding tiles and they are burnt in a special kiln. Tile can be divided into different classes such as first, second, third. The projecting portion of the tile interlocks other tile. Special type of valley tile, hip and ridge are used while covering the roof with these tiles. Ridge tile has been shown in Fig. 1·22 and valley tile has been shown in Fig. 1·23. According to Indian Standards Institution effective length of Mangalore tile should be 320 to 350 mm and



RIDGE TILE

Fig. 1·22



VALLEY TILE

Fig. 1·23

effective width should be 210 to 220 mm. Average weight of six tiles should not be less than 2 kg. and more than 3 kg.

Classification of tile

Name of properties	*Class AA*		*Class A*
Degree of absorption of water maximum	19		24
Load bearing capacity in kg. minimum	Average	102	82
	Above	91	66

2. **Sialkot tile**. Sialkot tile has been shown in Fig. 1·24. This is also a patented product and is of inter-locking type.

These tiles have following advantages :

(*a*) Its weight is less than other tiles and is very much useful for roofs having flat slope.

(*b*) Repair is not necessary each year.

(*c*) They are beautiful to look at.

(*d*) Placement and fixing of tiles on the roof is easy.

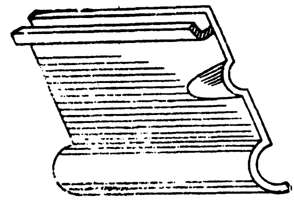


Fig. 1·24

3. **Pot tiles**. Pot tiles are semi-circular (Fig 1·25) and they are laid in rows on the roof. Its concave side is kept up while laying. Over these and convering the adjoining edges of each pair of tiles, are laid rows of the same tile with convex side up. Mainly pot tiles ara kept over flat tiles. These tiles are made from good clay. Mixing of soil should be done intimately. The consistency of mixing clay should be thicker in comparison with brick. The tiles are made on potter's wheel. The potter produces the shape of the tile by his wetted hand. After that he polishes it by means of wet cloth. After keeping the lump of soil on the wheel, it is given the shape of a tapered tube. The cross-section of the tube is circular. The potter makes two vertical cuts just before removing the tile from the wheel. These cuts assist in splitting the tiles into two parts. Afterwards tile is dried. After drying, the tiles are burnt in an open clamp. While burning, pot tiles are stacked over flat tiles. Dry cowdung is used as fuel. After burning, it is allowed to cool. Following are the disadvantages of pot tile—(1) Its shape and size is not uniform because they are hand made. (2) It is difficult to repair broken tiles laid on roof. (3) These tiles are brittle and break under pressure.

4. **Pan tile**. Pan tile (Fig. 1·26) is also like pot tile but it is smaller in size. It is heavier but its curvature is less. Moulding of pan tile is done carefully and its size is also uniform. It is stronger than pot tile and hence it is assumed to be better than pot tile. Following implements are used for making pan tile : 1. Mould (Fig. 1·27) 2. Bow (Fig. 1·28) 3. Strike (Fig. 1·29). 4. Horse (Fig. 1·30).

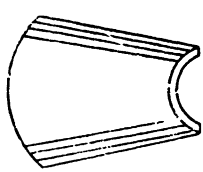


Fig. 1·25

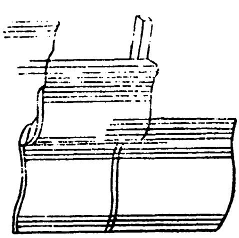
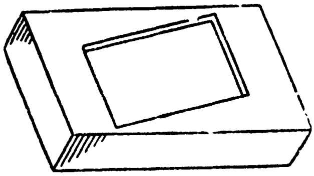


