Engineering Materials

5Th Revised Edition

Surendra Singh

ENGINEERING MATERIALS

SAAD
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By the Same Author :

STRENGTH OF MATERIALS

Engineering Materials

[For the Architecture and Civil Engineering Students preparing for Degree, Diploma and other Competitive Examinations]

(In MKS Units)

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To
Dear Neetu

PREFACE

Persistent demand of students and of my colleagues in teaching made me present this revised edition after it had, for reasons beyond my control, been out of print for some time. The primary objective of attempting this venture was to present the subject-matter to students of Architecture and Civil Engineering in an easy to understand style and at the same time providing basic knowledge about the materials needed in the field of constructions. The warm welcome that the text received from the students more than testified the fulfilment of the objective.

Course contents have been planned to meet the requirements of the degree and diploma students of Architecture and Civil Engineering. A few modern materials of use to Architects and Interior Decorators have been included. Information of use to practicing professionalists has been provided for. The text has been updated by incorporating the latest recommendations of the Indian Standards Institution, the National Buildings Organization and the Central Building Research Institute. Information supplied by reputed manufacturers regarding their products has been included.

The treatise should be of use not only to the academic fraternity but also to practicing professionalists engaged in building construction. Latest additions and alterations have certainly enhanced the utility of the text to students.

In spite of all efforts made to improve the treatise it is difficult to claim perfection. Suggestions for improvements shall be gratefully acknowledged.

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STONES

1.1 STONES

Stone is a natural material of construction and is obtained from quarries. Since prehist‹ric days it has been used for constructing different components of buildings like foundations, walls, lintels, floors, roofs etc. It has also been used for constructing bridges, weirs, dams etc. *Stones that are used for construction of structures are known as* **building stones.**

Most of the ancient temples and forts of India were built with stones. The Taj and the Victoria Memorial (Calcutta) were built in white marble had from Rajasthan. Red Fort and Jama Masjid (Delhi) were built with red sand stone from Agra. Parliament House, Rashtrapati Bhawan and the Central Secretariat (Delhi) were built with red and grey sand stones from Rajasthan.

Stones are gradually losing their universal use as a building material because of the following reasons:

(*i*) Important buildings these days are being constructed of steel or RCC, because of their being less bulky, stronger and more durable.

(*ii*) Strength of structures made of stones cannot be so rationally analysed as of those made with steel and RCC.

(*iii*) Suitable, durable and more easily workable alternative materials are now available.

(*iv*) Cast stone, sand faced rusticated bricks, furnace ware etc., can be given architectural treatment more easily and have therefore overshadowed the use of stones.

(*v*) Stones are not cheaply and conveniently available in the plains.

(*vi*) *Dressing of stones is time-consuming and results in slow pace of construction.

*Bringing the stone to required shape and size.

1.1.1. **Uses.** Stones are extensively used for the following:

(*i*) As stone ballast (*broken stone*) for railway track; for road construction; for preparing cement concrete required for foundations, flooring, hollow and solid blocks, artificial stones and reinforced cement concrete.

(*ii*) As crushed stone (*stone dust*) is used as a substitute for sand.

(*iii*) As blocks in the construction of buildings; lintels; arches; walls; columns; abutments and piers of bridges; in weirs and in dams etc., etc.

(*iv*) As blocks and slabs for face work of buildings requiring architectural treatment.

(*v*) As thin slabs for roofing and for flooring buildings and pavements.

(*vi*) As lime stone, it is used in the manufacture of lime, cement and in various other chemical processes.

(*vii*) Thin slabs of impervious stones are used for laying Damp-proof Courses in buildings.

1.2 CLASSIFICATIONS

Stones are obtained from rocks. A rock forms portion of earth's crust having no definite shape or chemical composition. It is usually a mixture of two or more minerals and is not homogeneous.

Rocks from which stones can be had for building purposes are classified in the following three different ways:

(*i*) **Geologically** (depending upon how the rock was originally formed).

(*ii*) **Physically** (depending upon what its structure is).

(*iii*) **Chemically** (depending upon its chemical composition).

1.2.1. **Geological classification.** Geologists classify rocks into three main categories:

(*i*) *Igneous, primary, unstratified or eruptive rocks.* Inner layers of earth are at such high temperatures that masses of silicates melt. This molten mass, known as *magma*, is forced up. Magma solidifies into rocks when it reaches the surface of earth and forms *Basalts* and *Traps* If, however the magma solidifies before reaching the surface of earth it forms solid crystalline rock known as *Granite*.

(*ii*) *Sedimentary, aqueous or stratified rocks.* Surface of earth is subjected to the destructive action of rain; frost, winds and chemical actions. These destructive agents break up the surface of earth which gets further broken up when carried down by rains and rivers. In the journey of river from mountains to sea the velocity goes on decreasing as the river moves further. As the velocity of river decreases so it goes on depositing the debris carried by it. The heavier ones being the first to be deposited followed by the deposit of smaller and finer ones. Sand and silt get deposited in the voids of deposited debris—the latter having the binding properties (Fig 1.1). Due to seasonal variations the materials are deposited in layers. The deposit in layers continues for millions of years in which period the deposited layers subjected to enormous pressure of overlying layers and of flowing water get consolidated forming stratified, sedimentary or aqueous rocks. *Sand stones* and *lime stones* belong to this class.

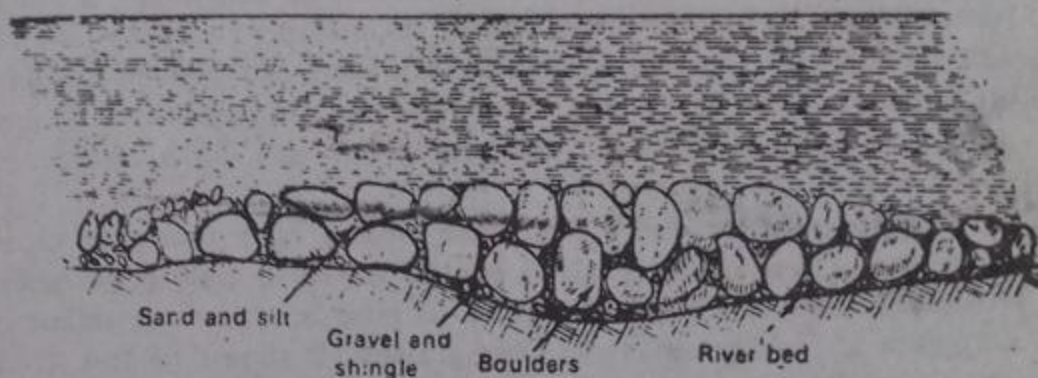


Fig. 1.1

(*iii*) *Metamorphic rocks*. Due to structural changes in earth igneous or sedimentary rocks find their way deep in earth where they are subject to high temperature and heavy pressure which cause changes in texture or in mineral composition or in both resulting in the formation of new types of rocks known as *metamorphic rocks*. Following are some of the changes to "metamorphic rocks" : (*i*) Granite (igneous) changes to Gneiss, (*ii*) Sand stone (sedimentary) changes to Quartzite, (*iii*) Lime stone (sedimentary) changes to Marble, and (*iv*) Shale (sedimentary) changes to Slate.

1.2 2. Physical classification of rocks. Physically rocks are classified as (*i*) *Stratified rocks* showing distinct layers along which it can be easily split into thin slabs e.g., Slate, Sand stone and Lime stone, (*ii*) *Unstratified rocks* which show no sign of stratification and cannot be easily split into thin layers e.g., Granite, Basalt and Trap.

All sedimentary rocks are essentially stratified whereas all igneous rocks are unstratified. Metamorphic rocks may be either stratified or unstratified depending upon the type of rock that has undergone transformation.

1.2.3. Chemical classification of rocks. Chemically rocks are classified on the basis of *Chief Constituent Mineral* as: (*i*) *Agrillaceous*, where the principal constituent is clay (alumina Al_2O_3) as in Slate and Laterite; (*ii*) *Silicious*, where the chief constituent is Sand (Silica SiO_2) as in Quartzite and Granite, and (*iii*) *Calcareous*, where the chief constituent is Lime as in lime stone and marble stone.

1.3 CHARACTERISTICS OF GOOD BUILDING STONES

A good building stone should essentially have the following qualities:

(*i*) *Appearance*. For the face work of buildings this property is of extreme importance. From architectural point of view colour of the stone should be such as to go well with the surroundings. Lighter shades should be preferred to the darker ones as the latter are less durable. Red and the brown shades of sedimentary rocks are due to the presence of oxide of iron—which, if present in excess, is liable to disfigure the stone with rust stains and to disintegrate it. Stones should be of uniform colour and free from clay holes, bands or spots of colour whatsoever.

(*ii*) *General structure*. Stone, when broken in a direction other than that of cleavage (if it exists), should not give dull appearance. It should show uniformity of texture. It must be either crystalline in structure of homogeneous and close-grained. It should be free from cavities, cracks or patches of soft or loose material. For ornamental carvings it should be fine grained. Stratification (found in sedimentary rocks) should not be visible to naked eye except by difference in colour. These can be easily split along their planes of stratification known as *planes of cleavage*, and are, therefore, useful for use in pavings, floorings and roofings etc.

(*iii*) *Heaviness*. Heavier varieties of stones are more compact, less porous and have greater specific gravities. For constructions in water, like weirs, barrages, dams, docks, harbours and for retaining walls the heavier varieties of stones are to be preferred. For construction of domes and for roof coverings and similar other usages the lighter varieties have to be used.

(*iv*) *Strength*. In usual constructions the stones used are generally quite strong to withstand the forces likely to be encountered yet in case of construction where unusually bigger forces are likely to come the stone to be used should be tested for its strength. Stones of igneous class are generally stronger than those of the sedimentary class. Stones with compact fine crystalline texture are stronger.

(*v*) *Hardness*. It is the resistance of stone to abrasive forces caused by much wear and friction as in floors, pavements and aprons of bridges and weirs in rivers. Stones to be used at such places should be hard.

(*vi*) *Toughness*. It is a measure of the impact that a stone can withstand. Stones used at places subject to vibrations of machinery and to moving loads should be tough. Stones used in the construction of roads should be hard and tough.

(*vii*) *Ease of working*. The ease with which the stone can be worked upon *i.e.*, cut, dressed, carved and moulded etc., is an important consideration from economy point of view. But this property is opposed to strength, durability and hardness.

(*viii*) *Porosity and absorption*. More porous building stones are unsuitable for use in construction especially for exposed surfaces of structures. Rain water while coming down carries some acidic gases forming light acids which lodge on the surface of stones and soak in them. Very often it is driven in the pores of stones by the prevailing winds. Acids react with the constituents of stones causing them to crumble. In cold regions water freezes in the pores of stones. This water causes the disintegration of stones because of its increase in volume on freezing.

Stones should as such be tested for porosity and care should be taken to use more porous stones only at places where they are not likely to encounter frost, rain or moisture in any other form.

(*ix*) *Seasoning*. All freshly quarried stones contain a certain amount of moisture known as *quarry sap*, which makes them soft and easier to work upon. As such all work such as dressing, carving and moulding etc., should be done as early after quarrying as possible. Stones become considerably harder on seasoning. After quarrying, when all the work has been done upon stones, they should be left to season under sheds having no walls so as to permit free circulation of air. Sheds protect them from rains. A period of 6-12 months is generally enough for proper seasoning. *Dressed faces should not be disturbed after seasoning* as the crystalline film left by the quarry sap on evaporation weathers much better than the actual face of stone left after removal of that film.

(*x*) *Weathering*. It is the extent to which the face of a stone resists the action of weather. The best way of knowing the weathering properties of a particular stone is to inspect ancient buildings made with the same quality of stone possibly in the nearby place or at a place having similar atmospheric conditions. Inspection of an old face of some quarry could also be informative. If sharp edges and corners are preserved on an old building particularly on the faces exposed to rains and prevailing winds and on which sunlight does not play and if the chisel marks on such faces are distinctly visible then that variety of stone has good weathering qualities. Stones with good weathering properties only should be used in the construction of important buildings.

(*xi*) *Resistance to fire.* To be fire-resistant stones should be free from calcium carbonate and oxide of iron and be not composed of minerals with differing co-efficients of thermal expansion.

1.4 TESTS OF STONES

To know the suitability of building stones for meeting the specific requirements of different Engineering works the following few tests may be performed. The tests listed below meet the requirements of various relevant Indian Standard Codes.

For subjecting a particular grade of stones to a specific test a truely representative sample of the grade of stones is to be taken. To satisfy IS requirements a sample shall be selected from quarried stone or from natural rock. In case of quarries the face of stone shall be inspected to observe difference in colour and structure of various strata. Separate samples, weighing at least 25 kg each shall be collected from all the differing stratas. Test pieces for toughness or compressive strength tests shall be not smaller than $10.0 \times 12.5 \times 7.5$ cm in size and shall be free from seams or fractures. Pieces damaged by blasting shall be excluded. In case of field stones and boulders separate samples shall be selected of all classes of stones based on visual inspection.

1.4.1. Test for weathering of natural building stones. The test pieces shall be representative of the true average of the type and grade of the stone under consideration and shall be either cylinders, 5 cm in diameter and 5 cm high or 5 cm cubes. These test pieces shall be finished smooth and the edges shall be rounded to a radius of approximately 0.3 cm by grinding. Three such test pieces shall be dried in a well ventilated oven for 24 hours at 105 ± 5°C and cooled in a desiccator to room temperature of 20 to 30°C.

Let the weight of a cooled and dried test piece weighed to the nearest 0.01 gram be W_1. Let W_2 be the weight of the specimen while totally immersed and freely suspended in water after it has been kept under water at 20 to 30°C for 24 hours. Let W_3 be the weight of the specimen after it has been removed from water and its surface wiped with damp cloth (the weighing is completed within three minutes of its removal from water).

Each specimen is now placed in a flat dish of glass or porcelain or stone ware. In the dishes is placed a solution of 25 ml of water and 2 gm of powdered gypsum. The dishes containing the specimen are kept in a well ventilated oven at 105 ± 2°C for at least five hours or till the water has evaporated. The dishes are now removed from the oven and cooled to 25±5°C to complete the first cycle. The cycle is now repeated 29 times more except that only 25 ml water is now added to each dish for each subsequent cycle.

When 30 cycles are completed, the specimen are cleaned by brushing with a stiff wire brush to remove any particles of gypsum adhering to the surface. Each specimen is kept under water for 24 hours, taken out, surface dried and weighed, first in air(W_4) and then immersed in water and freely suspended (W_5).

The increase in absorption and in volume of each specimen after 30 cycles of the test shall be calculated as follows:

$$A_1 = \frac{W_3 - W_1}{W_1} \times 100$$

$$V_1 = \frac{W_3 - W_2}{d}$$

$$A_2 = \frac{W_4 - W_1}{W_1} \times 100$$

$$V_2 = \frac{W_4 - W_5}{d}$$

Where A_1 = Original absorption of the specimen on 24 hours immersion in water, expressed as percentage.

A_2 = Final absorption of the specimen after 30 cycles of the test expressed as perçentage by weight.

V_1 = Original volume of the specimen after 24 hours immersion in water.

V_2 = Final volume of the specimen after 30 cycles of the test.

d = Density of water at the temperature of observation.

For details refer to IS 1125–1974.

1.4.2. Test for durability of natural building stones. At least three test pieces, each 50 mm cubes or 50 mm dia cylinders of 50 mm height shall be dried for 24 hours and weighed (W_1).

The test pieces are then suspended in a saturated solution of sodium sulphate decahydrate for 18 hours at room temperature 20 to 30°C. These are then air dried for 30 minutes and then left to dry for four hours in an oven at 105±5°C. These are then cooled to room temperature (20 to 30°C) to complete one cycle.

The cycle is repeated to complete 30 turns. Test pieces are weighed after every fifth cycle to know the change in weight due to disintegration. The test pieces shall be weighed after they are thoroughly freed of the sodium sulphate solution by repeated washing. Weight W_2 at the end of 30 cycles is noted.

$$\text{Change in weight is} = \frac{W_1 - W_2}{W_1} \times 100$$

Average for all the three test pieces is taken as durability value of the specimen.

The above analysis is based on IS 1126—1974.

1.4.3. Test for water absorption and porosity. Test pieces shall be crushed and the material passing through 20 mm IS sieve shall be washed to remove dust particles and about 1 kg shall be immersed in distilled water in a glass vessel at room temperature of 20 to 30°C for 24 hours. At the beginning and the end of the soaking period entrapped air shall be removed by quick rotational motions in clockwise and anti-clockwise direction. The test pieces are then taken out of the water, placed on a dry cloth and gently surface dried with the cloth till the cloth removes no further moisture. The test pieces are then spread one stone deep on another cloth and left exposed to atmosphere in a shade for ten minutes by when they appear completely surface dry. Weight of the sample (W_1) is then recorded.

The sample is then put in a 1000 ml capacity glass measuring cylinder and distilled water added to it by 100 ml capacity measuring cylinder. Care is taken to remove the entrapped air. Water is added to the cylinder containing the sample till it reaches 1000 ml mark. The quantity of water added is thus recorded in ml or in gram weight (W_2).

The sample is then taken out of the cylinder and dried in an oven at 100 to 110°C for at least 24 hours, then cooled in a desiccator to room temperature and the weight (W_3) recorded.

$$\text{Water absorption} = \frac{W_1 - W_3}{W_3} \times 100$$

$$\text{Apparent porosity} = \frac{W_1 - W_3}{1000 - W_2} \times 100$$

$$\text{Apparent specific gravity} = \frac{W_3}{1000 - W_2}$$

All weights of samples are in grams and the results are the average of tests on three samples.

The above tests are based on IS 1124—1974.

1.4.4. Test for determination of true specific gravity. Crush 0.5 kg of thoroughly washed specimen to 3 mm size particles, thoroughly mix and make samples of 50 gram each. Each sample is ground in an agate mortar to such fineness that it passes 150 micron IS sieve. All magnetic materials introduced in crushing or grinding are removed with the help of magnets.

The sample is dried at 105 to 110°C, cooled in a desiccator and weighed in a weighing bottle. The specific gravity bottle is cleaned, washed and dried to constant weight at 105 to 110°C, cooled in a desiccator and weighed (W_1) in an analytical balance.

About 15 gm of crushed stone from the weighing bottle is placed in the specific gravity bottle and the bottle closed with stopper and weighed (W_2). The specific gravity bottle is now filled to about three fourth of its capacity with distilled water. The bottle is boiled for ten minutes and gently rolled on sides to remove the entrapped air. The bottle is then cooled to room temperature, filled with distilled water and stoppered to weigh (W_3) after cleaning its outside dry. The bottle is then emptied, washed, filled with distilled water, stoppered and weighed (W_4) at room temperature. If the room temperature is t°C then:

$$\text{True specific gravity at } t^\circ\text{C} = \frac{W_2 - W_1}{(W_4 - W_2) - (W_3 - W_2)}$$

Average of results obtained from three different samples is taken as the result. The test is based on IS 1122-1974.

Note: True porosity $= \dfrac{\textit{True specific gravity} - \textit{Apparent specific gravity}}{\textit{True specific gravity}}$

1.4.5. Tests for compressive strength. Test pieces made out of samples shall be in the form of cubes or cylinders whose height shall be equal to the lateral dimension which shall not be less than 50 mm. The load bearing surface shall be finished to as nearly true, parallel and perpendicular planes as possible by using mechanical devices. The dimensions of the faces loaded shall be measured to the nearest 0.2 mm.

The test pieces shall be kept immersed in water at 20 to 30°C for 72 hours and thereafter tested in saturated condition. The test pieces shall also be dried in an oven at 105±5°C for 24 hours and cooled in a desiccator to room temperature of 20 to 30°C and tested dry.

In applying the test the load shall be gradually increased @ 140 kg/cm² per minute until the resistance of the test piece breaks down. The maximum load applied to the test piece divided by the area of the bearing face of the specimen is taken as the compressive strength of the specimen.

The test is based on IS 1121-1974.

1.5 QUARRYING

The art of taking stones of various sizes from natural rocks is known as *quarrying*. Open part of the natural rock from which useful material is obtained is known as *quarry*. Purpose of quarrying is to obtain stones for masonry, for ballast in concrete, road nstruction, on railway track or for any other purpose. Depending upon the nature and structure of rocks and the purpose for which stones are needed, quarying is done by one of the following four methods in common use.

(*i*) Excavating, (*ii*) Wedging, (*iii*) Heating (*iv*) Blasting.

1.5.1. Quarry and its location. In locating a quarry the points that should be kept in view are:

(1) The required building stone should be available in sufficient quantities at or near the surface of the ground.

(2) Sufficient labour at cheap rates should be locally available.

(3) Ample means of communications should be available.

(4) Power should be cheaply available.

(5) Sufficient quantities of clean water should be available all the year round.

(6) Drainage of rain water should present no problem.

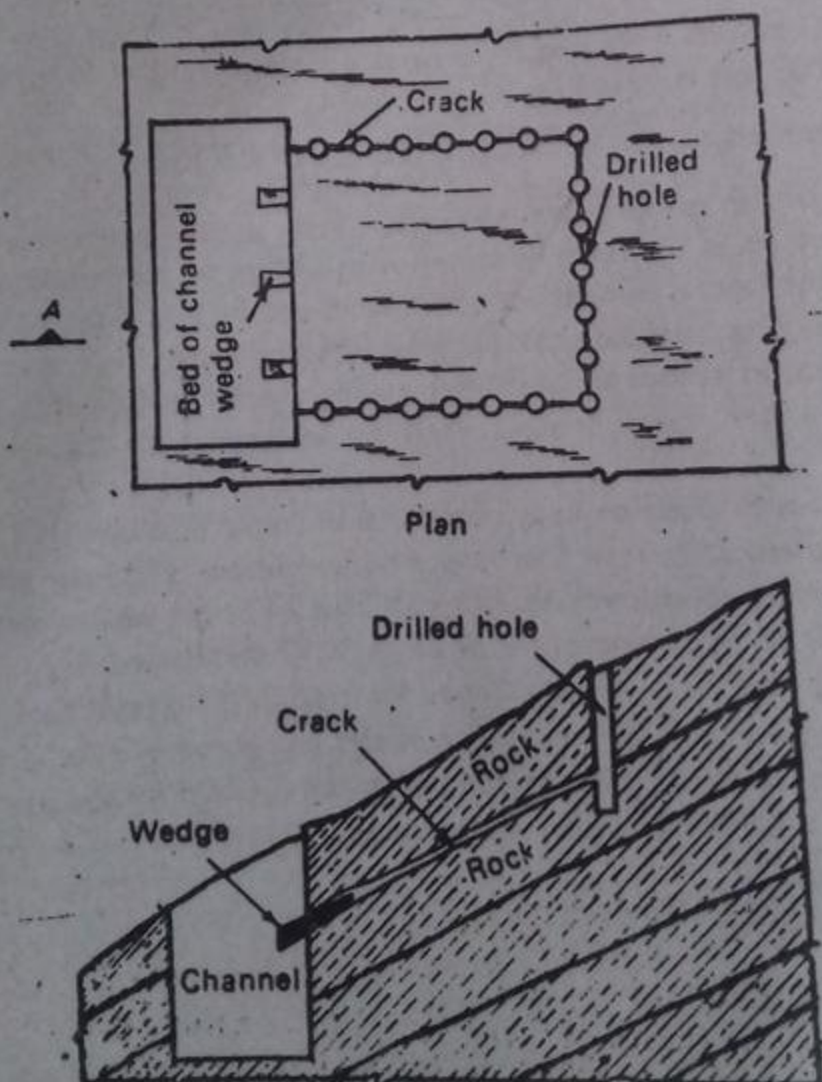


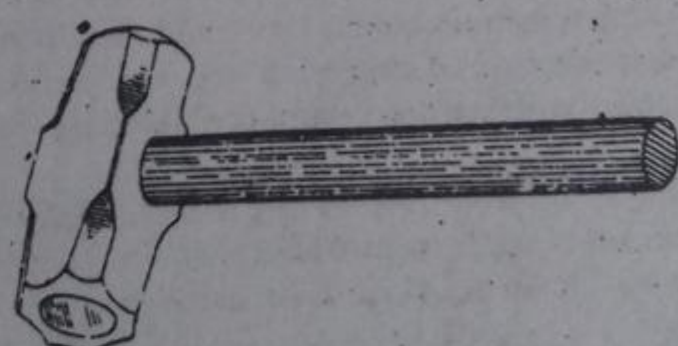
Fig. 1.2

(7) Site for the dumping of refuge should be easily available nearby.

(8) There should be no permanent structures nearby in the case of quarrying by *Blasting*.

1.5.2 Excavating. The method is employed when stones to be quarried are lying buried in earth or under loose over-burden. Showels, pick axes, hammers and chisels etc., are made use of for the purpose. On west coast laterite stone blocks are quarried by this method.

1.5.3. Wedging. This method is suitable for quarrying soft stratified rocks. The operation is started near a vertical face in the absence of which one is created by cutting a channel in it (Fig. 1.2). Then 10 cm to 15 cm deep holes about 10 cms apart are bored or drilled along the boundary of the slab to be quarried. Steel plugs are then struck with heavy steel hammers called *sledge hammers* (Fig 1.3) simultaneously in all the holes in a row. Use of steel feathers with plugs is to be preferred (Fig. 1.4). It will split the slab along the line of holes drilled. In case of softer rocks same result could be achieved by hammering in tightly dry wooden pegs in a row of holes and then pouring water over them so that they expand on becoming wet thereby exerting forces enough to cause a crack along the line of holes. This operation when repeated all along the periphery would detach the slab. Sledge hammer blows on wedges placed at the joint of two layers (known as *plane of cleavage*) on the exposed face of rock shall detach the slab completely. It could then be taken away on trolly or rollers. By this method slabs of required sizes could be quarried with minimum of wastage. The method is suitable for quarrying costly stratified rocks.



Sledge hammer

Fig. 1.3

1.5.4. Heating. This method is suitable where only smaller blocks of more or less regular shape are required and suitable rocks bedded in horizontal layers of not much thickness are to be quarried.

It consists in piling a heap of fuel on a small area of the exposed. face of rock and burning a steady fire for some hours. It results in uneven expansion because of unequal heating of the two layers and consequent separation of the upper and lower layers. The separation is indicated by a dull bursting sound. Separated area can be ascertained by noting the hollow sound on striking the area gently with a hammer or with a crowbar.

In Soviet Union, quarrying has successfully been done by heating intermediate layers electrically which results in the separation of that layer from the top and bottom layers. This way not only is the work done quickly but also it becomes more economical.

The loosened portion is then broken into smaller pieces as desired and removed with pick axes and crowbars. Fairly rectangular blocks required for *coursed rubble masonry* could be had by experienced workmen. Small sized stones to give road metal and ballast for railway track could, however, be not conveniently had by this method.

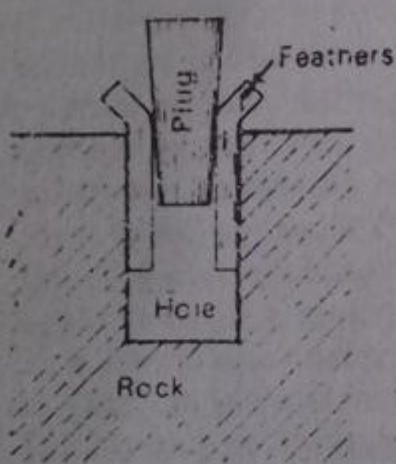


Fig. 1.4

1.5.5. Blasting. It is quarrying stones with explosives. Blasting may sometimes have to be done to excavate foundations for buildings, road structures in rock work and for tunnelling etc. The purpose of blasting for quarrying is to loosen large masses of rocks and not to violently blow up the whole mass causing the breakage of stones into small pieces of no use. The operation of blasting constitutes the boring or drilling of holes, charging them with some suitable explosive and then firing the charge.

Various implements used in quarrying are the jumper or boring bar, scraping spoon, priming needle and the tamping bar (Figs. 1.4 and 1.5).

Scraping spoon is an iron rod having a circular plate attached to one end and the other end is provided with a loop to facilitate handling as shown. It is used to take crushed stone out of the hole.

Priming needle is a thin copper rod pointed at one end provided with a loop handle at the other. After filling the hole with explosive, the hole is filled with tamped earth. This needle is kept in the centre so that on withdrawal it provides a passage for insertion of fuse to cause explosion.

Tamping bar is a heavy brass rod of 10 mm to 15 mm in diameter which tapers a little at ends and is used for tamping the material used for filling the hole.

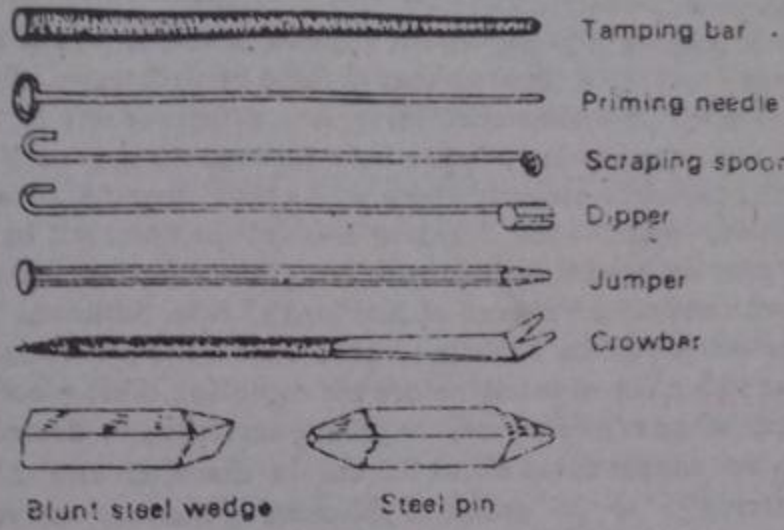


Fig. 1.5. Tools used in blasting of rocks.

Generally two workmen operate the *jumper*, one man guides the lower end to the same point whereas the other one strikes it down with a force while standing. While striking he turns it now and then so as to cut a hole in the rock. A little water is poured in the hole while the jumper is striking it again and again. This water softens the rock and makes the crushed rock into a fine paste which is taken out frequently with a scraping spoon. Jumper is more effective in boring a nearly vertical hole. Boring bar has to be used for drilling an inclined or an horizontal hole. One man holds the cutting edge against the rock and turns it again and again while two workmen strike its flat end with hammers.

The diameter and the depth of each hole depends upon the quantity and nature of rock to be loosened, the type and the quantity of explosive used.

Hand drilling of holes, as explained above, is the most commonly used method in India but drilling by machines is done when large quantities of hard rocks are required to be exploded in a short time or in tunnelling.

After they have dried, the holes are charged with the right quantity of explosive to be used. Well greesed priming needle is then placed in the hole so that it projects a little outside the hole. The hole is now filled in layers with burnt clay powder. Each layer is well tamped with a brass tamping rod before the next layer is put in. The brass tamping rod is of a little lesser diameter than that of the hole.

The tamping rod and the priming needle are *not to be of steel* as otherwise they may cause a spark while the tamping is going on and thereby cause an accident.

While the tamping is going on, the priming needle is turned a little now and then to keep it loose so that it could be withdrawn after the hole is fully filled up with tamped earth. Any deficiency left in tamping would cause the explosive to fire back through the hole itself without releasing sufficient quantity of stone. As such *tamping should be done extremely well.* About 2/3rd to 3/4th of the hole, left by withdrawal of priming needle, is filled with fine grained powder in connection with which is placed a piece of Bickford's* fuse. Sufficient length of the fuse is left outside the hole so as to enable the person igniting it to retreat to a place of safety before the explosion takes place. The useful effect of an explosive may be greatly increased by detonation. Detonators are copper tubes about 0.5 cm in diameter and 2.5 cm long containing 5 to 20 grains of *fulminate of mercury* and can be exploded by an ordinary fuse or by an electric current. Electric ignition is to be preferred where several charges are to be fired simultaneously or where charges are to be fired from a distance or for exploding charges under water.

Gun cotton or dynamite should be exploded by detonation while ordinary *blasting powder* or *gun powder* and *cordite* can be ignited by means of a fuse. The quantity of rock released by an explosion depends, in addition, on the depth and the location of hole.

The path of least resistance followed by the gases, generated on

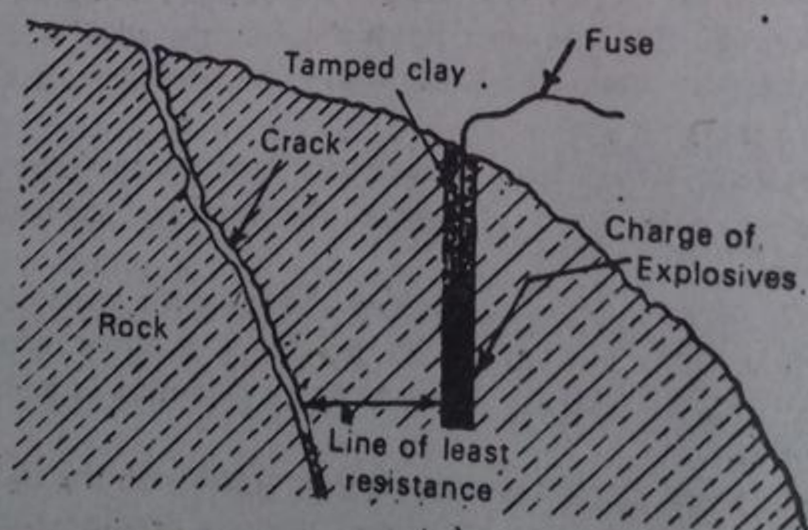


Fig. 1.6

*Bickford's fuse consists of a small rope of cotton coated with tar. Its' core is formed by a fine thread of gun powder and burns @ 60 cm to 90 cm per minute. It is not affected by dampness.

ignition of the explosive, for their escape to air—which usually is the shortest distance from the explosive in hole to the nearest face, crack, fissure or fault in the rock is called the *line of least resistance* (Fig. 1.6). If while filling the hole tamping has not been properly done then the explosion may fire back through the hole when the LLR will be the hole itself. For good results the depth of hole filled with tamped material should be 1½ times the length of the LLR.

1.6 PRECAUTIONS TO BE TAKEN WHILE BLASTING

(*i*) Blasting operations should not be carried out in evenings or early in mornings, It should be done at fixed hours made known to the public.

(*ii*) Before actual firing, siren should give timely warning to workmen and others to retire to safety.

(*iii*) Red danger flags should be prominently displayed at a safe distance of about 200 meters all around the area of explosion. No person except those who have to light the fuses should be allowed in the danger zone till the explosion has taken place.

(*iv*) Responsible person should satisfy himself that all the charges have exploded by comparing the number of charges fired with the number of explosions heard. In case of a misfire necessary precautions should be taken.

(*v*) All fuses should be cut to proper lengths before inserting them into the holes.

(*vi*) For making holes in cartridges to take detonators only hard wooden pegs should be used. No metallic implement should in any case be used for the purpose.

(*vii*) Cartridges should preferably be handled with rubber or polythene gloves on.

1.7 PRECAUTIONS AGAINST MISFIRES

(*i*) Misfires can prove to be very dangerous. In case of doubt sufficient time should be allowed to elapse before entering the danger zone.

(*ii*) Withdrawal of a charge that has not exploded should under no circumstances be allowed.

(*iii*) The hole should be flooded with water and marked boldly.

(*iv*) Not more than 10 bore holes should be exploded at a time and those too successively and not simultaneously.

(*v*) Bore holes should be thoroughly cleaned before inserting the charge in them.

(*vi*) If the misfire is due to defective explosive, detonator or fuse then the whole of that material should be sent for check before being used.

(*vii*) To avoid misfire the safety fuse should be cut off in an oblique direction with a knife and after inserting fuse in the detonator it should be fixed by nippers.

(*viii*) If there be moisture present in the bore hole then the junction of fuse and detonator should be rendered watertight by means of tar, tough grease or white lead and the fuse used should be water-proof.

(*ix*) In case of misfire another hole should be bored at a distance of at least 50 cm and blasted as usual.

1.8 EXPLOSIVES USED IN QUARRYING

Below is given a description of the composition, properties and uses of some of the more commonly used explosives in quarrying:

1.8.1. Blasting powder or gun powder. It is composed of 70 per cent of saltpetre, 15 per cent of sulphur and 15 per cent of charcoal.

(*i*) When exploded it is comparatively slow in action.

(*ii*) It has great lifting power but no great shattering effect.

(*iii*) It is easily ignited and as such special precautions must be taken in its storage and transportation.

(*iv*) It must be kept dry.

(*v*) It is cheaper than dynamite.

(*vi*) It is used mainly in quarrying where great lifting and absence of shattering affect is required.

(*vii*) It is quite useful in quarrying large blocks.

1.8.2. Dynamite. It is 75 per cent of nitroglycerine absorbed in 25 per cent of a porous solid. It is pasty and is ordinarily available in cartridges.

(*i*) It requires very careful handling as it gets detonated even by a strong shock.

(*ii*) It is easily lighted but burns quietly in small quantities.

(*iii*) It is not very suitable for use in cold climates.

(*iv*) It is very poisonous and causes violent headaches through touch with the skin.

(*v*) It is disintegrated by water and is then highly dangerous to use.

(*vi*) It is the most shattering and powerful explosive in practical use.

(*vii*) It is blasted by detonators which consist of 6 to 9 grains of the *fulminate of mercury* in copper cylinders.

Uses: It is well suited for use in small bore holes and in narrow and irregular spaces where cutting or shattering effect is required. It is used in damp situations and under water.

1.8.3. Blasting cotton or gun cotton. It is the most powerful form of nitrocellulose form of explosive and consists of cotton saturated with nitric acid:

(*i*) In dry form it is highly inflammable and is easily detonated even by a shock.

(*ii*) The addition of water increases its explosive effect but renders it non-inflammable, easy to handle and store without deterioration.

(*iii*) In wet conditions it can be exploded by a primer of dry gun cotton and a detonating fuse.

(*iv*) Dry gun cotton may explode even in sunlight.

(*v*) As it decomposes on storage and the rate of decomposition depends on the temperature so it should be stored only in cool places.

(*vi*) Properly stored gun cotton is a stable explosive in all climates.

(*vii*) Its detonation has a good cutting and shattering effect but no good lifting effect.

Uses. It is used only where good cutting and shattering effect is required as in demolitions.

1.8.4. Cordite. It is a modern gelatinized combination of nitroglycerine and nitrocellulose.

(*i*) It is a comparatively slow burning smokeless explosive producing powerful gas.

(*ii*) If charges are well rammed then its results are similar to those of dynamite and three times stronger than those of blasting powder.

(*iii*) It is more economical.

(*iv*) It is blasted by a gun powder primer and fuse.

Uses: It can be effectively used even under water. It can be used with good results in quarrying.

1.9 STORAGE OF EXPLOSIVES

(*i*) Packages containing explosives should not be handled roughly.

(*ii*) Only wooden tools and not the metallic ones should be used when they are likely to come in contact with the explosive.

(*iii*) Explosives should be stored in pucca buildings far away from residential areas, petrol depots, industrial areas or other important public places.

(*iv*) All explosives should be protected from extreme heat or cold and from moisture.

(*v*) They should be kept free from all foreign matter.

(*vi*) Smoking or any other inflammable matter should not be allowed within a radius of 50 metres of the store.

(*vii*) The store should be surrounded by a high barbed wire fencing.

(*viii*) Flame lights should not be used in a *magazine* (*store for explosives*).

(*ix*) If electricity is not provided there, then light arrangements may be made from batteries.

(*x*) Electric fittings should be checked frequently.

(*xi*) Entry in the magazine with bare feet should not be allowed. Only magazine shoes having no nails should be used.

(*xii*) Magazine should be kept properly locked allowing entry to no-unauthorised person.

(*xiii*) In case of storms or cyclones nobody should remain inside the magazine.

(*xiv*) Detonaters fuses and percussion caps should never be kept in the same containers and should always be stored away from other explosives, preferably in separate buildings and should be kept quite dry.

1.10 NATURAL BED

It is the plane or bed on which the sedimentary stone was originally deposited. It may not necessarily be horizontal. Natural bed has an important effect on the durability of stone. As such all sedimentary stones should be used with due regard to its position. Stones should always be placed in such a manner that the *natural bed* is at right

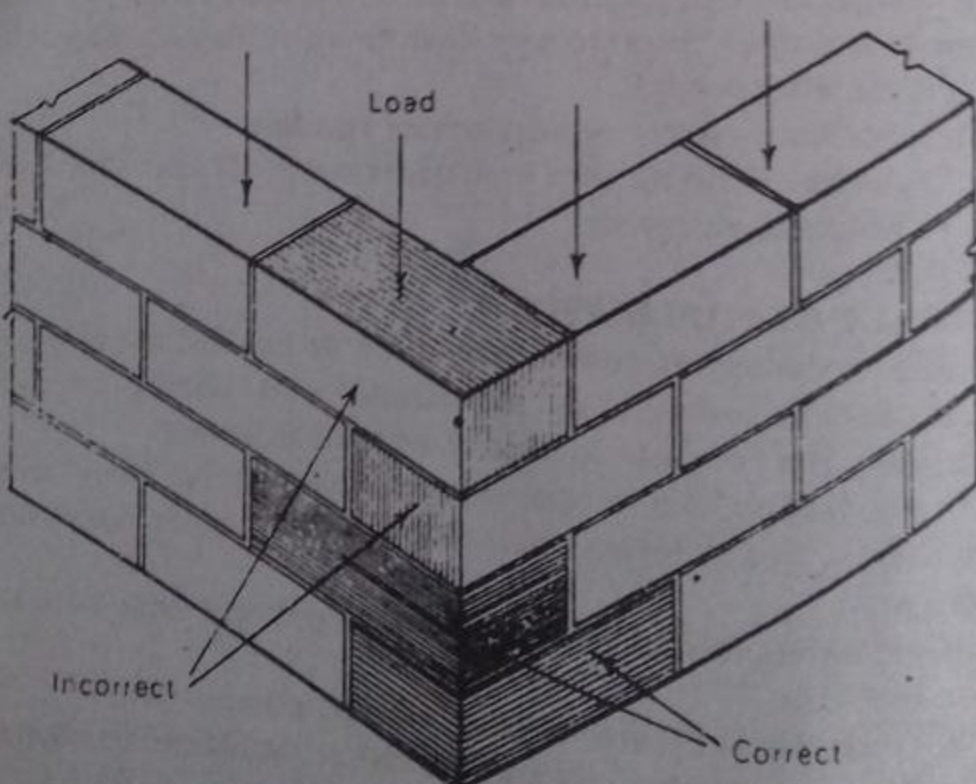


Fig. 1.7

angles to the pressure that the stone is to carry. In doing so stones offer maximum resistance to crushing and offer greatest resistance to disintegration by frost and rain. If the stones are used with their natural beds parallel to the direction of load then the stones will split at much lesser loads and also will be attacked more severely by frost and rain water (Fig. 1.7). As such, stones in walls shall be placed horizontally whereas in arches they should be placed with the natural bed parallel to the line of voussoirs and at right angles to the face of arch (Fig. 1.8). In cornices with mouldings on the lower side,

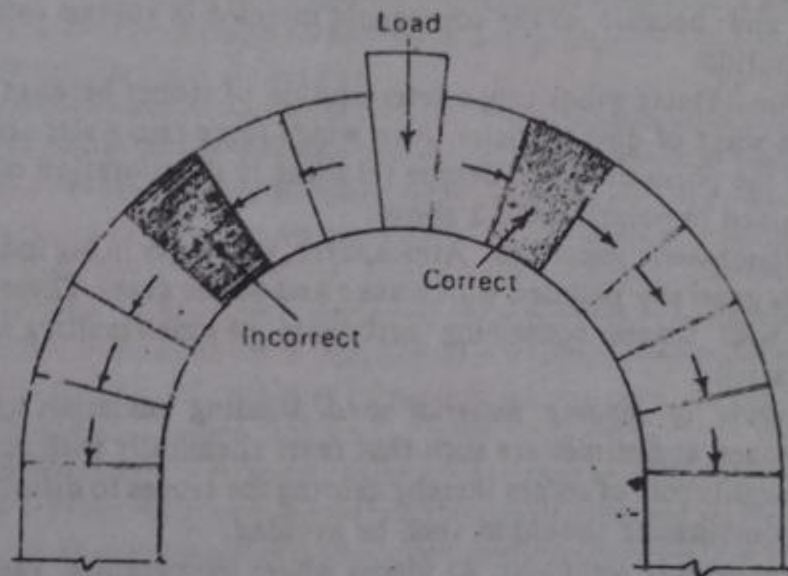


Fig. 1.8

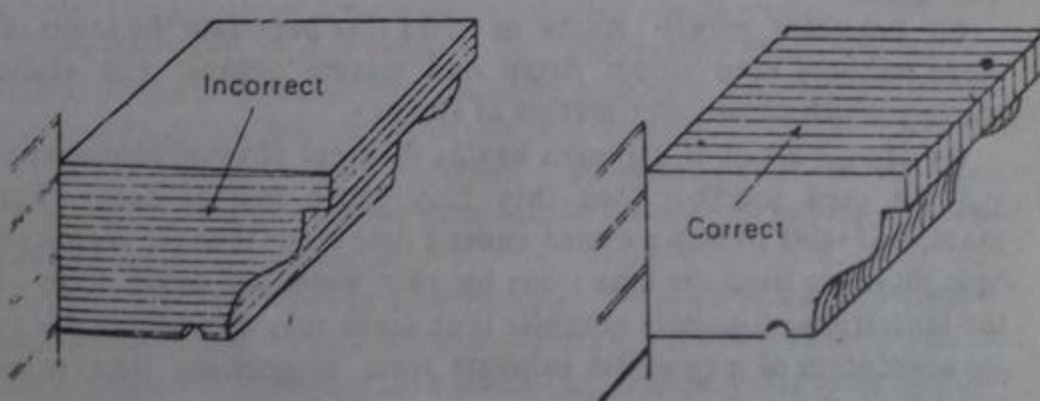


Fig. 1.9

stone should be used with natural bed vertical for if placed horizontal the lower layers of the projecting part are liable to scale off (Fig. 1.9).

1.11 DETERIORATION OF STONES

Deterioration of stones is caused by the chemical and physical changes brought about by various agencies of weather. Following are the main climatic agencies bringing about deterioration of stones:

(1) *Rain*. Frequent wetting and drying of stones by rains and sun causes internal stresses thereby resulting in the disintegration of stones. Also while coming down rain water carries with it acids present in atmosphere particulary of industrial towns. This acidic rain water reacts with the constituents of stone causing its deterioration.

(2) *Frost*. At very cold places frost on entering the pores of stones freezes and because of the consequent increase in volume causes its disintegration.

(3) *Wind*. Dusty winds cause deterioration of stones because of the abrasive effect of dust particles. Also winds force rain water and frost to enter the pores of stones deeper resulting in deterioration of stone as explained in points 1 and 2 above.

(4) *Atmospheric impurities*. Atmosphere, especially in big industrial towns, is generally polluted with smoke and acidic gases. These react readily with stones containing carbonate of lime resulting in their deterioration.

(5) *Nature of binding material used*. Binding materials used for laying stones, sometimes are such that react chemically with any one of the constituents of stones thereby causing the stones to disintegrate. Such a combination should as such be avoided.

(6) *Temperature variations*. At places where temperature variations are too much or too frequent, stones, if used, would crumble because of the setting up of internal stresses. Stones should not be used at such places.

(7) *Vegetable growth*. Roots of trees that penetrate the joints of stone masonry keep stones damp and secrete organic and acidic matters which cause deterioration of stones.

(8) *Mutual decay*. If materials having different physical characteristics are used together then they may cause mutual decay. For example if sand stone were used under a lime stone then the chemicals brought down from the lime stone by rain water will cause decay of the sand stone. Similarly granular lime stone may deteriorate due to the absorption of magnesium sulphate from magnesium lime stone when the two are used together.

1.12 COMMON BUILDING STONES OF INDIA

A detailed description of the characteristics, uses and occurrence of common building stones of India discussed follows:

1.12.1. Granite. *Origin and Composition.* It is an igneous rock composed of quartz, felspar and mica. It is unstratified according to physical and silicious according to chemical classifications.

Characteristics (*i*) It is hard, strong and durable unstratified stone.

(*ii*) It is crystaline and fine to coarse grained.

(*iii*) Fine grained granite takes high polish.

(*iv*) It is heavy (specific gravity varies from 2.63 to 2.75).

(*v*) It is difficult to work upon hence costly and unsuitable for ordinary building works.

(*vi*) Its colour depends upon the colour of felspar that it contains. Usual colours being white to light grey and pink.

(*vii*) It cracks badly under fire.

(*viii*) Its compressive strength is 1,000 to 2500 kg/cm^2.

(*ix*) Quantity of quartz and quality of felspar present in the granite determine its strength and weathering properties. One containing large quantity of quartz and good quality of felspâr will be hard and shall weather well.

Uses. Good quality granite is used in important constructions like piers and abutments of bridges, light houses, weirs and barrages across rivers. Inferior qualities of it are used as road metal and as railway ballast.

Occurrence. It is quarried in Ajmer (Rajasthan), Jhansi (UP), Jabalpur (MP), Dalhousie and Kangra (Himachal), Mysore, Bangalore, Nilgiris, Pallaram (Madras), Secunderabad (Andhra) and in Gujarat.

1.12.2. Gneiss or stratified granite. *Origin and Composition.* It is a metamorphic rock. As granite changes to gneiss so its composition is the same as that of granite. According to chemical classification it is silicious and stratified according to physical classification.

Characteristics. Except that it is stratified its characteristics are same as those of granite. Because of its stratified constitution it can be split into slabs. It is not as strong as granite is.

Uses. It is used for paving and flooring in addition to those for which granite is used. It is not commonly used for major works due to its deliterious constituents.

Occurrence. It is found in Madras, Mysore, Kerala, Kutch, Andhra and Bihar.

1.12.3. Basalt and trap. *Origin and Composition.* It is an igneous stone. It chiefly consists of felspar, augite, alumina, silica and other minerals.

Characteristics. (*i*) It is hard, compact and durable unstratified stone as such difficult to work upon. But it gives a fairly good surface on dressing.

(*ii*) It is heavier than granite (specific gravity varies from 2.6 to 3.0).

(*iii*) It can not generally be obtained in large blocks.

(*iv*) It has grey, dark grey, green, blue, black, red and yellow colours.

(*v*) Its compressive strength is 1500 to 3000 kg/cm^2.

(*vi*) It weathers well.

Uses. It is used for paving, road metalling, as aggregate in concrete and for constructing ordinary buildings. Red and yellow varieties, which are soft, are used for ornamental work.

Occurrence. It is found mostly in Deccan, Bombay, Bihar, Rajasthan, Dehra Dun (UP), Poona and Western Ghats. Rock cut temples of Ajanta, Ellora and Elephanta are in trap.

1.12.4. Slate. *Origin and Composition*. It is a metamorphic stone and is Agrilaceous according to chemical and sedimentary according to physical classification. It is usually composed of Alumina mixed with sand or carbonate of lime and sometimes with carbonaceous matter.

Characteristics. (*i*) A good slate is hard and tough. It gives metallic ringing sound when struck with a hammer.

(*ii*) It is fine grained and less absorbant.

(*iii*) Good slate is uniform in colour and free from patches. Purple, blue, black, green and grey are the usual colours of slate.

(*iv*) These are hard and rough to touch. Those with smooth and greesy touch or with purple colour are inferior in quality.

(*v*) These can be easily split into thin laminae.

(*vi*) Its compressive strength is 1000 to 2000 kg/cm^2.

(*vii*) Its Sp. Gr. is 2.6 to 2.8.

Uses. It is used mostly for roof covering, flooring, damp proofing, shelves, mantel pieces, sills of windows, sun shades and for making electrical switch boards. Because of its non-absorbant nature, it is used in baths, cisterns and urinal partitions etc.

Occurrence. It is found at Monghyr and Singbhum (Bihar), Cuddapah (AP), Bijapur (Mysore), Simla and Kangra (Himachal), Gurdaspur (Punjab), Gurgaon (Haryana), Baroda (Gujarat), Chamba (MP) and Alwar (Rajasthan).

1.12.5. Lime stone. *Origin and Composition*. As per geological, physical and chemical classification it is sedimentary, stratified and calcareous respectively. It consists chiefly of calcium carbonate with small portions of silica, magnesium carbonate, iron and clay. Stones containing calcium carbonate and magnesium carbonate in equal quantities are known as dolomites.

Characteristics. (*i*) It is easy to work upon and is a fairly good building stone but unsuitable for use in industrial areas.

(*ii*) Its texture is bedded, granular and fine grained.

(*iii*) Good qualities of it are fairly durable.

(*iv*) Its usual colours are white, grey, pink, red, blue, buff, brown, green, yellow, black etc.

(*v*) It effervesces in contact with acids.

(*vi*) Its compressive strength is 300 to 2500 kg/cm².

Uses. It is used in the manufacture of lime and cement. Also it is used in blast furnaces, bleaching, tanning and other industries. It is used as road metal and in construction of not very important buildings.

Occurrence. It is found in Bombay, Andhra, Jabalpur (MP), Madras, Alwar (Rajasthan), Hoshiarpur (Punjab), Simla (Himachal).

1.12.6. Marble. *Origin and Composition.* It is a metamorphic rock. Physical and chemical classifications being sedimentary and calcareous respectively. It contains calcium carbonate.

Characteristics. (*i*) It is available in many colours, white, green, grey, black, red, blue and yellow.

(*ii*) It is fine to coarse grained, massive, crystalline and granular in texture.

(*iii*) It is quite hard and takes a fine polish.

(*iv*) It can be easily carved. Varieties of it with finer grains are better suited.

(*v*) Good marble is extremely durable.

(*vi*) Its compressive strength is 1000 to 2500 kg/cm².

Uses. Because of its scarcity and consequent high cost its use is restricted to ornamental buildings, carved work, monuments and statues.

Occurrence. It is found at Ajmer, Jaipur, Jodhpur, Jaisalmer (Rajasthan), Gwalior, Jabalpur (MP) and Baroda (Gujarat).

1.12.7. Kankar. *Origin and Composition.* It is an impure form of lime stone containing about 30% of clay and sand.

Characteristics. (*i*) It is found either in solid layers or as irregular shaped nodules.

(*ii*) Nodular kankar is grey or *khaki* in colour and has porous structure.

(*iii*) Block kankar is hard.

Uses. 1. Block kankar, if hard, is used in building constructions.

2. Nodular kankar, if hard and tough, is used as road metal.

3. Nodular kankar on burning gives excellent hydraulic lime.

Occurrence. It is found at varying depths at a number of places in Northern and Central India.

1.12.8. Sand Stone. *Origin and Composition.* It is sedimentary, stratified rock which according to chemical classification is silicious. It contains grains of sand cemented together by calcium carbonate. Besides almost all sand stones contain oxide of iron upon which depend their colour. Carbonate of magnesia and Alumina are the other usual constituents.

Characteristics. (*i*) It is porous.

(*ii*) It is a soft and moderately stratified stone and fine to coarse grained.

(*iii*) The more a sand stone is free from lime and iron the more durable it is.

(*iv*) It is easy to work upon and is particularly suited for carved work.

(*v*) It is available in red, grey, yellow and blue colours.

(*vi*) Good quality sand stones are suitable for all types of building work.

(*vii*) It weathers well.

(*viii*) Its compressive strength is 200 to 1700 kg/cm².

Uses. Fine grained sand stones are good for carved work. Good weathering sand stones are used for all types of building work. Rough and coarse grained sand stones are good for rubble work. Though not very suitable yet at times it is used as road metal.

Occurrence. Good quality sand stones are available in Mirzapur, Chunar and Fatehpur Sikri (UP), Jabalpur, Raipur, Gwalior (MP), Bikaner, Dholpur, Jodhpur and Jaisalmer (Rajasthan), Nagpur (Maharashtra), Mysore, Karnool (Andhra), Cuttack (Orissa), Kangra and Dharamsala (Himachal).

1.12.9. Laterite. *Origin and Composition.* It is a metamorphic rock which is Agrilaceous according to chemical classification. It is a sandy clay stone with a high percentage of oxide of iron because of which it gets deep brown or red colour.

Characteristics. (*i*) It has a porous and cellular structure.

(*ii*) It can be easily quarried in blocks suitable for use as building stone.

(*iii*) It has yellow, deep brown, red or black colour

(*iv*) It is soft and easy to work upon.

(*v*) It is not fit for use at places subjected to action of water or heavy loads. Unseasoned stone should not be used.

Uses. Blocks of laterite are used as building stone. Nodular laterite is used as road metal.

Occurrence. It is found in Bihar, Orissa, Mysore, Belgaum, Ratnagiri, Dharwar and Mahableshwar in Maharashtra.

1.12.10. Serpentine. *Origin and Composition*. It is derived from Igneous rocks.

Characteristics. (*i*) Its mottled and striped appearance resembles the skin of a serpent.

(*ii*) It is found in shades of green and red with spot of various colours.

(*iii*) It is compact but soft and can be easily worked upon.

(*iv*) It does not weather well and is affected by smoke.

Uses. It is used in the construction of superior buildings and for interior decoration works.

1.12.11. Moorum. It is decomposed laterite and is available in the vicinity of laterite quarries where it is collected as red earth. It is of organge to pinkish colour. It is a fine blindage for metalled roads. It is used for surfacing fancy paths in gardens and bunaglows.

1.12.12. Gravel. These are water worn pebbles of any kind of stone and are up to 7.5 cm in diameter. Usually found in river beds or in alluvial tracts. These are used for road blindage, surfacing and in concrete.

1.12.13. Shingle. These are water worn pebbles of any kind of stone and bigger in size than gravel. It too is found in river beds and alluvial tracts. It is used as road metal and in concrete.

•**1.12.14. Chalk**. It is pure white lime stone, easily powdered and hence unsuitable for building purposes. Used in the manufacture of Portland Cement and making of glaziers putty. It is also used for marking and as colouring matter.

1.13 SELECTION OF STONE

In selecting stone for use in a particular work the conditions under which it would remain have to be considered. No one kind of stone is suitable for all purposes and for all situations. Colour and appearance are important deciding factors in the choice of stones for the face work of high class buildings. Availability of required quantity, proximity of quarry, transport facilities and availability of labour are some of the factors to be kept in view while making the choice of a particular kind of stone for any work. Stones suitable for various types of works with reasons favouring the choice are listed on page 26.

1.14 PRESERVATION OF STONE WORK

To increase the life of a stone structure it should be cleaned with water or with steam so that dirt and soluble salts are removed and threat of decay is reduced. Following few points, if kept in view, will

SELECTION OF STONE

S.No.	Purpose	Suitable Stones	Reasons for choice
1.	Construction of heavy engineering works like piers & abutments of bridges, retaining walls, weirs, dams, docks, harbours, light houses and break waters etc.	Granite and Gneiss.	Strength, durability and weight.
2.	For carved and ornamental work, statues and face covering (veneer) over less costly brick or stone masonry from Architectural considerations.	Marble, granite and close grained sand stone.	Soft, even grained stones without distinct beds and can be easily worked into required shapes and sizes.
3.	For buildings facing sea and exposed to strong dusty winds.	Granite and fine grained sand stone.	Compactness and hardness due to the presence of silica.
4.	For construction in industrial towns.	Granite and compact sand stone.	Not affected by acids, fumes and smoke.
5.	For road metal and as aggregate for concrete.	Ballast of quartzite granite and basalt.	Hardness, toughness and resistance to abrasion.
6.	For ballast along railway track.	Sand stone, compact lime stone and quartzite.	Hardness.
7.	For fire resistant constructions.	Compact sand stone.	Better fire resistance.
8.	For electrical switch boards.	Slate and marble slabs.	Poor conductivity of electricity, ease in cutting *to any shape or size and the quality of taking fine polish.*

help increase the life of a stone structure particularly in the polluted atmosphere of big industrial towns.

1. *Selection*. It is much better to initially use a durable compact and crystalline stone rather than to depend upon preservatives late . Instead of lime stones or calcareous sand stones use of compact crystalline sand stone with its grains cemented with siliceous matter would be the right choice for industrial areas. Use of less porous stones on exposed faces of buildings is to be preferred even in non-industrial areas.

2. *Seasoning*. Use of stones seasoned after they had been cut and dressed immediately after quarrying will increase the life of structure. Quarry sap on evaporation leaves behind a thin hard skin which increases weathering property of the stone. This skin should not be disturbed. Also seasoned stones are less liable to deterioration because of frost and acids.

3. *Size*. Bigger sized stones are more durable than the smaller ones.

4. *Natural bed*. Care should be taken to so place the stones that loads act at right angles to the natural bed of stones used as otherwise the stone will flake off. Also with the natural bed vertical effect of rain and frost shall be more detrimental.

5. *Surface finish*. Well dressed, smoothly finished and polished surfaces are more durable than the rough and rugged ones.

6. *Workmanship*. Good workmanship helps in the preservation of stone work. All joints should be properly filled in leaving no hollows or cavaties inside the masonry.

7. *External rendering*. Either the entire external surface should be plastered over with cement sand plaster or at least it should be properly pointed so as to stop rain water from entering the joints.

8. *Proper maintenance*. Maintenance of structure in neat condition is quite effective in preserving it. To do so, it should be washed with water or with steam so that the dirt and soluble salts are removed and the rate of decay is reduced.

9. *Application of preservatives*. The best way of preserving a stone is to eliminate as far as possible the causes of its deterioration *e.g.* not to use lime stone and sand stone together, not to let vegetable growth take place in joints of masonry, not to use lime stone in industrial areas etc., etc.

Several propietary makes of preservatives have been put on the market from time to time but no satisfactory preservative for stones has yet been evolved. *Szerelmy's liquid*, has been very commonly used but rather than preserving the treated stone it renders a porous stone somewhat water proof. The most common method used is painting the exposed face of stones with lead paint or with some other oil paint. But for the apparent defect that this treatment would change the colour and appearance of stone it remains still the best preservative for surface application if the paint be renewed from time to time.

1.15 DRESSING OF STONES

Stones are dressed to give them a definite and regular shape with smooth faces. The degree to which these objects are achieved depends upon the quality of masonry work in which the stone is to be used.

Dressing should be done as quickly after quarrying as possible and the stone should be allowed to season thereafter. Stones fresh from quarry have the quarry sap because of which it is easier to dress them, Also as time passes quarry sap evaporates away leaving a *film* on the surface of stone. This *film* imparts better weathering properties to stone. Now we shall discuss the various methods of dressing which are commonly used.

1.15.1. Pitched faced dressed. In it the edges shall be made level to a minimum width of 2.5 cm and shall be absolutely square with the end of the stone (Fig. 1.10). Superfluous stone on the face shall be allowed to remain there and left raised.

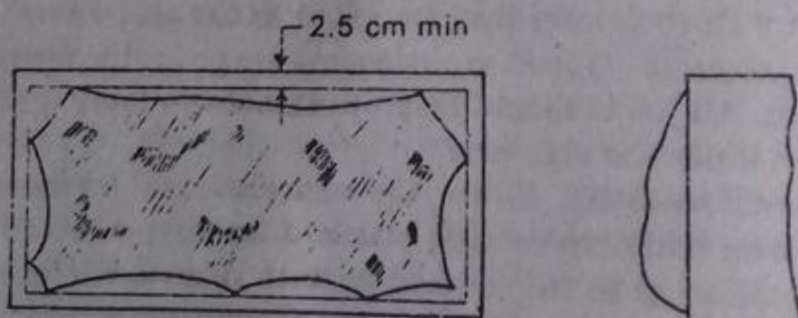
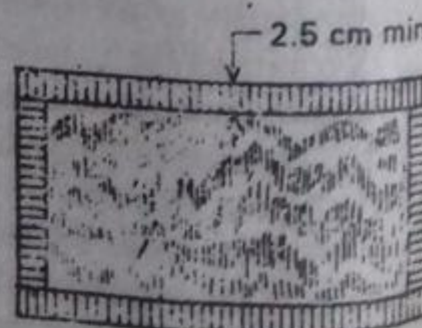


Fig. 1.10. Pitched faced dressed.

1.15.2. Hammer dressed, hammer faced, quarry faced or rustic faced. It has no sharp or irregular corners and has comparatively even surface so as to fit well in masonry. Hammer dressed stone also has rough todling for a minimum width of 2.5 cm along the four edges of the face of stone (Fig. 1.11).



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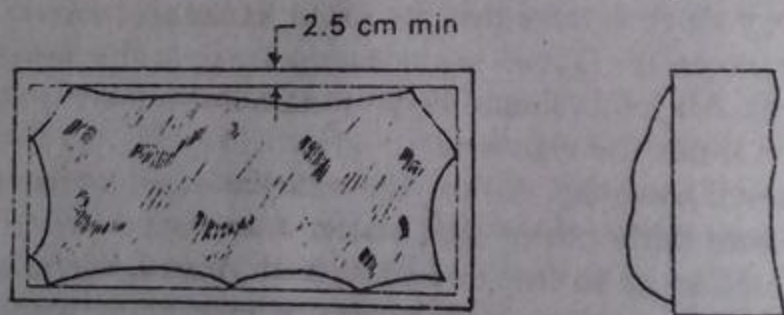


Fig. 1.10. Pitched faced dressed.

1.15.2. Hammer dressed, hammer faced, quarry faced or rustic faced. It has no sharp or irregular corners and has comparatively even surface so as to fit well in masonry. Hammer dressed stone also has rough tooling for a minimum width of 2.5 cm along the four edges of the face of stone (Fig. 1.11).

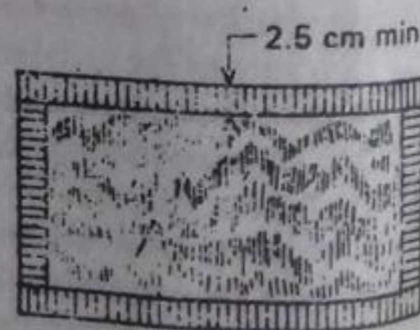


Fig. 1.11. Hammer dressed.

1.15.3. Rock faced and chisel drafted. It has a minimum 2.5 cm wide Chisel Draft at the four edges. All the edges are at the same plane. Superfluous stone at the centre shall be removed by pitching tool or Scappling Hammer (Fig. 1.12.)

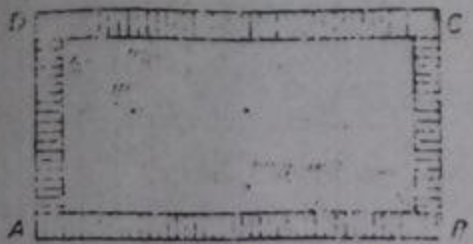


Fig. 1.12. Rock faced & Chisel drafted.

1.15.4. Rough tooled. Edges and corners of it are made perfectly square and true. Rest of it has series of bands 4 to 5 cm wide, more or less parallel to tool marks all over surface (Fig. 1.13).

These bands may as desired be vertical horizontal or inclined at 45°. On holding a straight edge against the surface a depression of not more than 3 mm is permissible. Rough tooled stones are used when a fairly smooth surface finish is desired.

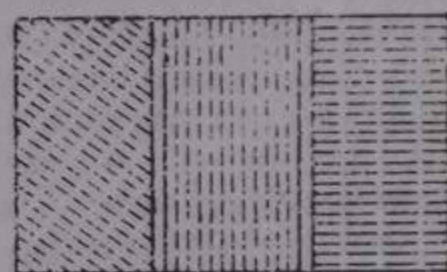


Fig. 1.13. Rough tooled.

1.15.5. Punched dressed A rough tooled surface is further dressed by making parallel cuts with chisel. When a straight edge is held against its surface a depression of not more than 2 mm is permissible. This finish is also known as brouched, stugged or two line dressed finish (Fig. 1.14). These stones are used when an even surface is required.

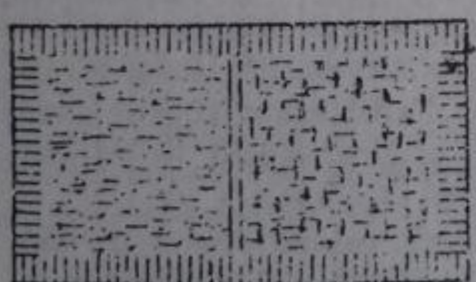


Fig. 1.14. Punched dressed.

1.15.6. Close picked dressed. A punched dressed stone is given a further smooth finish with chisel cuts. Only very small chisel marks are left. Not more than 1 mm gap should be left between the surface and a straight edge held against it. This finish is also known as sparrow finish or three-line dressed (Fig. 1.15).

1.15.7. Fine Tooled. Close picked stones are further dressed for *Ashlar Work*. All projections are removed and a fairly smooth surface is obtained. There are not more than 3-4 lines per centimetre width of the surface (Fig. 1.16).

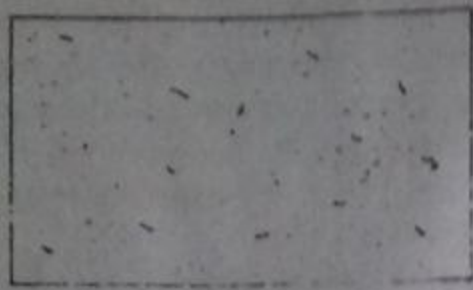


Fig. 1.15. Close picked dressed

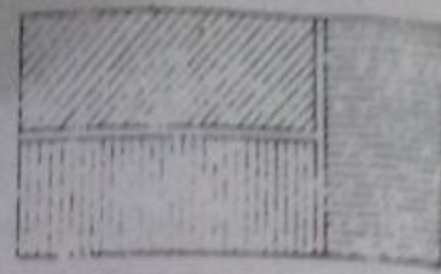


Fig. 1.16. Fine tooled

1.16 ARTIFICIAL STONE OR CAST STONE

It is the term adopted to represent a building material made with cement and natural aggregate cast to various shapes with a good surface finish for use in place of natural stone. A good cast stone should resemble a natural stone fully. To achieve it white cement with aggregate of the crushed stone and sand selected to have matching colour are used. Aggregates must be clean and durable. Use of rapid hardening cement shall enable the use of moulds frequently. Pigments used for colouring the cast stone should be judiciously chosen, so that they do not interfere with the setting of cement. They should not be used in a proportion greater than 15% by volume of the cement used. Cement and aggregates are usually mixed in 1:3 proportion. Sometimes only the facing is made of cast stone material whereas the rest of stone is made of ordinary concrete. To make cast stones lighter the backing may be made of breeze concrete. Facing should be made thicker if carving is to be done on it. Care must be taken to ensure uniformity of colour on the facing of cast stone and use it only after full maturity. Cast stone is equally good in resisting deterioration and disintegration caused by various atmospheric agencies like rain, frost, acids etc., etc.

Cast stones have added advantage over natural stones in that architectural details and ornament can be moulded in it. These may be cast to any shape or size. Being not lamminated no precautions have to be taken regarding natural bed. On being manufactured on a mass scale these stones prove to be much more economical than the natural stones.

EXERCISES

1. Comment on the uses of stone as a material of construction.

2 Name the three chief "geological" classes into which rocks can be divided describing the process how they are formed.

3. What are the main classifications of rocks? Mention the Chief Constituents of Stones.

4. State the requirements of a good building stone and mention any two types of good building stones available in your state giving the characteristics and Geological Structure.

5. What are the essential qualities of a good building stone?

6. Give in details the characteristics of good building stones and name the common type of stones used in building construction and where they are found in India.

7. Enumerate the characteristics of a good building stone. What are the different methods used in dressing it?

8. Give detailed description of test for determining the specific gravity of stones.

9. Based on IS recommendations give detailed account of test for compressive strength of stones.

10. Name the various methods of quarrying stone. Describe any one in detail.

11. Describe briefly the operation of blasting. What are the various tools used? Illustrate by means of neat sketches.

12. What precautions you would take while blasting and against misfires?

13. Name some explosives generally used for quarrying.

14. What precautions you would take in the storage of explosives?

15. Write short notes on:

(*i*) Artificial Stone

(*ii*) Dressing of Stones

(*iii*) Line of least resistance

(*iv*) Stratified and unstratified rocks

16. How does the deterioration of stones take place in nature? Describe briefly the methods of their preservation.

17. What is the *Natural Bed of a stone*? What is the correct position to lay it in building work? Give reasons and explain with sketches.

18. What do you understand by artificial preservation of stone? Name some preservatives.

19. Classify giving briefly the characteristics and uses of the following stones.

(*i*) Granite, (*ii*) Red Sand Stone, (*iii*) Slate, (*iv*) Lime Stone, (*v*) Marble.

20. Name and describe any five varieties of Indian Stone. In what parts of the country they are available in sufficient quantities? Describe their properties and suitability for various types of Construction.

21. Briefly describe how the stones are dressed after they are quarried.

22. State with reasons the kind of stone you would recommend for use in the construction of:

(*i*) External wall of a building situated on the sea-shore.

(*ii*) Platform of a railway goods shed.

(*iii*) Ornamental Cornice of a building.

2

BRICKS

2.1 BRICKS

Bricks are blocks of tampered clay moulded to suitable shapes and sizes while it is still in plastic condition, dried in the sun and burnt, if desired so as to make them more strong, hard and durable.

Common building brick is not only one of the oldest but also the most extensively used material of construction. Popularity of bricks as a material of construction is because of their local and cheap availability, strength, durability, reliability and insulating property against heat and sound.

Depending upon the nature of soil from which the bricks are made, the moulded finish and the quality of burning, the bricks are classified into different categories.

2.2 CLASSIFICATION

Bricks are broadly classified into two categories. (1) *Sun-dried bricks or kacha bricks or unburnt bricks, and* (2) *Burnt bricks or pucca bricks.* While burnt bricks or pucca bricks are further classified as: (*a*) *First-class bricks*, (*b*) *Second class bricks*, (*c*) *Third class bricks*, *and* (*d*) *Overburnt bricks or Jhama bricks.*

2.2.1. Characteristics and uses. Below are discussed the characteristics and uses of each one of them:

(*i*) *Sun-dried or Kacha bricks.* These bricks after moulding have been dried in the sun, and are used in the construction of temporary and cheap structures. These types of bricks should not be used at places exposed to heavy rains.

(*ii*) *Burnt or Pucca bricks.* There are four types of bricks:

(*a*) **First class bricks**

Characteristics. (*i*) These are sound well burnt bricks of a uniform colour.

(*ii*) All the faces are uniform and smooth. All the edges are sharp.

(*iii*) These are free from cracks or flaws.

(*iv*) A broken surface shows a uniform compact texture.

(*v*) Scratch with finger nails leaves no mark.

(*vi*) These do not absorb more than 15% of their weight of water when kept immersed for 24 hours.

(*vii*) Two first class bricks when struck with each other give a sharp metallic ringing sound.

(*viii*) These are free from nodules of free lime.

(*ix*) These may have a slight presence of efflorescence.

Uses. (*i*) Used for all s und work of a permanent character.

(*ii*) Used in the face work of structures not to be plastered but only pointed.

(*iii*) Used in flooring and in reinforced brick work.

(*b*) **Second Clas bricks**

Characte i i . These are as hard and well burnt bricks as the first class brick may be somewhat irregular in shape or size and may h ve a slig surface. Other qualities are the same as those of first cl...

Uses. i unimportant situations or at places ere the masonry s be plastered.

(*ii*) Used as brick ballast in R.C.C. work and i ime Concrete.

(*c*) **Third class or pilla bricks**

acteristics. (*i*) These are a little under urnt bricks.

ese are soft.

These have gh colour.

(*iv*) These e .o when struck against each other.

Uses. These re used n tem ora constructions not subjected to heavy loa r to too hea

(*d*) **Overburnt or Jham bricks**

Characteristics These are erburnt bricks that being near the fire in the kiln get fused and lose their shape.

Uses. (*i*) Used for constructing inferior structures.

(*ii*) Used in the foundations of structures.

(*iii*) Used as aggregate for concrete.

(*iv*) Used as road metal.

2.2.2. Classification as per ISI. As per IS 1077-1976 common burnt clay bricks are classified on the basis of their average compressive strength as shown in Table 2.1.

Each class of brick is further subdivided into two sub-classes A and B based on tolerances and shapes e.g. brick of classification 100 is further sub-classified as 100A and 100B and so on. Bricks of sub-class A shall have smooth faces, sharp edges and corners and uniformity in

TABLE: 2.1 Classes of Common Burnt Clay Bricks

Class designation	*Average compressive strength*	
	Not less than kg/cm²	*Less than kg/cm²*
350	350	400
300	300	350
250	250	300
200	200	250
175	175	200
150	150	175
125	125	150
100	100	125
75	75	100
50	50	75
35	35	50

colour whereas bricks of sub-class B may be *slightly* distorted or may have *slightly* rounded edges subject to the condition that these distortions do not cause any difficulty in laying of uniform courses.

2.3 COMPARISON OF STONE WITH BRICK AS A MATERIAL OF CONSTRUCTION

S.N.	*Stone*	*Brick*
1.	It is a natural material.	It is manufactured from clay.
2.	It is heavier.	It is lighter.
3.	It costs much to dress it to required shape and size.	It can easily be moulded to any shape or size.
4.	It is more costly except in hilly areas.	Except in hilly areas, it can be locally manufactured and is cheaper.
5.	It is less porous and as such better suited for construction of water retaining structures.	It is more porous and requires costly water proofing treatment when used for constructing water retaining structures.
6.	Because of more strength it is better suited for constructing structures carrying extra heavy loads or subjected to heavy pressures e.g. harbour, dock and forts etc.	Reasonably good for normal loads.
7.	It is a better conductor of heat.	It is a poorer conductor of heat.
8.	It withstands attacks of weather better.	It is good for normal conditions but needs protection by way of plastering and pointing.
9.	Superior qualities of stones are used for constructing monuments and for decoration.	Good quality bricks are sometimes left unplastered to achieve some Architectural effect.

2.4 BRICK EARTH

2.4.1. Composition. A good brick earth should be such that when prepared with water it can be easily moulded, dried and burnt without cracking or warping. It should contain a small quantity of finely divided lime to help in binding the particles of brick together by melting the particles of sand. A little oxide of iron should also be present which would give the brick its peculiar red colour and act in the same manner as lime.

A good brick earth should preferably conform to the following composition:

Clay (*Alumina*)	20 to 30 per cent by weight
Silt	20 to 35 per cent by weight
Sand	35 to 50 per cent by weight

The total content of clay and silt should not as far as possible be less than 50% by weight.

2.4.2. Functions of constituents. (*i*) *Silica or Sand*. It is present either free as sand or in combination as silicate of alumina. Silica is infusible except at very high temperatures but in the presence of alumina in nearly equal proportions and the oxide of iron it fuses at lower temperatures. Unlike Silicate of Alumina its presence in clay produces barduess, resistance to heat, durability and prevents shrinkage and warping. Excess of it makes the bricks brittle.

(*ii*) *Alumina*. It is a tenacious finely-grained mineral compound present in brick earth. It is plastic, when wet, and is capable of being moulded to any shape. On drying it loses its plasticity and becomes hard, shrinks, warps and cracks. Burning causes the fusion of its constituents thereby making it homogeneous, harder and stronger.

(*iii*) *Lime*. When present in small quantities in finely divided state it reduces shrinkage of bricks and acts as a flux causing silica to melt. It results in binding the particles of brick together resulting in greater strength of brick. Excess of lime causes the brick to melt and lose its shape.

(*iv*) *Magnesia*. In the presence of iron it gives a yellowish tint to the bricks. It should not be present in excess. However, the presence of small quantity of manganese with iron will give the brick darker or even black colour. Total lime and magnesia in case of alluvial soil shall not be more than one per cent and in other cases it will preferably not exceed 15 per cent.

(*v*) *Oxide of iron*. In the presence of Silica and Alumina, it helps the fusion of brick particles. Also it influences the colour of bricks. It produces a tint varying from light yellow to red depending upon the percentage of iron present in clay. Excess of it makes the colour dark blue. It should not be present in the form of *iron pyrites.*

2.4.3. Harmful ingredients. (*i*) *Lime*. If present in excess it melts the brick particles as a result of which the brick loses shape. Lime should also be not present in brick earth in the form of lime stone or kankar modules. On the burning of bricks, these get converted to quicklime which expands on absorption of moisture and causes the cracking and disintegration of bricks.

(*ii*) *Iron pyrites*. Iron pyrites get oxidized in the brick, crystallize and split the brick to pieces. These should be carefully removed from brick-earth.

(*iii*) *Pebbles of stone and gravel etc*. Their presence makes it difficult to mix the brick-earth thoroughly as a result of which the bricks are not homogeneous. It gives weak and porous bricks. Also such bricks cannot be readily cut or worked.

(*iv*) *Alkalies*. Their excessive presence in earth renders it unsuitable for bricks. These act as flux causing the bricks to melt, twist and warp. Presence of common salt in earth taken from sea shores or from near salt formations has similar effects to those narrated above and also make the bricks *hygroscopic* thereby causing efflorescence.*

(*v*) *Reh or Kallar*. It is the sulphate of soda mixed with a little carbonate of soda and common salt. Its presence in brick-earth prevents bricks from being properly burnt. After the bricks have been burnt these salts recrystallise and appear as irregular and unsightly white patches on the surface of bricks. They cause the plaster and the surface of bricks to peel off layer by layer and to ultimately crumble away. Presence of reh or kallar in soil could be easily detected by the presence of efflorescence on the sides of fresh excavation, if the soil is moist.

2.5 FIELD TESTS FOR SOILS FOR BRICK MANUFACTURE

Soil to be tested is ground to a fine powder, mixed with sufficient quantity of water and kneaded into a plastic mass of required consistency. Balls of about 8 cm diameter are then moulded with hands and allowed to dry in the sun.

If the dry balls show deformation in shape and crumble easily on pressing the excessive sand content in the soil is indicated. If however, the sand content is deficient then the balls shall develop surface cracks on drying.

A second field test is performed by moulding bricks of standard sizes from well kneaded soil of plastic consistency which is capable of

*Article 2.18.

being rolled in threads of 3 mm in diameter. The edges and corners of such bricks should be sharp. These bricks are left to dry for four days in the sun and examined for shrinkage cracks.

2.6 PREPARATION OF BRICK-EARTH

Following are the various operations involved in preparing Brick-earth.

2.6.1. Digging. If the area from where soil is to be taken is grassy or has other vegetation then the top layer (about 20 cms deep) is excavated and thrown away as it contains roots of vegetation and other organic matter. The excavated lumps of soil are broken. It is ensured that the soil is free from gravel, coarse sand, lime and kankar particles, vegetable matter etc.

2.6.2. Weathering. Excavated soil, after the clods have been broken, is mixed with a little water and is left in heaps to weather for a period varying from a few weeks to as long as it can be left. This improves its plasticity and strength. To keep the soil wet water may be sprayed on the heap from time to time and the heap turned over.

2.6.3. Blending. The earth is then thoroughly broken and mixed with sandy soil *if needed*. The whole mass is thoroughly mixed up and reasonable amount of water is added if needed.

2.6.4. Tempering. Blended soil is kneaded under the feet of men or cattle after desired quantities of water have been added to it. The whole mass becomes homogeneous and plastic. It is then left covered with mats and allowed to dry gradually in layers about 30 cm thick for not less than 36 hours, till it is just soft enough for moulding. Pug mill, as described below, is used for tempering earth needed for the manufacture of bricks either on large scale or for use on superior works like arches and mouldings etc.

2.7 PUG MILL

It is a conical iron tub of the shape and size shown in Fig. 2.1. In the centre of the tub there is a vertical iron shaft. To this shaft are fixed a number of horizontal arms with several vertical cutting blades attached to each arm. The mill is sunk 60 cms deep in earth and fixed on a pair of square timbers 20 cm × 20 cm. The central vertical iron shaft is rotated by bullocks yoked at the end of a horizontal arm the other end of which is fixed to the top of shaft. The mill could, however, by worked by using steam, diesel or electric power.

Blended brick-earth along with the required quantity of water is fed in the mill from top. When the shaft rotates the cutting blades, fitted to horizontal arms, cut through the clay and break up all clods or lumps of clay. After the clay has been thoroughly *pugged* then it is

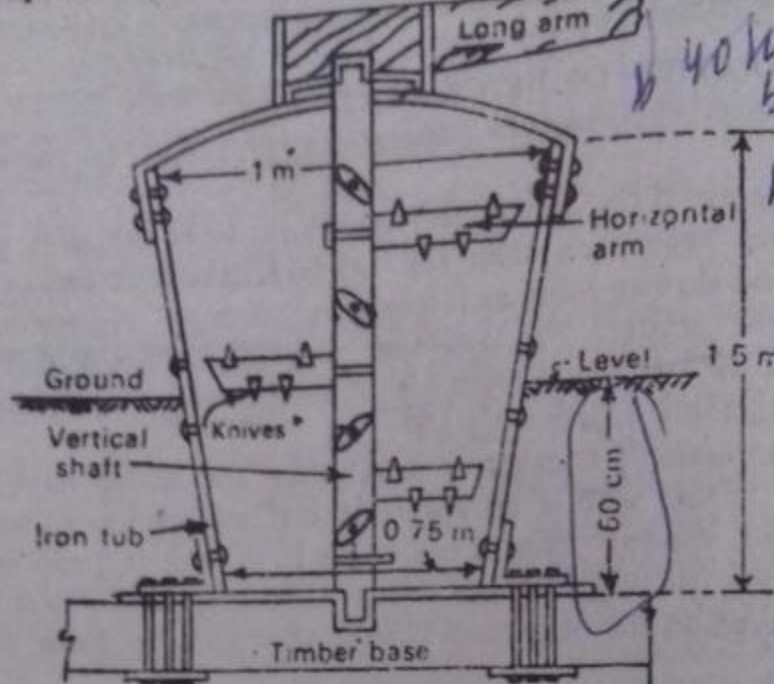


Fig. 2.1. Pug Mill.

taken out through an opening provided in the side near the bottom. A pug mill of the size shown yields sufficient earth for a daily output of approximately 15,000 bricks.

2.8 MOULDS

Moulds are rectangular boxes of wood or steel without top and bottom and the longer sides projecting a few centimeters to act as

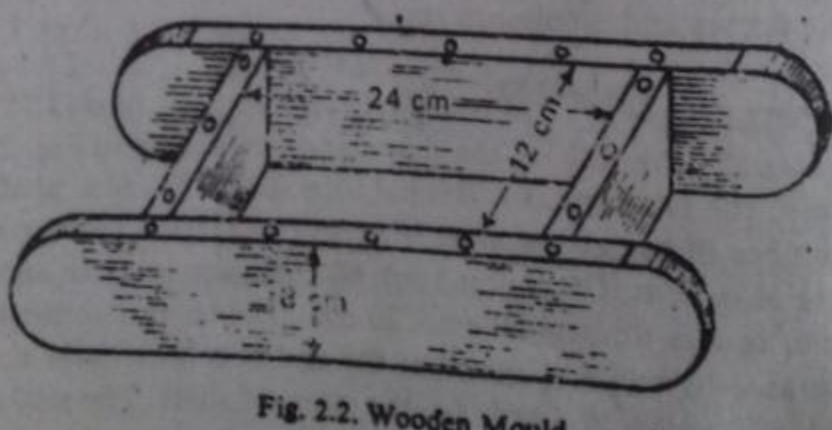


Fig. 2.2. Wooden Mould.

handles. The edges of the wooden moulds Fig. 2.2 should be protected with strips of brass or steel screwed on them. Only best seasoned wood should be used for making moulds. Steel moulds Fig. 2.3 keep their shapes and last longer than the wooden moulds and are used for heavy works. These prove to be ultimately cheaper than the wooden moulds.

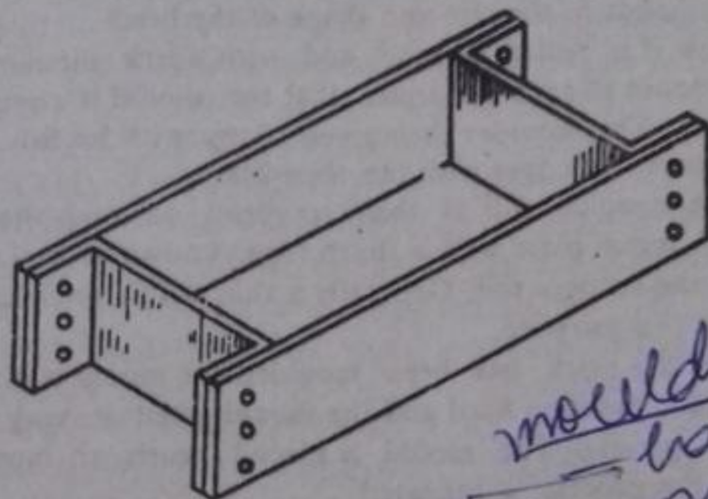


Fig. 2.3. Steel Mould.

Inside dimensions of the moulds are kept a little larger than the size of burnt brick (generally about 1/10th of the size of brick each way). It is done to allow for the shrinkage of the moulded brick on drying and burning. The exact allowance to be made for shrinkage can be ascertained by field tests.

2.9 MOULDING OF BRICKS

Giving the required shape to the prepared brick earth is known as moulding of bricks. There are two different ways of doing it: (*i*) Hand moulding and (*ii*) Machine moulding.

2.9.1. Hand moulding. Hand moulding of bricks is extensively used in India and the neighbouring countries. This could be done on ground or on table known respectively as *Ground moulding* and as *Table moulding*.

(*a*) *Ground moulding*. This method is adopted when a large and level area of land is available for the purpose. The area of land on which moulding is to be done is levelled, plastered smooth and sprinkled over with sand.

(*i*) To prevent the moulded bricks from sticking to the moulds either sand is sprinkled on the inner sides of the mould or the mould is dipped in water each time before moulding is done. When sand is used to prevent the sticking of earth to moulds the moulded bricks are known as *sand moulded* and if the mould is dipped in water each time before moulding a brick then the bricks are known as *slop moulded* bricks. Sand moulded bricks have better finish and sharper edges.

(*ii*) After either sprinkling sand on the inside of the mould or dipping the mould in water take a lump of well prepared earth, the volume of which is a little more than that of the brick. This lump is shaped in hands to the size and shape of the brick.

(*iii*) Now it is rolled in sand and with a jerk the lump is dashed into the mould in such a manner that the mould is completely filled with earth. The moulder then gives blows with his fists and presses in the corners and edges with the thumbs.

(*iv*) The surplus soil is then scrapped off and the top surface levelled. A metal plate with a sharp edge, known as *strike* is used for removing the surplus soil. Generally a thin wire stretched on a frame is used for this purpose.

(*v*) After the brick has been moulded the mould is given a gentle stroke with something hard and the mould lifted leaving the brick to dry on the ground. The mould is placed nearby to mould another brick and the process is repeated.

Bricks moulded directly on the ground have their lower faces

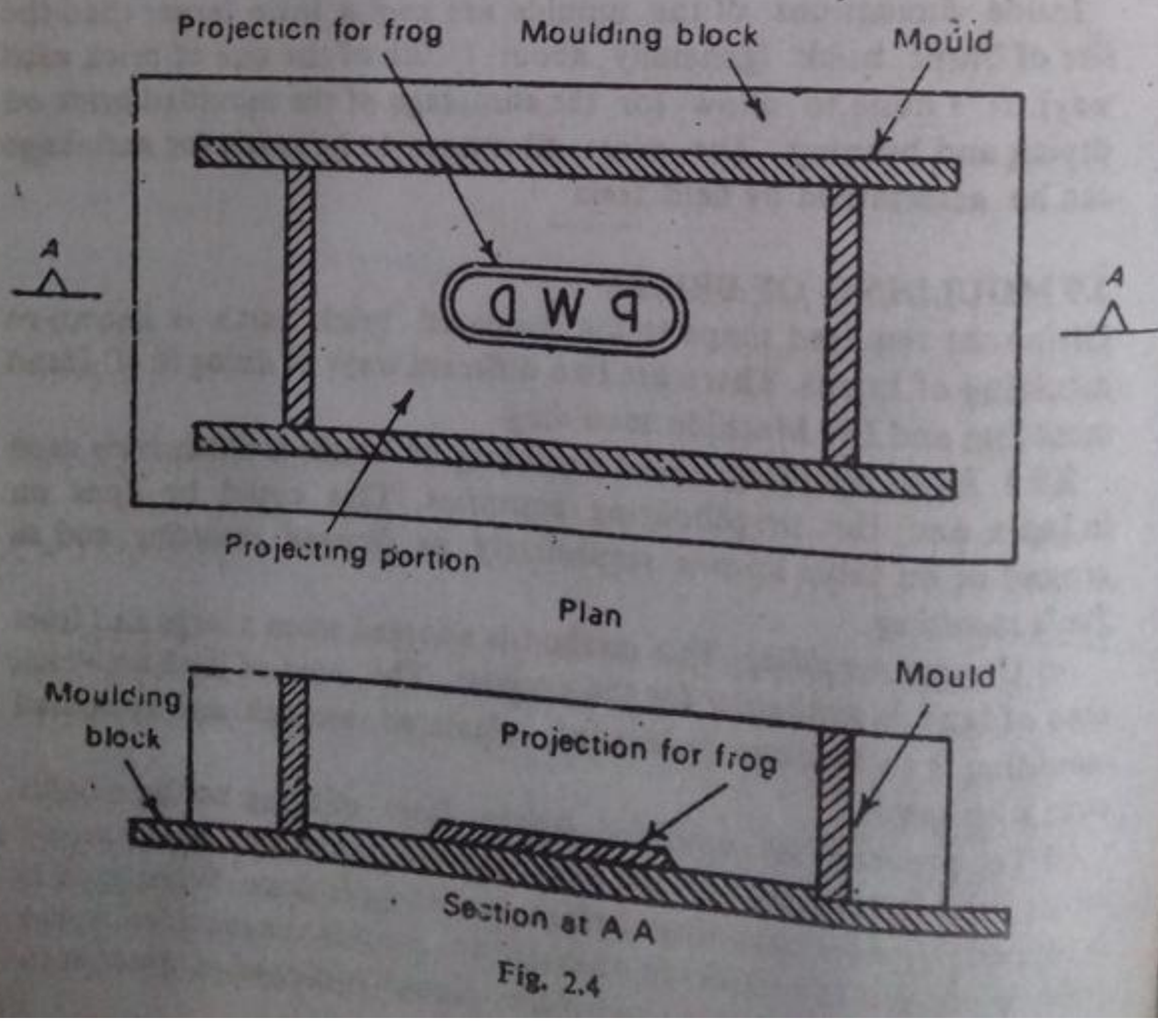


Fig. 2.4

objectionably rough and can have no *frog**. To avoid it bricks are moulded on a block of wood known as the moulding block, having a projection 0.5 cm thick and of same length and breadth as the inside of the mould (Fig. 2.4.) In this case the mould should be made 0.5 cm deeper than the thickness of brick. The mould is so placed on the moulding block that it closely fits round the projection. The projected portion is protected by means of metallic strips. To provide frog or any other impression on the finished brick a corresponding raised projection is provided on the projection itself as is clear from the figure. The clay is then filled in the mould as explained before and the brick is moulded. Then a thin flat board a little larger than the mould, known as the *pallet* is placed on the mould containing the brick. The moulder then lifts the mould containing the brick and sandwitched between the pallet and the moulding board, inverts it bringing the pallet below. He then removes the moulding board and the mould, leaving the brick on the pallet. Another pallet is then placed on the brick which is then carried between the two pallets to the drying site and laid on side. The next moulded brick is placed by its side and the process repeated. As the bricks in this method are not laid flat for drying, as in moulding directly on the ground, but on sides so lesser space is required for drying in this method. The bricks dry better and quicker, and also the faces are all smooth.

Table moulding. In it the moulder carries out the moulding of bricks on a table. He does so while standing by the side of the table (Fig. 2.5). He moulds bricks on boards known as *stock boards*. Stock boards are of the same size as the moulds and have a projection for the frog. Sand is sprinkled inside the mould and on the stock board. The mould is placed to fit the stock board and then filled with earth. Sufficient quantity of earth is dashed into the mould, pressed hard and the surplus earth is removed with a *strike* or a thin wire. A pallet is then placed on the mould. The mould containing the brick is then smartly lifted off the stock board and inverted so that the whole rests on the pallet. The mould is then given a gentle blow and lifted leaving the brick on the pallet. One more pallet is placed on the brick and it is carried to drying site between the two pallets. It is allowed to dry on side.

A moulder can mould between 500 to 1000 bricks per day.

2.9.2. Machine moulding. There are a variety of moulding

*Frog is an indentation provided in a face of the brick. It may carry the trade mark of the manufacturer. Bricks are laid in masonry with frog up. Frog provides a key for the mortar and holds the bricks on top firmly in place.

machines in use in the "West". Description of even the simplest of them is beyond the scope of this book. However, Central Building Research Institute, Roorkee has developed a hand operated brick moulding machine. Operational principle of these machines in brief is that after these have thoroughly pugged the soil and made a plastic

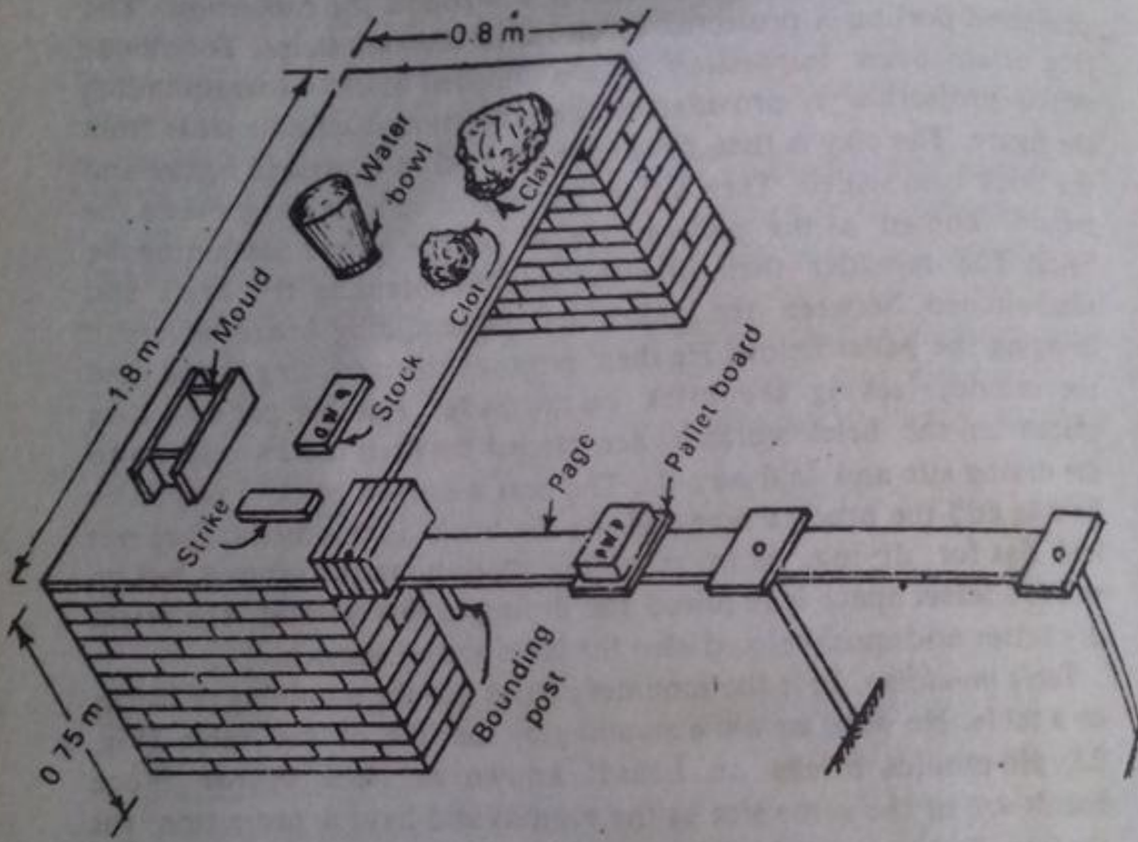


Fig. 2.5. Table Moulding of bricks.

mass of it then it is pushed under pressure through an opening whose length and breadth is equal to the length and breadth of the brick. This pushed out plastic band is cut to the desired thickness of bricks by wires fitted in a frame at distances equal to the brick thickness.

Such machines are common in "West" but are rarely used in India because of their initial high cost, cheap and plentiful availability of labour. These machines are capable of manufacturing large number of bricks quickly. Frog cannot be provided on machine moulded bricks.

2.9.3. **Pressed bricks.** These bricks are used when they are required for brick work of a high quality or for positions where they will be subjected to great pressures. These are made by subjecting moist powdered clay to a great pressure of about 40 kg/sq cm These bricks are stronger and are more compact than ordinary bricks. They do not require drying and can be burnt directly. They need careful burning otherwise they are likely to crack. These are heavier, stronger more impervious, have sharp arises, regular and smooth external surfaces. These can be provided with clean and distinct frogs.