Fig. 1·26

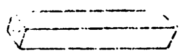


MOULD FOR PAN TILE

Fig. 1·27

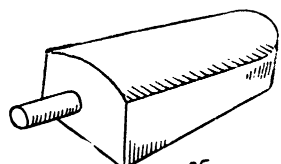
BOW

Fig. 1·28



STIUCE

Fig. 1·29



HORSE

Fig. 1·30

Moulding is done after mixing clay throooughly with water. At first ash is sprinkled in the mould. A lump of mixed clay, slightly more than sufficient to fill the mould, is pushed into the mould and is pressed to fill all the corners. Superfluous clay is cut by passing the string of bow across the surface of the mould. After the strike is moved over it in backward and forward directions so that the surface becomes smooth. The moulder then places his moistened left palm with wide spread fingers over the tile and lifts it gently. After that he keeps it over a burnt pan tile. In this way a heap of twenty tiles is made by keeping them one over the other. When the tile dries a little (but has plasticity) then is placed over the horse and pressed. Due to this the shape of tiles becomes curved. Ash is sprinkled over the horse before placing the tile. After 5 or 6 hours tile is again placed over the horse and pressed so that it assumes the required shape. Finally its edges are trimmed and ashes cleaned. It is allowed to dry for about 8-10 hours. During this interval tiles become so hard that it can be carried from one place to another. After drying, tiles are stacked over the other.

5. **Flat tile.** Flat tiles are used below the roofing tiles. Flat tiles of large size are used for floors also. Flat tile made by the same method as that of pan tile. Moulding is done exactly in the same manner as that of pan tiles. On the third day after moulding the tiles are beaten gently with flat mallet so that the shape of the tile is corrected and warping and wrinkles are removed. On the fourth day the tiles become so hard that it can be moved from one place to another by hand. After that tiles are left for drying in any shady place. It is burnt in a kiln after urying. According to I.S.I. its size should be 20×20, 20×10 or 15×15 cm. Machine made tile should not absorb more than 19% of water where as hand made tile should not absorb more than 24% of water. Its flexural strength varies from 15 kg. per sq. cm. to 10 kg per sq. cm.

Kiln for burning tiles. Circular kiln is used for burning tiles which has been shown in Fig. 1·31. 30 to 50 thousand tiles can

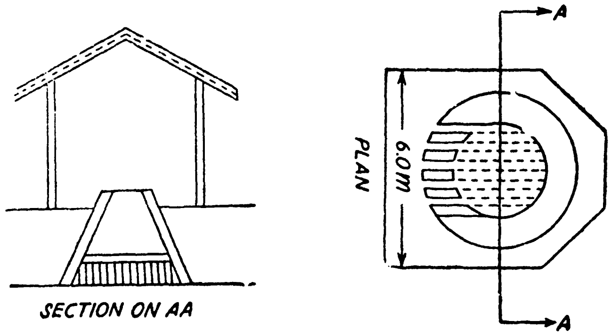


Fig. 1·31

be burnt in such kiln of 6 metres diameter. The time required for burning is three days. The floor of kiln is made of bricks. Bricks are laid flat on the floor in such a way so that some spaces are left between them. Wood fuel is kept in between these spaces. The tiles are laid on edge on the floor When kiln is filled with tiles ; then the door of kiln is closed by brick and mud mortar. Upper portion of the kiln is covered with old tiles. Initially the fire should be slow. White smoke starts coming out after fire. When white smoke stops coming out then the temperature is again lowered for six hours. Again the temperature is raised upto 1300°C and this temperature is maintained for three hours. After that the temperature is again lowered for six hours. Again temperature is raised upto previous level which is maintained for four hours. Finally flue paths are filled with fuel and mouth is closed with brick and mud. Slowly the wood burns. The time required for full burning is about 72 hours. If it is required to burn small quantity of tiles, then these may be burnt by keeping them on the top of brick clamp.

6. **Concrete interlocking tile.** Concrete tiles are made from ordinary concrete (1 : 3) using different cement. Size of aggregate should be 3 mm. Thickness of tile should be 9 to 10 mm and its size 37·5×22·5 cm. Its colour may be that of cement or it may be given different colour by using colouring pigment. Iron oxide, chromium oxide and manganese oxide can be used as colouring pigment because weathering capacity of these colours is more.

Cement and sand is mixed in open mixer for making cement tile. Firstly cement and sand are mixed for one minute in dry condition and then water is added to it. If necessary colouring pigment is also added at this stage. Tiles are made on steel pallets which are shaped to the underside of the tiles and provided with recesses to form the ribs. Pallets are placed on the bed of the machine whose upper surface is coated with coil. Concrete is passed through a roller which compresses it. A rotary knife cuts the concrete longitudinally forming the tiles on each pallet. The pallets and the tiles are then carried out by means of roller conveyer. The tiles are kept on their pallets at least for about 24 hours. After that these tiles are dipped in a special tank for seiting.