2.10 DRYING

Before burning it is essential that the bricks have dried and have become sufficiently hard to be handled and stacked in clamps or kilns without getting damaged. Also if the bricks have not completely dried then they are likely to get cracked and distorted when burnt in the kiln.* The following points are kept in view to ensure successful completion of drying operation.

(*i*) As soon as the moulded bricks become dry enough so that they do not get damaged on handling they should be turned on edge and left for a day or two more to further harden. In the initial stages of drying bricks should be protected from severe sun and winds as otherwise rapid drying of bricks might result in their developing cracks.

(*ii*) They should then be stacked in such a way that each brick gets full circulation of air all around it. Best form of stack is of a breadth equal to two bricks laid longitudinally with intervals between them. (Fig. 2.6). The alternate layers being along and across the stack and all placed on edges.

(*iii*) The drying area should be higher than the surroundings so that it does not get flooded due to any occasional rain. (In India manufacture of bricks is usually suspended during monsoons). It should have a gentle slope to facilitate drainage of rain water.

(*iv*) A layer of sand should be spread at the drying area so as to keep it dry in wet weather.

(*v*) To protect the drying bricks from damage caused by occasional rains temporary bamboo frames and *sirki* should be provided. The *sirkis* should be weighed down with heavy planks to stop them from being blown away by winds. The height of stack may be of eight to ten layers of bricks.

A gap of about 1 metre should be left between adjacent stacks so as to facilitate free movement of workers.

*In India because of plenty of sunshine bricks are dried by the effect of sun and wind whereas in the "West" artificial methods are adopted for the purpose.

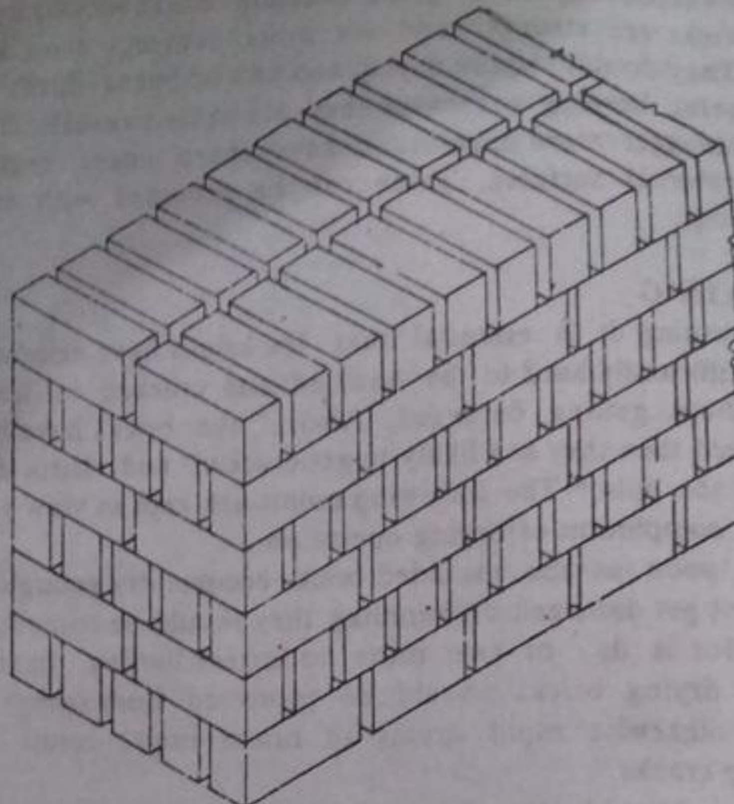


Fig. 2.6. Stack for drying of bricks.

Length and height of all the stacks should be kept the same. Every stack should contain bricks in multiples of a thousand. This shall make it easy to count the number of bricks.

Depending upon weather it takes three to eight days for bricks to thoroughly dry.

2.11 BURNING OF BRICKS

After the bricks have dried in sun these are burnt in kilns to make them harder, stronger, denser, less absorbent and consequently more durable. The bricks are burnt either in a: (*i*) *Clamp or Pazawah* or (*ii*) *Kiln*—(*a*) *Intermittent*, (*b*) *Continuous*. Working of each one of them is described below.

2.11.1. Clamp or Pazawah. Basic working remaining the same there are various variations of it in use in different parts of India. Below is given a description of the one in common use in Northern India:

A trapezoidal floor is prepared slopping upwards at an angle of 15° (Fig. 2.7). The shorter end is slightly in excavation while the wider end is raised a little above the ground. The sides in excavation and opposite to it are parallel, the one in excavation being about half as long as the wider one.

A layer of fuel consisting of grass, cowdung and litter, about 75 cm thick is laid on the floor. On it four or five courses of bricks

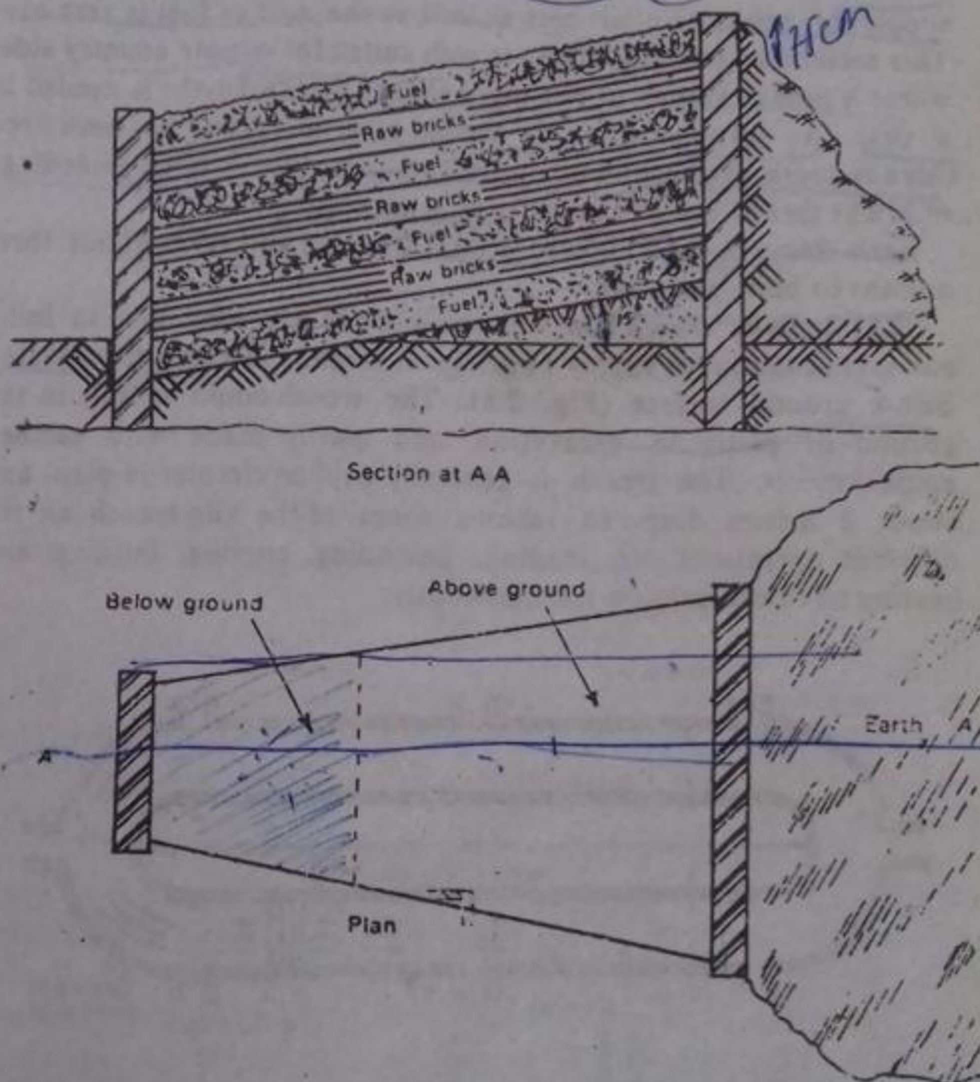


Fig. 2.7. Clamp or Pazawah.

are arranged on edge with small spaces all around each one of them. A second layer of fuel followed by another four to five courses of bricks on edge are laid and so on. The thickness of fuel layer goes on decreasing towards the top. The clamp is fired at the lower end at bottom when about one-third of it has been loaded. Further loading continues. It is done so that the lower portion is fired when spaces for upward draught are still open. When the loading is completed the whole of clamp is plastered over with mud so as to check the loss of heat. It is then left to burn itself and then to cool. Wood or coal dust could also be used as fuel in clamps.

When the clamp has cooled down, it is unloaded and then it is reloaded as before and refired. It thus clearly gives intermittent supply of bricks. Initial cost as well as the cost of fuel is very low. This method of burning bricks is well suited for remote country side where a limited supply of not more than 1,00,000 bricks is needed at a time. As no supervision is needed after the clamp has been fired there is consequent economy in its operation too. A large percentage of bricks turned out of clamps is of a poor quality.

Each clamp burns 25,000 to 1,00,000 bricks and takes about three months to burn and cool.

2.11.2. Bulls' trench kiln. It is the most widely used kiln in India and gives continuous supply of bricks. It is made in a trench excavated below ground surface (Fig. 2.8). The trench could be fully in the ground or partly in excavation and partly made with earthen embankments. The trench is generally oval or circular in plan and about 2 metres deep. In various zones of the kiln trench all the different operations *viz.* loading, unloading, cooling, burning and heating of bricks goes on simultaneously.

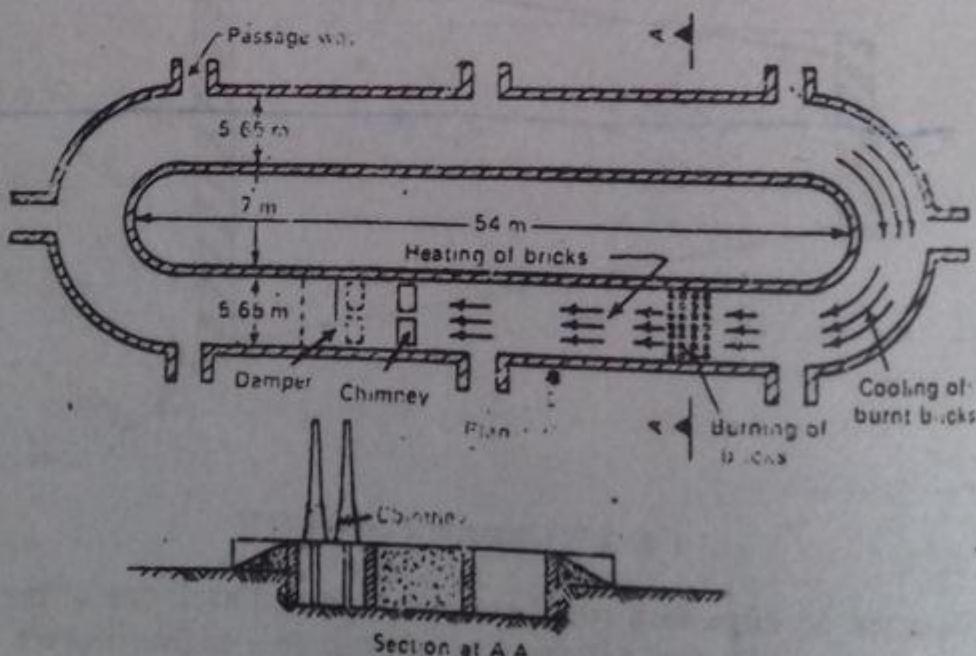


Fig. 2.8. Bulls' Trench Kiln.

As per Fig. 2.9 assume the following to be the sequence operations at some stage:

Zone 1—Burnt bricks being cooled.
Zone 2—Bricks being burnt.

Zone 3—Loaded sundried bricks are being heated by hot air from zone 2.

Zone 4—Fresh sundried bricks being loaded.

Zone 5—Cooled bricks being unloaded.

The whole working is so arranged that operations in all the zones are completed simultaneously. At this stage, the operational cycle shifts by one stage. Instead of in Zone 1 cooling of burnt bricks starts in Zone 2, burning of bricks in Zone 3 instead of in Zone 2; heating of loaded sundried bricks in Zone 4 instead of in Zone 3; loading of fresh sundried bricks in Zone 5 instead of in Zone 4 and unloading of cooled bricks in Zone 1 instead of in Zone 5.

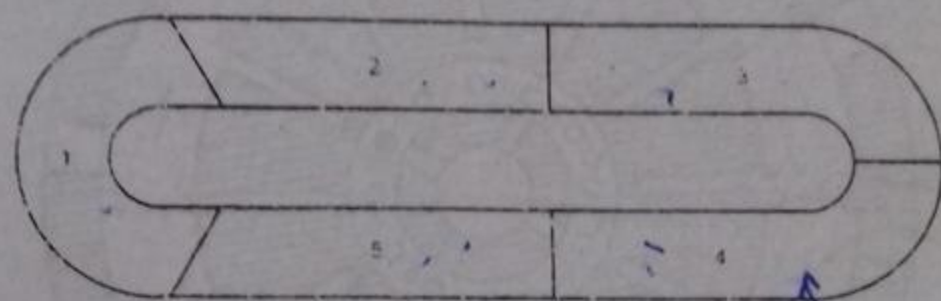


Fig. 2.9

This cycle of operations continues whereby we get regular supply of bricks. While loading, sundried bricks are so stacked in the kiln as to leave spaces around each brick. Vertical flue holes, to feed fuel to the fire burning at the bottom, are provided at about one metre intervals. The kiln is loaded in section about 3.5 metre long with a clear space of 15 cm between the section over which two draught chimneys are provided. After a section of the kiln has been loaded, it is covered over with earth and ash to prevent the loss of heat. Even the flue holes are closed after the fuel has been fed to the fire.

Draught of fresh air is admitted to the zone where the bricks are being cooled. In cooling the bricks the air gets heated. It is this hot air that helps burning of bricks. Hot air from burning zone passes through the next zone when the bricks to be burnt are heated. In heating the freshly loaded bricks the hot air gets cold when it escapes through the chimneys.

When the heated bricks are fired then chimneys are shifted to the next zone. The chimneys go on being shifted as the burning operation progresses. Each section takes one day to burn.

Advantages. (*i*) It gives a continuous supply of bricks.

(*ii*) It gives a high percentage of first class bricks.

(*iii*) It saves cost of fuel as the hot gases from the burning zone heat the bricks to be burnt next, before escaping through the chimneys.

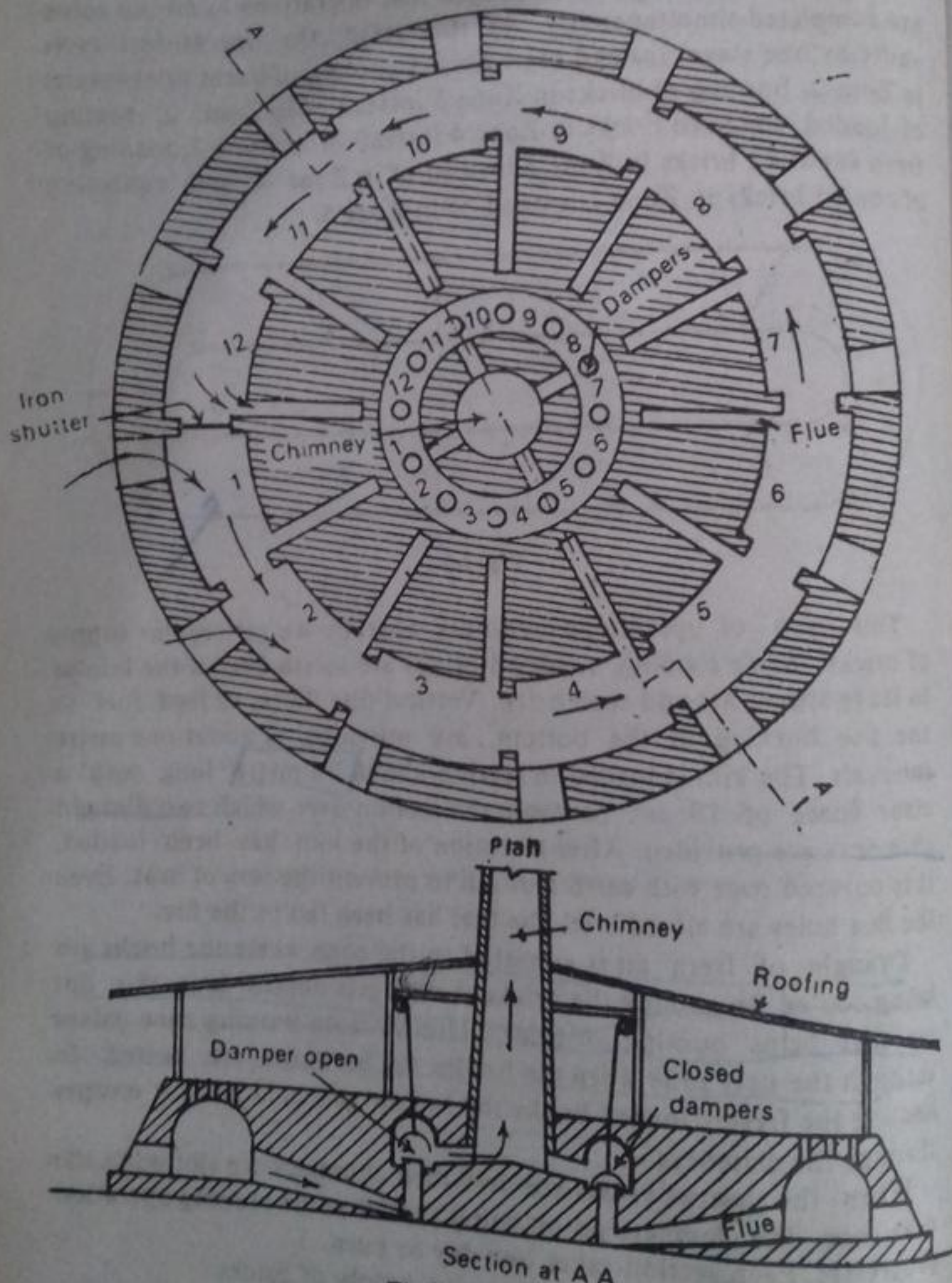
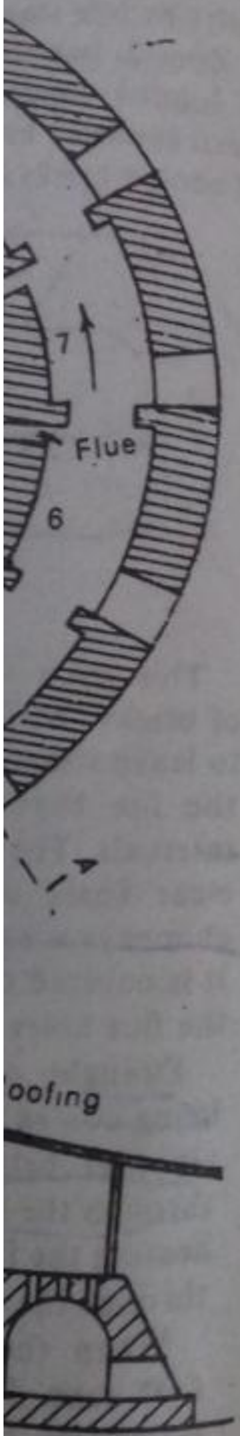


Fig 2.10. Hoffman's Kiln.

the burning zone
ping through the



(*iv*) Drying space is saved as even raw bricks can be loaded in it which are dried before being burnt by hot air coming from burning zone.

Disadvantages. (*i*) It needs constant skilled supervision.

(*ii*) Its initial cost is high.

2.11.3. Hoffman's kiln. It is a continuous kiln and has a permanent roof as a result of which it can function even during rains. It is circular in plan and is built above ground. It has a fixed chimney at the centre around which the kiln is divided into 12 chambers in a ring. Each chamber has a door communicating with the outside and a flue leading to the chimney. The door could be closed with dry brick wall having sand packing. The flue could be closed or opened as desired by operating a metal plate known as *damper*.

Air enters the kiln through doors 1 and 2 as shown in Fig. 2.10. While passing through the burnt bricks in chambers 1 to 4, it cools them and gets heated in turn. This hot air then passes through chambers 7 to 10 heating the bricks to be burnt. The iron shutter at the end of chamber 10 is closed and the flue number 10 is open through which the hot air, which has now cooled down while heating the bricks in chamber 7 to 10, escapes through the chimney. Bricks in chamber number 11 are being loaded whereas those in chamber number 12 are being unloaded. When chamber number 11 has been loaded then the iron shutter is shifted to the end of chamber number 11 and also flue number 11 is opened after closing flue number 10. The whole cycle of operations has thus move . one step forward and this process continues.

Fuel is fed through fuel holes provided for the purpose. In this kiln great economy in the use of fuel is effected and at the same time percentage of first class bricks obtained is higher than those from any other kiln. Also as in Bull's trench kiln raw bricks can be loaded in this kiln which saves the drying space. Its initial cost of construction is high. A chamber 11 metre long 4.5 metre wide and 2.75 metre high is capable of yielding 25,000 bricks/day.

Advantages. (*i*) Working of the kiln is not interrupted by even rains.

(*ii*) Fuel consumption is low as hot gases are utilized to dry and heat raw bricks.

(*iii*) Percentage of first class bricks obtained from the kiln is fairly high.

(*iv*) Space and time are saved in drying as raw bricks are directly loaded into the kiln.

Disadvantages. (*i*) Initial cost is very high.

(*ii*) Highly skilled labour is required to operate it.

2.12 MERITS AND DEMERITS OF CLAMP AND KILN BURNING OF BRICKS

S.N.	Points of comparison	Clamp burning	Kiln burning
1.	Nature	It is a temporary structure.	It is a permanent structure.
2.	Initial cost	Initial cost is low.	Initial cost is high.
3.	Fuel cost	Least if fire wood, straw, cowdung and litter are used.	It is generally high as coal dust is used.
4.	Supervision	Once fired no more supervision is needed.	Constant skilled supervision is necessary throughout.
5.	Percentage of Ist class bricks	Percentage of Ist class bricks turned out is the least and the quality of bricks is poor. On an average 60% bricks are first class.	On an average 90% of the out-turn is first class bricks. Quality of bricks turned out is good.
6.	Regulation of fire	Fire once started cannot be regulated. Care should be taken to put only perfectly dry bricks in clamps as otherwise sudden application of heat is likely to warp them.	Fire always remains under control and can be regulated. Even moist raw bricks can be burnt safely.
7.	Time for burning and cooling	Depending upon the size it takes 3-6 months to burn and cool the bricks.	Actual time for firing is 24 hours and time for cooling is 12 days. As the bricks are burnt daily so a continuous daily supply is assured.
8.	Out-turn	It is used when a small number of bricks are required at a time. Each clamp turns out about one lac bricks at a time.	It is used when a continuous supply of a large number of bricks is required at a time. These yield about 25,000 bricks per day.
9.	Wastage of heat	There is no arrangement for utilising the heat from hot gases. Much heat is wasted from top and sides.	Heat of hot gases is utilized in heating bricks to be burnt. There is no wastage of heat either from top or from sides.

2.13 COMPARISON OF BULL'S TRENCH KILN WITH HOFFMAN'S KILN

S.N.	*Points of comparison*	*Bulls trench kiln*	*Hoffman's kiln*
1.	Initial cost	It is lesser.	It is higher..
2.	Cost of fuel	Consumption of fuel is more.	Consumption of fuel is lesser.
3.	Quality of bricks turned out	Percentage of first class bricks turned out is lesser.	Percentage of first class bricks turned out is higher.
4.	Continuity of working	During monsoons it stops working.	It works all the year round as it is covered.
5.	Drying Space	It requires more drying space.	It requires lesser drying space.
6.	Popularity	As the building activity slackens during rainy season and the land for drying bricks is cheaply available so this Kiln is more popular because of lesser initial investment required.	Because of higher initial investment required and the comparative advantages being of not much relevance this Kiln is not much popular in India.
7.	Type	It is semi-continuous.	It is of continuous type.

2.14 QUALITIES OF GOOD BRICKS

Bricks required for use in important buildings should have the characteristics and essential features of first class bricks as detailed below:

(*i*) These should be sound and well burnt bricks having uniform red colour.

(*ii*) These should have even surfaces free from flaws or cracks and should have sharp and well defined edges.

(*iii*) These should give clear ringing sound when struck against each other.

(*iv*) These should be so hard that no impression should be left when scratched with finger nails.

(*v*) No brick should absorb more than 15 per cent of its weight of water when kept immersed in it for 24 hours.

(*vi*) No brick should have a crushing strength less than 55 kg/sq cm.

(*vii*) On breaking the surface should show a bright homogeneous and compact surface free from voids or grit.

(*viii*) A brick soaked in water for 24 hours should not show deposits of white salts on drying in shade.

2.15 FIRE BRICKS OR REFRACTORY BRICKS

These bricks are capable of withstanding very high temperatures without melting or becoming soft. A fire clay must as such be free from iron oxide, free lime or any other such substance that causes the early fusion of bricks.

Fire bricks are of white or yellowish white colour and are used for lining the interiors of fireplaces, ovens, kilns, chimneys and furnaces. In laying fire bricks only fireclay should be used as mortar as the ordinary mortars made of lime or cement shall not be able to withstand high temperatures and shall thus disintegrate.

Fire bricks are manufactured in exactly the same manner as the ordinary bricks. The clay is dug out, broken, weathered, blended and tempered. It is then intimately mixed in pug mill. Then it is moulded, preferably with machines, to the shape and size needed. After drying these are then burnt in kilns at temperatures ranging from 1350°C to 1900°C. The heating and cooling has to be done slowly.

Fire clay is found under the seams of coal in the coal fields of Raniganj and Raj Mahals (Bihar). It contains nearly pure hydrated silicate of alumina. The greater the percentage of alumina in proportion to silica the more it shall withstand the higher temperature without disintegrating or softening. Usual composition of good fire clay is: Silica 56 to 96 per cent. Alumina 2 to 36 per cent, Iron Oxide 2 to 5 per cent and Lime, Magnesia, Potash and Soda 1 to 2 per cent.

2.16 SIZES AND WEIGHTS OF BRICKS

The Indian Standards Institution, New Delhi has specified standard bricks of 19 cm × 9 cm × 9 cm with 1 cm thick mortar joints (the size of brick with mortar joints becomes 20 cm × 10 cm × 10 cm). Brick tiles should be 19 cm × 9 cm × 4 cm in size.

The minimum compressive strength of the standard brick has been specified as 35 kg/sq cm, however, different state PWD's have adopted different sizes. A few of them are given below:

In UP: Brick size 24 cm × 11.4 cm × 7 cm
Number of bricks used per cubic metre of masonry—476.

In Punjab PWD: Brick size 23 cm × 10.8 cm × 7 cm
Number of bricks required per cubic metre—536.

In Punjab Irrigation: Brick size 22 cm × 11 cm × 7 cm
Number of bricks used per cubic metre—560.

Bricks should be of such size that it could be easily burnt to the core and its weight should be such that the mason could conveniently lift and place it with one hand without fatigue.

In general the length of brick should be twice the width plus the thickness of one mortar joint.

2.17 TESTS FOR BURNT CLAY BRICKS

Burnt clay bricks are subjected to the following tests as per IS 3495-1976.

2.17.1. Test for compressive strength. Grind the two bed faces to provide smooth, even and parallel faces. Immerse the specimen in water at room temperature. Remove the specimen from water after 24 hours and drain out any surplus water at room temperature. Fill up flush the frog and all voids with cement mortar (1 part cement and 1 part clean coarse sand of grade 3 mm and down), store under damp jute bags for 24 hours and then immerse in clean water for 3 days. Remove and wipe out any traces of moisture.

Place the specimen between two three plywood sheets, each 3 mm thick, with flat faces horizontal and mortar filled face facing upwards. The specimen sandwiched between the plysheets are carefully centred between plates of compression testing machine. Apply axial load at a uniform rate of 140 kg/cm² per minute till failure. The maximum load at failure divided by the average area of the bed faces gives the compressive strength.

2.17.2. Test for water absorption. There are two tests to determine the water absorption, per cent by mass, for common burnt clay bricks *viz.*, 24 hours immersion cold water test and the five hour boiling water test. Each one of these is described below.

(*a*) *24 hour immersion cold water test*. Dry specimen is put in an oven maintained at a temperature of 105 to 115°C, till it attains substantially constant mass. Weight of specimen (W_1) is recorded after cooling it to room temperature. The dry specimen is then immersed completely in water at a temperature of 27±2°C for 24 hours. Take the specimen out of water and wipe out all traces of water with damp cloth. Complete weighing of the specimen 3 minutes after the specimen has been removed from water. Let this weight be (W_2).

Water absorption per cent by mass, after 24 hours immersion in cold water is given by the relation:

$$\frac{W_2-W_1}{W_1}\times 100$$

(*b*) *Five-hour boiling water test*. The specimen is dried in an oven at 105 to 115°C till it attains constant mass. Cool the specimen at room temperature and record its weight (W_1). Now immerse the specimen into a tank of water in such a way that water can circulate all around the specimen. Stir the water off and on so that any air inside it is removed. Heat the water at such a rate that it starts boiling in an hour. Continue to boil it for five hours. Then allow it to cool to 27±5°C by natural loss of heat for 16 to 19 hours. Take the specimen out of water, let the water drain out completely and wipe it with damp cloth. Complete the weighing of the specimen in three minutes (W_3).

Water absorption, per cent by mass, is given by the relation:

$$\frac{W_3-W_1}{W_1}\times 100$$

2.17.3. Test for efflorescence. Place on ends the bricks in 25 mm depth of water in a dish of minimum diameter 150 mm and depth 30 mm. The dish is made of glass, porcelain or of glazed stone work. The experiment is performed in a well ventilated room (at 20 to 30°C) till all the water in the dish is either absorbed by the specimen or is evaporated. After the specimen have dried add similar quantity of water to the dish and let it too be absorbed by the specimen and evaporate as before. Examine the specimen for efflorescence after the second evaporation. Presence of efflorescence shall be classified as *nil*, *slight*, *moderate*, *heavy* or *serious* as defined below:

(*i*) *Nil*. When the deposit of efflorescence is imperceptible.

(*ii*) *Slight*. When the deposit of efflorescence does not cover more than 10 per cent of the exposed area of the brick.

(*iii*) *Moderate*. When the deposit of efflorescence is heavier than *slight* and does not cover more than 50 per cent of the exposed area of the brick surface. The deposit should not, however, powder or flake of the surface.

(*iv*) *Heavy*. When the deposit of efflorescence salts is heavy and covers 50 per cent or more of the exposed area of brick surface. The deposit, however, does not powder or flake of the surface.

(*v*) *Serious*. When the deposit of efflorescence salts is heavy and is accompanied by powdering and/or flaking of the exposed surfaces.

2.18 DIFFERENT FORMS OF BRICKS

Below are described a few important forms in which bricks are made in various shapes to suit the different situations in which they are used.

2.18.1. Ordinary bricks. These are ordinary bricks with rectangular faces and of standard size.

2.18.2. Perforated bricks. These bricks have cylindrical holes through their thickness (Fig. 2.11). It is done by pushing iron bars through the brick at the time of moulding. The advantages and disadvantages of having such bricks are as follows:

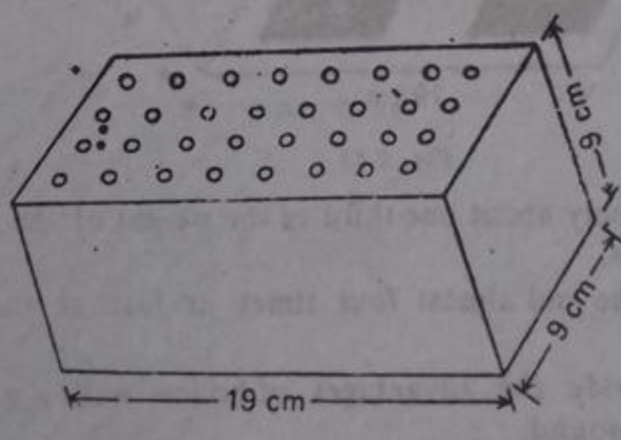


Fig. 2.11

Advantages. (*a*) These dry and burn more easily and quicker as the hot gases can penetrate them.

(*b*) Because of reduced weight these are easier to handle.

(*c*) Because of saving in clay more bricks can be cast out of the same quantity of earth.

Disadvantages. (*a*) These transmit sound quicker.

(*b*) These are unfit to be used in hydraulic structures.

2.18.3. Hollow bricks or **Cavity bricks.** Volume of solid material in them should not be less than one-half of its gross overall volume. No web should be less than 1.5 cm thick (Fig. 2.12 and 2.13). Hollow bricks have the following advantages over ordinary bricks.

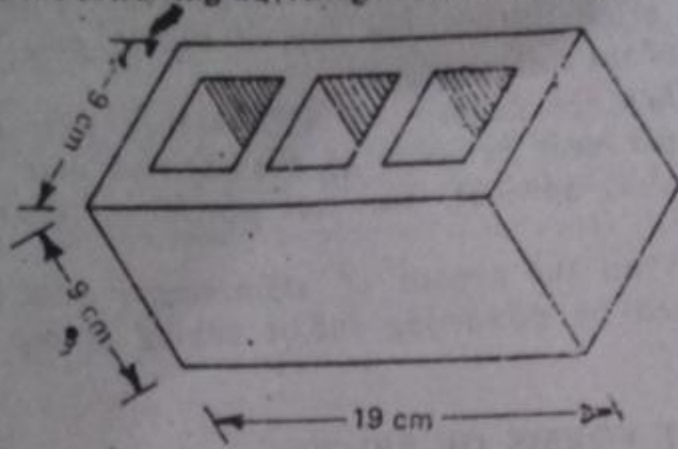


Fig. 2.12.

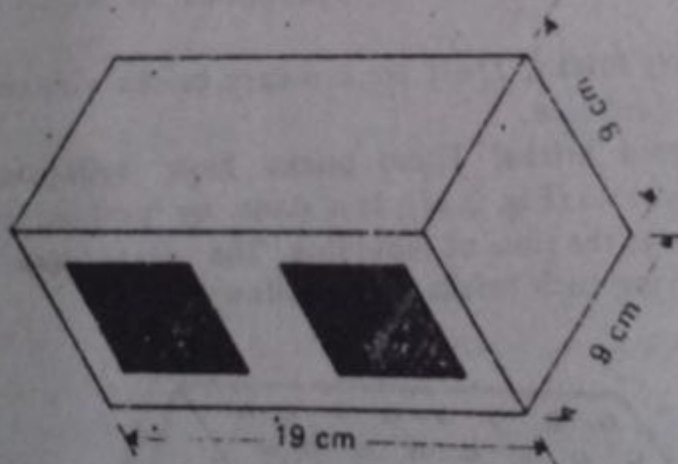


Fig. 2.13

(*a*) These are only about one-third of the weight of the same size of ordinary bricks.

(*b*) These can be laid almost four times as fast as the ordinary bricks.

(*c*) These provide the advantages of hollow walls *e.g.*, insulation against heat and sound.

(*d*) These are sufficiently strong for all purposes except for concentrated loads. These are ideally suited for the construction of non-load bearing (*partition*) walls.

2.18.4. Splay, Cant or Plinth bricks. These have a bevel taken off on one side as shown in Figs. 2.14 and 2.15. These are used in door and window jambs and in plinths. The splay could be on the header or on the stretcher as shown.

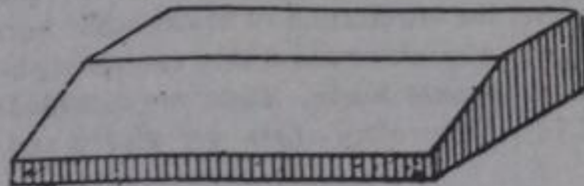


Fig. 2.14

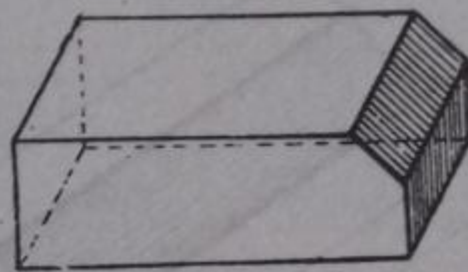


Fig. 2.15

2.18.5. Coping bricks. These are of different shapes and sizes to suit various conditions of use. These are used as topmost course on parapets and their shapes are so made as to expeditiously drain off rain water from the top of parapets. When projecting the undersides of the projecting portions are provided with throats so as to throw the rain water off the faces of walls. One such type is shown in Fig. 2.16.

2.18.6. Bull-nosed bricks. These are used to round off sharp corners (Fig. 2.17.).

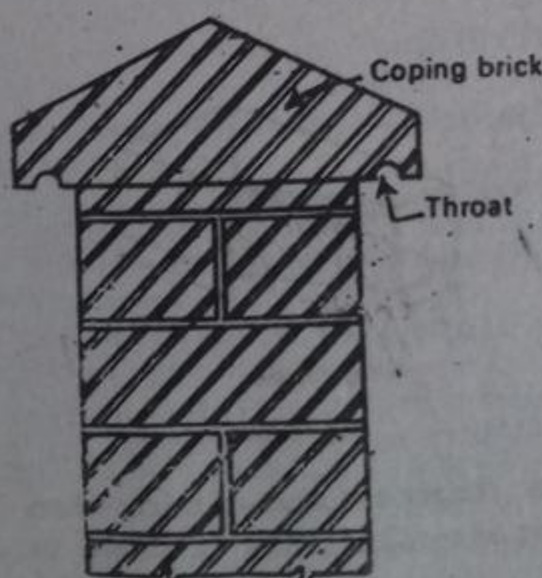
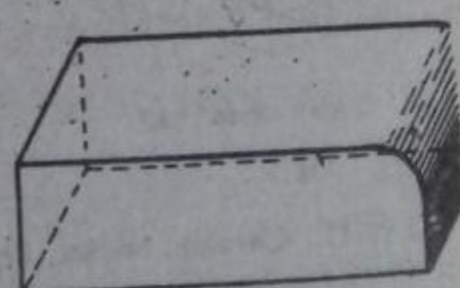


Fig.216.



Bull-nosed brick

Fig. 2.17

moulded to the exact wedge like shape required. Such bricks are known as arch bricks or voussoirs.

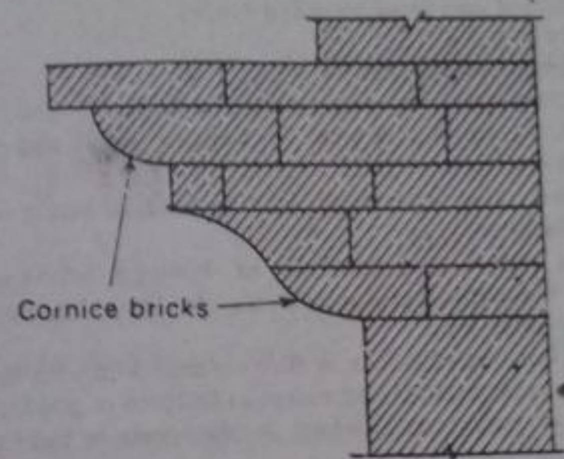


Fig. 2.21. Cornice brick.

2.18.13. Circle bricks. These are bricks made to the exact curve of the desired circle and are used in the construction of circular walls for circular towers and wells etc. While ordering such bricks the radius should always be specified.

2.18.14. Purpose-made bricks. These are bricks of special shape and size made to suit a particular requirement. These are generally more costly than the ordinary bricks but ensure quicker and cleaner construction as no cutting to shape is involved. Also as the surface skin of the brick is left intact so it can withstand weather far better than those bricks that have been cut to the shape required.

EXERCISES

1. What are the classifications of bricks? Discuss the characteristics and uses of each one of them.
2. Describe the characteristics *and uses* of all the three classes of bricks.
3. Describe the characteristics and essential features of good quality bricks.
4. Discuss the relative advantages and disadvantages of bricks as compared with stones as a building material.
5. Write an account of the composition of good brick earth describing the effects and properties of the constituents.
6. What are requirements of soil suitable for burning bricks?
7. (*a*) Enumerate briefly the harmful ingredients you would care to eliminate while choosing earth for making bricks.

   (*b*) Give specifications for first class brick.
8. Describe, giving sketch, the preparation of brick-earth in a Pug-mill.
9. Describe the process of moulding, drying of bricks and burning of bricks in a kiln.

10. Describe the various methods of moulding bricks in India.

11. Write short notes on:

(*i*) Table moulding of bricks.

(*ii*) Refractory bricks.

(*iii*) Slop moulded and Sand moulded bricks.

(*iv*) Pressed bricks.

(*v*) Machine moulding of bricks.

12. What is the purpose of providing *Frog* in a brick.

13. Name the kilns commonly used for burning bricks and describe any one type of continuous kilns.

14. Describe briefly the method of manufacture of bricks using continuous kiln, with suitable sketches.

15. Compare the merits and demerits of burning bricks in clamps and in kilns. Describe fully the method you would use for burning one lac (1,00,000) bricks in a remote country side.

16. Compare the burning of bricks in Bull's trench kiln with Hoffman's kiln

17. Describe the characteristics and essential features of good quality bricks.

18. Explain the various tests to which a brick may be put before using it an important work.

19. What is efflorescence in bricks? What are its causes and remedies?

20. Describe the various tests of bricks as per IS standards.

TILES AND TERRA COTTA

3.1 TILES

Tiles are thin slabs used for covering roofs, for flooring or for making drains and may be formed of: (*a*) Brick earth burnt in kilns, and (*b*) Concrete.

Brick earth used for manufacturing brick tiles is more pure and is prepared more thoroughly than the one used for manufacturing bricks. Tiles, being thinner require careful burning.

3.2 DIFFERENT KINDS OF TILES

Mainly there are three kinds of tiles: (*i*) roofing tiles, (*ii*) flooring tiles or paving tiles, and (*iii*) drain tiles. Important varieties of each one of these are discussed below:

3.2.1. Roofing tiles. These may be flat like slates or may be made to different shapes. Some of the common varieties are discussed below:

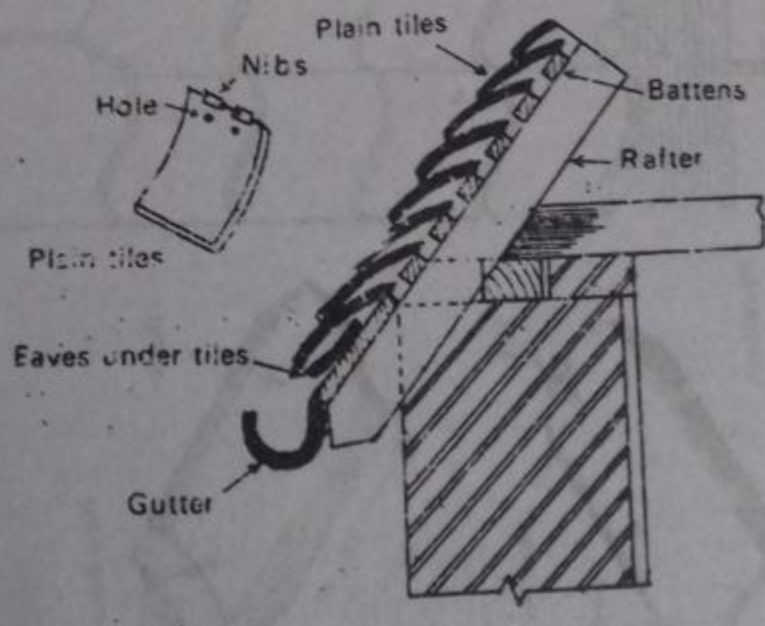
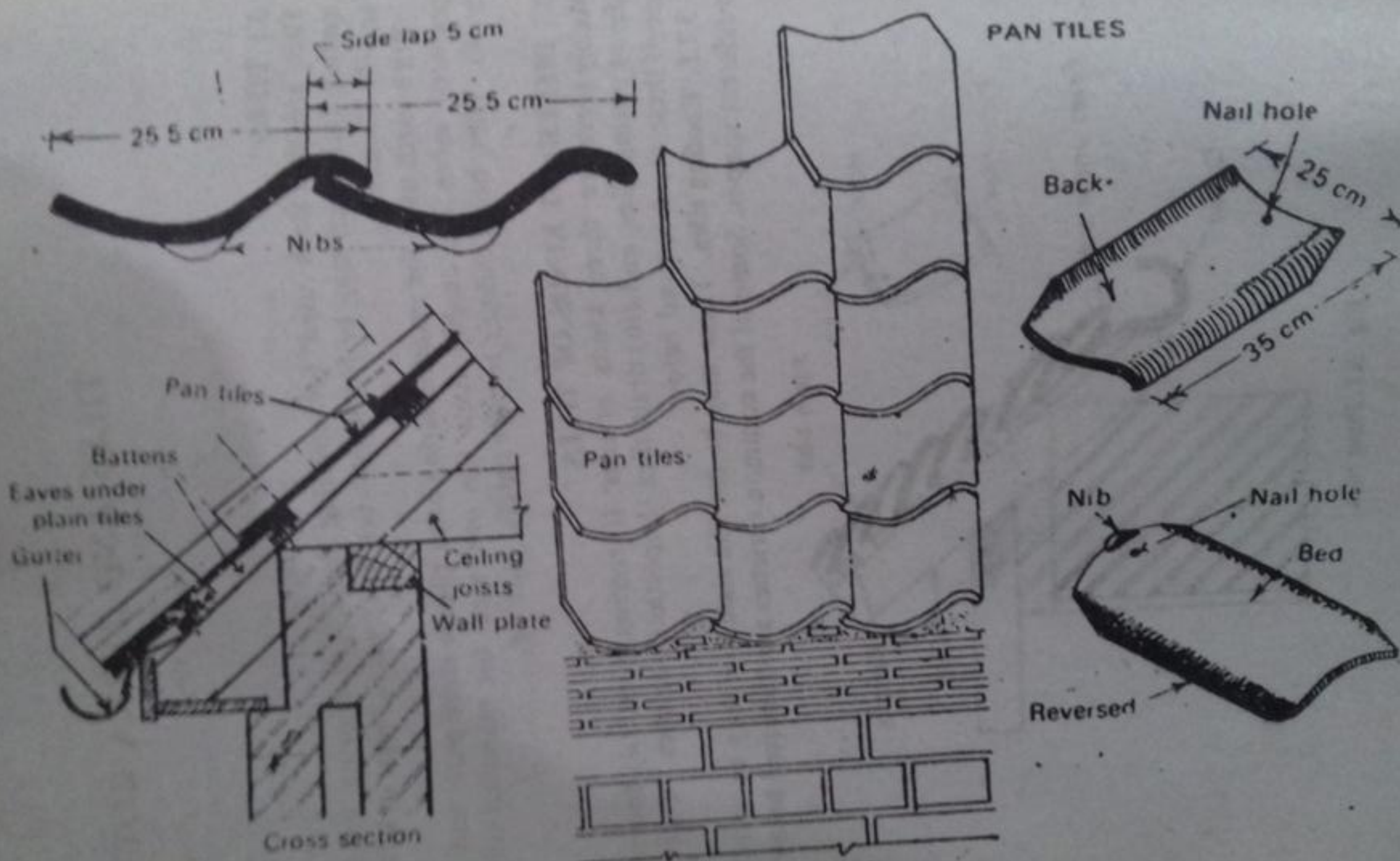


Fig. 3.1. Plain tiles.

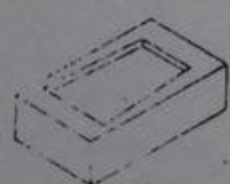


PAN TILES
Side lap 5 cm
25.5 cm
25.5 cm
Nibs
Pan tiles
Battens
Eaves under plain tiles
Gutter
Ceiling joists
Wall plate
Cross section
Pan tiles
Front elevation
Nail hole
Back
25 cm
35 cm
Nib
Nail hole
Bed
Reversed

Fig. 3.2

3.2.2. Plain tiles. (Fig. 3.1) measure about 25 cm × 15 cm to 28 cm × 18 cm and from 10 mm to 17 mm thick. These may have a continuous projection at one end or two small projecting *nibs* (as shown). These nibs should not be less than 2 cm wide and 1 cm deep. Camber should be between 5 mm and 10 mm for hand made tiles. The camber could be reduced for machine made tiles.

3.2.3. Pan tiles. The tiles, as shown in Fig. 3.2 are curved in section. These are 33 cm to 38 cm long and 23 cm to 28 cm wide. Implements needed for its moulding are a mould, a horse, a bow and a strike (Figs. 3.3 to 3.6). For moulding *pan tiles* a ball of prepared clay is pressed well to fill all corners of the mould. All surplus earth is cut with the bow and removed. Strike is then passed over the wet top of tile in mould. It is done so many times as to render the top surface of tiles smooth. The tile is then carefully removed and placed over an already burnt tile to dry. After the tile has dried *a little* it is then placed on the curved top of *horse* and pressed with hand to make it curved. After another five to six hours the raw tile is once again shaped on the *horse* and its edges trimmed with a sharp knife. To stop the clay from sticking to the *mould* or *horse* their top is sprinkled over with *ash* every time before use.

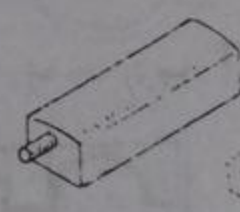


Mould for pan tile

Fig. 3.3

Bow

Fig. 3.4



Horse

Fig. 3.5

Strike

Fig. 3.6

3.2.4. Pot tiles. These are semi circular in section and taper along the length (Fig. 3.7). Diameter at larger end is about 23 cms and at the smaller end it is about 20 cms. Rows of these tiles are laid with the concave side up. Then rows of same tiles with convex sides up are laid to cover the adjoining edges of every pair of the previously laid tiles.

3.2.5. Allahabad tiles. These consist of two sets of tiles. The lower ones are flat tiles with upturned sides. End widths reduce from 27 cm to 23 cm and the length is about 38 cm. The over tile is half round in section and tapers from 16.5 cm to 12 cm in diameter. Taper allows the tile in the next course to fit in (Fig. 3.8). Half round tiles are moulded on a potter's wheel as a round tapering cylindrical tile. Two longitudinal cuts are given to the cylinder while still not dry. With this it is easy to break it into two semi circular tiles after burning.

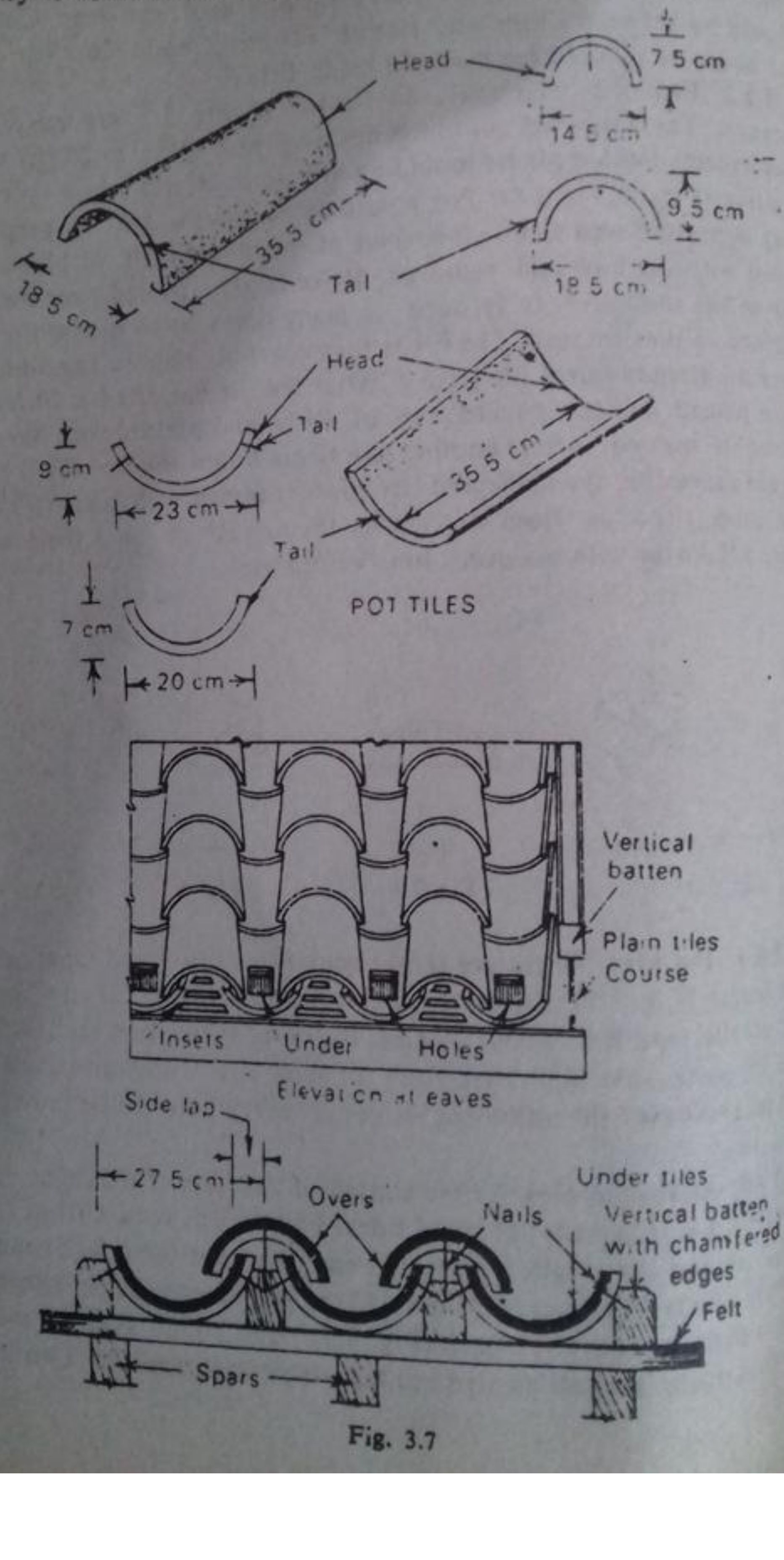


Fig. 3.7

3.2.6. Mangalore tiles. These are flat pattern tiles with suitable key projection. About 16 tiles are required to cover one square metre of

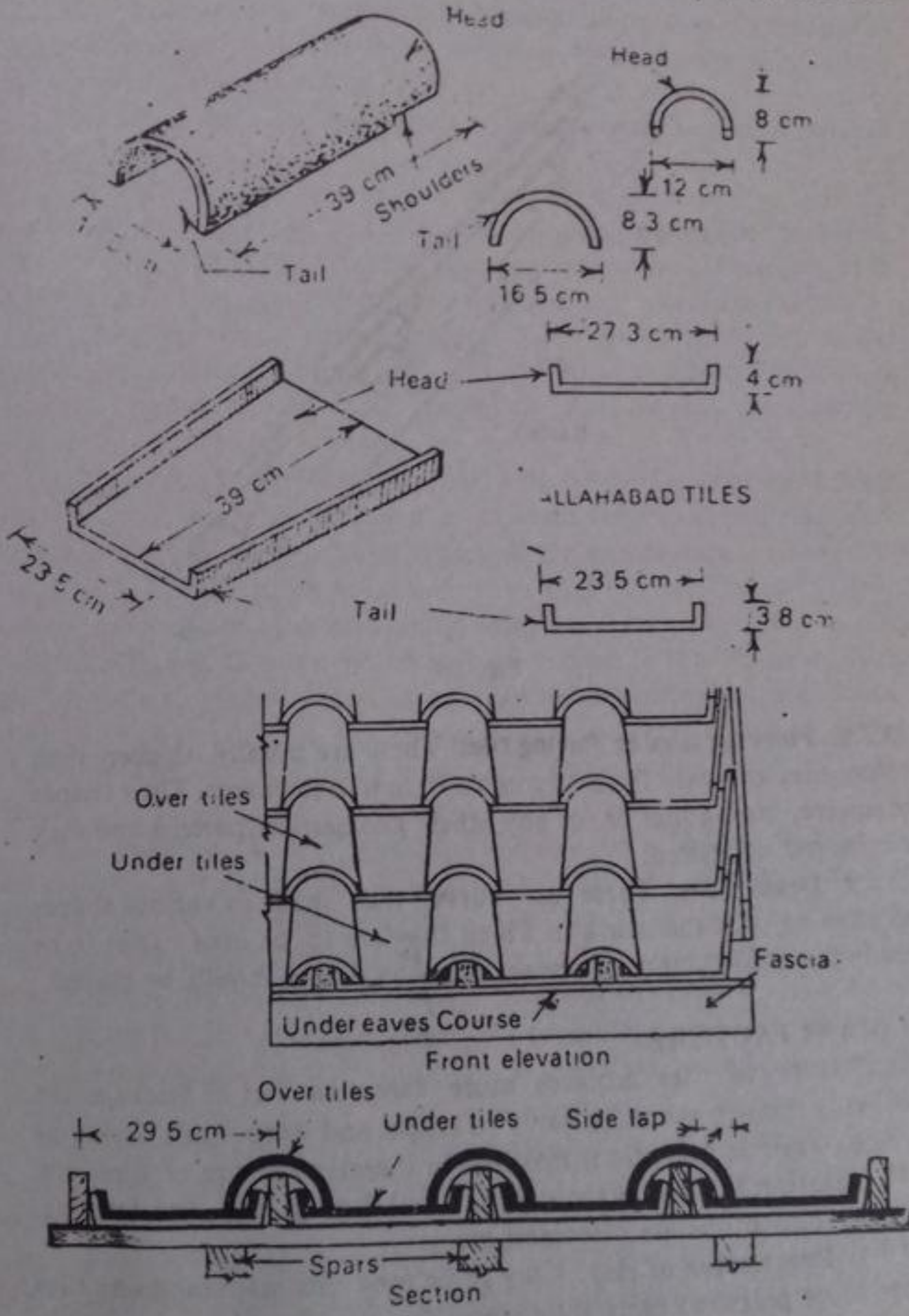


Fig. 3.8

roof. Arrangement of Mangalore tiles on a sloping roof is shown in Fig. 3.9.

3.2.7. **Concrete roofing tiles**. Tiles of any shape, size or colour could be made with cement concrete. These are more strong, durable and weather resistant.

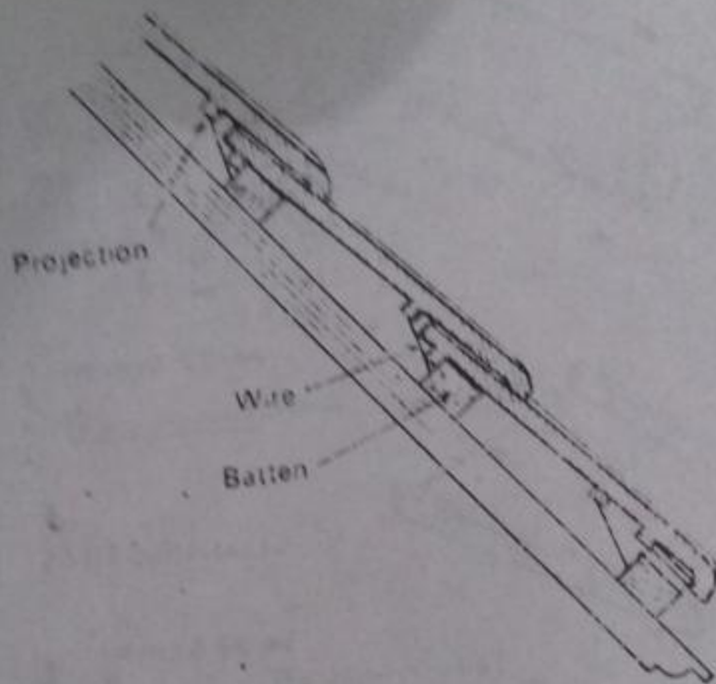


Fig. 3.9

3.2.8. **Flooring tiles or Paving tiles.** These are usually thicker than roofing tiles and vary from 15 mm to 30 mm in thickness. Their shapes are square, hexagonal or of any other geometrical pattern and may be coloured, if desired.

3.2.9. **Drain tiles.** These are curved tiles made in various shapes and sizes to suit the work in which they are to be used. Tiles to be used in the construction of sewage carrying drains should be glazed.

3.3 MANUFACTURE

Manufacture of tiles requires more care than that of bricks as the tiles being thinner are more likely to crack and warp while drying or burning. Various operations involved in the manufacture of tiles are: (*i*) Preparation of clay, (*ii*) moulding, (*iii*) drying, and (*iv*) burning. All these operations are discussed below:

3.3.1. **Preparation of clay.** Clay to be used for manufacturing tiles needs to be prepared more intimately. The clay should have no pebbles or grit. For ordinary tiles the clay may be ground finely in a grinding crushing mill (Fig. 4.3 or 4.4) and then intimately mixed in pug mill. For superior tiles the clay is finely ground in the crushing mill and then mixed with sufficient quantity of water in a tank. The solution is then allowed to stand quietly in the tank resulting in the settling of heavy coarse particles. Water containing fine clay in solution is drained off to other tanks where it is allowed to dry leaving fine clay ready for moulding.

3.3.2. Moulding. Three common methods are in use for moulding tiles in India.

(i) *Moulding by wooden patterns*. Tiles that do not have a uniform section throughout their length are moulded on wooden patterns. The tile is first moulded flat and when it has become a little dry then it is pressed round a wooden pattern to give it the desired shape.

(ii) *Moulding on a potters' wheel*. Tiles having perfectly circular shapes are conveniently moulded on a potter's wheel. Tiles with diameters varying with their lengths can also be very conveniently moulded on the potter's wheel.

(iii) *Moulding by mechanical means*. This method is applicable when the tiles to be moulded have a uniform section throughout their lengths. In it the prepared clay is forced under pressure through an opening having the same cross section as that of tile. The tile is then cut to the desired length with a fine wire.

3.3.3. Drying. Great care has to be exercised in the drying of tiles. In the initial stages these should not be subjected to the action of direct sun or strong winds otherwise because of resulting quick drying the tiles are likely to crack and warp. These should be dried in the shade.

3.3.4. Burning. Like drying, burning of tiles too has to be done carefully so as to avoid cracking and warping. The bunring has to be done gradually and if the bricks and tiles are being burnt in the same kiln then the upper part of kilns, where the heat is less, is reserved for tiles as those are thinner and require lesser heat. However, if the tiles are being burnt separately then a special type of kiln known as Sialkote kiln is used for the purpose. Its working could be seen in Fig. 3.10.

Over the rows of narrow flues is spread course of bricks laid flat and having spaces in between each. The flues are packed with fuel wood and sundried tiles are laid on edge on the brick flooring, course upon course. This is done till the kiln is packed with sundried tiles. The doorways, about 0.75 metre wide through which the kiln is loaded, are closed with bricks laid in mud. The top of kiln is covered up with old tiles and the fire started gently. The temperature is gradually raised to about 800°C when the tiles become red hot. The fire is then reduced for about three hours when it is again raised to white heat (about 1300°C) and kept steady for three hours. The fire is now

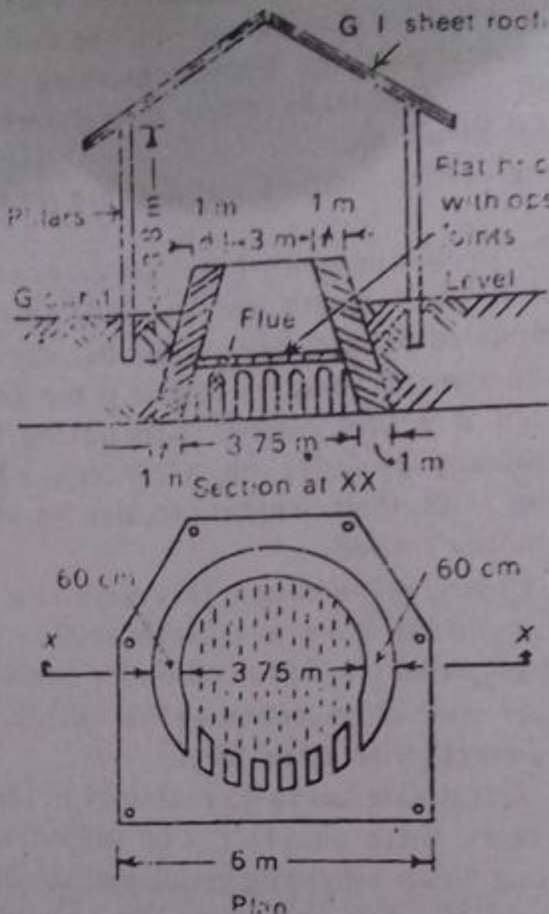


Fig. 3.10. "Sialkote" Type Kiln.

reduced for six hours and again raised to white heat for another four hours. The flues are now filled with fuel and their mouths closed with brick and mud. The kiln is unloaded after it has cooled down. It is an intermittent kiln. The whole operation takes about three days.

3.3.5. Properties of good tiles. Good tiles should have the following properties:

(*i*) It should be of a regular shape and size.
(*ii*) It should be free from twists, cracks or flaws.
(*iii*) It should be well burnt and have uniform colour.
(*iv*) It should give a clear ringing sound when struck.
(*v*) It should be sound and hard.
(*vi*) Its broken surface should show an even and compact structure

3.4 TERRA COTTA

It is a kind of earthenware used as a substitute for stones on the ornamental parts of buildings. Five parts of good quality fine clay are mixed with three parts of crushed pottery, one part of powdered glass, two parts of clean white sand and a suitable colouring substance to have the desired shade.

3.5 MANUFACTURE OF TERRA COTTA

It involves the three operations—(*i*) Preparation of clay; (*ii*) Moulding and drying, and (*iii*) Burning. Each one is explained below in brief.

3.5.1. Preparation of clay. Dry clay is *sifted* well and then mixed in a large tub with sufficient quantity of water. Powdered pottery, glass and white sand in proper proportions are added to it. The whole mixture is intimately mixed with spades. The intimate mixture thus obtained is then placed in wooden boxes with joints sufficiently open to allow the water to drain off. After the water has drained off the remaining mixture is passed through the pug mill severol times till it has become fit for moulding.

3.5.2. Moulding and drying. Special porous moulds made of plaster of paris or of zinc are made six to ten per cent bigger in size than the finished product to allow for shrinkage. The prepared clay is pressed in the moulds with hands and after a few days these are taken out of moulds and dried further. Drying should be done slowly.

3.5.3 Burning. Terra cotta's has to be burnt with utmost care to get unformity of colour. The terra cottas are enclosed in a *muffle*, which is a casing of fire bricks built inside the kiln. There is an air space all around the **muffle**, between it and the walls of kiln, as shown in Fig. 3.11.

Hot air passing through the air space heats the tiles placed inside the muffle.

3.6 VARIETIES OF TERRA COTTA

The terra cotta is of two types: (*i*) Porous Terra cotta; and (*ii*) Polished or Fine Terra cotta or Faience.

3.6.1. Porous terra cotta. Porous and sound proof terra cotta is had by mixing saw dust, or ground cork to the clay before moulding. When the terra cotta is burnt the organic matter burns away leaving the terra cotta porous. It is structurally weak and light. It can be *sawed* and nailed easily.

3.6.2. Polished terra cotta or fine terra cotta or faience. This is a high class glazed terra cotta. These have to be burnt twice in the kilns. The moulded articles are at first burnt to a low temperature of 700°C after which these are cooled down. This burning is known as *Biscuiting*.

Cooled articles are then coated with glazing compounds, dried again and burnt at a high temperature of 1200°C.

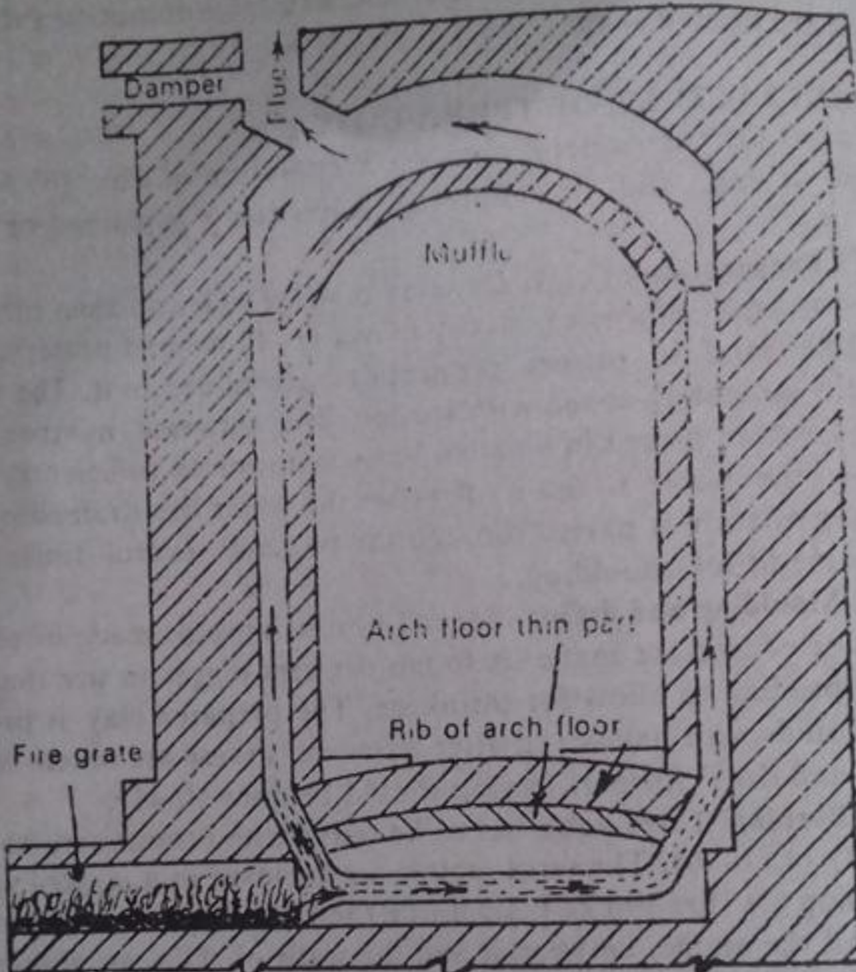


Fig. 3.11. Muffle furnace.

3.6.3. Characteristics of good terra cotta. The main characteristics of this are: (*i*) It is dense and uniform in texture, (*ii*) It is durable, fire resistant and unaffected by acids, (*iii*) It can be made in any desired colour and pattern, and (*iv*) It is hard and strong but light in weight.

3.6.4 Uses. (*i*) Used for all sorts of ornamental work, (*ii*) Used as a substitute for stone, and (*iii*) It is used for masonry, fire proof casing of steel columns and beams etc.

3.7 COLOURED BRICKS

There are two methods in use for colouring bricks or tiles—(*i*) By mixing some suitable colouring matter in the clay before burning, and (*ii*) By dipping the burnt brick or tile in a colouring liquid.

(*i*) If the colouring matter is available in plenty and is cheap then some suitable type of it is mixed with clay before burning. However, if the colouring matter is costly then the following method is made use of.

(*ii*) Suitable colouring matter is dissolved in a mixture of linseed oil and turpentine oil to which a little litharge, which serves as a drier is added. Hot bricks are dipped in the colouring solution and left to dry in shade. When dry these are washed clean in a trough of cold water. Hot colouring solution may be applied with brush on a clean surface of an already built wall. For giving black colour boiling coal tar may be used.

3.8 GLAZING

Surfaces of earthware, stoneware, bricks and tiles etc. are glazed to improve their appearance, make them impervious and to protect them from the action of sewage, acids, atmosphere and other destructive agents. To do so the two methods used are: (*i*) Salt Glazing, and (*ii*) Enamelling.

3.8.1. Salt glazing. It is done by throwing common salt in the kiln at the close of burning operation. At the high temperature of about 1300°C obtaining in the kiln the salt vaporises. The vapours adhere to the exposed surfaces giving them a glossy finish. The colour of articles so glazed is brownish.

3.8.2. Enamelling. This treatment improves the appearance of the burnt article in addition to increasing their durability and makes them impervious. Combination of borax, kaolin, chalk and a colouring matter is fused with all or part of felspar, flint and lead oxide. The resulting molten glass is poured into water to give shattered *frit*. The frit is then ground with the remaining materials and water to thick cream known as *slip*. Fully burnt earthenware (which are normally porous) known as *biscuits* is dipped in the *slip*. It absorbs water and forms a thin layer of glaze. After it has dried it is again fired to a lower temperature so as to fuse the glaze.

3.9 EARTHENWARE

These are made of ordinary brick earth but superior qualities of it are made from blends of kaolin, felspar, flint and ball clay. These are vitrified porous wares and should be glazed. Their characteristics are similar to those of terra cotta. These are used for sanitation work.

3.10 STONEWARE

These are [illegible] than the earthenware and are made from refractory clay mixed with crushed pottery and stone. These are burnt at a high temperature. Glazed stoneware are impervious to water and unaffected by weather. These are largely used as sanitary ware and as jars for storing chemicals.

3.11 PORCELAIN

It is a fine white glazed highly vitrified transluscent pottery. It is made from kaolin (*China Clay*) mixed with high porportion of fluxes *e.g.* bone ash for *bone china* and felspar for hard procclains. Because of white colour it is sometime called as *white ware*. These are acid proof and can stand high temperatures. These are, however, attacked by hydrofluoric acid and by concentrated alkalies and show low thermal shock resistance and low resistance to tensile stresses.

Because of their poor conductivity of electricity these are used as electric insulators.

EXERCISES

1. What are tiles and how are they manufactured? Discuss in details.
2. What are different types of tiles? Mention their various uses in building construction.
3. What is Terra Cotta and how is it manufactured? Discuss.
4. Differentiate between porous and polished Terra Cotta.
5. What are the characteristics of good Terra-Cotta? Give its uses.
6. What is the purpose of glazing tiles and how is it done?
7. Differentiate between earthenware and stoneware. What are the uses to which they are put?

4

LIME

4.1 LIME

Lime has been used as a cementing material since times immemorial. In India up to very recently, lime has been extensively used for all types of constructional purposes. Big palaces, forts, monuments, temples and bridges etc. that were constructed centuries back and that are still existing in perfectly good condition substantiate that the technique of using lime for constructional purposes had reached perfection in the past. Egyptians and Romans made extensive use of lime with remarkable dexterity. But in recent times cement has replaced the use of lime to a great extent. Even though cement is a remarkable material of construction yet lime mortars have some peculiarly advantageous properties *e.g.* good workability and plasticity, less shrinkage on drying and durability etc. Defects in lime mortar, particularly its slow setting compared with that of cement could be got rid of by adding to it a definite proportion of 5-20 per cent of cement. It should then be used up within two to three hours of gauging with cement. Lime is cheaper too and is locally available.

4.2 CLASSIFICATION

Limes are usually divided into three classes: (*i*) Fa rich, pure, high calcium, or white lime; (*ii*) Poor or lean lime; and (*iii*) Hydraulic lime—(*a*) feebly hydraulic lime, (*b*) moderately hydraulic lime, (*c*) eminently hydraulic lime, (*d*) magnesium lime.

4.2.1. Fat, rich, pure, high calcium or white lime. It is the lime which has a high calcium oxide content and is dependent for setting and hardening solely on the absorption of carbon dioxide from the atmosphere. It contains about 93 per cent calcium oxide and less than five per cent impurities such as Silica and Alumina (in the form of clay). It is obtained by calcining the purest available calcium carbonate. On calcination carbon dioxide is driven off leaving behind quick lime. Addition of water breaks up lumps of quick lime to powder gives out considerable heat and swells to two to three times of its original volume giving *fat lime*. It is slow in setting and takes much time in hardening. It is used for plastering and white washing. It is not suitable for being used as mortar because of poor strength and slow hardening. When MgO exceeds one tenth of the CaO and the MgO in the lime, the lime shall be termed *magnesium lime*, and when the MgO exceeds one quarter of the CaO and MgO, the lime shall be termed *dolomitic lime*. Their properties are similar to those of fat lime but slake with difficulty as such their slaking needs more care.

4.2.2. Poor or lean lime. It contains more than five per cent of clayey impurities because of which it takes longer to slake than fat lime. It sets and hardens slowly. It is used both for plaster and lime mortar.

4.2.3. Hydraulic lime. Unlike pure and lean limes which set only by absorbing carbon dioxide from the atmosphere this class of lime sets even under water, hence the name *Hydraulic lime*. It is used in building works where strength is required. It is not suited for use in plastering because any unslaked particle may slake after a long time resulting in blistering of plaster. Lime stones from which Hydraulic Lime is obtained contain varying proportion of Silica and Alumina (in the form of clay) in addition to calcium carbonate. On calcination of these stones carbon dioxide escapes leaving behind quicklime which reacts with Silica and Alumina forming Silicates and Aluminates of lime. On addition of water to the finely ground lime chemical action starts among its constituents resulting in its setting and hardening. Depending upon the amount of silica and alumina present in Hydraulic lime it is sub-divided into three classes:

(*a*) *Feebly hydraulic lime.* It contains less than 15 per cent Silica and Alumina. Increase in volume on slaking is small. Rate of slaking is very slow.

(*b*) *Moderately hydraulic lime.* It contains 15 to 25 per cent Silica and Alumina. There is a little increase in volume on slaking. Rate of slaking is very slow. It gives stronger mortar than the feebly Hydraulic Lime and is suitable for good class masonry works.

(*c*) *Eminently hydraulic lime.* Its composition is very similar to that of ordinary Portland Cement. It contains 25 to 30 per cent silica and alumina. It must be very finely ground and screened before use otherwise the coarse particles are likely to slake after use. In properties, it resembles moderately Hydraulic Lime but gives stronger mortar. It is used in place of Portland Cement because of similarity in properties.

4.3 SETTING ACTION OF LIME

(*i*) *Fat lime*. It sets only in the presence of carbon dioxide present in the atmosphere. Quick lime (CaO) forms calcium hydroxide [$Ca(OH)_2$] when it comes in contact with water. But when this calcium hydroxide comes in contact with carbon dioxide present in air it solidifies forming calcium carbonate.

Addition of sand to the slaked lime makes the mortar porous thereby enabling carbon dioxide from the air to reach inside and start the setting action. As fat lime depends on carbon dioxide for its setting so it is not used in thick walls and in structures below ground level. Its plaster hardens quickly but does not weather well so it is used for plastering only the internal walls and for white washing.

(*ii*) *Hydraulic lime*. It does not need the presence of carbon dioxide for its setting action. Silica and alumina present in *kankar* (from which it is manufactured) form complex silicates and aluminates of calcium. These compounds start a chemical reaction in the presence of water added to the mortar resulting in its setting.

Because of its not depending upon the presence of carbon dioxide for setting it is used in the construction of thick walls and structures below ground level. Its strength is second only to cement.

4.4 IS: SPECIFICATIONS FOR LIME

Following standards have been laid down by the Indian Standards Institution, New Delhi so as to standardise lime. Variations in the quality of lime caused by the variations in the qualities of locally available lime stones are bound to be there. Regional standards for lime so as to cover regional differentiations are being compiled by the Indian Standards Institution.

Following requirements are based on IS: 712-1973.

4.4.1. Scope. This specification covers the chemical and physical requirements of eminently hydraulic lime in its hydrated state and of moderately hydraulic limes and of fat limes in their unhydrated and hydrated states.

4.4.2. Terminology. For purposes of this standard, the following definitions shall apply:

(*i*) *Quicklime*. The calcined material, major part of which is calcium oxide in natural association with a relatively smaller amount of magnesium oxide and capable of slaking with water.

(*ii*) *Hydraulic lime*. Lime containing small quantities of silica and alumina and/or iron oxide which are in chemical combination with some of the calcium oxide content giving a *putty* or mortar which has the property of setting and hardening under water. Hydraulic limes are classified as class 'A' (eminently hydraulic limes) and as class 'B' (semi hydraulic limes).

(*iii*) *Hydrated lime*. A dry powder obtained on treating quicklime with sufficient water to satisfy its chemical affinity for water under the condition of its hydration.

(*iv*) *Lump lime*. Quicklime as it comes from kilns.

(*v*) *Milk of lime*. A thin pourable suspension of slaked lime in water.

4.4.3. Classification (based on IS: 712-1973). Building limes shall be classified as below:

Class A—Eminently hydraulic lime used for structural purposes.

Class B—Semi-hydraulic lime used for masonry mortars.

Class C—Fat lime used for finishing coat in plastering, white washing, etc. and with addition of pozzolanic material for masonry mortar.

Class D—Magnesium lime used for finishing coat in plastering, white washing etc.

Class E—Kankar lime used for masonry mortars.

Chemical and Physical requirements. Building limes as classified above shall comply with chemical requirements as in Table 4.1 and Physical requirements as in Table 4.2.

4.5. MANUFACTURE OF LIME

Fat lime is obtained by burning lime stones which are the purest forms of calcium carbonate whereas the hydraulic lime is had by burning kankar. Hydraulicity of lime obtained from kankar is because of clay present in it. Kankar is of two types: (*i*) Nodular kankar, and (*ii*) Quarried or Block kankar.

4.5.1. Nodular kankar. It is found either on the surface or a few feet below surface in alluvial soils. Kankar found below the soil has better hydraulic properties than those of the one found on surface. Nodular kankar is far superior to block or quarried kankar because of its better hydraulic properties, better weathering properties and easier collection.

4.5.2. Quarried or block kankar. It is found in blocks a few feet below ground or on or near the banks of rivers or their tributaries. Blocks are generally 5 to 30 cms thick. The principal stages in the manufacture of lime are: (*i*) Calcination or burning, and (*ii*) Hydration or slaking.

4.5.3. Lime burning. Like bricks, lime stones too are burnt in either clamps or kilns.

(*i*) *Clamp*. When the quantity of lime stone to be burnt is so small that it would be undesirable to spend much for setting up of a kiln,

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TABLE: 4.1 Chemical Requirements

S. No.	Types of test	Class A Hydrated	Class B Quick	Class B Hydrated	Class C Quick	Class C Hydrated	Class D Quick	Class D Hydrated	Class E Hydrated	Methods of tests (Ref to IS: 6932—1973)
		Requirements for Building Limes								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(i)	Calcium and magnesium oxides, per cent, *Min*	60	70	70	85	8'	85	85	25	Part I
(ii)	Magnesium oxides, per cent *Max*	5	5	5	5	5	—	—	5	Part I
	Min	—	—	—	—	—	5	5	—	
(iii)	Silica, alumina and ferric oxide, per cent, *Min*	25	15	15	—	..	—	—	—	Part I
(iv)	Unhydrated oxides, per cent *Max*	--	—	—	—	—	8	8	—	Part V
(v)	Insoluble residue in hydrochloric acid less the silica, per cent, *Max*	2	3	2	—	—	—	—	—	Part I
(vi)	Insoluble matter in sodium carbonate solution, per cent, *Max*	5	5	5	5	5	5	5	5	Part I
(vii)	Loss on ignition, per cent, *Max*	—	5 for large lump, 7 for lime other than large lump	—	5 for large lump, 7 for lime other than large lump	—	5 for large lump, 7 for lime other than large lump	—	5	Part I

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(viii)	Carbon dioxide, per cent, *Max*	5	5	5	5	5	5	5	—	Part II
(ix)	Cementation value† *Min*	0.6	0.3	0.3	—	—	—	—	—	Part I
	Max	—	0.6	0.6	—	—	—	—	—	

Note 1. Percentages shall be expressed on ignited basis in respect of items (*i*) to (*vi*).

Note 2. The sign (—) means no requirements for the test.

* Methods of test for building limes:

Part I. Determination of insoluble residue, loss on ignition, insoluble matter, silicon dioxide, ferric and aluminium oxide, calcium oxide and magnesium oxide.

Part II. Determination of carbon dioxide content.

Part V. Determination of unhydrated oxide of quicklime.

† The value is equal to $\frac{2.8P+1.1Q+0.7R}{1.0S+1.4T}$

Where

P = silica (SiO_2) content, per cent by weight;
Q = aluminium oxide (Al_2O_3), per cent by weight;
R = ferric oxide (Fe_2O_3), per cent by weight;
S = calcium oxide (CaO), per cent by weight; and
T = magnesium oxide (MgO), per cent by weight.

TABLE: 4.2. Physical Requirements

Requirements for Building Limes

1.05+1.4 T

Where

P = silica (SiO_2) content, per cent by weight;
Q = aluminium oxide (Al_2O_3), per cent by weight;
R = ferric oxide (Fe_2O_3), per cent by weight;
S = calcium oxide (CaO), per cent by weight; and
T = magnesium oxide (MgO), per cent by weight.

TABLE: 4.2. Physical Requirements

S. No.	Types of test	*Requirements for Building Limes* Class A Hydrated	Class B		Class C		Class D		Class E Hydrated	Methods of tests, Ref. to
			Quick	Hydrated	Quick	Hydrated	Quick	Hydrated		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(i)	Fine	Shall leave no residue on 2.36-mm IS Sieve, not more than 5 per cent on 850-micron IS Sieve and the fraction passing through 850-micron IS Sieve shall leave not more than 10 per cent	—	Shall leave no residue on 2.36-mm IS Sieve, not more than 5 per cent on 850-micron IS Sieve and the fraction passing through 850-micron IS Sieve shall leave not more than 10 per cent	—	Shall leave no residue on 850-micron IS Sieve, not more than 5 per cent on 300-micron IS Sieve and the fraction passing through 300-micron IS Sieve shall leave not more than 10 per cent (of this	—	Shall leave no residue on 850-Micron IS Sieve, not more than 5 per cent on 300-micron IS Sieve and the fraction passing through 300-micron IS Sieve shall leave not more than 10	Shall leave no residue on 2.36-mm IS Sieve, not more than 5 per cent on 850-micron IS Sieve and the fraction passing through 850-micron IS Sieve shall leave not more than 10 per cent (of this	IS : 6932 (Part IV) 1973*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
		(of this fraction) on 300-micron IS Sieve		(of this fraction) on 300-micron IS Sieve		fraction) on 212-micron IS Sieve		per cent (of this fraction) on 212-micron IS Sieve	fraction) on 300-micron IS Sieve	
(ii)	Residue on slaking (on the basis of quicklime taken), *Max*, per cent by weight	—	10 on 850-micron IS Sieve	—	5 on 850 micron IS Sieve, the fraction passing through this sieve when further passed through 300-micron IS Sieve shall leave residue 5	—	5 on 850 micron IS Sieve, the fraction passing through this sieve when further passed through 300-micron IS Sieve shall leave residue 5	—	—	IS : 6932 (Part III) 1973
(iii)	Setting time	In the putty of standard consistency as prepared in 3.2.2. of IS : 6932 (Part VIII) 1973 initial set shall take place	—	—	—	—	—	—	In the putty of standard consistency as prepared in 3.2.2. of IS : 6932 (Part VIII) 1973 initial set shall take place in not	IS : 4031 1968

							residue 5			
(iii)	Setting time	In the putty of standard consistency as prepared in 3.2.2. of IS : 6932 (Part VIII) 1973 initial set shall take place in not less than 2 h and final set with in 48 h	—	—	—	—	—	—	*In the putty of standard consistency as prepared in 3.2.2. of IS : 6932 (Part VIII) 1973 initial set shall take* place in not less than 2 h and final set within 48 h	IS : 4031 1968
(iv)	Compressive strength, *Min*	17.5 kg/cm² after 14 days and 28 kg/cm² after 28 days shall, however, show an increase over that at 14 days	—	12.5 kg/cm² after 14 days and 17.5 kg/cm² at 28 days shall, however, show an increase over that at 14 days	—	—	—	—	10.5 kg/cm² after 14 days and 17.5 kg/cm² after 28 days shall, however, show an increase over that at 14 days	IS : 6932 (Part VII) 1973 II
(v)	Transverse strength	Modulus of rupture not less than 10.5 kg/cm² at 28 days	—	Modulus of rupture not less than 7.0 kg/cm² at 28 days	—	—	—	—	Modulus of rupture not less than 7.0 kg/cm² at 28 days	IS : 6932, (Part VII) 1973
(vi)	Workability	—	—	—	Shall require not less than 12 bumps to attain	shall require not less than 10 bumps to attain an average	shall require not less than 12 bumps to attain an average	shall require not less than 10 bumps to attain an average	—	IS : 6932 (Part VIII) 1973

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
					an average spread of 19 cm from an initial spread of 11 cm on the flow table	spread of 19 cm from an initial spread of 11 cm on the flow table	spread of 19 cm from an initial spread of 11 cm on the flow table	spread of 19 cm from an initial spread of 11 cm on the flow table		
(vii)	Volume yield	—	—	—	1.7 ml per g or as agreed to between the purchaser and the supplier	—	1.4 ml per g or as agreed to between the purchaser and the supplier	—	—	IS : 6932 (Part VI) 1973
(viii)	Soundness	The Le Chatelier moulds shall not exhibit more than 10 mm expansion	—	The Le Chatelier moulds shall not exhibit more than 10 mm expansion	—	—	—	—	The Le Chatelier moulds shall not exhibit more than 10 mm expansion	IS : 6932 (Part IX) 1973
(ix)	Popping and pitting.	—	—	—	—	Shall not exhibit any disintegration popping or pitting on the surface	—	Shall not exhibit any disintegration popping or pitting on the surface	—	IS : 6932 (Part X) 1973

Note. The sign (—) means no requirements of the tests.

then the burning is done in a clamp.

On a clear surface about 5 m in diameter alternate layers of broken stone and fuel are laid to form a heap about 4 m high. First and the last layers should be of the fuel. In case coal is used as fuel then it could be well mixed up with stones and laid in a heap. Sides of the heap, which incline slightly inwards are plastered over with mud to stop loss of heat. A little opening at top is provided for draught. The clamp is then fired at the bottom. Disappearance of blue flame at top is an indication of the burning of lime having completed. The clamp is allowed to cool down, after the burning operation is over. Pieces of quick lime are then hand picked.

Clamp burning of lime is uneconomical as the fuel consumption is more due to loss of heat and as some lime powder is lost in fuel ash. Also the quick lime carries an admixture of ash.

4.5.5. Kiln. When the quantity of lime to be obtained is large then permanent structures of kilns are constructed. Kilns could be either of the intermittent type or of the continuous type. Whenever the lime is desired intermittently or the supply of stones or fuel is not regular then the intermittent kiln is used.

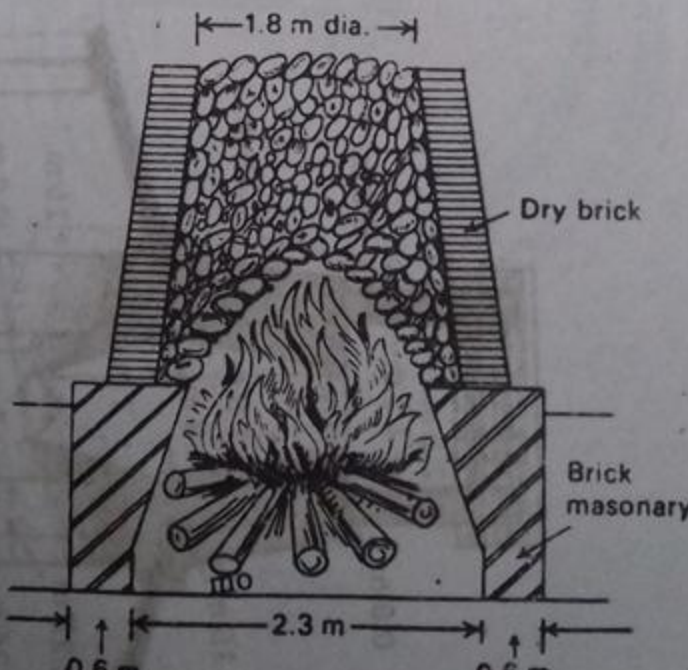


Fig. 4.1. Intermittent Kiln.

(i) *Intermittent kiln.* (Country Kiln). An intermittent kiln in which the fuel is not in contact with the lime is shown in Fig. 4.1. Big

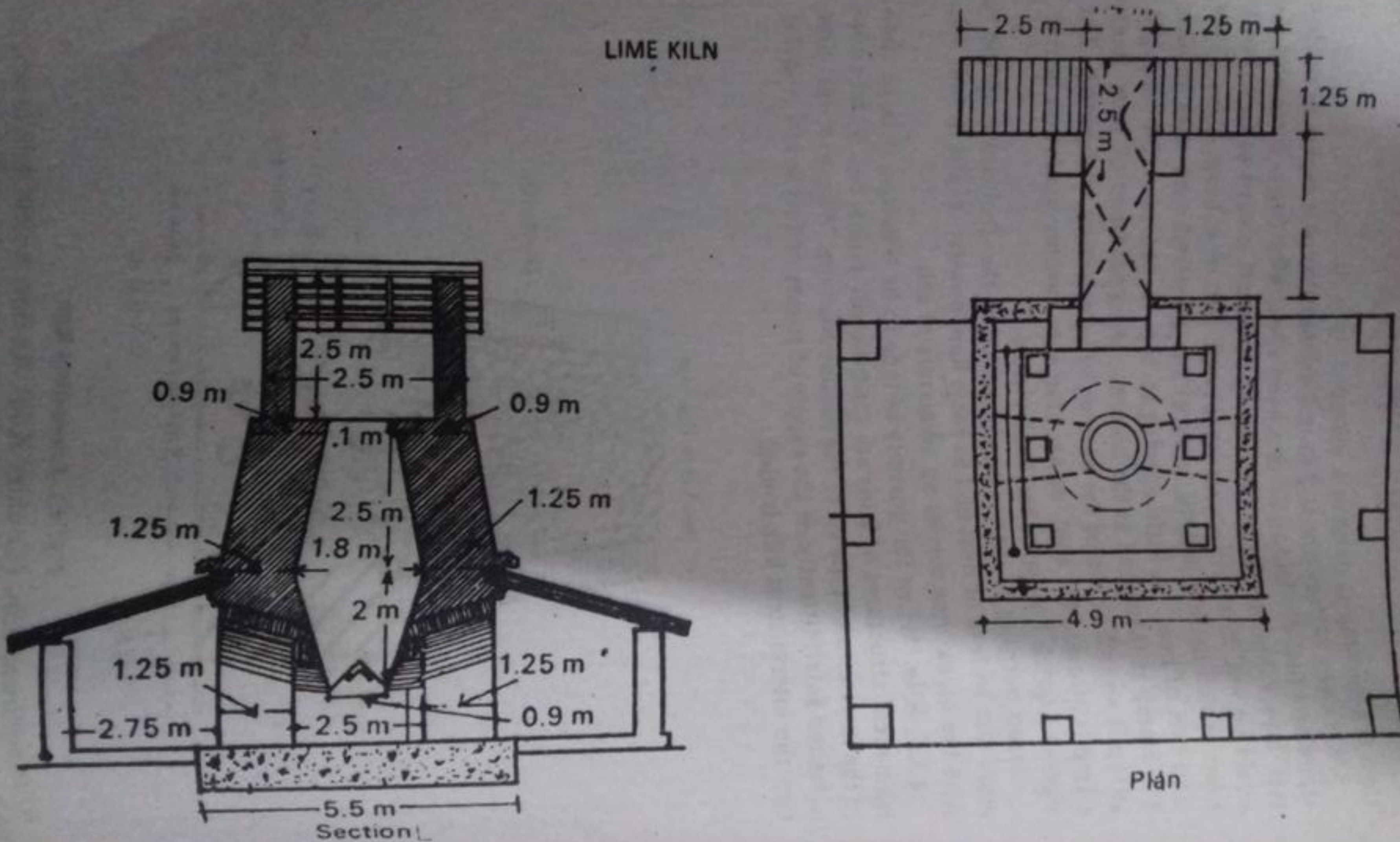

LIME KILN
2.5 m
2.5 m
0.9 m
0.9 m
.1 m
2.5 m
1.8 m
2 m
1.25 m
1.25 m
1.25 m
1.25 m
0.9 m
2.75 m
2.5 m
5.5 m
Section
2.5 m
1.25 m
2.5 m
1.25 m
4.9 m
Plan

Fig. 4.2

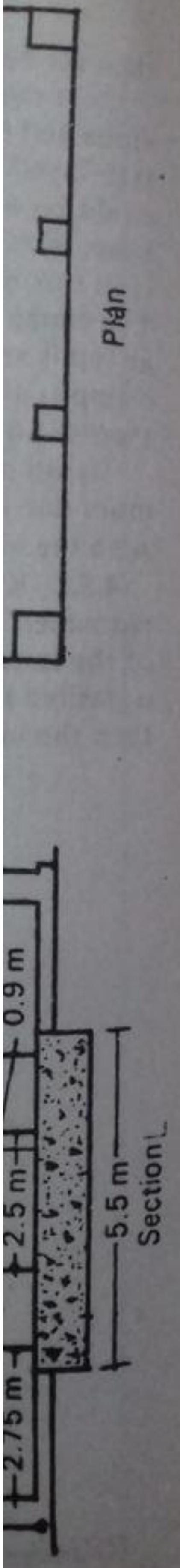


Fig. 4.2

pieces of lime stone are used to make a sort of arch on which smaller pieces of lime stone are loaded. Fire is lighted below the arch formed with big pieces of lime stone. It is only the flame and not the fuel that comes in contact with the stones. Burning should be gradual so that the stones forming the arch do not get split. Shells too could be burnt in this kiln. It normally takes two days to burn and one day to cool the charge.

(ii) *Continuous kiln.* Commonly used continuous kiln is shown in Fig. 4.2. Wood, or charcoal could be used as fuel. Stone or kankar free from earth or other impurities is broken into small pieces to about 5 cm gauge. Either alternate layers of 75 mm stone and 6 mm

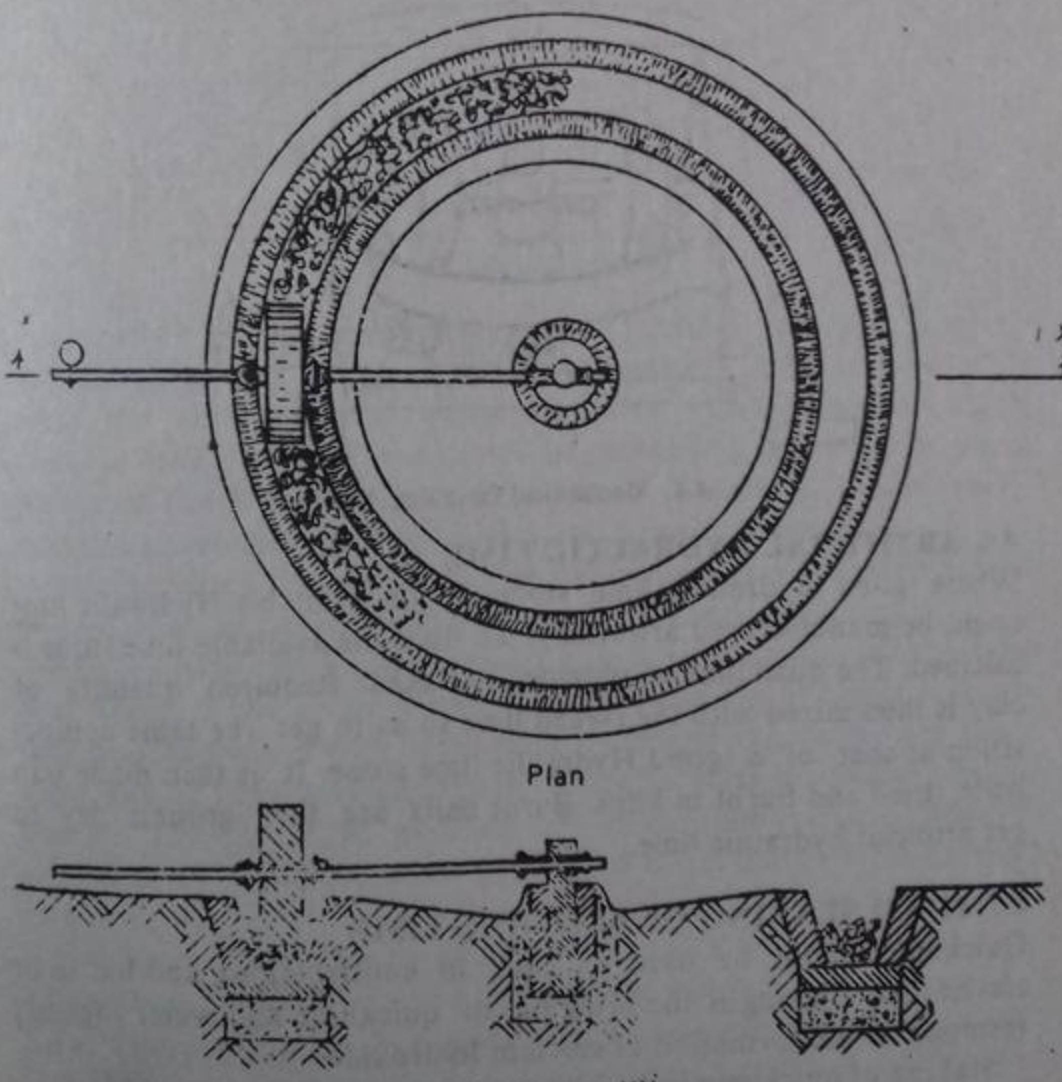


Fig. 4.3. Bullock driven grinding Mill.

coal dust or a foundation of 1.25 metre of fuel followed by alternate layers of stone metal and wood each 0.5 metre thick are fed into the klin. Top should be covered over with mud leaving a hole 0.5 metre in diameter in the centre.