7. **Flooring tiles.** Flooring tiles are thicker and stronger than ordinary tiles so that they can withstand the load on the floor. Principally they are made from cement concrete. Sometimes they are made from good quality clay.

8. **Drain tiles.** Drain tiles may be circular or semi-circular. They are used for carrying sullage water from houses. The length of drain tiles is 40—45 cm. and can have any diameter. These tiles are made by hand and hence their sizes are not uniform. Now a days these tiles are not used because other tiles are used for carrying sullage water.

9. **Glazed tile.** Glazed tiles are used in walls, floors and other places for decoration. Wall of hospital, operation theatre and bath rooms are made from glazed tiles because they can be cleaned easily. Tiles are made from good quality clay named as kaolin. Little amount of silica is added in clay to prevent shrinkage. Flint, felspar or sand can be used as silica. After grinding the soil, water is added to it to make slurry. The slurry is passed over electric magnet so that iron particles are not left in slurry. After that slurry is collected in big tank. Solid parts of slurry slowly get deposited at the bottom of the tank. Water from the top portion is flown out and the solid particles are dried in an oven. The bried material is then powdered and 10% of water is added to it. Tiles are moulded with this mixture. Moulding is done by press mould. Tiles are burnt in a kiln at a temperature of 1200°C. The outer surface of burnt tile is glazed. Tile is dipped in glaze. Glaze is made from iron oxides, copper oxide, cobalt oxide or manganese oxide. After glazing, tiles are again burnt in the kiln at a temperature of 1000°C.

1·14. Glazing. Bricks, tiles etc. are glazed for protection of the surface. Glazed surfaces are very little affected by chemicals or other things. Glazing can be divided into two parts 1. Transparent glazing 2. Opaque glazing.

Transparent glazing. There are many methods for transparent glazing but salt glazing is very important among them. The solution of sodium chloride is thrown in the kiln when the temperature of kiln is 1200—1300°C and when tile or brick has almost burnt. Sodium chloride starts evaporating due to high temperature and combines with the silica of soil to made soda silicate. Soda silicate again combines with alumina, lime or iron in the clay to form a thin layered surface coating which is as transparent as that of glass. Greatest merit of salt glazing is that vapour of the volatilised salt gets into every pore of the tile and thus making the tile impermeable. This method is used for those materials which are rich in silica content so that soda silicate can be formed easily. Sewer pipes or chemical stonewares are normally glazed by this method.

Lead glazing. Brick, tile or any other material is burnt nicely before lead glazing. The burnt material is then dipped in a solution of lead oxide in admixture with kaolin, felspar and flint. After that they are again burnt in potter's kiln. The particles of these different materials adhere to the surface of bricks or tiles when they are dipped in solution. When they are burnt in potter's kiln these particles melt and form a thin layer on the outer surface which is transparent. This method is used for wares of inferior clay which cannot withstand the high temperature required for salt glazing.

Leadless glazing. Borax can also be used as flux instead of lead oxide. Lead is absent in such type of glazing. Glazed surface is harder but lacks brilliance. This type of glazing is undesirable for chemical stoneware because its surface is damaged by acidic solution.

Opaque glazing. At first earthenware is burnt nicely. After that glaze is prepared. Glaze is prepared from borax, kaolin, calcium carbonate, cobalt oxide or some colouring pigment. Little amount of felspar or flint is mixed with these materials, and then heated. Water is thrown over the melted material. This process is known as *Fritting*. Due to fritting, soluble substance becomes insoluble and carbon dioxide is expelled out. After fritting, the material is powdered and again water is added to it. Amount of water should be such that it has a efficiency of cream. This thick substance is known as glaze. Burnt tile, brick or earthenware is dipped in the glaze. After burning, earthenware becomes porous and hence water of glaze goes into the pores of earthenware. After that they are again heated. Due to high temperature in kiln ; a thin layer is formed on the outer surface of material which is very hard. Opaque glazing gives a very good outer appearance.