Burning proceeds continuously and the kiln is not allowed to cool down. Burnt material is drawn out daily and fresh charge of stone and fuel is added from top. Withdrawn burnt material is handpicked. Overburnt pieces are discarded whereas the under-burnt ones are reloaded into the kiln. Remaining material is slaked or ground in a mill (Figs. 4.3 and 4.4) for use. One cubic metre of lime stone should give 0.81 cubic metre of burnt material and one cubic metre of burnt material should yield 0.82 cubic metre of ground line.

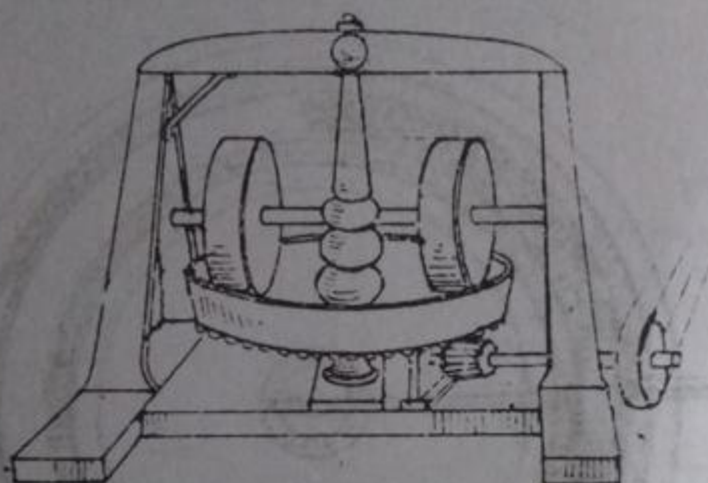


Fig. 4.4. Mechanical Grinding Machine.

4.6 ARTIFICIAL HYDRAULIC LIME

Where good hydraulic lime stone is not available Hydraulic lime could be manufactured artificially. To do it the available lime stone is calcined. The quicklime so obtained is slaked. Required quantity of clay is then mixed with the slaked lime so as to get the same composition as that of a good Hydraulic lime stone. It is then made into balls, dried and burnt in kilns. Burnt balls are then ground dry to get artificial hydraulic lime.

4.7 FIELD SLAKING OF BUILDING LIME

Quicklime cannot be used as such in constructions and has to be *slaked* first. Slaking is the bringing of quicklime and water together resulting in the formation of calcium hydroxide.

Slaking of quicklime in building construction is an essential feature, deficiency in which could lead to serious harmful effects. Proper care should be taken in slaking so that no improperly slaked or unsound particles are left, as these if used in structures, are likely to hydrate after use, thereby causing failure due to consequent expansion.

The method of slaking is thus very important and is described below as recommended by IS: 1635-1975.

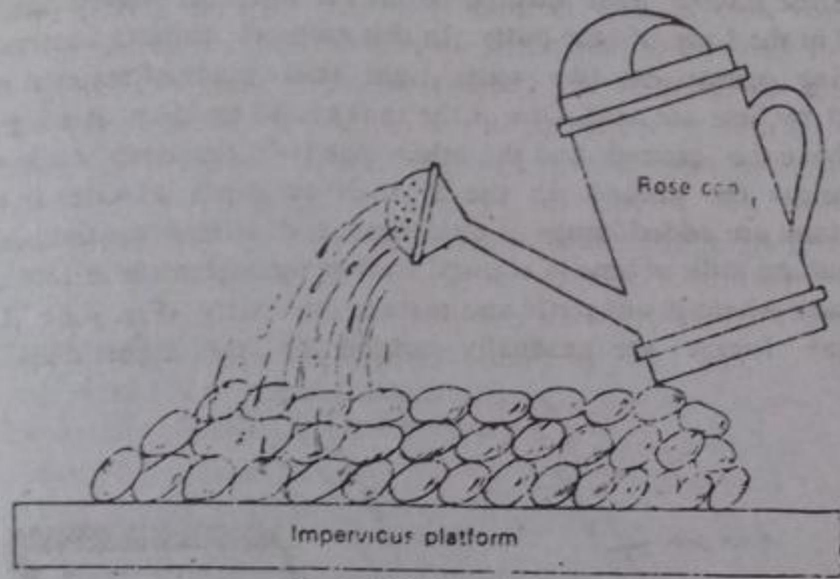


Fig. 4.5. Slaking Platform.

Quicklime should be slaked as soon as possible otherwise it deteriorates on exposure due to absorption of moisture and carbon dioxide from the atmosphere. If, however, delay in slaking is unavoidable then the lumps of quicklime should be stored in heaps piled on pucca platforms free from dampness or moisture. The heaps should preferably be covered to minimise direct atmospheric contact.

Before slaking the quicklime, the slaking platform or receptacle is cleared of all unslaked stone left over from previous slaking.

The lumps of quicklime for slaking shall be of uniform size between 5 to 10 cm. If quicklime pieces from the kiln be of bigger size then they may be broken with hammer or by sprinkling water over them. Slow slaking limes may be broken to smaller sizes or even crushed to powder. The trough or platform on which lime is slaked should be cleared of all unslaked stone pieces and other matter from previous slakings.

Slaking is done either by adding water to lime on a platform or by adding lime to water in tanks as described below:

(*a*) *Platform slaking*. Water is sprinkled in small quantities through rose cans over lumps of quicklime spread in 15 cm thick layer on a water tight masonry platform (Fig. 4.5) until the lumps break into fine powder. Only minimum quantity of water required for complete and uniform slaking is to be added while the stuff is being periodically turned over. The stuff is left over to allow the process of slaking to continue for 24 hours. The slaked lime is then screened through 250-micron IS sieves.

(*b*) *Tank slaking*. This method is of use when the slaked lime is needed in the form of lime putty. In this method, to have continuity of slaking operations, two water tight tanks made of material not affected by lime are used. One of the tanks is 40 cm deep at a higher level above the ground and the other one is 75 cm deep at a lower level below the ground. In the 25 to 30 cm depth of water in the higher tank are added lumps of quicklime and stirred continuously. The resulting milk of lime is allowed to flow through a sluice into the lower tank where it will settle and mature into putty (Fig. 4.6). The quicklime lumps are gradually added to the higher tank. It

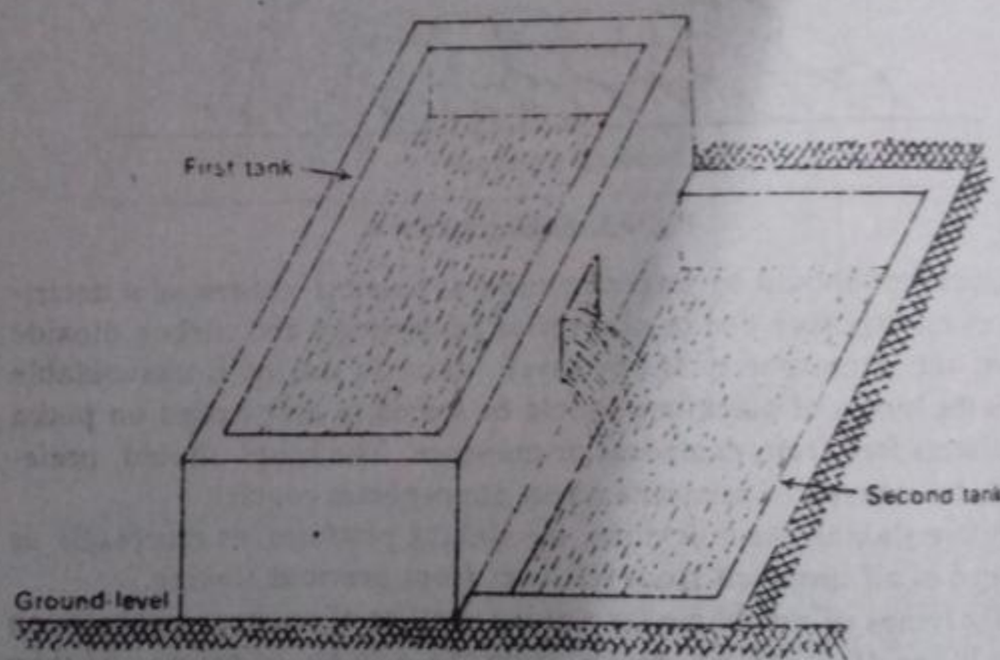


Fig. 4.6. Slaking Tank.

is better to have two tanks at the lower level so that when putty in one is maturing then the milk of lime from the higher tank is being received into the other tank at the lower level. Time of maturity of putty depends upon the quality of lime and varies from two to three days.

4.8 PRECAUTIONS TAKEN IN HANDLING LIME

The following precautions should be taken while handling lime:

(*i*) Quicklime shall not be allowed to come in contact with water before slaking.

(*ii*) While slaking, quicklime gives out immense heat as such all precautions against fire hazard should be taken.

(*iii*) Workers handling lime should be provided with suitable g-gles and respirators, as lime dust causes irritation.

(*iv*) Since lime causes skin burns, particularly if the skin is mois as such workers should be provided with rubber gloves, gum boots and skin protective cream.

(*v*) After working with lime exposed portions of the body should be washed with abundant fresh water.

(*vi*) Workers handling milk of lime, which is hot, should oil the skin daily to avoid skin burns.

4.9 PREPARATION OF PUTTY

It is prepared by stirring slaked lime powder in water so as to ge thick creamy consistency and allowing it to stand and mature for not less than 16 hours in case of class C and D limes and not more than 12 hours in case of class B and E limes before it is used.

4.10 STORAGE OF SLAKED LIME

If slaked lime is to be stored only for a few days then it may be stored on a platform suitably protected from sun and rain by covering. Storage for a period not exceeding two months may be done in dry and closed godowns.

Lime putty should, however, be stored under water. Putty of class C and D lime may be kept stored up to 15 days whereas that of class B and E lime should immediately be used after preparation.

4.11 FIELD TESTS OF BUILDING LIME

Since properties of lime undergo changes on exposure to atmosphere, it is desirable to check its quality at various stages *viz.*, after burning, slaking during storage and before actual use. The following few field tests are recommended as per IS: 1624-1974.

(*i*) *Visual examination test*. The lime shall be examined for its colour, which may be pure white, white or dirty white. Its state of aggregation i.e. whether it is soft, hard, powdery or lumpy is noted.

Pure white colour points to the class C lime. Lumpy state indicates quicklime or unburnt limestone. Porosity in appearance of lumps indicates quicklime.

(*ii*) *Hydrochloric acid test*. Fill a teaspoon (levelled flat with rim of the spoon), put it in a test tube, tap the test tube gently for about two minutes so that the sample in the test tube presents a neat level surface on top. Scratch with a glass marking pencil the level of the sample in the tube. Now add about 10 ml of 50 per cent hydrochloric acid by volume along a glass rod placed in the test tube. The contents are now stirred well till all effervescence stops. More acid may be added to ensure that none of the inert material is left in the form of calcium carbonate. The test tube with its contents is then kept standing in its stand for 24 hours.

Excessive effervescence indicates that the lime has an excessive proportion of calcium carbonate as either the lime has not been burnt properly or stored properly.

The proportion of inert material settled at the bottom of the test tube compared with the original shall give an idea of it (inert matter) being excessive or not.

Formation of a thick gel, which would not flow even when the test tube is turned upside down, indicates the class of lime to be A. If the gel is not quite thick and tends to flow when the test tube is titled the class of lime is B. If, however there is no gel formation then it is class C lime.

(*iii*) *Ball test*. Make balls of egg size with stiff lime paste formed by adding enough water and leave the balls undisturbed for six hours after which place them in a basin of water.

For class C lime there are signs of slow expansion and slow disintegration within minutes. However, very little or no expansion and numerous cracks indicate class B lime.

(*iv*) *Impurity test*. A known weight of fresh quick lime is added to sufficient quantity of water in a vessel and stirred well. It is then allowed to settle for two hours. The milk of lime, if needed, on dilution with water is then passed through 250-micron IS Sieve. Wash the residue with water till it is free from lime. Transfer with a jet of water the residue to a tray, allow it to settle and decant off the water from the tray. Dry the residue for 8 hours in hot sun and weigh. Calculate the percentage of the residue over the initial weight of material. Efficiency of burning of lime is indicated by the following gradation:

Less than 10 %	Good
Between 10 to 20 %	Fair
More than 20 %	Poor

(*v*) *Workability test*. It is a very crude test performed on the same mortar as is used on actual work. A handful of mortar is thrown, with the same force as for rough-cast work, on the surface on which it is to be used. By noting the area covered and the quantity of mortar picked up an experienced mason can judge the workability.

EXERCISES

1. What is lime? Describe briefly its classification and uses.
2. Enumerate the classification of lime and discuss briefly their main properties.
3. What is Hydraulic lime? Give its uses. How would you slake lime to (*i*) paste, (*ii*) powder.
4. What do you understand by the following:
(*i*) Eminently hydraulic lime, (*ii*) Fat lime, (*iii*) Quick lime, (*iv*) Hydrated lime.
5. Distinguish between fat lime and hydraulic lime in respect of their chemical composition, slaking, setting, strength and uses.
6. Describe the process of burning lime stone for lime manufacture. Sketch the kiln you describe.
7. Describe with sketches the manufacture of lime. State the chemical changes involved in the burning, slaking and setting of lime.
8. Describe the various field tests for lime.

5

CEMENT

5.1 CEMENT

Cement, commonly used for normal construction work, is known as *Ordinary Portland Cement*. However, for use under specific conditions a variety of cements are available these days.

Its quick setting property, strength and ease with which it can be used under variety of conditions has revolutionized the concept of construction and made it the most popular cementing material. It was first of all introduced in 1824 by Joseph Aspdin, a brick layer of Leeds, England. On setting, the colour of cement resembles the colour of rocks near Portland in England and hence the name of this cement. Below are discussed the composition, manufacture and tests etc. of *Ordinary Portland Cement*.

5.2 COMPOSITION

Approximate composition of raw materials used for manufacturing *ordinary portland cement* is:

Calcium Oxide (CaO)	=60 to 65 %
Silica (SiO_2)	=20 to 25 %
Aluminium Oxide (Al_2O_3)	= 4 to 8 %
Ferrous Oxide (Fe_2O_3)	= 2 to 4 %
Magnesium Oxide (MgO)	= 1 to 3 %

All the above compounds undergo some chemical combinations during the process of burning and fusion. Main constituents of Cement are Tri-Calcium Silicate ($3\ CaO.SiO_2$), Di-Calcium Silicate ($2\ CaO.SiO_2$) and Tri-Calcium Aluminate ($3\ CaO.\ Al_2O_3$). Tri-Calcium Silicate is the best cementing material and the more it is present in cement the better the cement is. In a properly burnt clinker Tri-Calcium Silicate should be about 40%. In case the burning is not done properly then the clinker shall have less of Tri-calcium Silicate and more of free lime. After the addition of water to cement it sets and hardens due to the hydration and hydrolysis of the above three compounds which act as a glue. The aluminate is the first to set and harden, Tri-Silicate is slower and the Di-Silicate is the slowest. As such the initial setting of cement is due to the action of aluminate. Further early gain in strength is due to Tri-Silicate. Di-Silicate takes 14 to 28 days to add to the strength. All the three compounds in their action with water give out heat. Maximum heat giving compound is the aluminate which is responsible for most of the undesirable properties of concrete. A cement having lesser aluminate shall have lesser initial strength but higher ultimate strength. Also there shall be lesser generation of heat, more volumetric stability, lesser cracking and more resistance to acid attacks. Incomplete burning of clinker leaves free lime in it. This free lime causes expansion and disruption of concrete after use. The silicates form a gel with water. The gel fills the pores of cement thereby making it impervious. The gel later on crystallises and firmly binds the particles.

According to IS 269-1975 composition of ordinary Portland cement shall satisfy the following conditions:

(1) Ratio of the percentage of lime to that of silica, alumina and iron oxide when calculated by the formula,

$$\frac{CaO-0.7SO_3}{2.8\,SiO_2+1.2\,Al_2O_3+0.65\,Fe_2O_3}$$ shall not be less than 0.66 and not more than 1.02.

(2) Ratio of percentage of alumina to that of iron oxide shall not be less than 0.66

(3) Weight of insoluble residue shall not be less than two per cent.

(4) Weight of magnesia shall not be more than six per cent.

(5) Total sulphur contents calculated as sulphuric anhydride (SO_3) shall not be more than 2.75 per cent.

(6) Total loss on ignition shall not be more than four per cent.

5.3 MANUFACTURE

Cement could be manufactured by any one of the two methods: (*i*) Dry process, and (*ii*) Wet process. In both these processes the three distinct operations of (*a*) Mixing, (*b*) Burning, and (*c*) Grinding are carried out.

5.3.1. Dry process. In this process lime stone and clay are ground separately to fine powders and are then mixed together in the desired proportions. Water is then added to it so as to get a thick paste of which cakes are then made, dried and burnt in kilns. To the *clinker* obtained after burning, is added three to four per cent of gypsum and ground to very fine powder. This, powder is cement ready for use.

This process is slow and costly. Also it is difficult to have the correct proportion of constituents and to do so is a cumbersome operation. The quality of cement is not so good as that of the one manufactured by the Wet process. This method has therefore become obsolete and the Wet process of manufacturing cement, described in details below, is widely used.

5.3.2. Wet process. (*i*) *Mixing*. The crushed raw materials in desired proportions are fed into ball mills (Fig. 5.1). A little water too is added to it. Ball mill is a rotating steel cylinder in which there are hardened steel balls. When the mill rotates the steel balls pulverise the raw materials which forms into a solution with water. This liquid mixture is known as *slurry*. This slurry is then passed into storage tanks known as *silos* where their proportioning is finally adjusted to ensure the correct chemical composition. Composition of raw mix can be controlled better by the *wet process* than in *dry process*. Corrected slurry is then fed into the *rotary kiln* for burning.

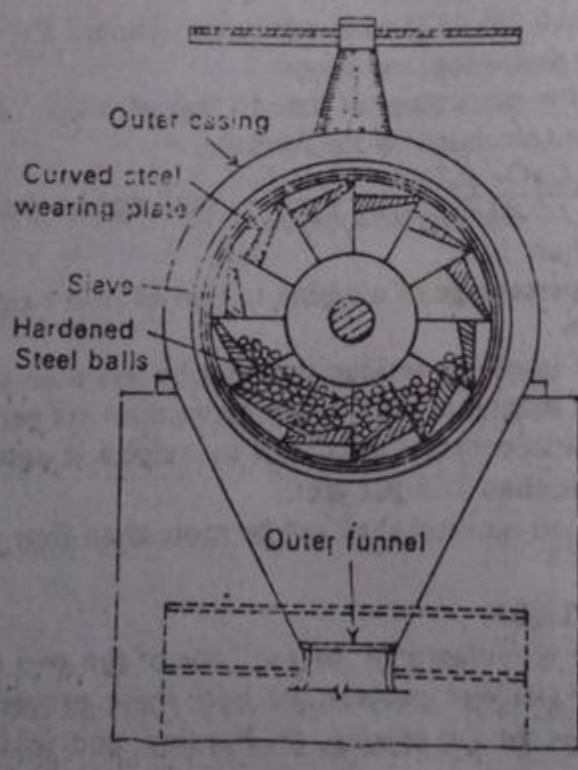
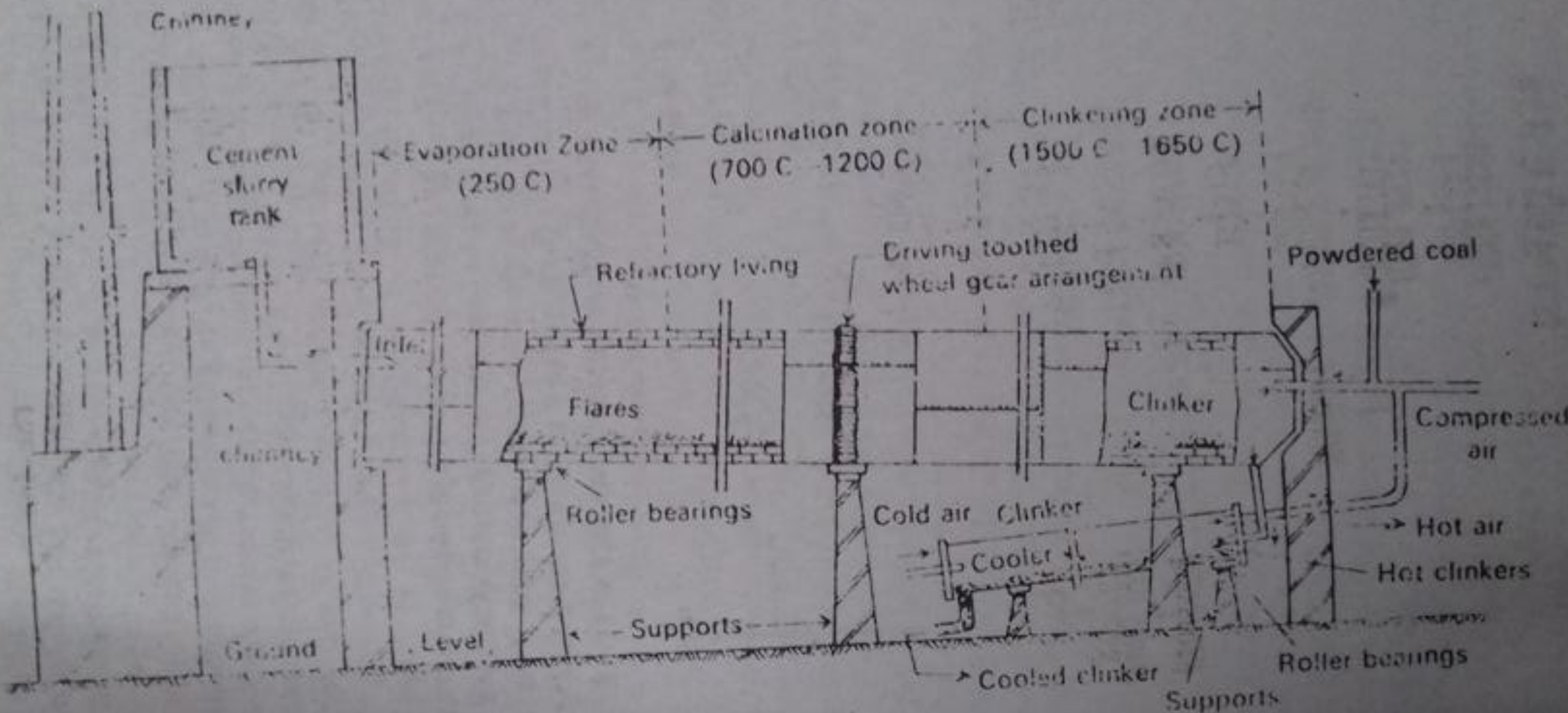


Fig. 5.1. Cross section of a Ball Mill.

(*ii*) *Burning*. Corrected slurry is fed at the higher end of the inclined rotary kiln (Fig. 5.2) whereas from the lower end of the kiln flame is produced by injecting pulverised coal with a blast of air. Rotary



ROTARY KILN

Fig. 5.2. Rotary Kiln.

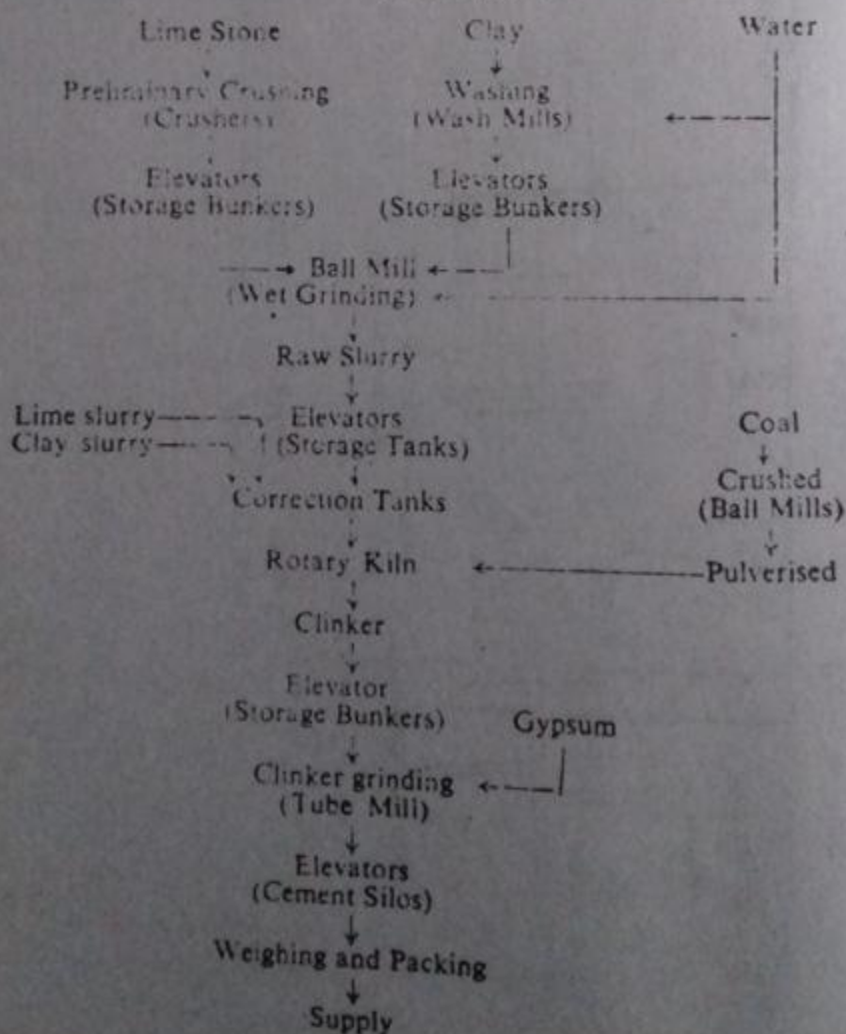
kiln is a steel tube lined inside with *fire bricks*. It is 90 to 120 metres long and from 2.5 to 3.5 metres in diameter. The kiln is mounted on rollers at a gradient of 1 in 25 to 1 in 30 and rotating once in every minute.

Slurry on entering the furnace losses moisture and forms into small lumps or "nodules". The nodules gradually roll down passing through zones of rising temperature until they reach burning zone where they are finally burnt at 1500 to 1650 C. At this temperature "nodules" change to *clinkers*. Clinkers are air cooled in another inclined tube similar to the kiln but of lesser length.

(*iii*) *Grinding*. Grinding of the clinker is done in large tube mills which are kept cool by spraying water on them from outside. While grinding the clinker three to four per cent gypsum (Calcium Sulphate) is added so as to control the setting time of cement. Finely ground cement is stored in silos from where it is drawn for packing.

FLOW DIAGRAM OF CEMENT MANUFACTURE

(Wet Process)



5.4 TESTING PORTLAND CEMENT

The Indian Standards Institution, New Delhi, has prescribed the following tests so as to control the quality of Portland cement.

5.4.1. Samples for testing. Each sample for testing shall consist of an intimate mixture of approximately equal portions selected from at least 12 different bags or packages when the cement is not loose or 12 different positions in the heap or heaps when the cement is loose. Selection of samples shall be done in such a manner so as to obtain a fair average sample. The weight of final sample shall be at least 5 kgs.

The sample so taken shall be stored in air tight container till the time of test.

5.4.2. Chemical composition. (*i*) *Loss on ignition*. Heat 1.0 gm of the sample for 15 minutes in a platinum crucible (or for one hour in porcelain crucible) at a temperature of 900°C to 1000°C. Cool and weigh. Loss on ignition should not be more than 4%.

(*ii*) *Insoluble residue*. Boil for ten minutes a well stirred mixture of one gram of cement, 40 cc of water and 10 cc of concentrated hydrochloric acid (sp. gravity 1.18). Filter the solution. Rinse the container five times and wash the filter ten times with hot water. Wash the residue on filter with hot water and boil for ten minutes with Na_2CO_3 solution (2N). Filter the solution again through the same filter paper and wash five times with water. It is now washed with Hydrochloric acid (2N) and finally with water till it is free from chlorides. The filter paper should be dried, ignited and weighed to give the insoluble residue.

The insoluble residue should not be more than 1.5 per cent.

(*iii*) *Lime and alumina.* The percentage of lime to silica, alumina and iron oxide when calculated by the formula:

$$\frac{CaO-0.7\ SO_3}{2.8\ SiO_2+1.2\ Al_2O_3+0.65\ Fe_2O_3}$$

shall not be greater than 1.02 nor less than 0.66. The ratio of the percentage of alumina to that of iron oxide shall not be less than 0.66. An excess of free lime shall cause unsoundness of cement.

(*iv*) *Magnesia.* If free magnesia exceeds five per cent then it makes the cement unsound.

5.4.3. Fineness. Finer cements react quicker with water and develop early strength, though the ultimate strength is not affected. However, finer cements increase the shrinkage and cracking of concrete. The fineness is tested by any one of the following two methods:

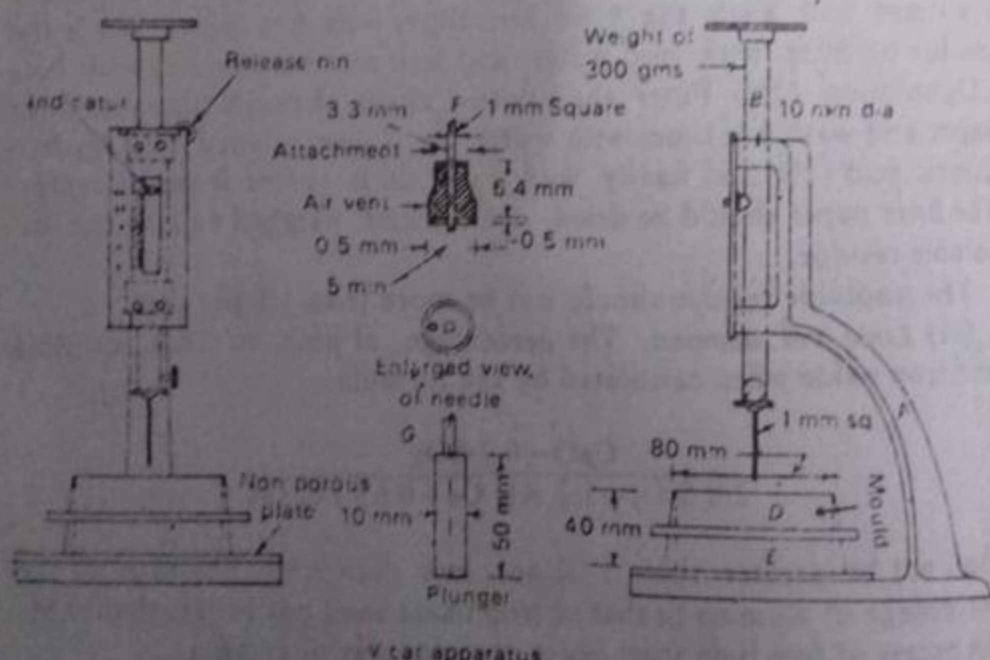
(i) By sieve analysis, and (ii) By specific surface.

(i) *By sieve analysis*. Break with hands any lumps present in 100 gms of cement placed in I.S sieve No. 9 and sieve it by gentle motion of the wrist for 15 minutes continuously. The residue when weighed should not exceed 10 per cent by weight of the cement sample.

(ii) *By specific surface*. Specific surface shall not be less than 2250 sq cm/gm as determined by Air Permeability method and 1600 sq cm/gm as found by Wagners' Turbidimeter method.*

5.4.4. Temperature for testing. The following physical tests should be carried out, as far as possible between the temperature range of 25°C to 29°C.

5.4.5. Consistency of standard cement paste. This test is performed to find out the correct amount of water to be added to a given quantity of cement so as to get a paste of "normal consistency." This test precedes the test of cement for soundness, setting time, tensile strength or for compressive strength. It is done with the help of *Vicat's apparatus* shown in Fig. 5.3. The frame *A* of Vicat Apparatus



Vicat apparatus

Fig. 5.3

has a movable rod *B* weighing 300 gms. Diameter of the rod is 1 cm and is 5 cm long. At its lower end is attached a detachable needle 1 mm square or 1.13 mm in diameter and 5 cm long. There is a vertical

*Detailed description of both these methods is beyond the scope of this book.

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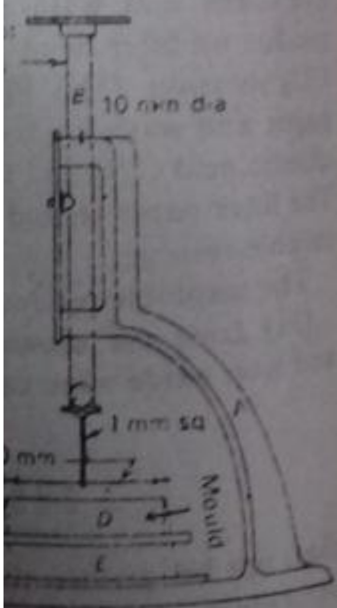


meter of the rod is 1 cm
a detachable needle 1
long. There is a vertical

ond the scope of this book.

scale *C* graduated from 0 to 40 mm in either direction to measure the vertical movement of the rod.

To start with 25 per cent of clean water is mixed with about 300 gms of neat cement in a crucible. The mixing is done with a standard *spatula* shown in Fig. 5.4. After about 30 seconds it is thoroughly mixed with hands for at least one minute. The kneaded paste is tossed about six times from one hand to the other and pressed into the hard rubber mould *D*, *E* through its bigger end. Fill the mould completely with paste and remove the extra paste by a single movement of the palm. Place the inverted mould (with larger end on glass plate *F*) and slice off extra paste from top by a single movement of trowel. Place the mould resting on glass plate under the needle. Bring 1 cm diameter end of needle in touch with the paste and release it without any jerk or force and note the penetration. Time taken from adding of water in cement to filling of mould should be between three to five minutes. Repeat experiment with trial pastes made with varying percentages of water. The paste giving a penetration of 33 to 35 mm is said to be of *normal consistency*. The amount of water mixed is expressed as a percentage by weight of dry cement. This is usually in the neighbourhood of 30 per cent for a paste of normal consistency.

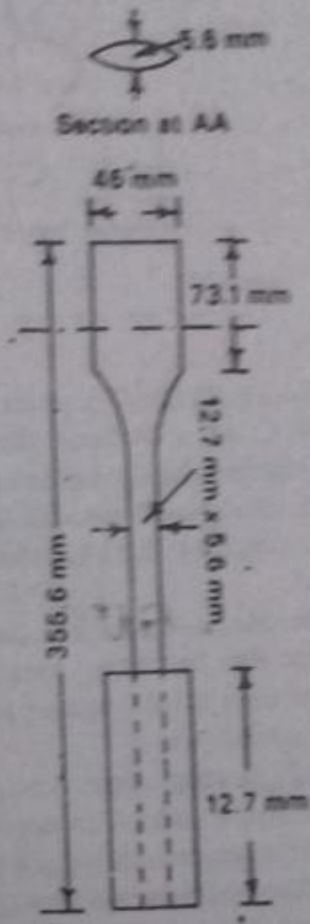
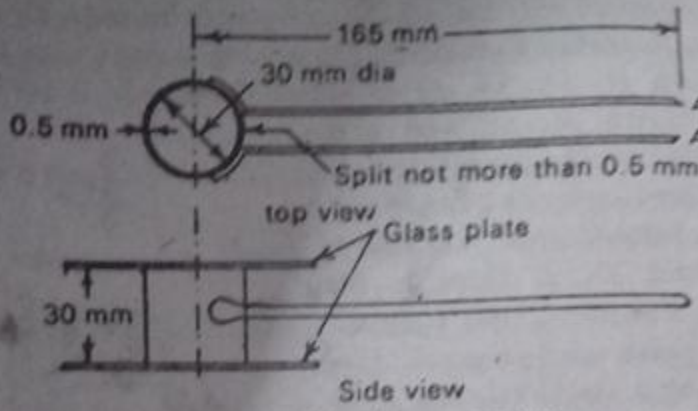


Fig. 5.4

5.4.6. Soundness. It is essential that cement concrete does not undergo large changes in volume after setting. This change in volume is known as *Unsoundness* and may cause cracks, distortion and disintegration of concrete.

The test is carried out with the help of "Le-Chatalier's apparatus" shown in Fig. 5.5. It consists of a split brass cylinder 30 mm high, 30 mm internal diameter and 0.5 mm thick. Two pointers *AA*, 165 cms in length up to the axis of cylinder are attached to the cylinder, one on each side of the split. Cement paste prepared with 0.78 times the water required to prepare a paste of normal consistency and 100 gms of cement is filled in the mould resting on a glass plate. Another glass plate is placed on the mould and weighed down. The whole is im-



Le Chatelier apparatus

Fig. 5.5

mediately placed in a water bath maintained at a temperature of 27°C to 32°C. After 24 hours the distance between the pointers is measured and the mould is transferred to a beaker of water heated to boiling point in 25 to 30 minutes, and kept at this temperature for one hour. After cooling the increase in the distance between the pointers is noted.

The increase in this distance should not be more than 5 mm for cement that had been aerated for seven days in a humidity of 50 to 80 per cent before test or 10 mm if the cement had been kept in air-tight containers.

5.4.7. Setting time. To enable the concrete to be laid in position properly the *initial setting* of cement should not start too quickly. Once the concrete has been laid it should harden rapidly so that the structure could be put to use early. *Initial setting of cement is that stage in the process of hardening after which any cracks that may appear do not reunite. Final setting is that when it has attained sufficient strength and hardness.*

Vicat apparatus shown in Fig. 5.3 is used to find the setting time for cement. The paste of 300 gms cement made with 0.85 times the amount of water required for a paste of normal consistency is filled in the mould as explained in Art. 5.4.5. At the lower end of the rod is fitted 1 mm square needle. This needle is brought in contact with the surface of paste and released. The *initial set* is said to have taken place when the needle fails to penetrate beyond a point 5 mm above the glass plate. The time taken from the instant water was added to cement to the moment when the needle fails to penetrate beyond 5 mm above the glass plate is known as initial setting time. It should not be less than 30 minutes for Ordinary Portland Cement.

For finding out the final setting time the 1 mm square needle is replaced by the needle F (Fig. 5.3). This needle has an annular attachment around 1 mm square needle and projecting by 0.5 mm below it. To find final setting time the needle shall be brought in touch with the paste in the mould and released instantly. Final set shall be considered as having taken place when the attachment fails to make any impression on the surface of paste whereas the needle makes one. The time from the moment water was added to cement to the moment the circular attachment fails to make impression on the surface of cement paste is known as final setting time.

For ordinary Portland cement the final setting time should not be more than ten hours. The test should be performed in an air conditioned room with 90 per cent humidity and at temperature between 27°C to 29°C.

5.4.8. Compressive strength. The compressive strength of cement is judged by finding the compressive strength of cement and sand mortar. For this purpose one part by weight of cement is mixed dry with three parts by weight of IS sand. To this dry mixture of cement and sand is added water given by the following formula:

$$P = \frac{P_n}{4} + 3.5$$

where P is the percentage of water by weight of dry materials and P_n is the percentage of water required for making a cement paste of normal consistency. Cement sand and water shall be intimately mixed to give paste of uniform colour but the mixing should not be for less than three minutes or for more than four minutes. Cubes of 7.06 cm sides are then moulded out of this paste and are kept in an atmosphere of 90 per cent humidity and 27°C to 29°C temperature for 24 hours. These are then removed from the moulds and kept submerged in clean water till the time of test and should not be allowed to dry.

Three cubes each are tested in a compression testing machine after three days and seven days. Compressive strength of ordinary Portland cement should not be less than the following values:

After 3 days	115 kg/sq cm
After 7 days	175 kg/sq cm

5.4.9. Tensile strength. Tensile strength of cement sand mortar is tested to judge the tensile strength of cement. To do so *briquettes* of standard dimensions as shown in Fig. 5.6 are prepared. Briquettes

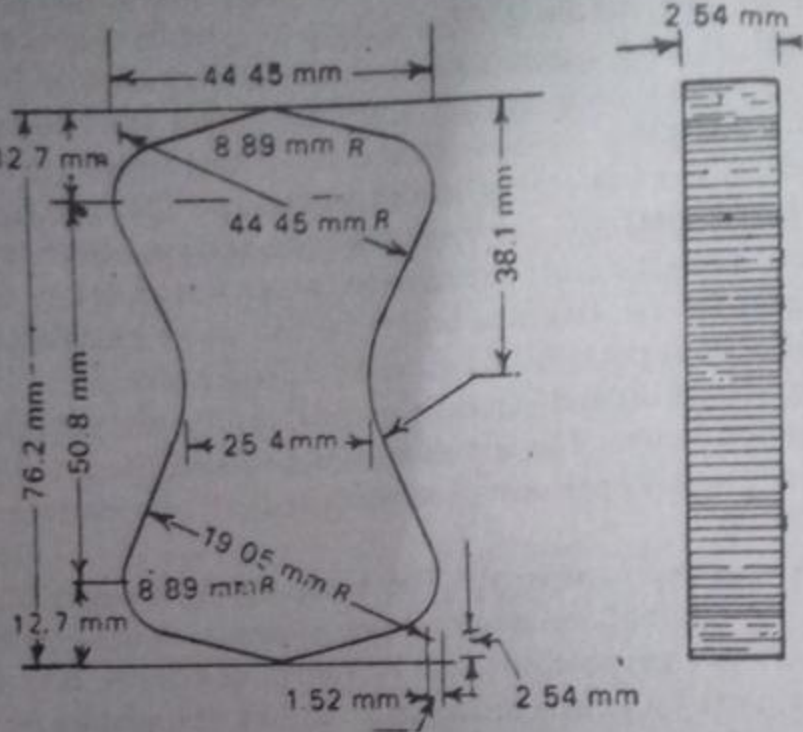


Fig. 5.6

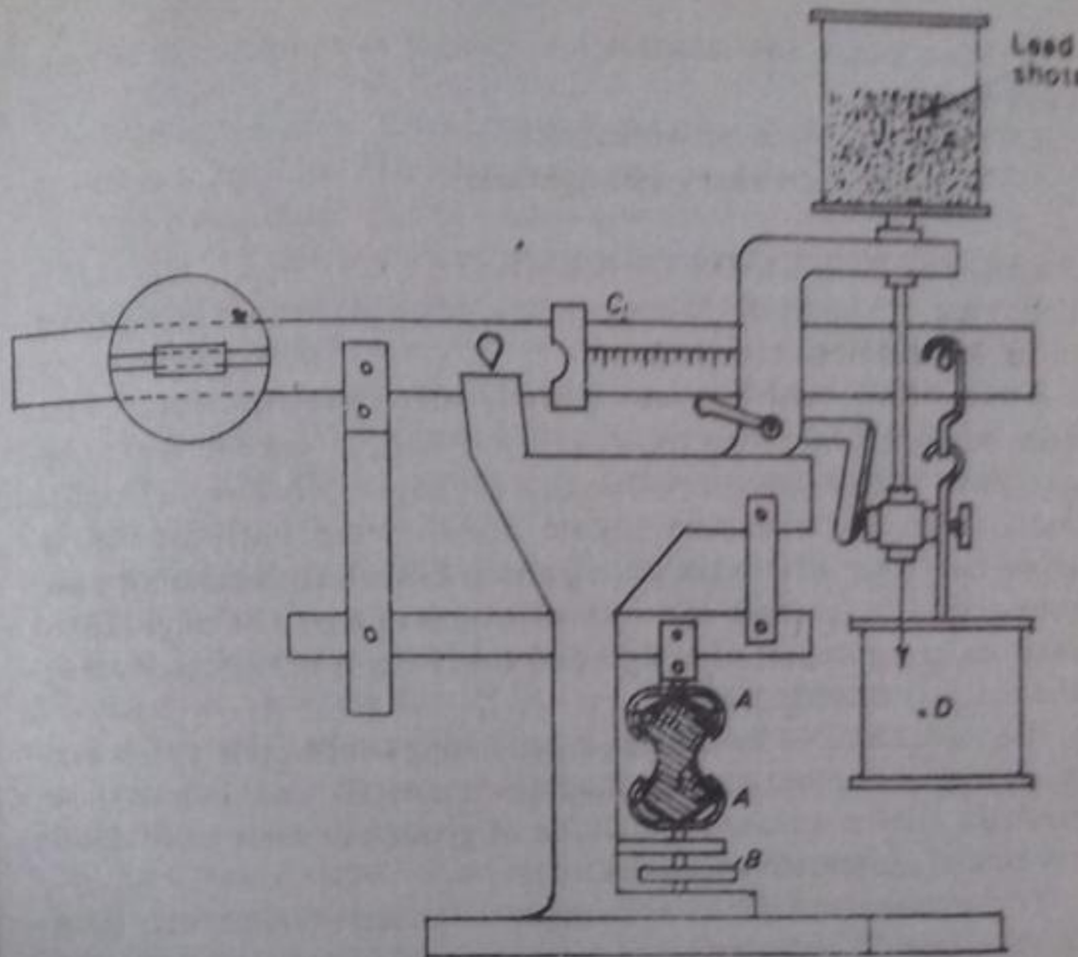
have a uniform thickness of 25.1 mm and a minimum sectional area of 645 sq mm at the central section. For preparing briquettes one part by weight of cement and three parts by weight of water are mixed with the quantity of water found from the following formula:

$$P = 0.2\,P_n + 2.5$$

Cement, sand and water are mixed intimately so as to get a uniform colour of the mortar. A small heap of mortar is placed on a briquette mould and filled as usual. It is then beaten down with the *standard spatula* (Fig. 5.4) till water appears on the surface. The mould is now turned upside down and as before again a small heap of mortar is placed and beaten down. The surfaces are smoothed with the blade of a trowel. The briquettes are taken out of moulds after keeping then in an atmosphere of 90 per cent humidity and a temperature of 25°C to 29°C for 24 hours. Six such specimen each are tested in a briquette testing machine (Fig. 5.7) after three days and seven days.

Tensile strength for good Portland cement should be as follows:

After 3 days	not less than	20 kg/sq cm
After 7 days	not less than	25 kg/sq cm



Ejg. 5.7. Briquette testing machine.

5.5 POZZOLANAS

These are silicious materials which, while having no cementitious values within themselves, will chemically react with Calcium Hydroxide at ordinary temperatures and in the presence of moisture to form compounds possessing cementitious properties.

The term includes natural volcanic material having pozzolanic properties as also other natural and artificial materials, such as calcined clay (Surkhi) and fly ash.

Clay pozzolanas have the following advantages:

1. These replace cement to the extent of 20 per cent in cement concrete and mortars without affecting the strength and also constitutes 20 to 30 per cent of the Pozzolana cement. A cement sand mortar of 1:6 mix can be better replaced by a mortar made by mixing one part of hydrated lime, two parts of clay pozzolana and eight parts of sand.

2. In conjunction with the standard quality dry hydrated lime, these can be used for preparation of mortar and plasters having the same strength as that of cement-sand mortars.

3. Lime pozzolana mortars are cheaper as compared to cement-sand mortars.
4. These give improved workability.
5. These give increased water tightness.

5.6 DIFFERENT KINDS OF CEMENT

Following are some of the important kinds of cements manufactured to suit the different requirements.

5.6.1. Rapid hardening or high early strength cement. This cement gains strength faster than the ordinary Portland cement. Its *initial and final setting times* are the same as those of ordinary cement. It contains more of tri-calcium silicate and is more finely ground. It gives out more heat while setting and is as such unsuitable for mass concreting. It is used for such structures as are to be subjected to loads early *e.g.* repair of bridges and roads etc. It is more costly than the ordinary cement.

It is manufactured by burning at clinkering temperature an intimate mixture of calcareous and argillaceous materials and grinding the resultant clinker *without* the addition of gypsum and not more than 1 per cent of air entraining agents.

The average compressive strength of at least three mortar cubes (area of face 50 cm²) composed of one part of cement and three parts of standard sand by mass and* $P/4 + 3$ per cent (of combined mass of cement and sand) water shall be as under:

(*a*) After 24 hours	Not less than 160 kg/cm²
(*b*) After 72 hours	Not less than 275 kg/cm²

For details refer to IS: 8041 E—1976

5.6.2. Quick setting cement. It sets faster than the ordinary Portland cement. Its *initial setting time* is 5 minutes and the *final setting time* is 30 minutes. It is used for making concrete that is required to set early, as for laying under water or in running water. Initial setting time being very little there is always the danger of concrete having undergone initial setting during mixing and placing. As such this cement is used only in exceptional circumstances.

5.6.3. High alumina cement. It is manufactured by fusing together a mixture of bauxite and lime stone in correct proportions and at high temperatures. The resulting product is ground finely. It developes strength rapidly. It is of black colour and resists well the attack of

*P is the percentage of water required to prepare a paste of standard

chemicals especially of sulphates and of sea water. Its ultimate strength is much higher than that of ordinary cement. Its initial setting time is more than 2 hours and the final set takes place immediately thereafter. Most of the heat is given out by it in the first 10 hours as a result of which it can be conveniently used in freezing temperatures but is used in thin layers in normal temperatures.

5.6.4. **Portland slag cement.** It is obtained by mixing Portland cement clinker, gypsum and granulated slag in proper proportions and grinding it finely. This cement has properties very much similar to those of ordinary Portland cement with the following improvements:

(*i*) It has lesser heat of hydration.

(*ii*) It has better resistance to soils, sulphates of alkali metals, alumina and iron.

(*iii*) It has better resistance to acidic waters.

This cement can advantageously be used in marine works.

Manufacture of Portland slag cement is aimed primarily at profitably utilizing blastfurnace slag—a waste product from blastfurnaces.

For details refer to IS: 455-1976.

5.6.5. **Low heat cement.** Heat generated by cement while setting may cause the structure to crack in case of concrete. Heat generation is controlled by keeping the percentage of Tri-Calcium aluminate and of Tri-Calcium silicate low. Its *initial and final setting* times are nearly the same as those of ordinary cement but the rate of its developing strength is very slow. It is not very suitable for use in ordinary structures, when not only the use of structure shall be delayed but also the shuttering shall have to be kept for long and curing shall be prolonged.