Stonewares are not so porous and hence glaze is given in the form of dry dust. Sometimes stonewares are glazed by mixing 4% of gelatine with wet glaze.

I.S.I. specification for tiles. Table 1·8 shows salient features and I.S.I. specifications for various types of tiles.

Table 1·8

Type of Tile (1)	*Salient Features* (2)	*ISI code Reference* (3)
Hollow clay tiles for floors and roofs (Filler type)	These tiles act as light weight material for floor and roof construction. Because of their hollowness they impart sound and thermal insulation. Their standard dimensions are—	
	Length—340, 390, 440, 490, 540, 590, 640, 690, 740 mm.	IS : 3951 (part I)—1975
	Width—350, 300, 250 and 200 mm	
	Height—80, 90, 100, 110 mm.	
	Water absorption should be below 20%	
	Thickness of any shell shall not be less than 11 mm and that of the work not less than 8 per cent.	
2. Hollow tiles for floors and roofs (Structural type)	Burnt clay floor-roof tiles have been used both as filler material, and as structural work. CBRI, Roorkee has established that a large variety of clays occurring in the country can be successfully utilised in the manufacture of such tiles.	
	The standard dimensions of the tiles are—	
	Length—290 and 390 mm	
	Width—90 to 190 mm in stages of 50 mm.	
	Height—125 to 200 mm in stages of 25 mm.	
	Bulk density shall be between 0·9 to 1·2 gm/cm^3	IS : 3951 (Part II)—1975
	Average compressive strength 200 kg/cm^2. Water absorption shall not exceed 100%.	
3. Burnt clay flat terracing tiles (Machine made)	Burnt clay flat terracing tiles, which may be machine pressed or hand made, are used for flat roof finishing over lime concrete or cement concrete base, and depending upon the degree of protection necessary, they are used in two or more courses.	
	The dimensions or terracing tiles are—	
	Length—250 to 150 mm in steps of 25 mm	IS : 2690 (Part I)—1975
	Width—200 to 100 mm in steps of 25 mm. Thickness—15, 20 and 25 mm.	
4. Burnt clay flat terracing tiles (Hand made)	The terracing tile is made from good soil of even texture.	
	The tiles should be uniform in size and free from irregularities. Water absorption $\not> 20\%$ and compressive strength $\not< 75$ kg/cm^2	IS : 2690 (Part II)—1975

(1)	(2)	(3)
5. Clay ridge and ceiling tiles	Clay ridge and ceiling tiles were originally manufactured in Mangalore, but are now being produced on a large scale in Malabar, Madras, Calicut and other places. Dimensions of these tiles are— (*a*) Ridge tiles— Length—375, 400 and 435 mm Width—265 mm Height—100 mm Thickness $\nless$ 10 mm (*b*) Ceiling tiles— Length— $\nless$ 30 mm Thickness $\nless$ 10 mm. Classification— These tiles are classified as Class AA and class A. Their characteristics are— AA A (*i*) Water absorption max. 19 24	IS : 1464—1973
	(*ii*) Breaking strength, kg (min.) Average 1·50 1·10 Individual 1·25 0·95	
6. Structural hollow clay floor tiles	Burnt clay hollow tiles have been used for structural floor and roof construction in certain parts of the country. These are generally to be supported on closely spaced joists to form the structural floor and upon which may be laid concrete or any other type of floor finish. These tiles provide light weight material for roof construction and because of their hollowness impart sound and thermal insulation to the building. The standard dimensions of these tiles are— Length—30, 45, 60 cm	IS : 3951—1967
	Width—24 or 19 cm Height—7 or 9 cm Web thickness $\nless$ 8 mm Thickness of shell $\nless$ 11 mm Crushing strength $\nless$ 175 kg/cm² Water absorption $\ngtr$ 20%	

(1)	(2)	(3)
7. Polystyrene wall tiles	Polystyrene wall tiles have found application in some of overseas countries and their great potential as an important building product has also begun to be appreciated in this country. They are useful for use in interior surfaces as walls, partition and ceilings of residential and office buildings. It is the lightest of commercially available rigid plastics.	
	Polystyrene wall tiles are manufactured in two sizes 99 × 99 mm and 148·5 × 148·5 mm Water absorption $\not>$ 19%	IS : 3463—1966
8. PVC(Viny) Asbestos floor tiles	PVC (Viny[1]) floor tiles have been found useful in covering floors in residential and office buildings. These floor tiles not only give a non-absorbent and sanitary surface. The tiles are 200 mm square having thickness of 1·5, 2·0, 2·5 and 3·0 mm	IS : 3461—1966
9. Ceramic unglazed vitreous acid resistance tiles	The tiles are being used in floors and tank linkings to prevent corrosion of the surface by acids and other chemicals—	
	These tiles are made in three sizes 98·5 × 98·5 mm, 148·5 × 148·5 mm and 198·5 × 198·5 mm. They are available in thicknes of 35, 30, 25, 20 and 15 mm. Water absorption < 2% Compressive strength 700 kg/cm^2	IS : 4457—1967
10. Glazed earthenware tiles	These tiles are used in finishing floors and walls of kitchens, bathrooms, water closets, hospitals etc. where cleanliness is an important criterion.	IS : 777—1970
	These tiles are made in two sizes 149 × 49 mm and 99 × 99 mm. They are available in thickness of 5, 6 and 7 mm. Water absorption $\not>$ 18%	

Testing of tiles. Standard tests applicable to, and standardized for the various tiles specified in table 1·8 are given in table 1·9.

Table 1·9. Tests of tiles

Types of tile (1)	*Standard Tests* (2)	*ISI Code Reference* (3)
1. Hollow clay tiles for floors and roofs (filler type)	(1) Determination of breaking strength. The tiles are simply supported without any mortar at the supports are at the centre of exreme shell webs. A load of 10 kgf/cm length is applied on a 20 mm wide steel plate kept centrally over the entire length of the tile and parallel to the supports. The breaking load should not be less than 10 kgf/cm length. (2) Water absorption test—The test specimen is dried to constant mass in a ventilated oven at 110° to 115°C. The specimen is then cooled to room temperature and weighed. The dry specimens are immersed in water at 27±2°C for 24 hours. The specimen is then removed and the surface water wiped off and specimen weighed. The percentage of water absorption by mass is given by $\frac{W_2 - W_1}{W_1} \times 100$ where, W_2=Mass after soaking in water W_1=Mass of dry specimen. Water absorption shall not exceed 20%.	IS : 3951 (Part I)—1975
2. Hollow tiles for floors and roofs (structural type)	(1) Determination of compressive strength—When the mortar strength has attained the desired value of the specimen it is crushed between two 3 ply wood sheets approximately 3 mm thick. The load is applied axially at a rate of 150 kg/cm² of base area per minute till complete failure. The average compressive strength of tiles shall not be less than 200 kg/cm² on the net area with a minimum value of 150 kg/cm². (2) Water absorption—Same as for 1 filler type. The water absorption shall not exceed 10 per cent.	IS : 3951 (Part II)—1975
3. Burnt clay flat terracing files (machine made)	(1) Water absorption—Same for filler type. The water absorption shall not exceed 15 per cent. (2) Flexural Strength—The tile is supported flat-wise on the bearers set, with a span equal to three-fourths the dimension of the tile and resting on the natural bottom surface. The load is applied perpendicular to the span at a uniform rate of 45 to 55 kg/minute. The flexural strength= $\frac{150\,Ws}{bt^2}$ kg/cm² where, W=Breaking load in kg s=Span in metres b=Width of tile in cm t=Thickness of tile in mm.	IS : 2690 (Part I)—1975