5.6.6. **Air entraining portland cement.** It is ordinary Portland cement mixed with small quantities of air entraining materials at the time of grinding. Usual air entraining materials used are resin, vinsol resin, oils, fats and fatty acids. Vinsol resin and darex are most commonly used. These materials have the property of entraining air in the form of fine air bubbles in concrete. These bubbles render the concrete more plastic, more workable and more resistant to freezing. However, because of air entraining the strength of concrete reduces and as such the quantity of air so entrained should not exceed five per cent.

5.6.7. **White cement.** It is a cement with pure white colour and having same properties as those of ordinary Portland cement. Greyish colour of ordinary cement is due to iron oxide as such white cement is manufactured from white chalk and clay free from iron oxide. Oil fuel and not the coal is used for the burning of this cement. It is much more costly than ordinary cement.

5.6.8. Coloured cement. By mixing suitable pigments ordinary Portland cement could be given red or brown colour. For other colours 5 to 10 per cent of desired pigments are ground with white cement.

Pigments used in cement should be chemically inert and also durable so as not to fade due to the effect of light, sun or weather.

5.6.9. Portland pozzolana cement. Portland pozzolana cement is produced either by grinding together Portland cement clinker and Pozzolana, or by intimately and uniformly blending Portland cement and fine Pozzolana.

This cement has properties similar to those of ordinary Portland cement, and can therefore be used for all general purposes where the latter is employed, with no change in the proportion of coarse or fine aggregates and cement. Gypsum is added in both cases.

Portland pozzolana cement produces less heat of hydration and offers greater resistance to the attack of aggressive waters or sulphate bearing soils than ordinary Portland cement. It also reduces leaching of calcium hydroxide liberated during the setting and hydration of cement. Consequently Portland pozzolana cement is particularly useful in marine works and also in mass concrete structures.

Pozzolana cement takes a little longer than ordinary Portland cement to gain strength. It is recommended that when Pozzolana cement is used in reinforced concrete, the centerings be left in position a little longer than would be the case with ordinary Portland cement.

Ultimate strength of this cement is more than that of ordinary Portland cement but initial and final setting times are the same.

A.C.C. manufactures this cement conforming to IS: 1489-1976.

5.7 CEMENT WATER PROOFERS

Under various trade names some patent products have been put on the market by different companies. These, if added to cement mortar or cement concrete in specific proportions make the mortar/concrete impervious. These chemicals may be in powder, liquid or paste form. If these are used in excess then the setting of cement is affected.

"Pudlo" and "Impermo" are the popular foreign water proofers. Indian products are "Cico", Acoproof and Proofit.

5.8 STORAGE

Portland cement is a finely ground material. It therefore readily absorbs moisture even from the atmosphere. It is therefore essential to protect it from dampness during storage. Lack of proper care may cause setting of cement or reduction in its strength due to partial setting. Following precautions must as such be taken in storing cement:

(*i*) Walls, roof and floor of the building in which cement is to be stored should be completely waterproof.

(*ii*) In case the cement store is newly constructed then its interior should have been throughly dried before cement is stored in it.

(*iii*) Doors and windows should be properly fitted and should be kept shut.

(*iv*) Except in case of dry concrete floor the cement bags should be stacked on wooden planks

(*v*) The bags should be stacked away from walls. A space of 25 cm all around should be left between the exterior walls and the piles.

(*vi*) Bags should be piled close together.

(*vii*) Bags should be piled in header stretcher fashion and not more than 15 bags high.

(*viii*) While removing cement from store do not take out bags from one tier only. Step back two or three tiers.

(*ix*) Each incoming consignment should be stacked separately and a placard bearing date of arrival of the consignment should be pinned to it. This would help in using cement in the same order as it arrives thereby avoiding *dead storage*, that is a stack remaining in position for a long time while other consignments of cement come in and go out.

(*x*) For temporary storage of cement at site of work, bags should not be stacked on the ground. Minimum number of bags needed should be piled upon raised dry platform and covered with trapaulins.

EXERCISES

1. (*a*) Briefly describe the manufacture of Portland cement.

(*b*) What is the chief chemical composition of Portland cement?

2. When and by whom was Portland cement first invented and manufactured? Write down the standard specifications for tensile strength, setting and fineness of Portland cement now in practice. What is the difference between "rapid hardening cement" and "slow setting cement" and for what particular requirements are these used?

3. (*a*) Draw a line diagram showing how cement is manufactured. Name the raw materials used.

(*b*) Define initial and final setting times. Give their usual values for ordinary Portland cement.

4. (*a*) Describe in details the manufacture of Portland cement by dry and wet process.

(*b*) Compare the advantages of both.

5. Write notes on:

(i) Rapid hardening cement.

(ii) Quick setting cement.

(iii) Blast furnace cement.

(iv) High alumina cement.

(v) Cement water proofers.

6. Enumerate the various tests for Portland cement.

7. What is the purpose of adding gypsum in cement while grinding.

8. (a) Describe the manufacture of ordinary Portland cement.

(b) Name three types of cements other than ordinary Portland cement.

9. What precautions would you take in storing cement (i) in a godown (ii) at site?

10. What do you mean by a cement paste of normal consistency? How is it tested and what is its significance in tests.

6

AGGREGATES

6.1 AGGREGATES

Aggregates are inert materials mixed with a binding material like cement, lime or mud in the preparation of mortar or concrete. Depending upon the size of their particles the aggregates are classified as *fine aggregates*, *coarse aggregates* and *cyclopean aggregates*.

6.2 FINE AGGREGATES

Particles of fine aggregates pass through 4.75 mm mesh and are entirely retained on 0.15 mm mesh. Most commonly used fine aggregates are sand, crushed stone, ash or cinder and surkhi. Aggregates that do not pass through 4.75 mm mesh are termed as coarse aggregates.

6.2.1. Sand. It consists of small grains of silica and is formed by the disintegration of rocks caused by weather. As per IS specification No. 1542-1960 sand should have the following qualities:

(*i*) Shall be hard, durable, clean and free from adherent coatings and organic matter and shall not contain appreciable amount of clay.

(*ii*) Shall not contain harmful impurities such as iron pyrites, alkalies, salts, coal, mica, shale or other materials which will affect hardening and attack reinforcement.

(*iii*) In natural sand or crushed gravel, the amount of clay, fine silt and fine dust should not be more than 4 per cent by weight and in crushed stone it should not be greater than 10 per cent.

Generally sea sand should not be used except in making precast piles and heavy stones for use in harbour works.

6.2.2. Kinds of sand. Depending upon the source from which sand is obtained it is classified as: (*i*) Pit sand or quarry sand; (*ii*) River sand; and (*iii*) Sea sand.

(*i*) *Pit sand or quarry sand.* It is found as deposits in soil and has to be excavated out. Grains of it are generally sharp and angular. If free from organic matter and clay, it is extremely good for use in mortar and concrete.

(ii) *River sand.* It is obtained from the banks and beds of rivers. It may be fine or coarse. There are chances of fine sand having silt and as such it should be washed before use. Coarse sand is generally clean and is excellent for all purposes.

(iii) *Sea sand.* It consists of fine rounded grains of brown colour and is collected from sea beach. It usually contains salt which absorbs moisture from the atmosphere and causes disintegration of the work in which it is used. It could be used locally after it has been thoroughly washed to remove the salts.

6.2.3. Crushed stone. It is obtained by crushing waste stone of quarries to the particle size of sand. Stone crushed from a good quality stone is an excellent fine aggregate. By using stone crush of the same stone, a mortar matching the colour of stone masonry can be easily had. Such mortars are usefully used in ashlar work.

6.2.4. Ash or cinder. These are obtained in the form of fine ashes from steam locomotive or from furnaces and are finely ground with lime to have cheap yet strong mortar known as *black mortar*. It should be free from unburnt or partially burnt coal.

6.3 SURKHI

Powdered broken brick (burnt brick) locally called *surkhi* is used as fine aggregate in lime mortar. Surkhi shall be prepared by finely grinding well burnt good quality bricks free from underburnt particles of soluble salts, pyrites and adherent coatings of soil or silt. The maximum quantity of clay, fine silt and fine dust present shall not exceed five per cent by weight.

The particle size grading of surkhi for use as fine aggregate in lime mortar in masonry works shall be within the limits specified in table below as per IS: 3182-1975.

Requirements for Broken Brick (surkhi) fine Aggregate for use in Lime Mortar

IS Sieve designation	*Percentage passing (By mass)*
4.75-mm	100
2.36-mm	90 to 100
1.18-mm	70 to 100
600-micron	40 to 100
300-micron	5 to 70
150-micron	0 to 15

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6.4 QUALITIES OF GOOD SAND

(*i*) Good sand should have coarse and angular grains of pure silica.

(*ii*) The grains of sand should be hard, strong and durable.

(*iii*) It should be free from silt, clay or any such salts that may hamper setting or attack the reinforcement.

(*iv*) It should not contain any organic matter.

(*v*) It should be well graded *i.e.* should contain in suitable proportions particles of various sizes.

(*vi*) It should not contain any hygroscopic matter.

6.5 FUNCTIONS OF SAND IN MORTAR

(*i*) It is used as an adulterant to increase the volume of mortar.

(*ii*) It reduces shrinkage and cracking of mortar on setting.

(*iii*) It helps pure lime to set because it allows the penetration of air which provides carbon dioxide needed for the carbonization and setting of lime.

6.6 BULKING OF SAND

Volume of sand fluctuates with the variations in its moisture content. When the sand (fine aggregate) is wet then each particle gets a coating of water which due to surface tension keeps them apart thereby causing an increase in the volume of sand. This increase in volume due to the sand being wet is known as "*Bulking of sand.*"

Figure 6.1. Shows a typical *bulking curve* for sand.

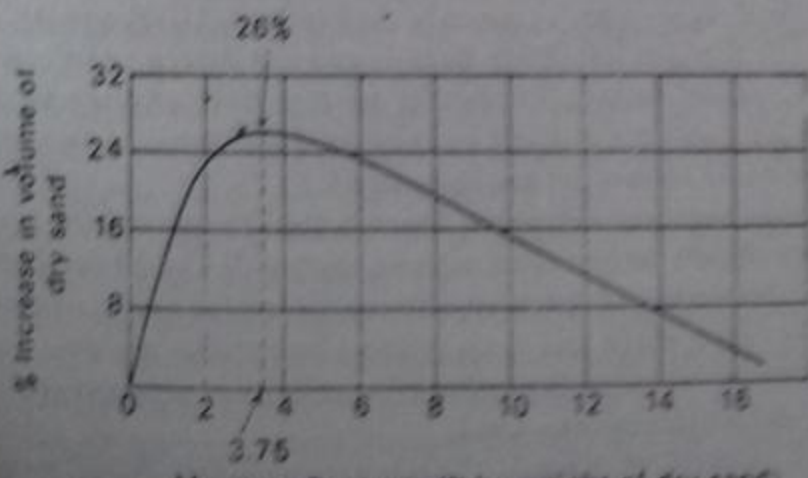

Fig. 6.1. Typical Bulking of Sand.

Bulking increases gradually with the increase in moisture contents. At four per cent moisture content by weight, the increase in volume

is about 25 per cent. It then decreases with the increase in moisture, till it becomes zero when the water is more than 20 per cent.

Bulking is more in finer sands than in the coarser ones. *In measuring sand by volume its bulking due to moisture content should be taken note of.*

6.7 TESTS FOR SAND

To check the suitability of sand for being used in mortar or concrete it maybe put to the following field tests:

(*i*) Rub a little sand between the fingers. Stains left on fingers will indicate the presence of (undesirable) clayey impurities.

(*ii*) Taste of sand shall provide a suitable check for the presence of salts.

(*iii*) Vigorously stir a sample of sand in a glass of water and allow it to rest. Amount of clay or silt present in it would settle on the sand.

(*iv*) Stir a sample of sand in a three per cent solution of caustic soda and keep the bottle corked for 24 hours. If the colour of liquid turns brown then the presence of organic matter is indicated.

6.8 FUNCTIONS OF SURKHI IN MORTAR

It is used as an adulterant but it imparts strength and hydraulic properties to the mortar. To develop more strength it should be ground very finely with lime in the mortar grinding mill. (Figs. 4.3, 4.4)

6.9 COARSE AGGREGATES

Aggregates the size of whose particles is bigger than 4.75 mm but smaller than 7.5 mm are known as coarse aggregates. Following are the coarse aggregates commonly used in India: (*i*) Stone Ballast; (*ii*) Gravel or Shingle; (*iii*) Brick Ballast; and (*iv*) Breeze and Clinker.

6.9.1. Stone ballast. Stones that are free from undesirable mineral constituents and are not soft or laminated are broken and screened to have stone ballast for use in concrete.

It is an excellent aggregate. Stone ballast to be used for preparing concrete should be free from organic matter. It should be thoroughly washed before use, if it has an objectionable proportion of clay in it. Granite, sand stone and close grained lime stones are well suited for the purpose. It is used for making concrete, in the construction of roads and on the railway track.

6.9.2. Gravel or shingle. These are obtained from river beds, quarries and sea shores. Being hard and durable these are extensively used as an aggregate in the preparation of concretes. Clay and salt (*in case of those had from sea shore*) are the common impurities which should be removed before use by washing; when locally available it is used in place of stone ballast.

6.9.3. **Brick ballast.** Broken brick is used as a coarse aggregate in lime concrete at places where aggregate from natural resources is either not available or is expensive. It is a reasonably good substitute for stone aggregate when well burnt good bricks are available in sufficient quantity. It can be used at places where lower strength is required or where it is exposed to less severe conditions of service.

The aggregate shall be free from dust and be of the grading specified in Table 6.1.

TABLE: 6.1 Grading Requirements

IS Sieve designation *mm*	*Per cent by weight passing*
80	100
40	95 to 100
20	45 to 75
4.75	—

The aggregate after immersion in cold water for 24 hours should not absorb more than 25 per cent of its weight of water. The ballast should be thoroughly saturated with water before using it in preparing the concrete.

For details refer to IS: 3068-1975

6.9.4. **Breeze and clinker.** These are the bye-products of burning of coal. Because of the presence of excessive sulphur in them they corrode steel and as such these should not be used for R.C.C. work or for encasing beams and pillars etc. They constitute a cheap and light material and are conveniently used for internal concrete blocks or slab partitions not carrying any loads. When used with cement they cause considerable expansion. Blocks of concrete made with breeze or clinker could easily be nailed.

6.10 CYCLOPEAN AGGREGATES

Size of this aggregate is from 7.5 cm to 15 cm. It should satisfy the requirements of IS 515—1959 whereas the coarse and fine aggregates should satisfy the requirements of IS 383—1970. Detailed description of it is beyond the scope of this book for which reference may be made to relevant IS codes.

6.11 HARMFUL MATERIALS

Aggregates should not contain any harmful material like clay, organic impurities, alkali, iron pyrites, shale, coal, mica, soft fragments and sea shells etc., in such quantities as to impair the strength and durability of the concrete. In case of R.C.C. the aggregates should not in addition contain any such matter that may attack the reinforcement. Also the aggregates should not be chemically reactive with cement.

EXERCISES

1. What are the different types of fine aggregates used in mortars nd concrete? Discuss each.
2. What are the sources of sand? Give its characteristics and uses
3. What is the purpose of the following:
   (*i*) Adding sand to cement mortar.
   (*ii*) Adding surkhi to lime mortar.
4. What is Bulking of sand? Discuss.
5. What is coarse aggregate? What are the different kinds of it used in making concrete? Explain.
6. How is surkhi prepared? What is its function in mortar?

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7

MORTARS

7.1 MORTAR

Mortar may be defined as a paste formed by mixing water, a fine aggregate and a binding material in a specified proportion. This paste hardens on drying and binds the bricks, stones or concrete blocks together.

7.2 USES OF MORTAR

(*i*) It is used in masonry to bind stones, bricks or concrete blocks together.

(*ii*) It provides an even bed to stones, bricks or concrete blocks and prevents their inequalities from bearing upon one another.

(*iii*) It is used for pointing the joints of masonry or for plastering the surface of masonry to protect it from weather and to give the work a pleasing and smooth finish.

(*iv*) In concrete it is used to bind the particles of coarse aggregate into one solid mass.

7.3 TYPES OF MORTAR

Different mortars that are in common use are: (*i*) Lime mortars, (*ii*) Cement mortar, and (*iii*) Lime cement or Composite mortar. Each one of the mortars are discussed in details below:

7.4. LIME MORTARS

Lime mortar may be lime and sand mortar, lime and surkhi mortar, lime, sand and surkhi mortar or lime and cinder mortar (*black mortar*).[1]

Slaked fat lime is used to prepare mortar to be used for plaster-

[1]Named after its colour.

ing and hydraulic lime in preparing mortar for use in masonry construction.

7.4.1. Choice of aggregates. For strength, coarse and well graded sand should be used. A poor sand could be used for non-load bearing work. Sand with fineness modulus[2] of 2 to 3 is quite suitable for lime sand mortars made with fat lime while sand of fineness modulus between 1.5 and 2.5 would be good for use with hydraulic lime. For details refer to § 6.3.

Surkhi is a pozzolanic[3] material. It should be well ground so that its pozzolanic properties are utilized in full. For details refer to § 6.2.5.

Use of cinder as a pozzolanic material gives good results. It should be clean, free from unburnt carbon contents and ground in a mill so as to pass through IS Sieve No. 320. For details refer to § 6.2.4.

7.4.2. Preparation of mortar. If the mortar to be prepared is to be used for the finishing coat of plaster then finer sand passing through IS 25 and surkhi passing through (IS 10) should be used.

The same specifications as for lime and surkhi mortars apply for the preparation of lime cinder, lime surkhi sand and lime cinder sand mortars.

Method of mixing the mortar affects the quality and strength of mortar. There are essentially two methods of mixing lime mortar: (*i*) Manual mixing on a platform, and (*ii*) Grinding it in a mortar mill (run by animal or mechanical power).

7.4.3. Manual mixing. Measured quantities of aggregate and slaked lime in the form of powder or putty are placed on a masonry platform or in a masonry tank. The constituents are first mixed dry by turning them over three or four times with spades. Then the mixing is continued, after adding water, till a mortar of uniform colour and consistency is obtained.

7.4.4. Mortar mill mixing. Bullock driven mortar mill (Fig. 4.3) is populary known as *lime chakki*. In this mill water, aggregate and lime which is usually in the form of *putty* are added in requisite proportions and grinding is done till a mortar of uniform consistency is obtained. As grinding proceeds the mixture is continuously raked especially on edges and on sides so as to get a uniform mix.

[2]*See* Chapter 8, § 8.

[3]Pozzola is an essentially silicious material which while in itself possessing no cementitious properties will, in finely divided form and in the presence of water react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

Grinding is done for 100 to 200 revolutions depending upon the nature of lime, aggregate used and the quality of mortar desired.

It takes $1\frac{1}{2}$ to 3 hours for the grinding of one batch of mortar, depending upon the size of mill and the number of revolutions specified. In case a mechanical mixer of rollar and pan type (Fig. 4.4) is used then equally good results are obtained in much less time.

7.5 LIME CEMENT MORTAR

It is also known as composite mortar or gauged mortar. When lime mortar made from *fal lime* is desired to be improved with regard to its initial setting time then cement is added to it. Cement should be added only to that much lime mortar which can be used within two hours of the addition of cement.

7.5.1. **Mixing.** Any one of the following three methods could be used:

(*i*) Cement and sand in requisite proportions is mixed dry. Lime in the form of putty dissolved in mixing water is then added to it and mixing continued till mortar of uniform consistency is obtained.

This method is better suited when the proportion of lime in the mortar is not much.

(*ii*) Lime and sand are first mixed separately, for the entire day's requirements, in the form of stiff paste and stored. Cement is then mixed with lime mortar in small batches as required.

When lime mortar is prepared in the grinding mill then this is the only method which can be adopted for making this mortar.

(*iii*) Cement, sand and slaked lime in required proportions are first mixed dry. Water is then added and mixing continued till a paste of uniform colour and consistency is obtained.

7.6 SELECTION OF MIX

Expert's Committee on "Economy in the use of cement in building construction" appointed by the Ministry of Works and Housing has recommended the specifications for lime mortar needed for different works as in Tables 7.1 to 7.4. However for general use lime sand mortar 1 : 6 and cement lime sand mortar 1 : 2 : 9 are quite satisfactory.

7.7 CEMENT MORTAR

It is far stonger than lime mortar and is therefore preferred for use in the construction of structures subjected to heavier pressures. When small quantities of it are required then it is prepared manually. In case the requirements are much then it is mixed mechanically in mixers.

TABLE: 7.1 Mortars for Foundation Concrete

Situation	*Type of mortar (all proportions by volume)*	*ISI Grading of lime*	*Remarks*
Dry sub-grade, with sub-soil water-level never within 2.5 m of the foundation level	(*i*) 1 lime, 2 sand	A	Normally suitable for buildings not more than three storeys high. The quantity of mortar to be used will depend on the grade of aggregate.
	(*ii*) 1 lime, 1 surkhi, 1 sand	B, C or A	
	(*iii*) 1 lime, 2 surkhi	B, C or A	
	(*iv*) 1 cement, 3 lime, 12 sand	B or C	
Moist sub-grade with high sub-soil water usually 2.5 m or less below foundation level	1 : 4 or 1 : 3 (Cement and sand mortar)		The corresponding concrete mix will be 1 : 4 : 8 or 1 : 3 : 6.

TABLE: 7.2 Mortars for Masonry in Foundation and Plinth

Loading condition	*Moist sub-grade with sub-soil water less than 2.5 m below foundation level with high percentage of soluble sulphate*	*Moist sub-grade as in (2) with little or no soluble sulphate*	*Dry sub-grade with sub-soil water never within 2.5 m of foundation level*	*ISI Grading of lime*
(*1*)	(*2*)	(*3*)	(*4*)	(*5*)
Heavy and medium loading (44 tonne/m³ and above)	1 cement, 3 sand (use of high lumina cement and pozzolanic cement is recommended)	1 cement, 1 lime, 6 sand	1 cement, 1 lime, 6 sand	B or C
Lighter loading (less than 44 tonne/m³)	(*a*) Below ground level 1 cement, ? sand (high alumina cement and pozzolanic cement are preferred) (*b*) In plinth 1 cement, 1 lime, 6 sand	1 cement, 1 lime, 6 sand	(*i*) 1 lime, 2 sand (*ii*) 1 lime, 1 surkhi, 1 sand (*iii*) 1 lime, 2 surkhi (*iv*) 1 cement, 3 lime, 12 sand	A B, C or A B, C or A B or C

TABLE 7.3 Mortars for Masonry in Super-Structure in Unframed and Framed Buildings

Situation	*Special conditions*	*Type of masonry unit*	*Type of mortar (proportion by volume)*	*ISI Grading*	*Remarks*
Load bearing walls	Very heavy loading (88-110 tonne/m²)	Brick of crushing strength of not less than 105 kg per sq cm	1 cement, 1 lime, 6 sand	B or C	Tests should be carried out to determine whether 1:3:12 cement, lime and sand mortar could give adequate strength for this purpose
-do-	Arch-work	Dense lime-stone, granite etc.	1 cement, 3 sand	—	
-do-	Heavy loading (66-88 tonne/m²)	Brick or stone with crushing strength 70 to 105 kg/cm²	1 cement, 2 lime, 9 sand	B or C	
-do-	Medium loading (44-66 tonne/m²)	-do-	(*i*) 1 lime, 1 sand, 1 surkhi (*ii*) 1 lime, 1 sand, 1 cinder (*iii*) 1 lime, 2 surkhi (*iv*) 1 lime, 2 cinder (*v*) 1 lime, 2 sand (*vi*) 1 cement, 2 lime, 9 sand (*vii*) 1 cement, 3 lime 12 sand	A, B or C A B or C	
-do-	Light loading below (44 tonne/m²)	Brick	All lime mortars included under serial No. 4 for medium loading can be used		
Cavity walls	Light loading below (44 tonne/m²)	Brick	1 cement, 1 lime, 6 sand	B or C	
Reinforced brick work		Brick	1 cement, 3 sand with 10 percent addition of class 'C' lime for better workability		Addition of lime is approved
Half-brick or brick-on-edge parapet walls		Brick	1 cement, 1 lime, 6 sand	B or C	
Non-load bearing partitions		Light weight concrete, wood wool slab, hollow blocks	1 lime, 3 sand	A or B	

Note: 1—All loadings given in this table are for a slenderness ratio of 10. Reduction factors are to be applied for slenderness ratio exceeding unity.

2—Lime mortars should be prepared and tested before specifying suitable proportions for important works. The proportions should be so adjusted that after 28 days curing in moist air, the mortar shall have a minimum tensile strength of 7 kg/cm². A bonding effieciency of 20 per cent is desirable.

TABLE 7.4. Mortars for Plasters

Situation	*Composition of mortars (Proportions by volume)*	*ISI grading of lime*
External plaster below damp proof course	1 cement, 1 lime, 6 sand	B or C
External plaster above damp proof course	1 cement, 2 lime, 9 sand	B or C
Internal plaster on all walls	(*i*) 1 lime, 2 sand	A
	(*ii*) 1 lime, 1 surkhi, 1 sand	B or C
	(*iii*) 1 lime, 1 ash, 1 sand	B or C
	(*iv*) 1 lime, 2 surkhi	B or C
	(*v*) 1 lime, 2 ash	B or C
	(*vi*) 1 cement, 2 lime, 9 sand	B or C
	(*vii*) 1 cement, 3 lime, 12 sand	B or C

Manual mixing. Clean dry sand is spread in a uniform layer on a *pucca* platform. On it the requisite quantity of cement is spread in a uniform layer. Then, it is mixed dry by working it over with spades two or three times till the whole mass becomes of a uniform colour.

Then a depression is made in the middle of it where-in the required quantity of water is added. Dry material from sides is placed on the edge of depression containing water. It is done gradually till the whole of water has been absorbed by the dry mass. Care is taken *not to let the water breach the banks and flow out.*

The wet mass of mortar is then worked with spades to have a mortar of uniform consistency. The mortar should be immediately used after mixing. Commonly used mixes of the mortar are:

For internal plastering	1 : 5
For external plastering and for plastering R.C.C. work	1 : 3
For masonry	1 : 6

7.8 PRECAUTIONS IN THE USE OF MORTARS

Following precautions in the use of mortars have been specified vide IS 1625—1966.

1. All mortars prepared for masonry works shall be used as soon as possible with the maximum limits given below:

(*a*) If eminently hydraulic lime (Class A) is present as an ingredient, the mortar shall be used within four hours after grinding.

(*b*) Lime mortar made with surkhi or other pozzolana is hydraulic and shall be used within 24 hours of grinding.

(*c*) Composite mortars shall be used within two hours of the addition of cement.

(*d*) Cement mortar shall be used within 30 minutes after adding water.

2. All lime mortars, after grinding shall be kept wet and shall never be allowed to go dry. This may be done by covering ground mortar with wet sacks.

3. Partly set and dried mortar should not be retempered and used.

4. All masonry using lime or gauged lime in the mortar shall be kept wet for a period of six days. After construction cement mortar is kept wet for longer periods (*from ten days to three weeks*).

5. In case of masonry works with lime mortars, it is desirable that works, after a height of every 1.5 metre or less, shall be allowed to set for at least two days before starting further construction over it.

6. Hydraulic limes and cements set and become hard in the presence of water. Bricks which are porous absorb greater part of water from the mortar (thus the mortar becomes weak). As such bricks should be fully saturated with water before laying them in the structure. Surfaces of stones should be made *just* before use.

7.9 TEST FOR MORTARS

To test the quality of mortars they may be subjected to the following tests.

7.9.1. Crushing. Bricks laid in mortar to be tested are crushed in a compression testing machine. The load which crushes the test piece gives the crushing strength to which a suitable factor of safety may be applied to get the safe strength. Safe strengths for a few mixes are given below.

Burnt brick in cement mortar	1 : 3	76.6 tonnes/sq metre
Burnt brick in cement mortar	1 : 6	43.7 ,,
Burnt brick in lime mortar (1 lime : 3 surkhi and/or sand)		43.7 ,,

7.9.2 Adhesiveness. Two bricks of size 19 cm × 9 cm × 9 cm are crossed together and cemented with the mortar under test. This gives a sectional area of 9 cm × 9 cm of common horizontal joint with 5 cm projections on either side of both the bricks. Upper brick is suspended from an overhead support and a board is hung from the ends of lower brick. The board is loaded till the joint between the bricks fails. The ultimate load causing failure divided by the area of contact (81 sq cm) gives the ultimate adhesives strength of the mortar per sq cm.

7.9.3. Coheslveness or tensile strength. A briquette made with mortar is tested in tension testing machine. Total tensile load applied at which the briquette breaks is divided by the area of cross section of the briquette at the place of break. This gives tensil strength of mortar.

7.9.4. Test for setting. Mortar is tested in a Vicat apparatus for the setting time. The tests may be conducted after one day, three days and one week.

7.10 FIRE RESISTANT MORTAR

Commonly used lime and cement mortar are unsuitable for setting refractory bricks or blocks used for the lining of furnaces where the temperatures are too high for these mortars. At such high tempera-tures these mortars fail due to shrinkage and cracking.

Accoset-50 is the trade name of a refractory cement mortar marketed by ACC. It is readymade air setting cement mortar and is excellent for use as a mortar for furnaces. One part of aluminous cement mixed with two parts of finely powdered fire bricks too gives a mortar meeting the requirements.

7.11 GROUT

It is cement mortar of fluid consistency. For repairs of cracks or fissures it is injected under pressure into the cracks. It is injected in the soil so as to increase its bearing capacity (it is known as *soll stabilization*). Vacant joints in masonry left due to bad workmanship are filled up by grouting. To fill up bigger cracks a little coarse aggregate also may be added to it.

7.12 GUNITING OF MORTARS AND CONCRETE

Sometimes mortar or concrete is applied under pneumatic pressure through a *cement gun*. This process is known as *guniting*. As the mortar is applied with pressure it results in good bond and high strength. Concrete becomes extremely strong by the process.

A rich mix of 1:3 of cement and sand made with controlled quantity of water is forced through a nozzle under pressure. Compressed air is used to get the pressure necessary for shooting the mortar through the gun. It is also ideal for repair works where the mortar penetrates all cracks.

7.13 PLASTERING

Masonry and concrete surfaces have often to be plastered to give protection to the plastered surfaces and to improve appearance.

The surface to be plastered should be clean, free from dust, loose material and greasy spots. If needed, the surface should be brushed and broomed. To provide a *key* to the plaster all joints in the masonry should be raked out to a depth of about 1.25 cm when the mortar is still not set. In case the surface is to be plastered with cement mortar or lime mortar (generally gauged with cement) the surface should be wetted for a few hours. *Too much of wetting should be avoided as the mortar does not stick well to such a surface.* In case the surface is to be mud plastered then it should *not* be wetted.

Plaster may be applied in one or more coats but the thickness of no single coat should exceed 1.25 cm. In case more than one coats of plaster are being applied then no coat should be applied before the previous one has attained full setting and shrinkage. Scratches should be made on a coat of plaster (over which another coat is to come) when it is still green. This is done so as to provide key to the next coat of plaster. Fine sand used in cement plaster gives a good finish but if the sand is too fine then the plaster shall have too many shrinkage cracks.

Cement plaster should preferably be gauged with fat lime which would reduce shrinkage cracks and improve workability but it would make the setting of plaster slow. Use of very fine sand would further slow down the setting of plaster. To attain smoothness in the plastered surface patches of plaster 10-15 cm square are made on the surface at regular spacings or wooden screeds or plaster profiles showing the finished surface of plaster are attached to the surface or made on it.

Freshly applied plaster should be protected from excessive winds, direct sun or frost. *It should be cured for a few days.*

7.14 WATERPROOF MUD PLASTER FOR MUD WALLS

Conventional mud plaster applied to mud walls or to walls made of *kuchcha* sun-dried bricks consists of local soil mixed with straw (*Bhusa*) to which *Gobri leep* is applied. Even though it is an extremely cheap plaster yet its drawback is that it fails to withstand erosion due to a few hours of rain. Also occasional rainfall and sunshine causes this plaster to come off in flakes.

Following pecifications arrived at on the basis of field tests conducted by the National Buildings Organisation, New Delhi give very satisfactory results.

Materials required

(*i*) Local soil (*neither too clayey nor too sandy*).

(*ii*) Straw (*Bhusa*).

(*iii*) Cowdung.

(*iv*) Bituminous Material.

(*a*) Janta Emulsion (H.R.P.);

or (*b*) Bitumen cut back;

or (*c*) Liquid Asphalt Number 2.

Preparation. (*i*) Dig up the soil and break its clods. The soil should not be either too clayey or too sandy.

(*ii*) Mix straw at the rate of one kg to 18 kg of dry soil.

(*iii*) Add sufficient water to it and work up the mass everyday with spades and under feet. This may be continued for a week or more till the straw rots.

(*iv*) A few hours before the plaster is to be applied 750 gms of Janta Emulsion (H.R.P.) or 875 gms of bitumen cut back or one kg of Liquid Asphalt Number 2 and mix the mass thoroughly.

While preparing Mud Plaster care should be taken to mix up the constituents very thoroughly.

Application. (*i*) Scrap loose surfaces to which the plaster has to be applied and wet it with water.

(*ii*) Apply 1.25 cm thick layer of plaster and rub it smooth with trowel. While rubbing, the surface may be sprinkled with water to avoid cracking.

(*iii*) After the surface has partially dried give the surface a finish with *Gobri Leep* which shall fill up cracks that might have appeared in plaster on drying.

7.15 POINTING

It is the filling up of masonry joints, raked out to a depth of at least 1.25 cm, with the same mortar as used in masonry laying or a different one. It is done primarily to seal off any crevices left in the mortar joint thereby stopping the entry of moisture inside the wall. Also the purpose of pointing the masonry is to improve the appearance of the pointed surface.

Sometimes the masonry surface is not desired to be plastered purely from architectural considerations and is simply pointed. Cement mortar, lime mortar or lime mortar gauged with cement are used for pointing. Masonry laid in mud mortar has got to be protected by pointing or by plastering.

Various types of mortar joints used to fill up masonry joints are shown in Fig. 7.1. The choice of a particular type depends upon the specific requirements and upon the appearance effect of the particular work. The raked out joints of masonry should be thoroughly wetted before the pointing is done.

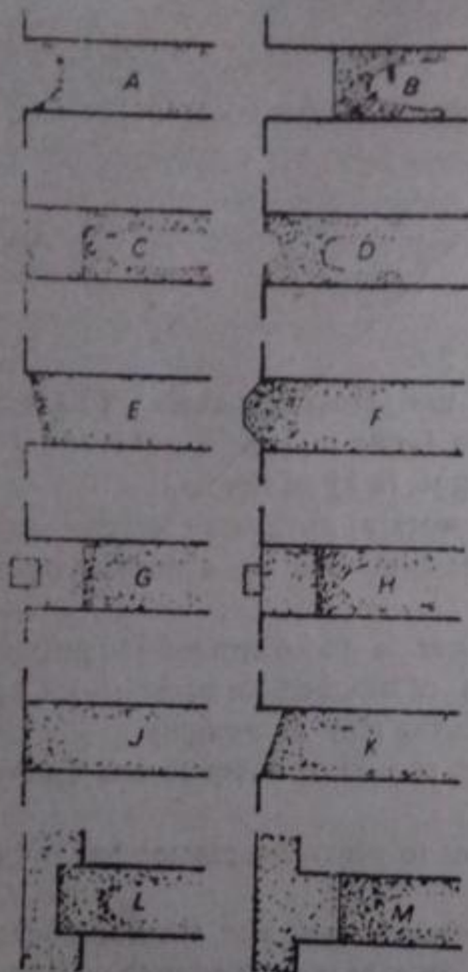


Fig. 7.1

Keyed joint (Fig. 7.1 *A*). It is made by passing a curved jointing tool of the thickness equal to that of the joint along it. It makes the mortar of joint dense and improves the appearance by giving them a distinct look.

Recessed joint or raked joint (Fig. 7.1 *B*). It gives only a better look to the joint but should be used only if the bricks are of a very good quality.

Flat or flush joint (Fig. 7.1 *J*). It is formed as the work proceeds and is done by pressing the protruding mortar with trowel blade. It is neatly trimmed with the sharp trowel blade and a straight edge. It is usually left on the inner faces of walls. It has the advantage of simplicity and of not providing any lodging place for dirt or dust.

Flat joint jointed (Fig. 7.1 *D*). It is similar to the flush joint and is obtained by first making a flush joint and then making a round groove parallel to the joint at its centre. It is done by passing a semicircular jointing tool along a straight edge. It makes the mortar in the joint dense.

Masons. V joint. It is the usual joint adopted by masons.

Struck joint or Weathered joint (Fig. 7.1 *K*). It is an excellent joint which not only gives a beautiful finish to the joint but also at the same time it does not provide lodging to dust and throws off rain water with ease. It is made by pressing the blade of trowel at the upper edge. To make a joint (Fig. 7.1 *E*) by pressing the mortar at the lower part of joint is a defective joint finish and should be avoided.

This type of pointing is called *overhand stuck pointing*.

Beaded-pointing. This type of pointing is shown in Fig.7.1 (*F*). The joint is filled with the mortar protruding out of it. The protruding mortar is then given the desired shape with the help of a properly made steel rule.

This type of pointing presents a pleasing appearance but is liable to be damaged.

Tuck-pointing. This type of pointing is shown in Fig. 7.1 (*G*). The mortar joints are raked out, brushed and saturated with water. The joints are then filled flush with mortar coloured to match the brick work. Before the mortar has set a groove 6 mm wide and 3 mm deep is accurately formed along the middle of each joint. The groove is now filled up or *tucked in* with lime putty mixed with a small quantity of silver sand. The filling done with lime putty is given a projection of not more than 6 mm top and bottom edges of the projecting putty are neatly trimmed straight.

Tuck-pointing is done both in new and old work but generally more so in the latter. Tuck-pointed surface presents neat and pleasing appearance but the lime putty projections are amenable to quick damage and have to be repaired now and then.

Bastard or Half-tuck-pointing. This type of pointing is shown in Fig.7.1 (*H*). In it the projecting *fillet*, as made with lime putty in tuck-pointing is made with the mortar in case of bastard-pointing. The fillet is trimmed straight and is not to project more than 6 mm. There is difference in the colour of the projecting fillets in case of true tuck-pointed and bastard-pointed surfaces.

Bastard-pointing is more durable than the tuck-pointing but the appearance of the former is not that pleasing as that of the latter.

EXERCISES

1. What is mortar and what for it is used? What are the functions of sand and surkhi in the mortar?
2. How is lime mortar prepared? What are the advantages of adding surkhi to lime mortar?
3. (*a*) What do you understand by:
   (*i*) Grout, (*ii*) Mortar.
   (*b*) How is surkhi prepared? What is its function in mortar?
4. Write short note on the preparation of cement mortar.
5. (*a*) What are the functions of sand and surkhi in mortar?
   (*b*) Describe the process of preparing cement sand mortar.
6. Write short notes on:
   (*i*) Lime mortar;
   (*ii*) Black mortar;

(*iii*) Gauged mortar;
(*iv*) Guniting;
(*v*) Pozzolana.

7. What are the various field tests for lime?
8. What are the precautions to be taken while using mortars?
9. What sort of a mortar and of what mix shall you choose for use on:
   (*i*) R.C. work.
   (*ii*) Masonry in one half brick thick wall.
   (*iii*) Plastering the walls of a room.
   (*iv*) Plastering exterior of a house.
   (*v*) Foundation concrete for single storey house.
10. Describe in details the process of plastering a masonry wall.
11. What is pointing? What is its necessity? What are its various types?
12. Bring out the difference between tuck-pointing and the bastard-pointing.
13. Give arguments in favour of your choosing a particular type of pointed finish at the following situations:
   (*i*) Exposed brick work in a luxury house.
   (*ii*) Exposed stone work in a luxury house.
   (*iii*) An old dilapidated brick wall.

8

CONCRETE

8.1 CONCRETE

Concrete is a composite material wherein a binding material mixed in water on solidification binds the inert particles of well graded fine and coarse aggregates.

Freshly prepared concrete till it has not yet set is called *wet or green concrete*. After it has thoroughly set and fully hardened it is called *set concrete* or just *concrete*.

Depending upon the cementing material used, we use lime concrete and cement concrete as explained below:

8.2 LIME CONCRETE

It is a mixture of lime mortar and coarse aggregates and should satisfy the requirements of IS 2541—1974. Coarse aggregate used in lime concrete shall be either natural stone ballast or brick ballast or cinder aggregate.

Sand, surkhi or cinder aggregate shall be fine aggregate. Eminently hydraulic limes corresponding to class A of IS 712—1964 (see art. 4.4.) are suitable for use in lime concrete. Semi-hydraulic or fat limes corresponding to class B and class C will require mixing of pozzolanic materials such as surkhi or cinder to give it the desired hydraulicity.

Water used in preparing or curing it shall be clean and pure. Drinkable water is fit for use in concrete.

8.2.1. Mixing. For preparing lime concrete coarse aggregate, well washed and thoroughly saturated (particulary if it is brick ballast) is spread evenly on a pucca platform. Lime or lime pozzolana mortar prepared as explained in Art 7.7 is then evenly spread on the coarse aggregate and the whole is thoroughly mixed by turning it over a number of times. Mixing should be done till a concrete of uniform appearance and consistency is obtained. Machine mixing of lime concrete could be done, if the magnitude of work so demands.

Only that much of concrete should be mixed which can be laid *within two hours*. If cement has been used in the mix then the concrete should be laid in position within 30 minutes after water has been added to it. Usual mix of lime concrete used in constructions is one part of mortar and 2 to 2½ parts of coarse aggregate.

8.2.2. Placing. Laying and consolidation of concrete shall be completed within three hours of adding water in case of concrete prepared with hydraulic lime mortar or lime pozzolana mortar and within one hour in case lime cement mortar has been used.

Concrete should be laid in layers not exceeding 15 cm in thickness when consolidated. Next layer of concrete is laid only when the previous one has been thoroughly consolidated. Lime concrete should not be dropped from a height as it would result in segregation of aggregates. If it is to be laid at a depth then *chutes* should be used.

Concrete should be well rammed with heavy rammers till a skin of mortar covers the surface and completely hides the aggregate.

Concrete shall be well cured for a period of at least 10 days after its laying, curing shall be done by spreading wet sand or gunny bags etc., and watering frequently.

8.2.3. Uses. It is used in building work generally for the following situations:

(*i*) As levelling course for foundation and for plain cement concrete footings for masonry walls and columns.

(*ii*) As base concrete under floors.

(*iii*) As filling for haunches over masonry arch work.

(*iv*) For roof finish.

8.3 CEMENT CONCRETE

It is a composite material wherein a paste of cement, made with water, on solidification binds firmly together the various particles of inert materials like sand and stone ballast. The inert material called "aggregate" is well graded in size from fine sand to pebbles or stone ballast or brick ballast.

Cement concrete is an extremely versatile material of construction which is used for a variety of works ranging from small cottages to massive dams and bridges. Cement concrete is quite strong in compression but not so in tension. To make good this deficiency of concrete steel bars (*reinforcement*) are embedded in concrete. The concrete then is known as *reinforced concrete*. Concrete without reinforcement is known as *plain concrete*. The four materials go to make cement concrete: (*i*) *Cement*; (*ii*) *Sand* (*i.e. fine aggregate* (*iii*) *Stone/Brick ballast* (*i.e. coarse aggregate*) and; (*iv*) *Water*.

To get quality concrete due attention should be paid in choosing the constituents, in mixing them in correct proportions, in mixing the concrete in correct manner and finally in using it properly followed by proper *curing* *

8.3.1. Selection of materials. Concrete forming materials shall be carefully selected so as to get quality concrete:

(*i*) *Cement*. Normally ordinary Portland cement satisfying the requirements of the Indian Standards Institution is used. However, for special conditions the type of cement suiting the requirements is used.

Cement, being hygroscopic, attracts moisture quickly and sets. So storage of cement should be carefully attended to and no set or even partially set cement should be used.

(*ii*) *Fine aggregates*. Sand and crushed stones are the commonly used fine aggregates in cement concrete. These should satisfy the requirements laid down in § 6.2.1. and 6.2.3.

(*iii*) *Coarse aggregate*. Stone ballast, gravel, shingle and brick ballast are the usual coarse aggregates used in making cement concrete. Size of aggregate shall depend upon the type of work and the reinforcement. The size of aggregate should be less than the distance between two consecutive steel bars in RCC. The aggregate used should satisfy the requirements laid down in § 6.8.

Strength of concrete shall depend to a great extent on the voids in it. As such to have lesser voids so as to get stronger concrete the aggregates should be well *graded i.e.*, they should have particles of various sizes so that the voids of bigger particles are filled up by the particles of smaller sizes.

Graded aggregates give solid and dense concrete (free from holes or voids) which is stronger, more durable and water tight.

(*iv*) *Water*. Only good clean water should be used for making concrete. It should be free from silt, salts or any organic matter. Generally speaking, water that is good for drinking is good enough for concrete work.

8.3.2. Batching of ingredients. There are two methods of batching the ingredients of concrete; (*i*) *by weight*; and (*ii*) *by volume*.

Except for very large projects the latter would do. The basis of batching by volume is generally one part of cement to *n* parts of sand and 2*n* parts of ballast. The ballast is usually twice the sand whereas

*Refer to Art. 8.9.

the ratio of cement to sand depends upon the desired strength of concrete. The ratio being less when the strength needed is great and *vice versa*. For details refer to § 8.6.

Volume of one bag of cement weighing 50 kgs is 34.5 litres. When it is taken out of bags it becomes loose showing a considerable increase in volume. As such batching cement concrete by taking into account the volume of loose cement is likely to result in less cement being mixed in the concrete. So in batching the ingredients by volume materials corresponding to a whole number of cement bags should only be taken. However, if fraction of a bag has to be used then it should be done so by weighing.

A convenient method of measurement is to use an open measuring gauge box with a capacity of 34.5 litres. Batches of fine and coarse aggregates required could then be measured in multiples of these boxes in accordance with the required proportions of the ingredients. In measuring 'sand' due allowance for bulking, if any, should be made (Refer to § 6.5). Not doing so would result in *under sanded concrete*.

8.3.3. Mixing. Mixing should preferably be done by machines called *concrete mixers*. If these machines are not readily available or are too expensive for the job on hand then perfectly good results could be obtained by hand mixing if the following procedure adopted.

Hand mixing. For hand mixing of cement concrete a closely joined platform of timber or bricks large enough to turn over the mix without spilling should be prepared. One bag of cement and the corresponding quantity of sand required is spread over this platform. Cement and sand should then be turned over thoroughly with shovels at least three times so as to produce a mix of uniform colour. Spread this mixture evenly over the correctly measured quantity of coarse aggregate in a layer. Now turn this mixture thoroughly with shovels so that the stone pieces are evenly distributed throughout the mixture of cement and sand. Then water is slowly poured on to the heap from a water can fitted with a hose and the turning of mixture continued till a workable, smooth and uniform mixture is obtained. Only the right amount of water should be used in mixing concrete (For details refer to § 8.4).

8.3.4. Placing of concrete. After mixing the concrete with water it should be used up ***within* 30 *minutes i.e.*,** before the initial setting of cement starts. Only so much of concrete should be mixed with water that can be easily used up in 30 minutes. ***In no case should cement concrete be remixed with water and used after 30 minutes.***

After the concrete has been placed in the proper place it should then be rammed with wooden tampers or iron rods. It is done so as to make cement mortar penetrate all corners particularly around the reinforcement bars in case of RCC work. In case of large and important projects this work is done by mechanical vibrators (Art 8.8).

A few hours after the concrete has been laid, the exposed surfaces of the concreted portion should be *cured* (kept wet) for at least ten days (Art 8.9).

8.4 WATER CEMENT RATIO

It is the ratio of water and cement (by weight or by volume) used in the preparation of concrete.

The quantity of water used in mixing concrete is very important. If the percentage of water used is less then there shall not be sufficient quantity of water to hydrate cement. It shall result in porous and weak concrete. However, the usual tendency is to use too much

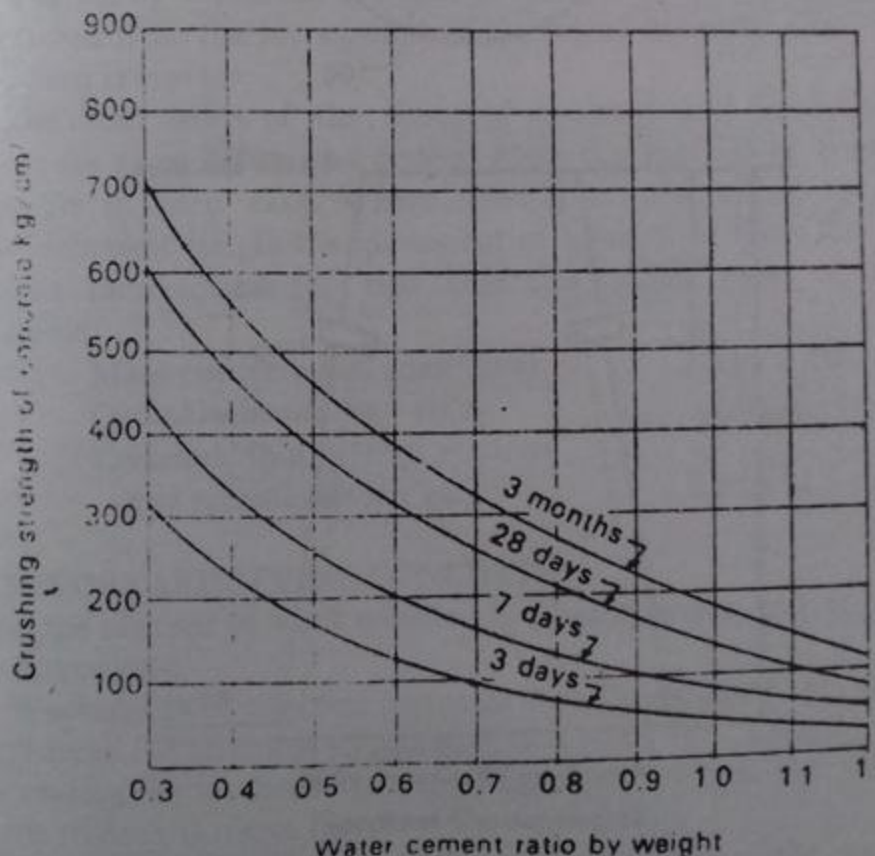
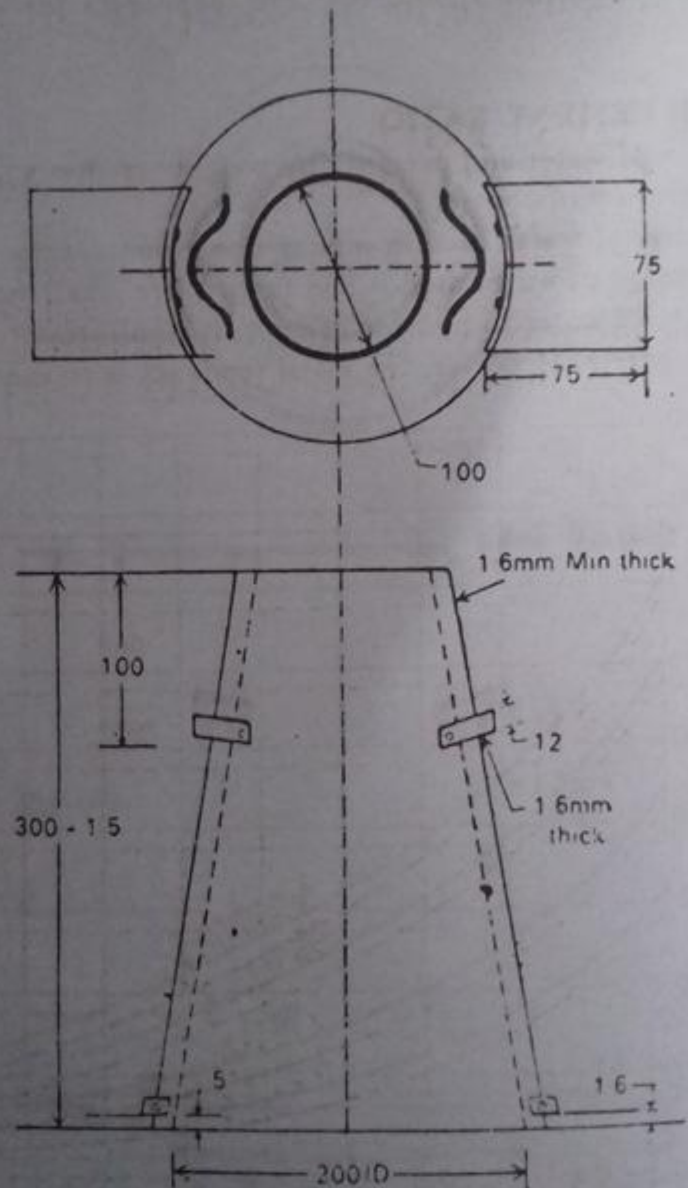


Fig. 8.1

water which gives a more workable mix but it does not give sound concrete. Too much of water results in segregation of aggregates and gives porous concrete of low strength and low density. (Fig. 8.1).