(1)	(2)	(3)
4. Burnt clay flat terracing tiles (hand made)	(1) Water absorption—Same as for 1 filler type. Water absorption by weight shall not exceed 20 per cent.	
	(2) Compressive strength—Same as for 2. Compressive strength shall not be less than 75 kg/cm^2	IS : 2690 (Part II)—1975
5. Clay ridge and ceiling tiles	(1) Water absorption. Same as for 1. Water absorption for class AA ≯19 Water absorption for class B ≯24	
	(2) Breaking strength—Same as for 1. Breaking strength for : Ridge tiles (average) Class AA Class B ≮1·50 ≮1·10	IS : 1464—
(Individual)	≮1·25 ≮0·95	1973
6. Structural hollow clay floor tiles	(1) Crushing Strength test—When the mortar strength has attained the required value of not less than 280 kg/cm^2 and not more than 420 kg/cm^2 the specimen is crushed between three ply wood sheets approximately 3 mm thick. The load is applied axially at a uniform rate. The average crushing strength shall not be less than 175 kg/cm.	IS : 3951–1967
	(2) Water absorption test—Same as in 1. The water absorption by weight shall not exceed 20%	
7. Polystyrene wall tiles	The polystyrene wall tiles are subjected to type tests—Acceptance and routine test as specified.	IS : 3465—1966
8. PVC (Vnyl) asbestos floor tiles	Same as for 4.	IS : 3461—1960
9. Ceramic unglazed vitreous acid resistant tiles	(1) Compressive strength test—Same as for 2. Compressive strength be 700 kg/cm^2	IS : 4457—1967
	(2) Water absorption test—Same as for 1. Water absorption shall not exceed 20%.	
10. Glazed Earth wave tiles	(1) Water absorption test—Same as for 1. The average water absorption shall not exceed 18 per cent.	IS : 777—1970
	(2) Glazing test—Whole dry tiles are subjected to this test. Tiles which have been used for water absorption test are not used for this test. The tiles are placed loosely in an autoclave of sufficient capacity and fitted with blow off valve. The blow off valve is kept open till stream begins to escape and expels most of the air. The blow off valve is closed and pressure of steam is increased to 7·5 kg/cm^2 within 11 hours. The source of heat is stopped and steam pressure	

(1)	(3)	(3)
	released slowly in not less than 30 minutes by opcning the blow of valve. The tiles are allowed to cool to room temperature in the autoclave. They are then removed and tested for crazing by blue black fountain pen ink to the glazed surface.	

After undergoing two cycles of test, the tiles shall not show any sign of crazing.

(3) Impact strength test—Two types of apparatus, namely, the pendulum type and falling weight type of prescribed for the determination of impact strength value of the tile

(*a*) Using pendulum apparatus—The tile is supported against three equally spaced steel pins in such a way that the pins are equdistant from the centre of the tile. The surface of the tile just touches the hammer at the position of rest and the hammer always strikes the tile at the centre. The tile is subjected to a series of impact of increasing energy until finally failure occurs. The impact strength is calculated from the formula

$$I=\frac{E}{T},$$

where I=Impact strength in kgf m/cm

E=Energy in kgf m and

T=Thickness in cm.

(*b*) Using falling weight type apparatus—The tile test piece is supported on a fixed steel ring (inside diameter 6·0 cm) and three equidistant projecting pins forming an equilateral triangle having one side as 6 cm. A hard steel ball weighing 30 gm and about 2 cm diameter supported inside a mild steel tube (inside diameter 2·5 cm) is allowed to fall from an initial height of 25 cm measured from the top surface of the tile under rest. The height of fall of the ball inside the tube is subsequently increased by 5 cm till a slight change in the ring of the tile is detected as the ball falls on it. The increment in height is then kept 1 cm till finally the tile breaks into pieces.

The impact strength of the specimen is given by $I=\frac{E}{T}$,

where I=Impact strength in kg fm/cm.

E=Energy in kfgm

=Weight of the ball in kg × Height of free fall in metres

T=Thickness of tile in cm.

(1)	(2)	(3)
	(4) Chemical resistance test—The surface of 5 test specimens is thoroughly cleaned. The glazed surface of each is partially immersed in 3 per cent hydrochlorine acid solution for 7 days (30 ml concentrated HCl of sp. gr. 1·18 made upto 1 litre). The specimen are then immersed and examined for any visible change. Take another set of 5 tile specimen and partially immerse the glazed surface in 3 per cent potassium hydroxide (made upto 1 litre) for 7 days. Remove the specimen and examine the glazed surface for any visible modifications.	
	The glazed surface of tile/tiles having a white or cream coloured glossy glaze show no deterioration.	

1·15. Terra cotta. Terra cotta is made from refractory clay. The clay that is used for manufacture of terra cotta must be superior to the fire clay used for brick. The fire clay should contain 5 to 8% of iron oxide and one per cent lime. Sand or any carbonaceous material should not be present in clay.

Sometimes ground glass, pottery or old terra cotta is mixed with fire clay to prevent shrinkage of clay. All these things are ground nicely. The ground material is then sent into large water tanks. After straining they are pugged and kneaded nicely. Mixing is done exactly in the same way as for fireclay brick. The mixed material is left for many days after covering it with wet cloth so that *tempering* takes place. During tempering some chemical changes also take place due to which it becomes more durable.

Moulding of terra cotta is done in a mould made of plaster of Paris. The size of mould should be 5 to 12% greater in all directions as compared to terra cotta so that after shrinkage desired size is obtained. The cost of mould itself is very high which increase the case of manufacture of terra cotta. Some sand is sprinkled in the interior portion of the mould before moulding. After that lump of mixed soil is pressed into the mould. After moulding it is allowed to dry in a closed room so that temperature can be regulated.

Terra cotta is burnt in kiln after drying. If glazing is to be done ; then the glazed material is spread over terra cotta by brush. In case of salt glazing this is not necessary. Burning is done in the ordinary way. Coal, gas or oil can be used as fuel. Terra cotta is burnt at a temperature of 1100° to 1200°C. It takes about four days in burning terra cotta fully. Cooling takes about five days. The colour of natural terra cotta is grey but colour of glazed terra cotta is different.

Terra cotta is used in the ornamental portion of building (such as cornice) instead of stone. It is used for facing and arches also.

It is quite strong, light and hard. Beside this terra cotta is cheaper than stone. Sometimes there is a danger warping of terra cotta while burning. Necessary precautions must be taken against this.

Porous terra cotta is made by mixing saw dust in clay. Saw dust gets burnt in the kiln leaving terra cotta porous. Such terra cotta is fire proof. It can be sawn, punched and bored.

Faience. Faience is also similar to terra cotta but it is burnt twice in kiln. Firstly it is burnt in the same way as terra cotta. This stage is known as *Biscuiting*. After that it is taken out from kiln and allowed to cool. Later on glaze is applied to it and is again burnt. This is used in industrial areas because faience is not affected by atmospheric condition.

Stone ware. Stone wares are used in chemical engineering, sewer pipes and basin etc. It is impervious to water and is not affected by chemicals. Rough quality stoneware is made from soil which contains 76% silica and 24% alumina. Salt glazing is also done while firing. Chemical stoneware is made from such soil which contains 30 to 60% Silica, 5 to 25% felspar and 30 to 70% clay.

Stoneware pipes are made such soil which contains more of silica. Ground flint or sand can be used as silica. Due to high percentage of silica, pipes do not shrink after burning. At first the material is ground to powder and water is added to it. After mixing it thoroughly moulding is done. Pipe is kept in vertical direction after moulding so that it dries. Pipes are burnt in kiln after drying. Pipes are placed in kiln in such a way so that spigot end of pipe is in downwards side. Spigot end is least affected at the time of salt glazing due to this and hence spigot end continues to remain rough. This makes the cement joint more perfect. Salt glazing is done exactly in the same manner as described earlier. Salt glazed pipes are not affected by acid and is also impervious to water. Length of these pipes are 60 cm and diameter varies from 7·5 to 60 cm. Joints in pipes (one way, two way) are also made in the same way.

Porcelain. Porcelain are of many types. Mainly it is made from kaolin. It is burnt at such high temperature that it melts and is glazed. It is translucent. Some flux is added with kaolin. Bone ash, felspar etc. are used as flux. Porcelain is mainly used in electrical industry. Porcelain for electrical industry is made from such soil which contains 20 to 28% felspar, 15 to 80% ordinary clay, 20 to 35% china clay and 15 to 25% flint. These materials are vitrified at a temperature of 1320°C.

Chemical Porcelain. Chemical porcelain has the capacity to resist bad effects of chemicals. This porcelain is made from such soil which contains 20 to 25% felspar, 0 to 1% whiting, 0 to 5% ordinary clay, 50 to 58% china clay and 10 to 15% flint. The porcelain can withstand high temperature and is strong. Its weight is same before and after heating. Several types of vessels, containers etc. for chemical industries are made from this type of porcelain.