A certain minimum proportion of water is necessary in order to hydrate the cement completely. To make the concrete sufficiently workable to be placed in position some more water is needed. So long as the concrete is sufficiently workable, for the method of placing used, its strength depends upon the proportion of water to the cement in the mix. Water cement ratio should not be allowed to



All dimensions in millimetres

Mould (seamless) for slump test of concrete

Fig. 8.2

exceed the specified limits for various types of concrete and should generally be kept as low as the methods of placing will allow.

Professor Abrahms as a result of large number of experiments states that "with given materials and conditions of test, the ratio of quantity of mixing water to the quantity of cement alone determines the strength of concrete so long as the mix is of a workable plasticity." This is known as *water cement ratio law*.

According to this law the strength of concrete will not increase by simply increasing the quantity of cement unless the water cement ratio is reduced.

A simple and a practical way of controlling the water content is by means of *slump test* explained below.

8.4.1. Slump test. To conduct this test a truncated cone of steel (Fig. 8.2) 30 cms high, 20 cm diameter at the base, 10 cm diameter on the top and provided with handles is used. Concrete is filled in the cone in layers of 7.5 cm at a time, each layer being rammed 25 times with a metallic tamping rod 16 mm in diameter and 60 cm long. Just after the *slump cone* has thus been filled then it is lifted. The extent by which the concrete drops is called the *slump*. It is measured from the top of cone to the top of concrete after the cone has been removed.

The usual values of the slump of concrete used for various purposes are given below and depend upon the method of compaction possible in each case. Where there is no obstruction by way of reinforcement etc., in the movement of concrete or where the concrete can be rammed hard in that case the smaller value of slump is required.

Mass concrete and road work	2.5 to 5 cm
Ordinary beams and slabs	5 to 10 cm
Columns, thin vertical sections and retaining walls etc.	7.5 to 12.5 cm

8.5 WORKABILITY OF CONCRETE

It is the amount of work required to place concrete and to compact it thoroughly.

Workability of concrete increases with the addition of water but it reduces the strength and as such it is not a very desirable way of increasing the workability. Use of aggregates which are round and have smooth surfaces increases the workability.

Keeping the cement, aggregates ratio the same if the quantity of coarse aggregate is increased then the workability improves.

Workability could also be improved by adding Air-entraining agents such as Vinsol resin or Darex etc. Use of *Lisapole* liquid @ 30 c.c. per bag of cement improves not only the workability but also the water tightness of concrete.

Slump test gives an idea of only the flowing property of wet concrete and not of the workability. Workability of concrete is better determined by *compaction factor test*.

Compaction factor test. In this test the amount of compaction obtained by spending a known amount of energy is measured. This gives an idea of workability. The apparatus (Fig. 8.3) used for the test consists of two hoppers *A* and *B* and a cylinder *C*. The hoppers are provided with hinged bottoms. There is a certain clear distance

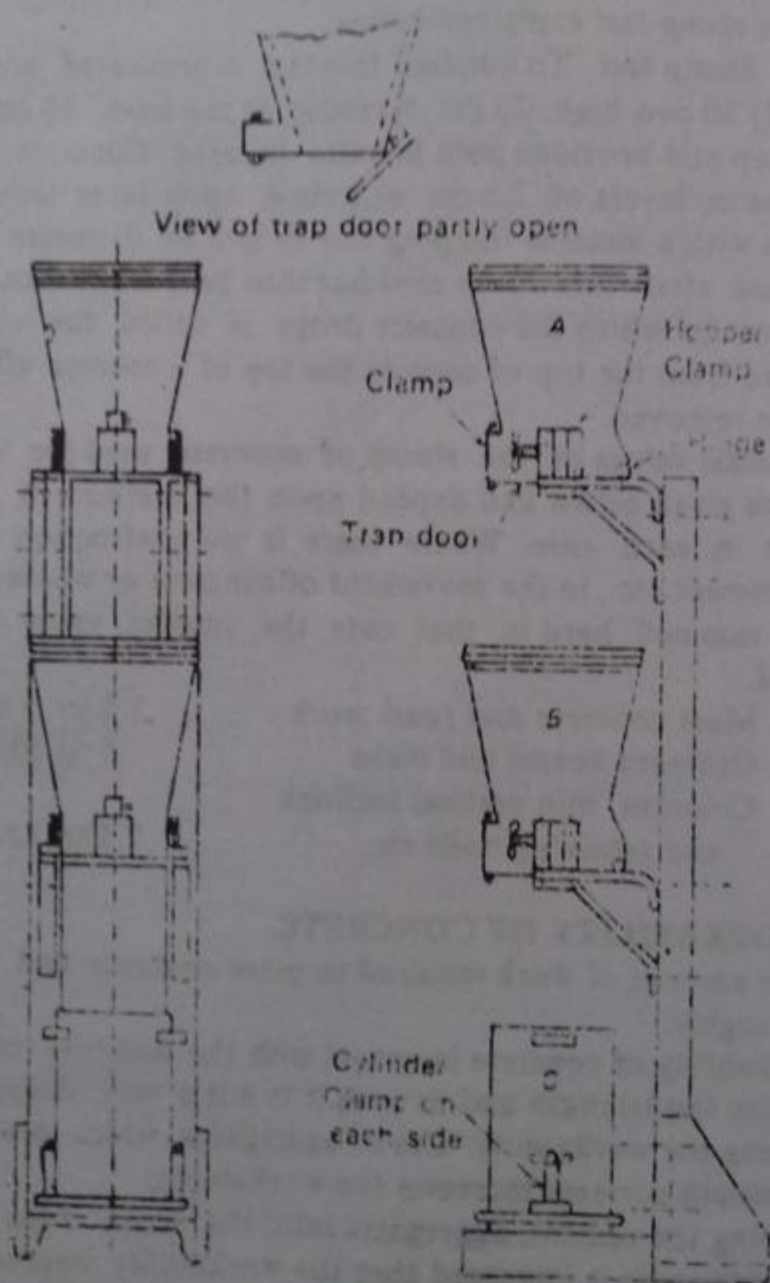


Fig. 8.3. Compaction factor test apparatus.

between the hoppers *A* and *B* and the hopper *B* and cylinder *C*. Diameter of cylinder *C* is 15 cm and is of 30 cm height. Cement concrete to be tested is placed in the hopper *A* and its bottom released. The concrete falling in hopper *B* achieves some compaction. The bottom of hopper *B* is now released so that the concrete now falls in cylinder *C*. Surplus concrete is removed from the top of cylinder by simultaneously moving towards the centre of cylinder two trowels held horizontally in both the hands. Sharp blades of the trowels rest on the top of cylinder. Concrete in the cylinder is now weighed. Let this weight be W_1.

After cleaning the cylinder it is refilled with concrete in layers of 5 cm each. Every layer of concrete is thoroughly compacted with an iron rod. Any surplus concrete from the cylinder is removed in the manner explained before. The weight W_2 of the concrete in the cylinder is found out.

The ratio of the two weights W_1/W_2 is known as the *compaction factor*.

A compaction factor of 0.85 represents a mix of poor workability, 0.92 represents medium and 0.95 good workability.

8.6 PROPORTIONING OF CONCRETE MIXES

Cement, fine aggregate and the coarse aggregate are mixed in a definite proportion so as to get a strong, durable, workable and economical mix. The proportion of the three constituents depends upon the specific requirements of a particular work in which the concrete is to be used. The three methods that are in common use for determining the mix are:

8.6.1. Arbitrary method. To get a dense concrete having least voids the quantity of fine aggregates used should be sufficient to fill up the voids of the coarse aggregates. To achieve it the ratio of fine aggregates and coarse aggregates should be between 1½ to 2½. The ratio of cement to aggregates depends upon the strength of concrete desired.

The proportion of various constituents in a concrete is known as the *mix* of concrete. Commonly used mixes are 1 : 1½ : 3; 1 : 2 : 4 and 1 : 3 : 6 in which the parts of sand are 1½, 2 and 3 respectively and those of stone ballast are 3, 4 and 6 respectively. Part of cement is one in all the three mixes.

Below are given the mixes of concrete commonly used for various types of works.

High strength concrete	1 : 1 : 2 and 1 : 1.2 : 2.4.
General RCC work	1 : 1½ : 3 and 1 : 2 : 4.
Mass Concrete work	1 : 3 : 6 and 1 : 4 : 8.

Adequate quantity of water is then added to the mix depending upon the consistency and workability required.

Due allowance should be made for wet aggregates.

8.6.2. Minimum void method. In it the mix is so adjusted that there is sufficient fine aggregate to fill up the voids of coarse aggregate and voids in the fine aggregate are filled up by cement. Ten per cent more of cement than the voids in sand and 15 per cent more of sand than the voids in coarse aggregates are added to account for additional voids created by moisture and wedge action of particles.

8.6.3. Maximum density method. This is an improvement on the minimum void method. In it the materials are so graded that the mixture has the maximum density. "Fuller" suggested the following empirical formula for grading the materials:

$$P = 100 \times \left(\frac{d}{D}\right)^{\frac{1}{2}}$$

Where P is the percentage of material finer than gauge d and D is the maximum size of materials used.

EXAMPLE 1: *Grade a mixture of cement concrete in which the maximum size of coarse aggregate is 20 mm and the maximum size of fine aggregate is 5 mm.*

SOLUTION: Using Fuller's formula,

$$P = 100 \left(\frac{5}{20}\right)^{\frac{1}{2}} = 50\%$$

Thus 50 kg of fine aggregate (including cement) is to be mixed with 50 kg of coarse aggregate.

If it is proposed to have the ratio of 1 : 9 of cement and aggregates then 10 kg of cement per 100 kg of mixture shall be required.

Quantity of sand required = 50—10 = 40 kg.

If the densities of cement, fine and coarse aggregates be 1.44; 1.76 and 1.6 kg per litre then the ratio of cement, sand and coarse aggregates by volume is—

$$\frac{10}{1.44} : \frac{40}{1.76} : \frac{50}{1.6} \text{ i.e. } 6.94 : 22.75 : 31.25$$

$$\text{i.e. } 1 : 3.3 : 4.5$$

Sufficient water is now added to it to make a workable mix. The concrete so obtained shall be dense.

8.6.4. Fineness modulus method. Fineness modulus is an index giving an idea of the mean size of aggregates which suggests the degree of fineness or coarseness of the aggregates. It is found by taking the cumulative percentage of the aggregates retained on a seof ten Indian Standard *sieves* and dividing the sum by 100. Numbers of the IS sieves used are from 80 mm to Number 15.

As a result of experimentation certain values of fineness moduli for fine, coarse and mixed aggregates have been found. These values give a good workability with a minimum quantity of cement.

TABLE: 8.1 Limits of Fineness Moduli

Maximum size of Aggregate	*Fineness modulus*	
	Minimum	*Maximum*
Fine aggregate,	2	3.5
Coarse aggregate 20 mm	6	6.9
" " 4 mm	6.9	7.5
" " 75 mm	7.5	8.0
" " 15 mm	8.0	8.5
Mixed aggregate 20 mm	4.7	5.1
" " 25 mm	5.0	5.5
" " 32 mm	5.2	5.7
" " 40 mm	5.4	5.9
" " 75 mm	5.8	6.3
" " 15 mm	6.5	7.0

Lesser values of FM indicate finer aggregates and more values show coarser aggregates. Fineness modulus of sand should not be less than 2.5 and not more than 3.0.

Very fine sand or very coarse sand are objectionable. Very fine sand requires more cement and more water whereas coarse sand gives harsh and unworkable mix. Values of FM of aggregates higher than those shown in the table above will give harsh mix whereas lower one's shall give uneconomical mix.

Sieves used to determine FM of coarse, fine and *All* in aggregates (mixed) are as below:

For coarse aggregates: 80 mm, 40 mm, 20 mm, 10 mm, and No. 480.

For fine aggregates: Nos. 480, 240, 120, 60, 30 and 15.

***All in* aggregates: 80 mm, 40 mm, 20 mm, 10 mm. Nos. 480, 240, 120, 60, 30 and 15.**

EXAMPLE 2: ***Determine the fineness modulus of fine and coarse aggregates for which results of sieve analysis are tabulated below. Total weight of coarse aggregate was 20 kg and of fine aggregate 5 kg.***

SOLUTION:

IS sieve no.	Coarse aggregate			Fine aggregate		
	Wt. retained	*Total Wt. retained*	*% Wt. retained*	*Wt. retained*	*Total Wt. retained*	*%Wt. retained*
	kg	kg	kg	kg	kg	kg
80 mm	0	0	0	—	—	—
40 mm	0	0	0	—	—	—
20 mm	5	5	25	—	—	—
10 mm	8	13	65	—	—	—
480	6.8	19.8	99	0.1	0.1	2
240	0.2	20.0	100	0.8	0.9	18
120	—	20.0	100	0.6	1.5	30
60	—	20.0	100	1.2	2.7	54
30	—	20.0	100	1.6	4.3	86
15	—	20.0	100	0.5	4.8	96
Total:			689			286
Fineness Modulus			6.89			2.86

EXAMPLE 3: *If a mixture of fine and coarse aggregates of fineness modulus 5.5 be desired then find out the proportion in which the two aggregates with respective fineness moduli of 2.85 and 6.95 should be mixed.*

SOLUTION: If F is the desired fineness modulus of a mixture of fine and coarse aggregates whose respective fineness moduli are F_1 and F_2 and if X be the percentage of fine aggregate to be mixed then:

$$X = \frac{F_2-F}{F-F_1} \times 100$$

$$= \frac{6.95-5.5}{5.5-2.85} \times 100$$

$$= 51\%$$

that is, the ratio of fine aggregate to coarse aggregate is 51 : 100.

8.7 PLACING OF CONCRETE

After mixing of concrete it should be placed before the initial setting starts *i.e.*, within 30 minutes of adding of water. As such after mixing it should be quickly transported to the place of laying. Mode of transportation depends upon the magnitude of work. Usual ways of transporting concrete are: In iron pans (*tasla*) manually, in wheel barrows, by pumping, in buckets moving on steel ropes, or by cranes.

Whatever the mode of transportation be, it is very essential to ensure that neither during transportation nor in placing it there is any segregation of aggregates.

In placing, concrete should be laid in thin layers. Each layer being thoroughly consolidated, before the next one is laid.

Compaction is very essential otherwise the concrete shall have voids and shall be weak.

Concrete should never be dropped from a height as it would cause segregation of aggregates. If concrete has to be laid at a depth then use of *chutes* should be made.

In case the concrete has more of water or it has been laid in thick layers then on compaction water and fine particles of cement come to the top forming a layer of weak substance known as *laitance*. In that case drier mix should be used and concrete should be laid in thin layers. If the laitance is formed, then before fresh concrete is placed on it the laitance should be broken, removed and the surface coated with richer mix.

8.8 COMPACTION OF CONCRETE

It is of utmost importance to develop qualities like strength, durability, imperviousness by making the concrete dense and free from voids. It should as such be ensured that there are no voids left in the concrete, it has reached all corners of the form work and has surrounded all reinforcement.

In case of R.C.C. compaction is done by pinning with an iron rod or even with trowel blade. As in case of R.C.C. work the concrete mix is more fluid, pinning (if done carefully) gets sufficient compaction. In case of mass concrete where the mix is comparatively drier, tamping is essential.

Excess of tamping should be avoided as otherwise water, cement and finer particles would come to the surface and result in non-uniform concreting.

In case of important and big works compaction of concrete is done with vibrators. Internal, external and surface vibrators are in use.

Internal vibrator consists of a rod which when inserted in concrete gives vibrations to it resulting in the consolidation of concrete. Care should be taken not to let it touch the reinforcement which is likely to get displaced.

External vibrators impart vibrations to the shuttering itself and are generally used in laboratory work. When these are used it should be ensured that the form work is watertight and is not loose.

Surface vibrators are in the form of plates which are used for the consolidation of mass concrete as in road construction.

Use of vibrators is the best and the most efficient way of compacting concrete. It gives very dense concrete. Use of vibrators permits adoption of lower water cement ratio thereby giving stronger concrete.

Care should be taken not to make excessive use of vibrators otherwise the concrete becomes non-homogeneous.

8.9 CURING OF CONCRETE

Strength and hardness to cement come because of its chemical reaction with water. This chemical reaction continues for a long time, however, a major part of it is complete in about three weeks period. As such sufficient water should be made available to concrete for about three weeks so that it gains full strength. The process of keeping concrete wet to enable it to attain full strength is known as *curing*.

Curing should be done for a period of three weeks but in no case for less than ten days. The object of curing is to prevent the loss of moisture from concrete due to evaporation or because of any other reason.

To do curing *i.e.*, to prevent the loss of moisture from the concrete any one of the following methods is used:

(*i*) The surface of concrete is coated with a layer of bitumen or similar other water-proofing compound which gets into the pores of concrete and prevents loss of water from concrete.

(*ii*) Concrete surface is covered with water-proof paper or with a layer of wet sand, saw dust or clay. It could be covered with wet gunny bags.

Immediately after placing the concrete it should be covered with wet gunny bags. After 24 hours a layer of bitumen or wet sand or clay should be laid on it. After laying concrete, it should be protected from direct rays of sun, from dry hot winds and from frost.

8.10 QUALITIES OF GOOD CONCRETE

Good concrete should be strong, durable, dense, watertight, workable and be able to resist wear and tear.

(*i*) *Strength.* Concete should be able to withstand the stresses that it is subjected to. It is quite strong in compression but weak in tension. As such it is safely used in the construction of load carrying structures like piers and abutments of bridges, columns, etc. In case of members subjected to tensile stresses it has to be reinforced with steel bars.

(*ii*) *Durability.* It should be able to withstand the weathering action such as of wind, rain, frost and variations of temperature. When used in the construction of drains and sewers or structures in touch with sea water it should be able to withstand the action of chemical salts.

(*iii*) *Density*. The concrete should be well compacted so that there are no voids or hollows left. It should weigh 3,000 kg/cu metre.

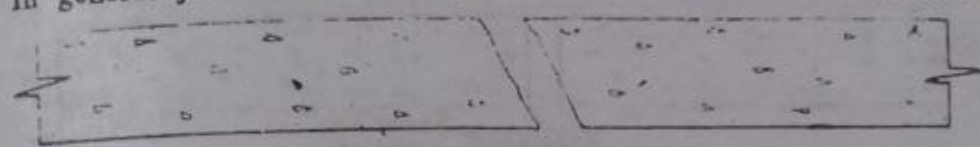
(*iv*) *Water tightness*. When used for the construction of water retaining structures such as dams, elevated tanks and water reservoirs then this property of concrete becomes very important. Otherwise the moisture inside the R.C.C. would corrode steel and leakage would start resulting in the ultimate failure of the structure.

(*v*) *Workability*. It should be easily workable.

(*vi*) *Resistance to wear and tear*. When used in floors and in the construction of roads the concrete should be able to withstand abrasive forces well.

8.11 JOINTS IN CONCRETE

In general joints have to be provided in cement concrete either due to the whole work being not complete at a time or to allow for the expansion of concrete with rise in temperatures. The two joints are known as: (*i*) Construction joints and (*ii*) Expansion joints.



Defective construction joint

Fig. 8.4

(*i*) *Construction joints*. It is not always possible to pour the whole of concrete in one operation. As such some device has to be adopted to join the old and the new concrete properly. The place where the joint has to be provided is decided before hand and is generally located at a place where the shear force is minimum.

The joints to be provided should be either horizontal or vertical as the case may be but *not inclined* (Fig. 8.4) as the thin edges of the joint are weak and flake off, Fig. 8.5 shows a correctly made horizontal joint.

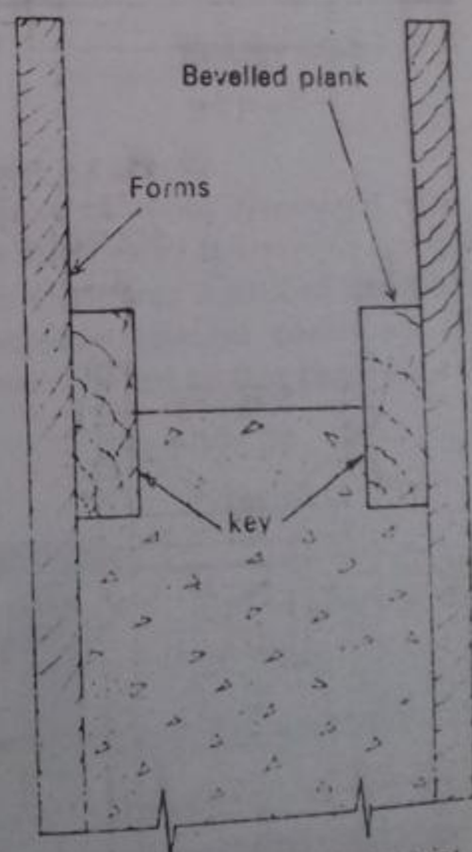


Fig. 8.5. Correct Horizontal joint in a wall.

In joining the new concrete with the old one it is essential to extend the reinforcement of the old concrete into the new one. A shear key as shown in (Fig. 8.6) should also be provided. Before the new concrete is laid the old surface of the joint should be scratched with wire brush—if it is still soft, but if it has hardened then the surface should be chiselled and cleaned. Thereafter, a rich mix of cement is applied by pouring new concrete.

When concrete has to be laid in high and long wall then both horizontal and vertical construction joints may have to be provided. If the wall is not intended to be watertight then just ordinary joints as explained before may be provided. However, if the wall is intended to be watertight then special care has to be taken in making these joints.

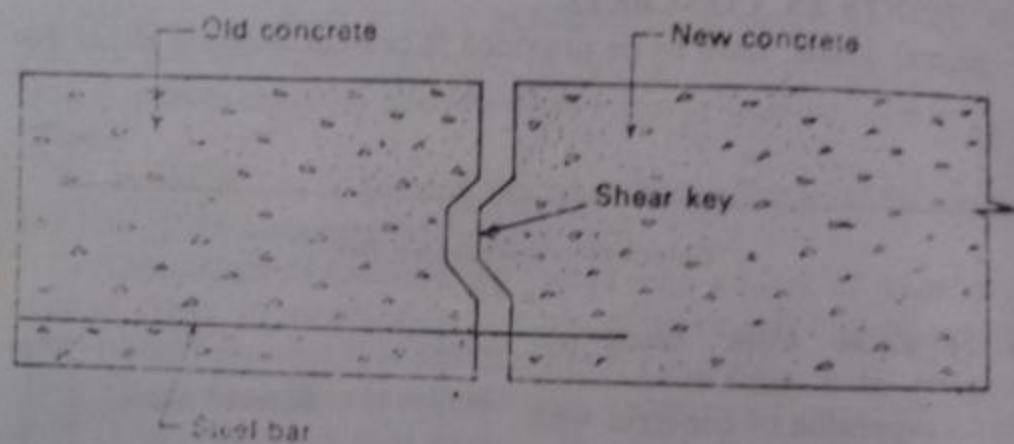


Fig. 8.6. Joints in Concrete.

For horizontal joints keys are provided as shown in Fig. 8.6. Whereas for vertical joints water stops have to be provided (Figs. 8.7. and 8.8).

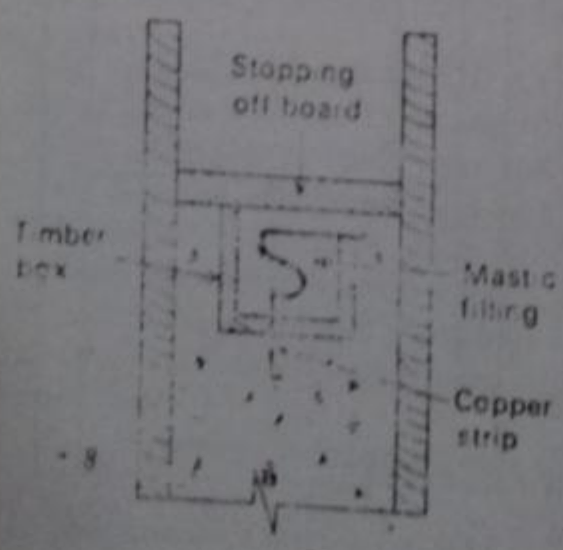


Fig. 8.7

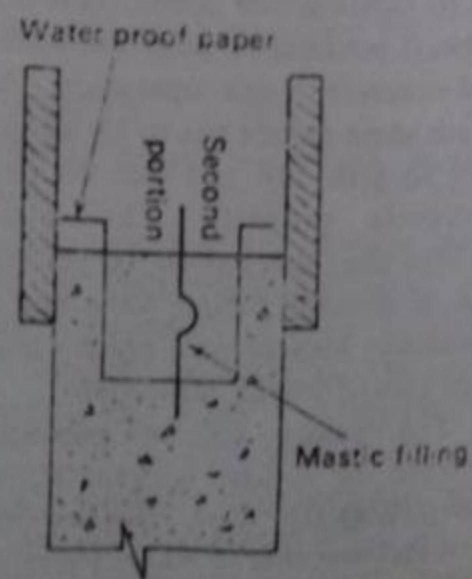


Fig. 8.8

In the construction of columns dowel bars are left in the old column whose top has been left horizontal. These dowels connect the newly cast column with the old one.

(*ii*) *Expansion joints*. Concrete expands and contracts with fluctuations in temperature. Also because of deflection there is movement of the member on the support. If these movements of members are not allowed freely then it could cause serious damages to the structure.

Expansion joints in floors should as far as possible be watertight. To avoid unsightly joints in ceiling these are usually provided on the supports (Fig. 8.9).

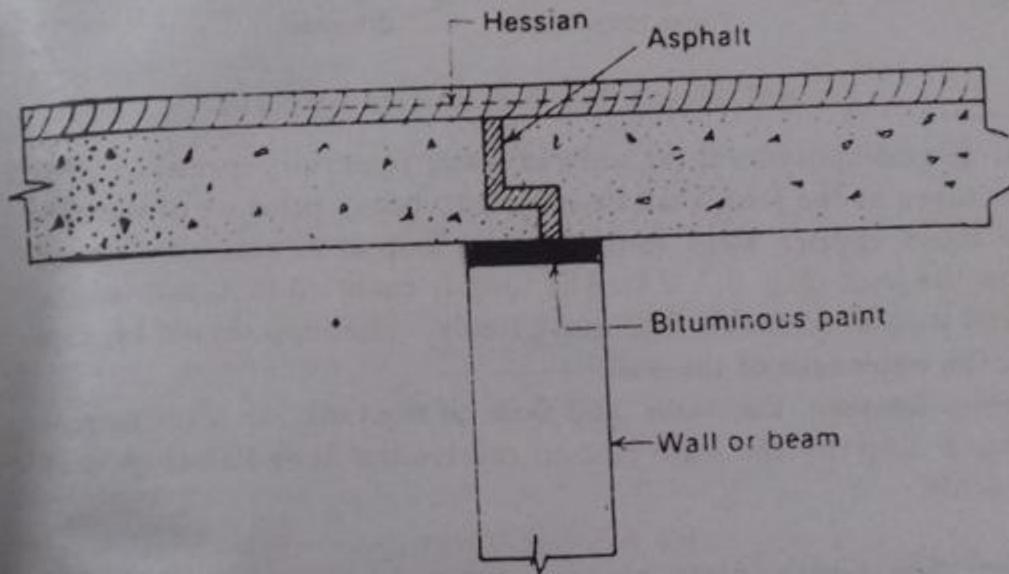


Fig. 8.9. Joint in Roof Slab.

In case of concrete roads the whole area is divided into panels which are cast separately. Joint between adjacent panels are filled with some plastic material like bitumen or felt so that they allow the free movements of each panel.

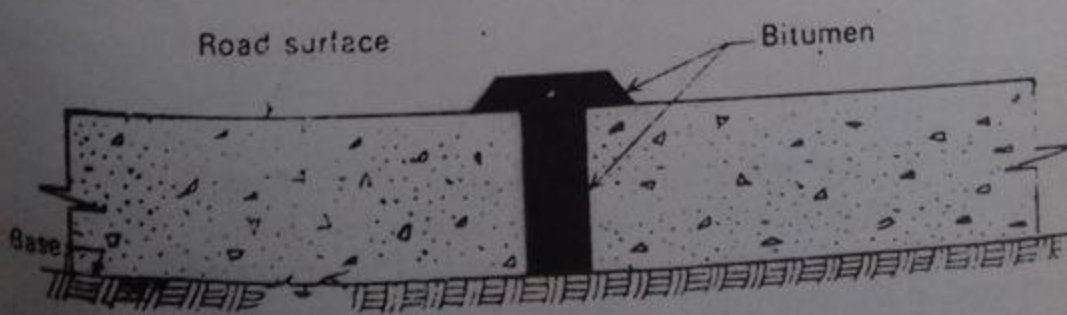


Fig. .10. Joi t in oad Slab

To prevent damage to road surface enough bitumen should be filled in the joint (Fig. 8.10.)

Where the traffic is very heavy the edges of each panel are protected by means of angle irons which are built in the slabs with hook bolts while concreting (Fig. 8.11).

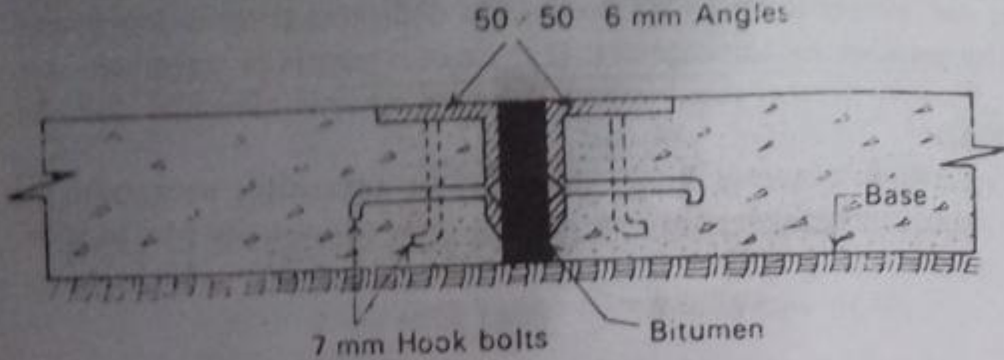


Fig. 8.11. Joint in Road Slab carrying heavy traffic.

In providing joints in the walls of water reservoirs special care has to be taken as the joint shall be subject to heavy pressure of water.

A loose copper strip in the form of loop at its centre is inserted across the joint (Fig. 8.7, 8.8). The loop is enclosed in a soft mastic around it so as to enable it to move freely. The loop should be kept near the water face of the wall.

Joints between the walls and floor of the tank are made by providing a step in the wall base to receive the floor slab (Figs. 8.12 and 8.13).

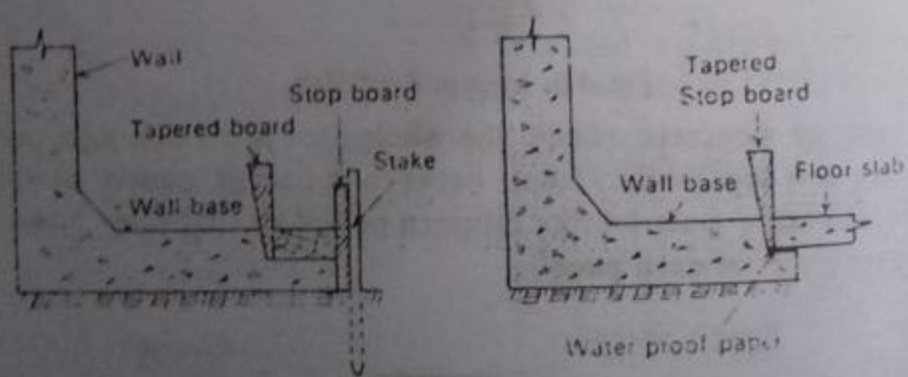


Fig. 8.12 and 8.13.

Tapered stop board is left at its place till the floor slab hardens. Thereafter it is withdrawn and the space left is filled up with a plastic material which allows for the free movements of base with changes in temperatures.

8.12 FORM WORK

To give the desired shape to the concrete when it sets and to hold concrete till it sets and gains enough strength to support its own weight and the live load coming on to it, a temporary staging is erected. This temporary staging is known as *form work, shuttering, centring* or *false work*. The cost of shuttering comes to about 25 per cent of the cost of concrete structure. Due attention in designing the form work, if not paid, could be disastrous resulting in the collapse of structure and possibly fatal accidents. A good form work should satisfy the following essential requirments:

(*i*) It should be strong enough to take the load of wet concrete, of reinforcement placed on it and of workmen laying the concrete.

(*ii*) It should not deflect more than the permissible limit of $\frac{1}{1600}$ of the span.

(*iii*) Its joints should be all watertight.

(*iv*) All lines of the form work should be true and the surface plane so that the finish of concrete does not require additional expenditure.

(*v*) The form work should be such as would not get deformed due to bulging etc.

(*vi*) It should be easy to remove without damage to any one of its parts so that it could be used repeatedly.

To stop the concrete from sticking to the form work inner faces of it should be coated with soap, whitewash or oil. If this is not done then while removing the form work either the form work or the concrete is likely to get damaged.

Commonly used form works are of wood or steel. The latter, though initially more costly, proves to be more economical in the long run and gives generally better finish.

Sizes of form work are also standardised so that the scantlings have not to be cut now and then resulting in waste thereby proving to be uneconomical.

In designing form work for columns (Fig. 8.14) hydrostatic pressure of water should also be taken into account. To reduce the effect of hydrostatic pressure it is better to lay concrete in layers at intervals so that a layer of concrete is laid when the previous one has set. Moving form works are used for columns so that after the concrete has set the same form work is raised and fresh concrete laid. It proves to be economical.

Time of removal. Shuttering helps in retaining the moisture in concrete. As such from the point of view of curing the shuttering should be left in place as long as possible. However, for other reasons like the necessity for its reuse etc., it may be desirable to remove it at the earliest.

The period after which the shuttering should be removed depends on curing, climate, type of structure, spans and the nature of loads likely to come on it. For the same structure if the atmosphere is dry and hot the shuttering may be removed earlier than where it is cold and wet.

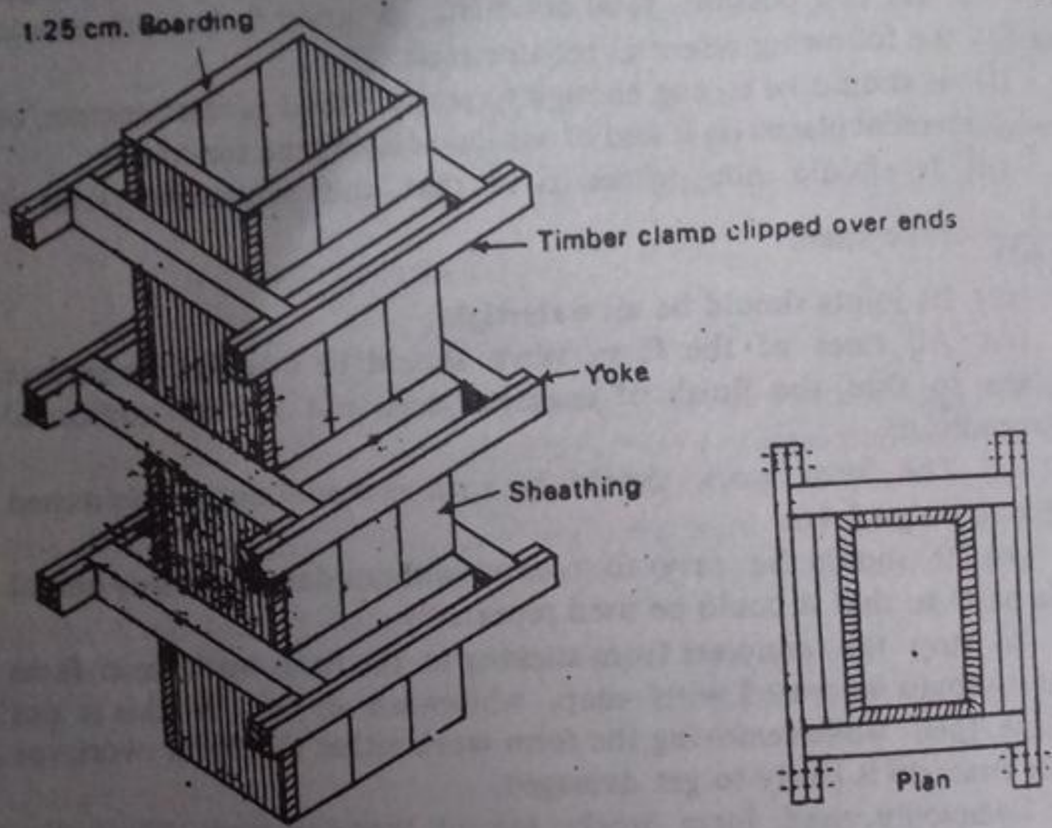


Fig. 8.14. Form work for a column.

For normal climatic conditions the form work from the sides of beams, columns or walls may be removed after four days. The supports to slabs may be removed after 14 days but for beams it should be allowed 28 days. However, these periods could be reduced if the weather is dry and hot and if the spans are small. With rapid hardening cement the above periods could be reduced to half.

8.13 REINFORCED CEMENT CONCRETE

Plain cement concrete is quite strong in compression but weak in tension and shear. In the construction of those members that are subjected to tension/shear the concrete is strengthened by embedding steel bars in it.

This concrete wherein steel bars have been embedded to enable it take up tension/shear stresses safely is known as *reinforced cement concrete*.

R.C.C. is such a versatile material of construction that it could be adjusted to the specific requirements of any sort of structure. It is these days being extensively used in the construction of all sorts of buildings, bridges, arches, tanks and massive dams etc.

8.14 PRESTRESSED CEMENT CONCRETE

It is manufactured with high grade controlled concrete having three to four times the strength of concrete normally used in R.C.C. High tensile steel with breaking strength nearly four times the strength of the normal mild steel used in R.C.C. is used in case of prestressed cement concrete.

Prestressed concrete is produced in factory. Most commonly used method is the "Hoyer Long Line Method." According to it high-tensile wires are stressed between too anchors about 90 metres apart. The concrete is cast to required shapes in moulds built around these wires. The wires are released from achors after the concrete has gained the required strength. The tendency of wires to return to original lengths sets up a compression in concrete which helps to resist the tensile stresses set up due to bending.

Prestressed beams, girders, flooring, roofing, bridge girders, railway sleepers, fencing posts and number of other components are extensively used.

Adoption of this technique of prestressing results in the saving of concrete to the extent of 50 per cent and of steel to the extent of 75-80 per cent in comparison to ordinary R.C.C. work. It gives an extremely high and durable quality of product and at the same time making the product smaller in section and weight.

8.15 AERATED CONCRETE

It is manufactured from calcarious and silicious materials like cement, lime, pulverized sand, fly-ash etc. Air cells are entrapped in it. Presence of air cells makes the material light, impervious to water and a nice insulator. It can be produced in varying densities depending upon the use to which it has to be put. It can be used in the form of precast blocks or may be cast-in-situ. It is used from mere lining material for cold storages (because of its insulation properties) to load bearing slabs for roofs and floors. If needed it could be reinforced like ordinary concrete.

This versatile material is produced in India only by the Hindustan Housing Factory, New Delhi under the trade name *Vayutan*.

8.16 PRE-PACKED CONCRETE

In it cement sand mortar is injected under pressure so as to fill voids of already packed coarse aggregate whose voids have been reduced to the minimum by compaction. It gives very dense concrete whose shrinkage is much smaller.

8.17 FOAM CONCRETE

It is manufactured by incorporating minute air bubbles with preformed foam process in a cement and pulverized sand slurry which inparts lightness to the product thus formed. These moulded blocks are then cured. This improves strength, reduces shrinkage and gives the blocks greyish white or greyish colour depending upon the type of fine aggregate used.

This light weight concrete is being produced in various varieties, having different properties each suited for a specific purpose and possesses excellent heat insulation properties, especially in lighter forms. It is used for heat insulation over roofs etc.; light weight partition walls, light weight roofs for factories and for light weight false ceiling.

EXERCISES

1. (*a*) How does a concrete mix gain strength?

(*b*) Describe the part played by quantity and quality of water used in concrete.

2. What is the importance of grading of aggregates in the preparation of cement concrete? What is the best grading of aggregates?

3. What is the fineness modulus of aggregates and how does it influence the choice of aggregates?

4. What is proportioning of concrete? Briefly explain the various methods of proportioning a concrete mix.

5. What is meant by workability of concrete? How is it tested in the field?

6. What is water cement ratio and how does it affect the properties of concrete?

7. (*a*) How are various ingredients measured for preparation of cement concrete?

(*b*) What precautions will you take in placing and compaction of cement concrete?

(*c*) What do you mean by water cement ratio?

8. (*a*) What is meant by "mix" in cement concrete? What are the various mixes used in plain and reinforced cement concrete works? In what type of constructions would you use each mix with advantage?

(*b*) Explain (*i*) Slump (*ii*) Fineness modulus (*iii*) Air entrained concrete (*iv*) Lean mix (*v*) Harsh mix.

9. Write short notes on:
(*a*) Grading of aggregates.
(*b*) Water cement ratio.
(*c*) Proportionihg of mix.
(*d*) Compaction.
(*e*) Curing.
10. What is curing and how does it influence the strength of concrete?
11. Write short notes on:
(*i*) Requirements of good concrete.
(*ii*) Slump test.
(*iii*) Prestressed concrete.
(*iv*) Foam concrete.

9

TIMBER

9.1 DEFINITION

Wood suitable for building or other engineering purposes is called timber. When it forms part of a living tree it is called *standing timber*. When the tree has been felled it is called *rough timber*. When it has been sawn to various market forms such as beams, battens and planks etc., it is called *converted timber*.

9.2 CLASSIFICATION OF TREES

Depending on the mode of growth trees are classified into two catagories as: (*a*) *Endogenous*, and (*b*) *Exogenous*

9.2.1 Endogenous trees are the ones that grow inwards in a longitudinal fibrous mass such as banana, bamboo, palm and cane. Even though the "stem" of trees of this class is light and tough yet it is too flexible and slender to furnish material suitable for engineering works, with the exception of bamboo.

9.2.2. Exogenous trees are those that grow outwards by the addition of one concentric ring every year. These rings are known as annual rings. Since one ring is added to the tree every year so the number of annual rings in the stem of a tree indicates its age in years. It is timber obtained from this class of trees that is extensively used in engineering works.

Timber available from exogenous trees is further classified into two catagories as:

(*a*) Conifers or evergreens yielding *Soft wood*. These are trees with pointed leaves. Deodar, Pine, chir and kail belong to this class.

(*b*) Deciduous are trees with broad leaf, yielding *Hard wood*. Teak, sal, shisham belong to this class.

This classification is based on different properties of the wood available from different trees.

9

TIMBER

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9.3 GROWTH OF TIMBER TREE AND ITS STRUCTURE

9.3.1. **Growth.** In spring season roots of the tree suck a solution of salts from the soil—salts that are food for the tree and transmit the same through the trunk of tree to its branches and leaves. This solution of salts looses some of the moisture because of evaporation and absorbs carbon dioxide from the air. This action in the presence of sun makes the solution a bit viscous. This transformed viscous solution is known as *sap*.

In autumn viscous sap descends below the bark and leaves a thick layer. Layer of sap left below the bark gets transformed to wood and is known as cambium layer. It goes on gaining strength with the passage of time. A fresh layer is thus added on the outside of the tree every year forming a new annual ring. The new ring represents a year's growth of tree.

Medullary rays carry the sap from below the bark to the interior thereby nourishing the tree.

9.3.2. **Structure.** On examining the cross section of the trunk of an exogenous tree, we see the different parts as shown in Fig. 9.1. A brief description of each part is discussed separately.

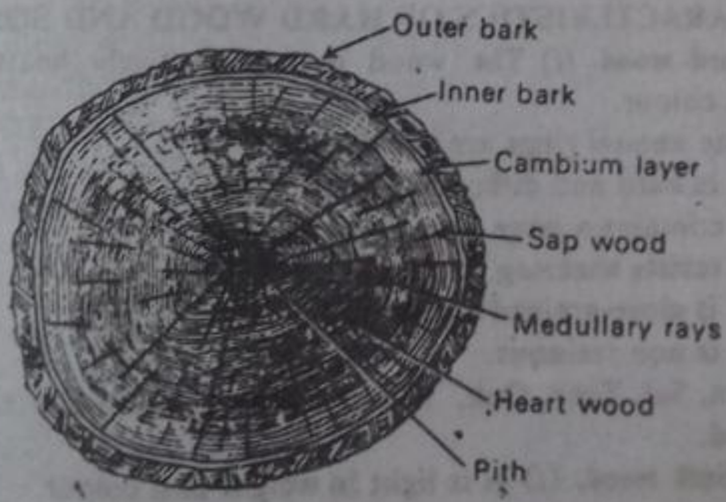

Fig. 9.1. Structure of an Exogenous tree.

9.3.3. **Pith or medulla.** It is the first formed portion of the stem of tree. It consists entirely of cellular tissues. The pith, which when the plant is young, contains a large amount of fluid and nourishes the plant. It dies up and decays when the plant becomes old. Sap is then transmitted by the woody fibres that deposit about the pith. Pith of branches is a mere prolongation of the pith of stem.

9.3.4. **Annual rings.** The rings of woody fibre arranged in concentric circle around the pith are known as annual rings because one such ring is added every year.

9.3.5. Heart wood. Innermost rings surrounding the pith constitute the *heart wood*. This wood is darker in colour, stronger, more compact and durable.

9.3.6. Sap wood. Outer annual rings of the tree constitute the sap wood which transmits the sap from roots to branches. Compared with heart wood, sap wood is lighter in colour, weaker and more liable to decay.

9.3.7. Cambium layer. Outermost one ring between the bark and sap wood which is not yet converted into wood is known as the cambium layer. In due course, cambium layer changes to sapwood. If the cambium layer is exposed by removing the bark, the cells cease to be active and results in death of tree.

9.3.8. Medullary rays. These are thin horizontal veins radiating from the pith towards the bark. They carry sap from outside to the inner parts of tree and nourish it. They keep the annual rings tightly gripped together. In some trees they might be found broken or may not even be clearly visible.

9.3.9. Bark. It is outermost protective covering of cells and woody fibres on a tree. In course of time older layers split and scale off.

9.4 CHARACTERISTICS OF HARD WOOD AND SOFT WOOD

9.4.1. Hard wood. (*i*) The wood is comparatively heavier and is darker in colour.

(*ii*) The annual rings are not distinct.

(*iii*) It is hard and difficult to work upon.

(*iv*) It contains a large percentage of acid.

(*v*) It resists shearing stresses.

(*vi*) It is close-grained and strong.

(*vii*) It is non resinous.

Shisham, Sal, Teak, Oak, Mahogony and Babul are examples of hard wood.

9.4.2. Soft wood. (*i*) It is light in weight and colour.

(*ii*) Annual rings are very distinct.

(*iii*) It is comparatively weaker and splits easily.

(*iv*) It has straight fibres.

(*v*) It is resinous *i.e.*, contains resins and turpentine. It has a peculiar fragrance.

(*vi*) It is strong for resisting tensile forces.

(*vii*) It is weak in directions across the grains.

(*viii*) Its texture is soft and regular.

Spruce, Deodar, Chir, Kail and Walnut etc., are examples of soft wood.

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9.5 CHARACTERISTICS OF GOOD TIMBER

(*i*) It should be from the heart of a sound tree and be free from sap.

(*ii*) It should have straight and close fibres.

(*iii*) It should be of uniform colour.

(*iv*) It should give a clear ringing sound when struck. Dull heavy sound is a sign of internal decay.

(*v*) It should have regular annual rings.

(*vi*) Timbers with narrow annual rings are generally the strongest.

(*vii*) Freshly cut surface should give sweet smell.

(*viii*) Teeth of saw should not get clogged while sawing.

(*ix*) It should have bright and smooth surface when planed. Dull appearance is a sign of defective timber.

(*x*) Out of same variety of timber, darker and heavier pieces are stronger.

(*xi*) It should be free from dead knots, from too many knots, shakes or other defects.

(*xii*) It should have firm adhesion of fibres and compact medullary rays.