Steatitic Porcelain. This porcelain is used as insulator. This also used for high tension cables. This is made from such soil which contains 70 to 90% talc, 0 to 10% Kaolin and 0 to 10% barium carbonate.

Zircon Porcelain. Zircon porcelain is used for spark plug. The porcelain contains 45 to 60% Zircon, 15 to 30% ordinary clay and 15 to 30% alkaline Zirconium silicate.

Kilometre stone and Mile stone. A sign is fixed after each kilometre on the road which is known as kilometre stone. If the sign is fixed at each mile on the road then it is called mile stone. Distances and other informations are written on kilometre stone. Ordinary kilometre stone is fixed after each kilometre. Some portion of the stones remain buried into the ground and some portion is above. The height of kilometre stone above ground is 56 cm. Upper portion is semi-circular. Ordinary kilometre stone has been shown in Fig. 1·32. Route number is written at the top. After the name of next important place is written and the distance is written at bottom. For example in Fig. 1·32 it has been shown that route number is 3 ; next important place is Balia and its distance is 115 kilometre.

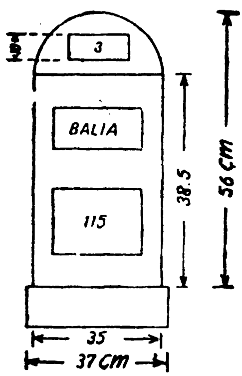


Fig. 1·32

Different type of kilometre stone is fixed after each five kilometre. Its height above the ground is 107·5 cm. It has been shown is Fig. 1·33. There are more informations in it. Route number (For example 3) is written at the top ; after that name of starting station (Gorakhpur) and then its distance is written. After that name of next important station and its distance is written. Different informations are written on different face of kilometre stone.

Kilometre stone is made from stone or cement concrete. The height of letters very from 13 to 8 cm. Longest letter is used for writing distance. The background of kilometre stone should be painted white and letters should be written in black colour. Top semi-circular portion should be painted in yellow colour. Kilometre stone is fixed at right angle to the centre line of the road. If a man walks from the starting station (from where distance is measured then all kilometre stones should be situated on the left side.

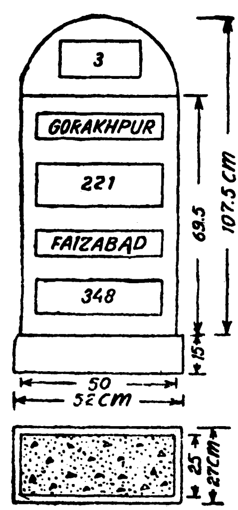


Fig. 1·33

QUESTIONS

1. Write down I.S.I. specification for the classification of bricks.

2. Write down the properties of a first class brick.

3. Sketch a Bull's Trench Kiln.

4. How good bricks can be manufactured from "Black Cotton Soil" ?

5. Differentiate between intermittent kiln and continuous kiln.

6. What are the common defects in a brick and hence they are detrimental to its use ?

7. What is terracota and what are its uses ?

8. What are the merits and demerits of clamp and kiln burning ?

9. How you will select the site for the manufacture of bricks ?

10. What are the constituents of earth for a good brick ? What constituents render earth unsuitable for brick work ?

11. Write down the analysis of soil to be used for manufacture of good quality brick.

12. Name the different stages of brick making.

13. Describe how table moulding is done.

14. What are the special properties of refractories ? Write about the different types of refractories which have important uses in engineering.

15. What are the test of good bricks ?

16. Give neat sketch of a pug mill and explain its working.

17. Differentiate between intermittent updraught kiln and intermittent downdraught iln.

18. What are the advantages of Hoffman's kiln ?

19. Discuss the uses of perforated brick. T-bricks and channel bricks.

20. Why soda lime brick is becoming popalar these days ? What are its advantages ?

21. What tests are performed for testing the qualities of a good brick ? Explain these fully.

22. Differentiate between Acid refractory brick, basic refractory brick and neutral refractory brick.

23. How tiles can be classified per I.S.I. ?

24. Name different types of tiles used for roofing purposes and state their special features.

25. What do you understand by "Glazing" ? How it is done and what are the advantages of glazing ?