9.6 DEFECTS IN TIMBER

These defects are mostly of two types: (*a*) Those developed during the growth of tree and (*b*) Those developed after the tree has been felled.

Below are discussed both these defects in details:

9.6.1. Defects developed during the growth of tree—(*i*) *Star shakes.* These are radial splits wider on the surface of the tree and becoming narrower as they move towards the centre (Fig. 9.2). They are caused by severe frost or by severe heat of the sun.

Fig. 9.2. Star shakes.

Fig. 9.3. Heart shakes

(*ii*) *Heart shakes.* These are wide splits running right through the heart wood of the tree (Fig. 9.3.). These splits, radiate from the pith running towards the sapwood. These are caused by the shrinkage of interior parts or by decay because of accumulated mixture.

(*iii*) *Cup shakes or ring shakes*. These are curved splits separating one annual ring from the adjacent one either wholly or partly (Fig. 9.4.). These are caused by strong winds swaying the tree and by excessive frost action on the moisture present in the tree, especially while it is still young. Supply of excessive moisture by the roots or striking of lightening or by freezing of frost during ascent may also cause this defect.

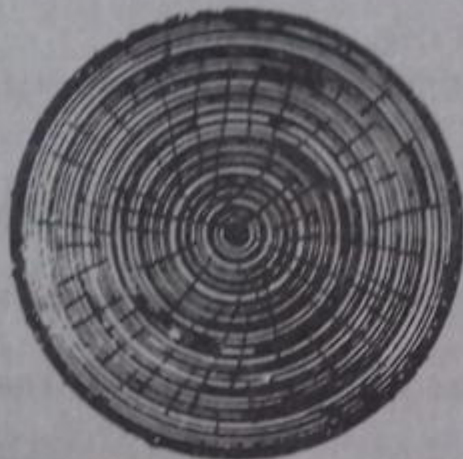

Fig. 9.4. Cup shakes.

(*iv*) *Twisted fibres*. Fibres are twisted by strong winds turning the tree constantly in one direction. Trees in exposed positions or on hill tops are the most affected (Fig. 9.5.).

Fig. 9.5. Twisted fibres.

(*v*) *Rind galls*. These are peculiar swellings (Fig. 9.6) caused generally by the growth of layers of sapwood over wounds remaining after a branch of tree has been imperfectly cut off. These new layers do not unite properly with the old root thereby leaving cavities wherein starts the decay.

(*vi*) *Upsets*. In this defect, during the growth of tree, fibres are sometimes injured due to crushing resulting in the breakage of continuity of fibres (Fig. 9.7.).

(*vii*) *Knots*. A knot is either the root of a branch that is embedded in the stem with the formation of annual rings at right angle to those of the stem or the tissues set in elliptical or concentric circles (Figs. 9.8,9.9). These knots are of two classes: (*a*) *Dead or loose knot*, and (*b*) *Live or sound knot*.

When the knot can be separated from the body of the wood it is known as dead knot. Because of the burning up or decay of outer tissues this type of knot becomes loose and falls out.

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Live knots are firmly attached to timber and cannot be separated. It is hard to work upon a knot and it remains rough even after planing. A live knot is not a serious defect. Only it reduces the strength of timber a little. It is hard to plane. *Timber with too many knots or with loose knots should not be used for structural purposes.*

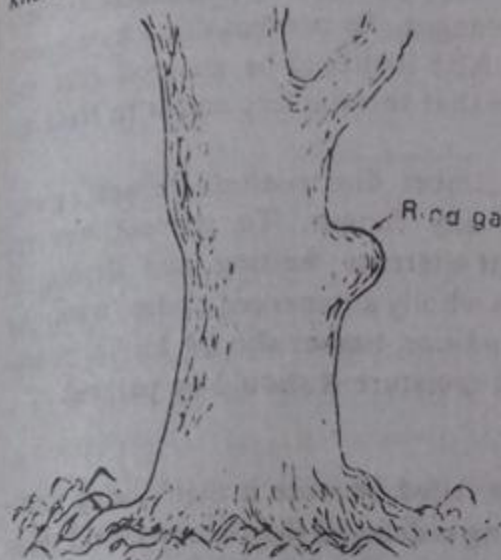

Fig. 9.6. Rind-gall.

Fig. 9.7. Upsets.

Figs. 9.8 and 9.9. Knots.

(*viii*) *Foxiness*. Presence of reddish or yellowish strains shows the beginning of decay in timber because of bad ventilation during storage.

(*ix*) *Doatiness*. It is a speckled stain found in some timbers indicating the beginning of decay of timber. It too is caused by either over maturity of timber or by bad ventilation of the place where it is stored.

(*x*) *Druxiness*. Presence of whitish spots or streaks in timber indicates early decay because of druxiness.

(*xi*) *Coarse grains.* Timber having very wide annual rings because of rapid growth of trees are said to have coarse grains. The wood is not durable and is deficient in strength.

9.6.2. Defects developed after the tree has been felled or diseases of timber. (*i*) *dry rot.* It is an attack of the timber by a fungus. The fungus reduces the timbers to a dry powder. Unseasoned timbers become an easy prey to the fungus. To prevent dry rot only well seasoned timber should be used. Also it should be ensured that the timber is used in such a manner that there is free access to fresh air to all parts of the timber.

(*ii*) *Wet rot.* It is decay of timber due to alternate wetting and drying. In it there is no attack of any fungus. To prevent wet rot timber should be protected against alternate wetting and drying. It should be so used that either it is wholly submerged under water or it is always dry. For the latter condition timber should be fully seasoned and as a protection against moisture it should be painted.

9.7 FELLING

Only a fully grown tree should be felled because it then yields maximum and strongest timber. If felling is delayed then decay would set in the heart wood which is the best and the most important part of a tree.

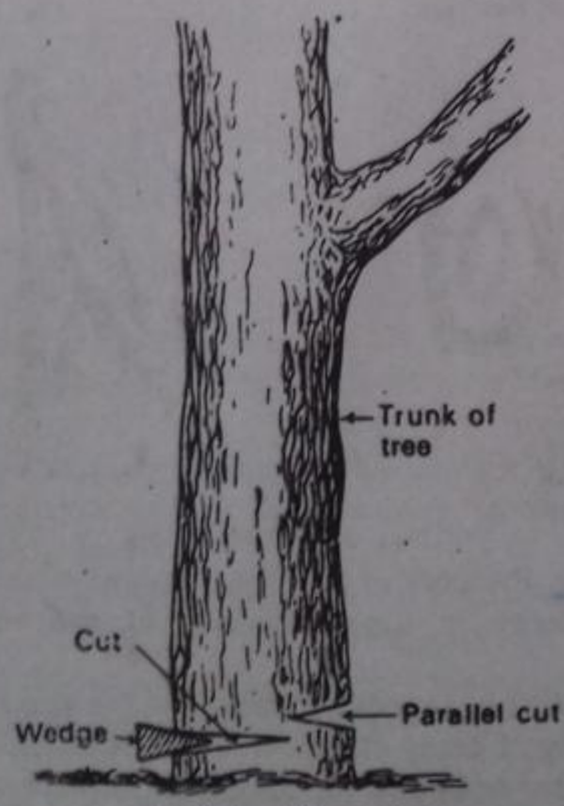

Fig. 9.10. Felling of tree.

Early felling would give lesser quantity of timber which has not

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As such a tree should always be felled only *after it has fully matured but before the heart wood starts deteriorating.*

The lower we go the more is the timber that the trunk of tree yields as such it would be wise to cut the tree from a place a little below the ground level but higher up than the roots.

Seasoning would be a problem if the tree is felled when the sap is moving. The tree should be felled when the sap has not started going up. Usually this condition is in summer season.

Process of felling. Make a deep cut with axe at the lowest possible point of the trunk. The trunk may be then sawn to a point beyond the centre of gravity of the trunk (See cut on the left side of trunk, Fig. 9.10.). This cut should be made on the side opposite to that on which it is intended to be felled. A cut is then made on a side opposite to the one on which first cut was made.

Top of tree is then tied with ropes on all the four diametrically opposite sides. The rope on the side the tree is to be felled is pulled and the one on the opposite side is loosened slowly.

The tree would break at the level of cuts and it should be allowed to fall gently otherwise it is likely to get damaged.

After felling its branches are chopped off and the log is cut to the needed sizes. It should be protected against rapid drying particulary at the ends. Its bark should be removed and the log sawn at the earliest. Till then care should be taken against any attack of fungi.

9.8 SAWING OF TIMBER

After felling if the logs are not cut for sometime, then because of drying of moisture from the outer rings, when the moisture still remains in the centre of the log, outer rings shrink without a proportionate corresponding shrinkage of the central portion. As in an uncut log shrinkage takes place in circumferential direction (Fig. 9.11) so it results in star shakes (cracks on the surface of log narrowing as they move inwards). As such logs should be converted as soon as possible after felling. Also conversior of timber accelerates seasoning by exposing to atmosphere greater

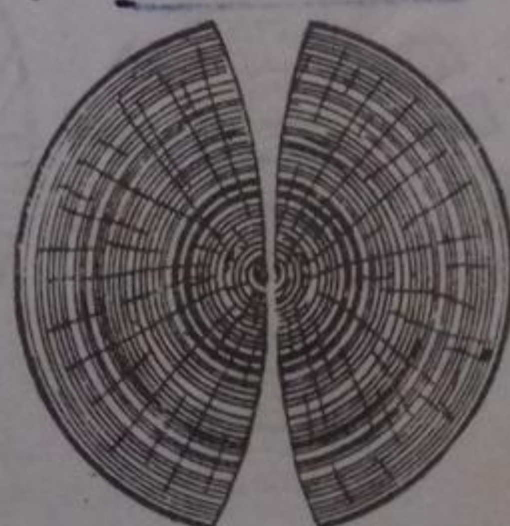


Fig. 9.11. Effect of circumferential shrinkage.

area of timber for drying.

Sawing. Methods commonly adopted for the conversion of timber are:

9.8.1. Ordinary sawn, bastard sawn, flat sawn or slab sawn. This is not only the easiest method of sawing timber (Fig. 9.12) but it is also the most economical one so far as the out-turn is concerned. In it only parallel cuts are made throughout the length of the log, thereby cutting parallel slices of planks.

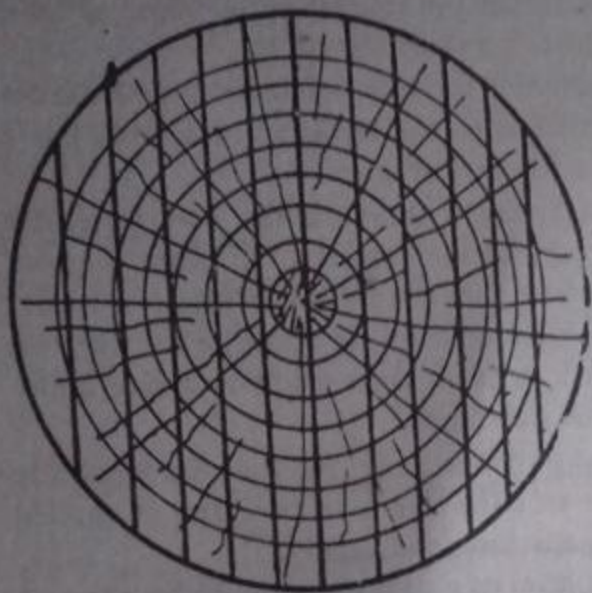


Fig. 9.12. Flat sawing.

Circumferential shrinkage is the greatest and sapwood shrinks more than the central heart wood portion. The thickness at the centre, therefore, remains almost unaltered while the sapwood shrinks causing warping and twisting of planks (Fig. 9.13).

Fig. 9.13

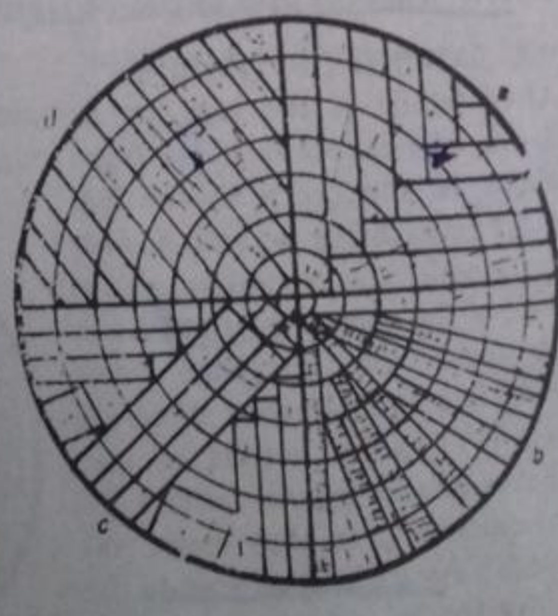


Fig. 9.14

9.8.2. Quarter sawing. In this method [Fig. 9.14 (*a*)], there is a tendency for the timber to cut or to bend in a transverse direction. This method of sawing gives very fine figure wood when adopted in case of timber having no distinct medullary rays.

9.8.3. **Rift or radial sawing.** Timber sawn according to this method is cut parallel to medullary rays and parpendicular to annual rings [Fig. 9.14 (*b*)]. This method gives least shrinkage but it is most wasteful. Hence, method known as limited rift [Fig. 9.14 (*c*)], is adopted. This method gives greater decorative effect of figuring in woods in which the medullary rays are most marked. This method is adopted when medullary rays are pronounced. Medullary rays have the property of resisting shrinkage. As such, rift sawn planks shrink by about one half of those cut tangentially due to the restraining action of the medullary rays. In positions subject to abrasive action as in floors the rift sawn timber gives a harder wearing surface than the other ones. Timber sawn as in [Fig 9.14 (*d*)] reduces wastage but gives a little inferior timber.

9.8.4. **Tangential sawing.** In this method boards or planks are sawn tangentially to annual rings but such boards are not very suitable for flooring. Planks obtained by this method of sawing warp too much. This method is adopted when the annual rings are very distinct and the medullary rays are ill defined (Fig. 9.15).

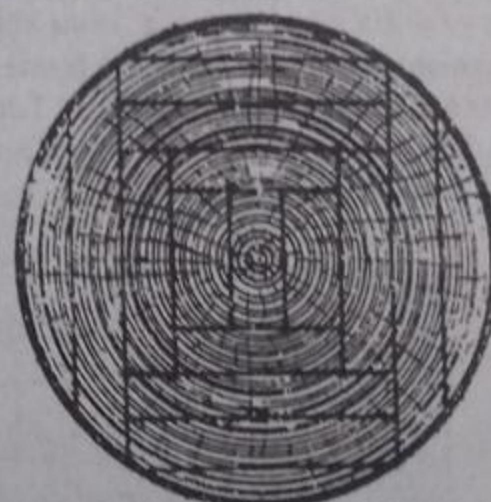


Fig. 9.15

9.9 SEASONING OF TIMBER

Newly felled tree contains a considerable quantity of sap. If this sap is not removed the timber is likely to warp, crack and shrink. It may even decay. The art of seasoning is to extract the moisture under controlled conditions as nearly as possible at a uniform rate from all parts of timber and to leave the remaining moisture, that cannot be extracted uniformly distributed throughout the mass. Irregular drying will cause irregular shrinkage resulting in the setting up of internal stresses between the fibres. When these stresses become strong enough to overcome the cohesion of the fibres then the timber warps and shakes are formed.

9.9.1. **Objects of seasoning.** (*i*) Wet timber is an easy prey to decay by fungi, borers, termites etc. Seasoning thus makes timber resistant to decay.

(*ii*) Seasoning makes timber lighter.

(*iii*) It becomes easier to paint and polish seasoned timber.

(*iv*) It is easier to treat seasoned timber with preservatives.

(*v*) Seasoned timber becomes stronger and more stable.

(*vi*) Seasoning stops shrinkage of timber on drying.

(*vii*) Seasoned timber has better electrical resistance.

9.9.2. Preventing drying of logs. After the tree has been felled its bark is removed and it is roughly squared and sawn as quickly as possible to avoid cracking of timber and to expedite seasoning. There is possibility of faster evaporation of moisture from ends of timber piece and if not checked then it is likely to result in cracking and splitting of ends. To avoid this, painting ends of logs or planks with sealing liquid, tar or asphalt, paraffin wax, mixture of molasses and lime or of rosin and lamp black and shading them with canvass or plywood etc., is adopted.

If however the logs cannot, immediately on felling be converted into planks or scantlings then rapid drying of logs should be minimised by storing them *completely submerged under water*. If the water is stagnant then the same should be changed at least once a fortnight sc as to remove the fermenting material.

9.9.3. Methods of stacking. Timber, before seasoning, should be stacked in yards free from weeds and debris. The yard should have big shady trees to protect the timber from direct sun.

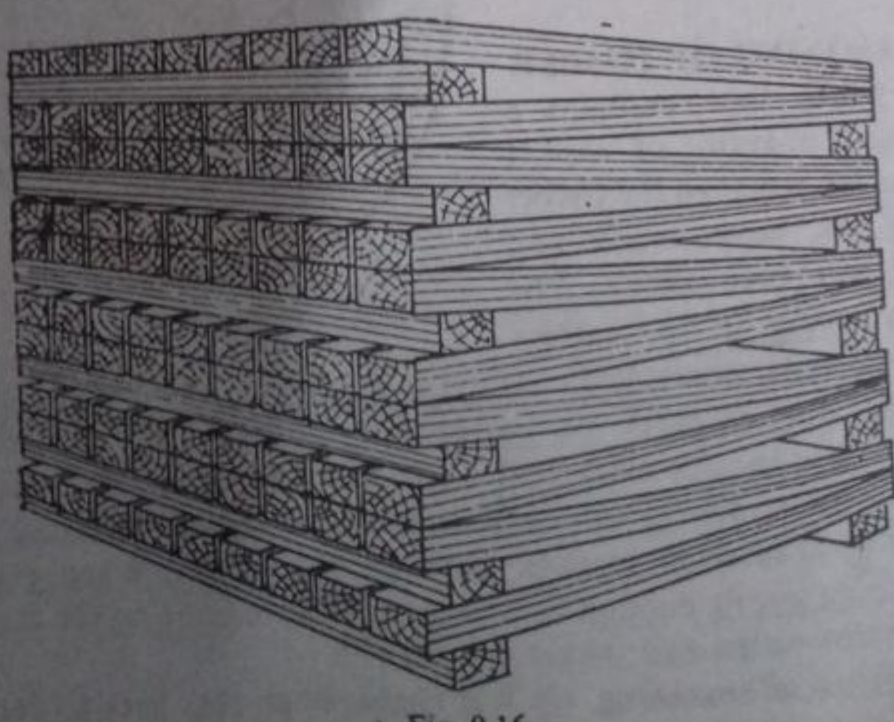


Fig. 9.16

Ends of logs should be protected against splitting by applying anti-splitting compositions and stacked on foundations in closed stacks in one or more layers. Stacks should be protected against direct sun by providing a covering—if needed.

The *one and nine* methods of stacking sleepers (Fig. 9.16) is best suited for moderately heavy coniferous sleepers in hot climate and for heavy timbers in moist climates. In the *Close Crib* method (Fig. 9.17) reduced air circulation slows down the pace of seasoning.

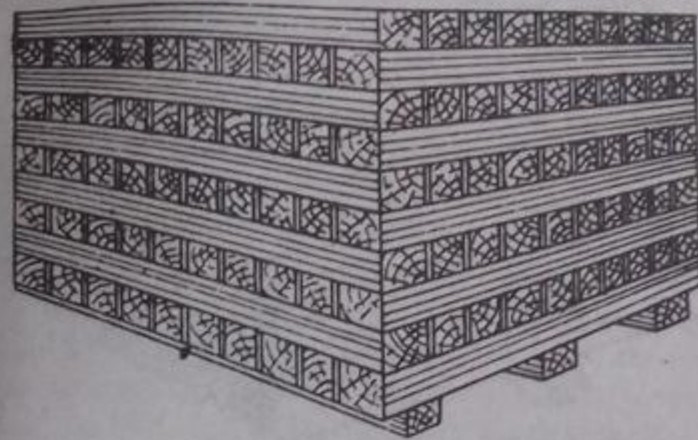


Fig. 9.17

This method is recommended for stacking heavy structural timbers like *sal* in hot and dry localities. *Open Crib* method (Fig. 9.18) is a

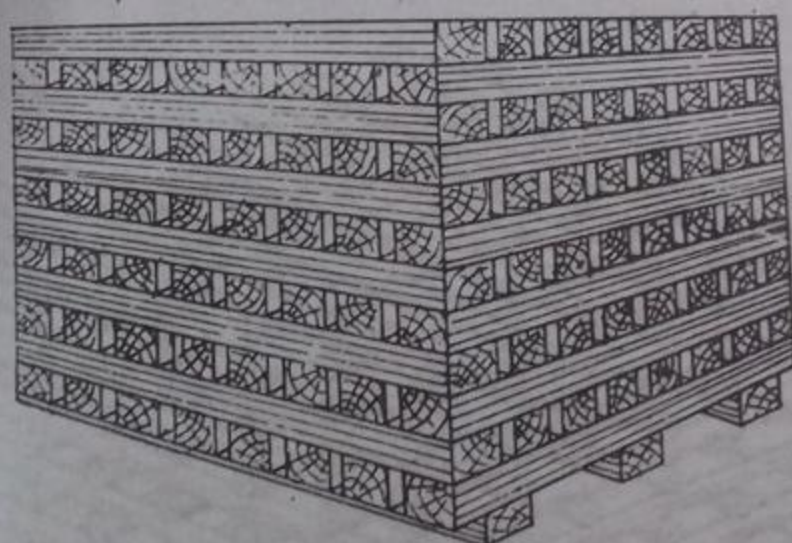


Fig. 9.18

modification of the close crib method and because of more air circulation taking place it is more akin to the one and nine method in its effects. Stacks of not more than 100 sleepers are recommended. Poles are stacked either in closed heaps or with crossers. If stacked in closed heaps (Fig. 9.19) then there should be alternate layers of butt ends and of top ends so that the two ends of the stack are level.

Poles themselves could be used as crossers, which should not be spaced more than three metres.

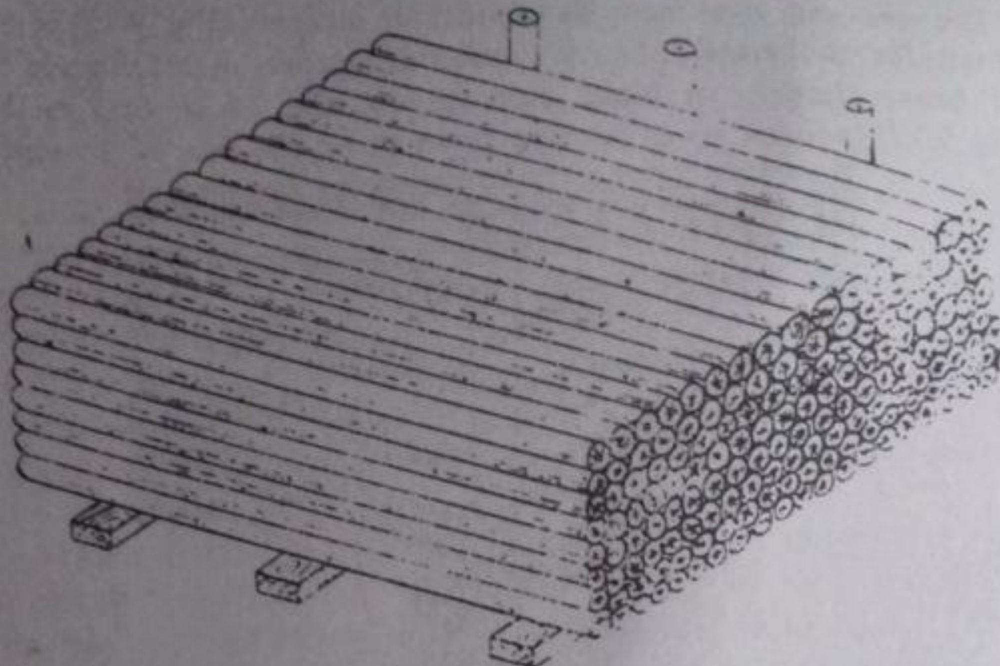
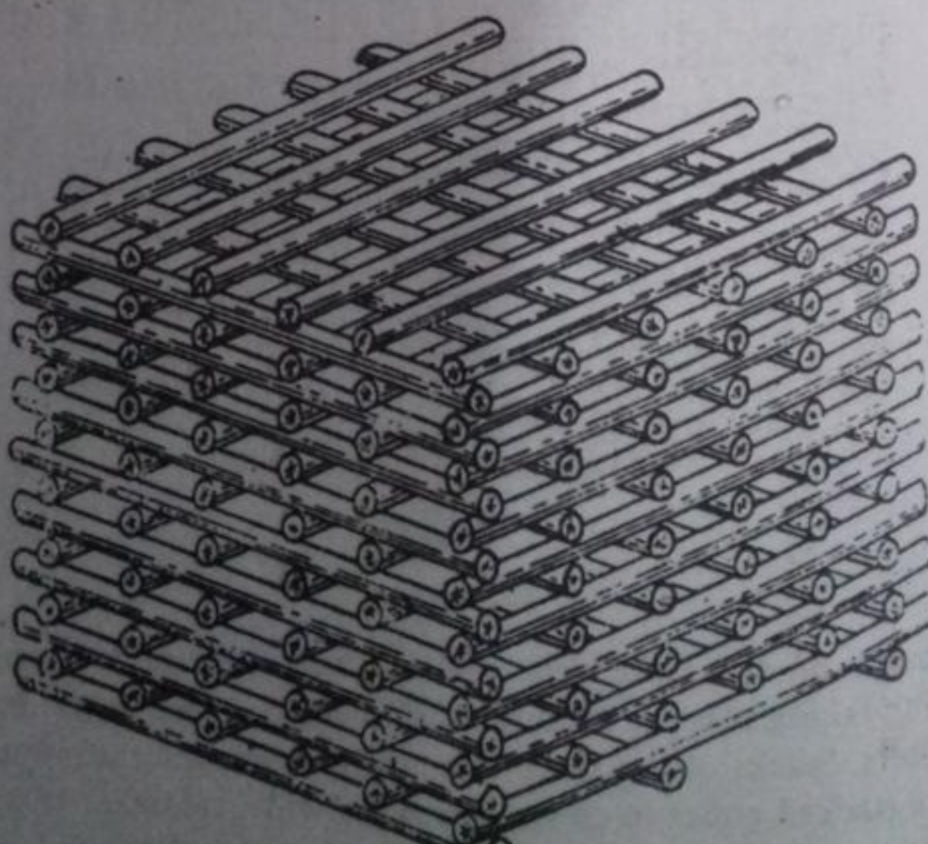


Fig. 9.19

. Fence posts should be stacked in open crib fashion (Fig. 9.20) in which successive layers of posts are at right angles to each other and



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there is a gap of about 8 cm between adjacent posts in the same layer. Centre to centre distance between crossers should not exceed 1.5 m and the height of stack should not exceed 3 metres.

Horizontal stacking of sawn timber is done on vertical pillars of treated timber, brick masonry or of cement concrete 30 cm square in section and 30 to 45 cm high. The pillars are spaced 1.2 m centre to centre along the length and the breadth of the stack. The length of material to be stacked decides the length of stacking unit. Long beams of cross section 10 cm × 10 cm and above are placed on the foundation pillars to form a frame work for stacking timber. These beams should obviously be from strong timbers.

Scantlings and squares should be stacked with crossers 5 cm 4 cm in section and spaced 2.5 to 3 m apart. The ends should be protected with moisture proof coatings.

Planks should be stacked on level platform with crossers of uniform thickness and section, which (the crossers) should be in vertical alignment in a stack (Fig. 9.21). Longer planks should form the

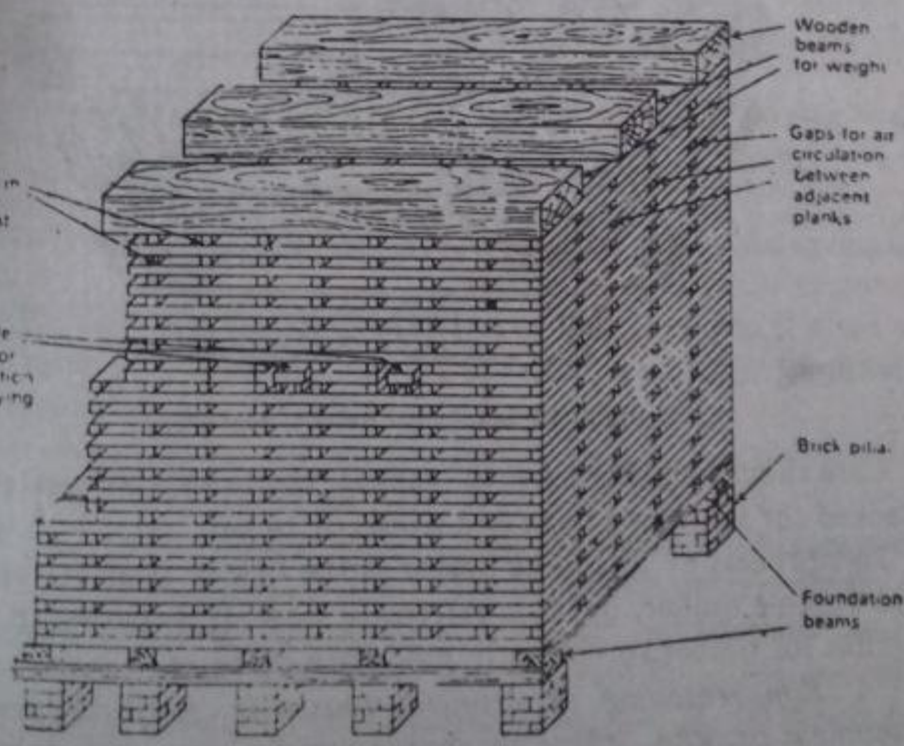

Fig. 9.21

bottom of the stack and the shorter one's the top. Heavy wooden beams should be placed on the top to prevent top layers from warping. A gap of about 2.5 cm should be left between adjoining planks for free circulation of air in the centre of stack. The stack should be protected against rain and sun by providing a shed over it.

For details refer to IS 1141—1973

9.9.4. Seasoning methods. Based on the recommendations of IS 1141—1973 the seasoning methods should be classified as: (*a*) Air seasoning or natural seasoning, and (*b*) Kiln seasoning or artificial seasoning.

(*i*) *Air seasoning or natural seasoning*. As soon as possible after felling, the log is converted by sawing it into battens and planks etc. These are then stacked on a well drained place in the shade. While stacking care should be taken to ensure free circulation of fresh air all around each piece (Fig. 9.22). The stacking should be done on masonry or concrete supports a few centimeters above the ground.

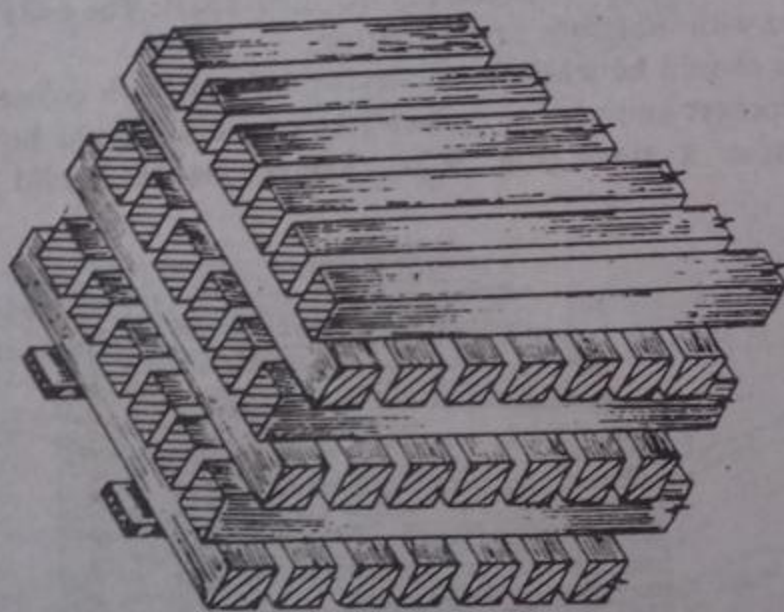

Fig. 9.22. Stacks for natural seasoning.

Care should be taken not to expose the freshly converted timber stacked for seasoning to severe winds or to sun.

This process of seasoning timber is the best as it gives very strong and durable timber, but it is extremely slow. It takes more than six months for timber to season in moderate climates.

(*ii*) *Kiln seasoning or artificial seasoning*. Artificial method of seasoning or kiln seasoning speeds up the seasoning process. For large scale production of seasoned timber kiln seasoning is a must.

Kiln seasoning is done in a chamber equipped with arrangements for heating and humidifying the air to required conditions of relative humidity and temperature and for its circulation across the timber stacked in the chamber for seasoning. Usually, it is steam that is used for heating and humidifying the air in the kiln. The seasoning of the timber is started at a comparatively lower temperature and high humidity. As the timber dries these conditions are gradually altered until at the end of the seasoning the temperature of the air inside the chamber is fairly high and the humidity is low. The kiln charge is allowed to cool inside the kiln to within 15 to 20°C of the outside temperature before removal. Seasoning of timber by this method takes about four to five days under normal conditions.

9.10 COMPARISON OF AIR SEASONING AND KILN SEASONING

Relative merits and demerits of the two methods of seasoning are as follows:

Air seasoning	*Kiln seasoning*
1. It is a slow process.	1. It is a quick process.
2. It is simple and economical.	2. It is quite technical and expensive.
3. It is dificult to reduce moisture content below 15 to 18%.	3. Moisture content can be reduced to any desired level.
4. Air seasoned timber is more amenable to attacks of insects and fungi.	4. Kiln seasoned timber is less amenable to attacks of insects and fungi.
5. It requires more stacking space.	5. It requires less stacking space.
6. It gives stronger timber.	6. A little weaker timber is obtained.

9.11 PRESERVATION OF TIMBER

Timber has to be protected from the attack of insects *e.g.*, white ants etc., and from internal decay due to dry and wet rots.

Perfect seasoning is the most effective means of preservation. Timber should be so used that either it is wholly dry and well ventilated or is wholly under water. It will not decay when kept under water but it will become soft and weak. Proper damp proofing of the building and providing free circulation of air around the built-in portions of timber are essential for the preservation of the timber used. However, when these conditions cannot be obtained then preservatives have to be applied for preservation. Timber should be well seasoned before the application of preservatives as otherwise the preservatives would block the pores of timber thereby causing its decay due to the entrapped moisture. When used in masonry, direct contact with lime mortar should be avoided. Following are some of the more common methods of preservation adopted:

9.11.1. Charring. Lower ends of the posts that are to be embedded in ground are generally charred with a view to prevent dry rot and attack of worms. It is done by quenching the ends of posts in water after they are charred on wood fire to a depth of 1.5 cm.

9.11.2. Tarring. It consists in coating with tar or tar mixed with pitch. Embedded portions of timber fence posts, ends of door and window frames, battens and beams built in wall are usually tarred. Tarring is not done in case of those portions of structural members that are open to view, because of unsightly black colour.

9.11.3. Painting. A paint when applied to timber acts not only as a good preservative but also it enhances the appearance of the surface so treated. Only well seasoned timber should be painted as otherwise the moisture entrapped in the timber, because of the closing of timber pores by paint, would cause decay. Paint, however, protects seasoned timber against moisture thereby prolonging its life. M/s. Solignum (India) Ltd. have put in market some paints with the trade mark of *solignum paints*. These have excellent preservative properties and protect timber against the attack of white ants. These are available in a variety of shades. Because of their comparatively higher costs, these are used mostly in the finishing coats while painting wood work.

9.11.4. Creosoting. Creosote oil is a dark brown thick oily liquid. Thoroughly seasoned timber dried for 24 hours before its treatment is placed in an airtight chamber. After the air has been exhausted from this chamber the creosote oil is then pumped in at a pressure of 9 kg/sq cm at a temperature of 50°C so long as the timber is not fully saturated with oil. The oil preserves the timber from rot and from the attacks of white ant. It is used in case of railway sleepers, piles and transmission poles. Undesirable colour and smell, inability to take paint well and the tendency to stain plaster limit its use.

9.11.5. Wolman salt. This salt consists of creosote and sodium flouride and is soluble in water. It is odourless and leaves no stain on wood. After treatment timber could be painted or varnished. These salts destroy many kinds of fungi that cause timber to rot. This renders the timber extremely fire resistant too.

Treatment of timber with zinc chloride, sodium flouride, magnesium, silico flouride or copper sulphate renders the timber immune from the attacks of fungi. The timber so treated is capable of being painted on drying.

9.11.6. Ascu treatment. Forest Research Institute, Dehra Dun has developed a new preservative known as Ascu. It is available in the form of powder and is made up of three chemicals mixed in the ratios given below:

—1 part by weight of hydrated arsenic pentaoxide ($As_2O_5.2H_2O$).

—3 parts by weight of blue vitriol ($Cu\,SO_4.5H_2O$).

—4 parts by weight of potassium dichromate ($K_2\,Cr_2\,O_7.2\,H_2O$).

Six parts of this powder are mixed with 100 parts by weight of water. Ascu solution can be applied or sprayed in two coats. To achieve better results timber may be soaked in the solution and impregnated with it under pressure. The timber should be allowed to dry for three to six weeks. This treatment renders timber immune to the attacks of white ant. Ascu treated timber may be painted, varnished, polished or waxed. The solution is odourless.

9.11.7. **Fire proofing of timber**. Timber cannot be made completely fireproof, however, by treating as below it can be made fire resistant to a sufficient extent.

Soaking timber in amonium sulphate, amonium chloride, amonia phosphate, sodium arsenate, zinc chloride, etc., or spraying on timber, a solution of sodium silicate, potasium silicate or amonia phosphate etc., imparts fire resisting properties.

Abel's methods of fire proofing timber is painting the surface firs with a dilute solution of sodium silicate ($Na_2\,SiO_3$) then with a cream-like paste of slaked fat lime and in the end with a concentrated solution of silicate of soda.

9.12 CHARACTERISTICS AND USES OF COMMON INDIAN TIMBER TREES

9.12.1. **Babul**. It is a thorny tree with small leaves and having yellow flowers. It grows all over India. It can grow in poor soils even without water.

Characteristics. (*i*) The wood is hard, tough and elastic.

(*ii*) It is very durable.

(*iii*) Somewhat brittle to work.

(*iv*) Generally not available in large and straight pieces.

(*v*) Difficult to procure seasoned.

(*vi*) It is close-grained.

(*vii*) Colour is pinkish white turning redish brown on exposure.

(*viii*) It takes good polish.

(*ix*) It weighs 880 kg/cu metre.

Uses. It is used for bodies and wheels of carts, agricultural implements, handles of tools and for inferior building work. Also used for well kerbs.

9.12.2. **Chir**. It is generally found in Himalayas at heights ranging from 500 metres to 2,500 metres.

Characteristics. (*i*) It is pale greyish to yellowish or redish brown in colour.

(*ii*) It resembles deodar but is lighter, softer and coarser-grained.

(*iii*) It is easily worked and seasons well.

(*iv*) It weighs 560 kg/cu metre.

It is inferior to deodar in all respects.

Uses. Used for inferior work in building construction, mostly interior work. It should in no case be used for outside work. With suitable preservative it can be used for electric transmission poles. It is good for matches and for railway sleepers if creosoted.

9.12.3. Deodar (Diar). It is a tall tree with pointed leaves found in western Himalayas from 1000 to 3000 metre height. It is one of the most important timbers of India.

Characteristics. (*i*) It is strong and durable timber.

(*ii*) Its colour is yellow but darkens on exposure.

(*iii*) Moderately hard.

(*iv*) Strongly scented and oily.

(*v*) It is close grained.

(*vi*) It is easily worked.

(*vii*) On planing and varnishing it looks beautiful.

(*viii*) It weighs 560 kg/cu. metre.

Uses. It is used in construction of buildings and for railway sleepers, bridges and piles.

9.12.4. Sal. It grows in sub-Himalayan ranges and in Madhya Pradesh.

Characteristics. (*i*) The timber is pale brown in colour, darkening on exposure.

(*ii*) It is close grained.

(*iii*) It is hard and heavy.

(*iv*) It is very strong and durable.

(*v*) It is not easy to work upon and does not take good polish.

(*vi*) It can be planed with only very sharp tools.

(*vii*) Common sizes of its trunks are up to 2½ metre in girth and 25 metre long.

(*viii*) It seasons slowly.

Uses. Excellent timber for almost all uses but as it does not give a good finish so it is unsuitable for ornamental work. Sal poles are used as foundation piles.

9.12.5. Teak. It is a large deciduous tree growing in Madhya Pradesh and in South India.

Characteristics. (*i*) The wood is golden yellow to dark brown in colour darkening on exposure ultimately becoming almost black with age.

(*ii*) It is strong and very durable under all climatic conditions.

(*iii*) It is easy to work upon and takes up smooth polish.

(*iv*) It is easily worked and does not warp or shrink.

(*v*) Its grains are even and straight.

(*vi*) It has resinuous oils which give it preservative, rust preventing properties and a characteristic scent.

(*vii*) Practically immune from the attack of white ants, fireproof and resists action of acids.

(*viii*) It seasons early and shrinks little.

(*ix*) It weighs 770 kg/cu metre.

Uses. It is used for railway sleepers, ship-building, furniture making, all sorts of building works, bridges and railway carriages. Owing to its comparatively higher cost its use is limited to only high class work.

9.12.6. **Shisham, tali. or sissu**. It is widely available in northern India and Madhya Pradesh. It is one of the most valuable timbers of India.

Characteristics. (*i*) The wood is dark brown in colour with golden and dark brown streaks, darkening on exposure.

(*ii*) It is close grained.

(*iii*) It is quite tough and durable.

(*iv*) It is very hard.

(*v*) It seasons well and takes a fine polish.

(*vi*) It weighs 880 kg/cu metre.

Uses. It is used for high class furniture, beams and other important building works. It is also used for making carriage wheels. It is very good for decorative works and carvings.

9.12.7. **Mango**. It is a famous fruit tree growing all over India.

Characteristics. (*i*) It is of deep grey colour.

(*ii*) It is coarse and open grained inferior timber.

(*iii*) If not dried quickly it is liable to strain but is easy to season.

(*iv*) It is easy to work upon.

(*v*) It weighs 650 kg/cu metre.

Uses. It is used for inferior building work, tonga bodies, packing cases, cheap furniture and toys.

9.12.8. **Walnut (Akhrot)**. It grows in the Himalayas and in upper Burma.

Characteristics. (*i*) Colour of wood varies from light greyish brown to dark brown streaked black or golden red.

(*ii*) It is strong, hard, tough and elastic.

(*iii*) It is uniform in texture and takes good polish when seasoned.

(*iv*) It is easily worked and does not split.

(*v*) It is slow to season and shrinks on seasoning

(vi) When seasoned it is quite durable but is vulnerable to the attack of worms.

(vii) It weighs 650 kg/cu metre.

Uses. Excellent timber for high class furniture, cabinet work, panelling, carving work and for making veneers and plywood. When available in plenty it may be used for house building.

9.12.9. Kail. It is a large evergreen tree, found in the Himalayas from Bhutan to Afghanistan at heights ranging from 2,000 metres to 4,000 metres.

Characteristics. (i) Wood is of pale brown colour.

(ii) Wood is close grained.

(iii) It is quite durable.

(iv) It seasons well.

(v) It is less brittle and more free from oil than Deodar.

Uses. Used for house building, water channels, poles, matches and match boxes and railway sleepers.

9.12.10. Mahogany. Found extensively on the western ghats.

Characteristics. (i) Colour of wood is redish brown.

(ii) It is moderately hard and durable.

(iii) It takes fine polish.

(iv) It contains resinuous oil which protects it from the attack of insects.

(v) It is hard but easy to work.

(vi) It has fine wavy grains.

(vii) It weighs 690 kg/cu metre.

Uses. Used for cabinet making, furniture, pattern making and for building work.

9.12.11. Bamboo. It is available in Hills and Terai areas almost all over India.

Characteristics. (i) It is flexible, very strong and durable.

(ii) Bamboos of smaller diameter with a thin bore are stronger than those of bigger diameter with bigger holes.

Uses. It is used for scaffolding, construction of temporary bridges, in thatch roofs and in the construction of cheap and big sheds.

9.12.12 Mulberry. It grows in the Punjab.

Characteristics. (i) It is of brown colour.

(ii) It seasons well.

(iii) It is strong, tough and elastic.

(iv) Easily turned, carved and finished.

(v) Easy to work and gives a good finish.

(vi) Weighs 670 kg/cu metre.

Uses. Used mostly for making sports goods like tennis and bad-but is vulnerable to the

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9.12.13. **Jack**. It is a large evergreen tree found wild in the warmer regions all over India and in jungles of western ghats up to a height of 1,000 metres.

Characteristics. (*i*) It is bright yellow in colour, darkening on exposure.

(*ii*) When dry it is moderately hard but is brittle.

(*iii*) It has coarse and crooked grains but can give a good finish.

(*iv*) It seasons well and keeps its shape.

(*v*) It weighs 590 kg/cu metre.

Uses. Used for making musical instruments, furniture and well kerbs, common house carpentry, carts and wheels.

9.12.14. **Toon**. It is a large evergreen tree found in sub-Himalayan tracts and Western Ghats.

Characteristics. (*i*) Its colour is dull red.

(*ii*) It is easy to work and gives a smooth finish.

(*iii*) It is light but not strong.

(*iv*) It seasons well and is not attacked by white ants.

(*v*) Under variations of temperature and moisture it is liable to shrink, expand, warp and split but is durable under cover.

(*vi*) It weighs 550 kg/cu metre.

Uses. Used mostly for furniture making. Also for planking and door panels.

9.12.15. **Haldu**. It is a large deciduous tree found in Deciduous forests of India.

Characteristics. (*i*) Wood is of yellow colour turning to grey on exposure.

(*ii*) It is moderately hard.

(*iii*) It is even grained, works easily and is capable of a smooth finish.

(*iv*) It is fairly durable and seasons well.

(*v*) Its weight is 670 kg/cu metre.

Uses. Used for furniture, planking and making agricultural implements. Suitable for ornamental and cabinet work.

9.13 MEASUREMENTS

Sawn timber shall be measured as follows (refer IS 190—1974)

(*i*) *Length*. Rounded or damaged end portions of the sawn timber shall be excluded from the length which shall be measured in metres. Fractions of a metre shall be rounded off to the nearest lower 0.01 m.

(*ii*) *Width and thickness*. It shall be nearest at the narrowest section in centimetres and shall be rounded off to the nearest centimetre.

(*iii*) *Volume*. It shall be measured in cubic metres correct to three places of decimal based on accepted sizes. The volume of a log of wood is calculated by the quarter girth formula as given below:

$$V = \left(\frac{G}{4}\right)^2 \times L$$

where
V=volume in m^3
G=girth in m and
L=length in m

9.13.1. **Dimensions.** Sawn timber is generally available in the following lengths and cross-sections:

Length 2; 2.5; 3 and 3.5 m

Cross-section 20×10 cm; 25×12.5 cm
20×12.5 cm; 25×15 cm and
20×15 cm; 30×15 cm

9.14. TESTS OF TIMBER

Based on the recommendations of IS 1708—1969 are given below a few laboratory tests to check up the physical properties of a test piece of timber.

9.14.1. **Moisture content test.** Variations in moisture contents affect properties and strength of timber materially. To determine the moisture contents of a specimen a test piece 5cm $\times$ 5cm $\times$ 2.5cm is taken and weighed fresh. It is then dried in an oven at a temperature of 103 ± 2°C. The weight of the specimen in the oven is regularly observed till the variation in the last two observations does not exceed 0.002 gm. The specimen is then considered to have dried. Let W_1 be the weight of fresh sample and W_0 the weight of the oven dry specimen. Moisture content is then calculated as below:

$$\text{Percentage of moisture content} = \frac{W_1 - W_0}{W_0} \times 100$$

9.14.2. **Specific gravity test.** As per requirements of IS 1708—1969 the specimens for the test shall be $5 \times 5 \times 15$ cm pieces and free from usual defects.

The specimens shall be weighed (W_1) usually green, correct to 0.001 gm and volume measured (V_1) by immersion method correct to 0.01 cm³. The specimens are then end coated with paraffin wax by immersion and left to air season at room temperatures till moisture contents of about 12 per cent are reached. The weight (W_r) and volume (V_r) of the specimen are then noted by the immersion method when the moisture content is r per cent.

The specimens are then kept in an oven at a temperature of $103 \pm 2°C$ till the weight becomes constant. Weight (W_0) and volume (V_0) are noted then:

$$\text{Specific gravity at test} = \frac{W_1}{V_1}$$

$$\text{Standard specific gravity} = \frac{W_0}{V_1}$$

$$\text{Oven dry specific gravity} = \frac{W_0}{V_0}$$

$$\text{Moisture content } r \text{ per cent} = \frac{W_r - W_0}{W_0} \times 100\%$$

$$\text{or} \qquad = \frac{W_1 - W_0}{W_0} \times 100\%$$

9.15 IDENTIFICATION OF TIMBER

To establish the identity of a timber, distinctive features of the cut surface are noted, if need be with the help of a magnifying glass. Diagnostic features of all important timbers are grouped together by the Indian standards Institution and are serially numbered. Table 9.1 shows the Serial numbers of diagnostic features that a Particular timber Should have. The Indian Standards Institution has devised a pack of *punched key cards* (Fig. 9.23), one each for a particular timber, whose scientific as well as commercial name is printed at the centre of the particular card. Opposite to each diagnostic feature the punch key card has a hole of 2 mm diameter at a uniform distance of 2 mm from the margin on all sides. On the card meant for a particular timber the holes corresponding to the diagnostic features present in that timber are clipped off with a scissor. The concerned hole is thus open at the edge. A corner of each card is cut so that while using the pack of cards is so arranged that cut corner of each card is on the same side and faces of all cards are upwards. This will ensure that the perforations with the same serial number on each card shall be in the same vertical alignment. The serial order in which the cards are arranged is of no importance.

Now to identify a particular timber note the serial number of the particular distinctive feature present in that timber. Insert a long stout needle in the appropriate hole through the entire stack and lift the whole pack on the needle. Give a gentle shake so that those cards in which hole of that number has been clipped (because of the presence of the feature) fall down. Those cards that separate out are restacked and by inserting the needle in the next relevant hole, corresponding to the number of the next diagonostic feature present in the timber, and the pack is shaken after lifting the whole of it on the needle. This time again some cards shall fall out which are again

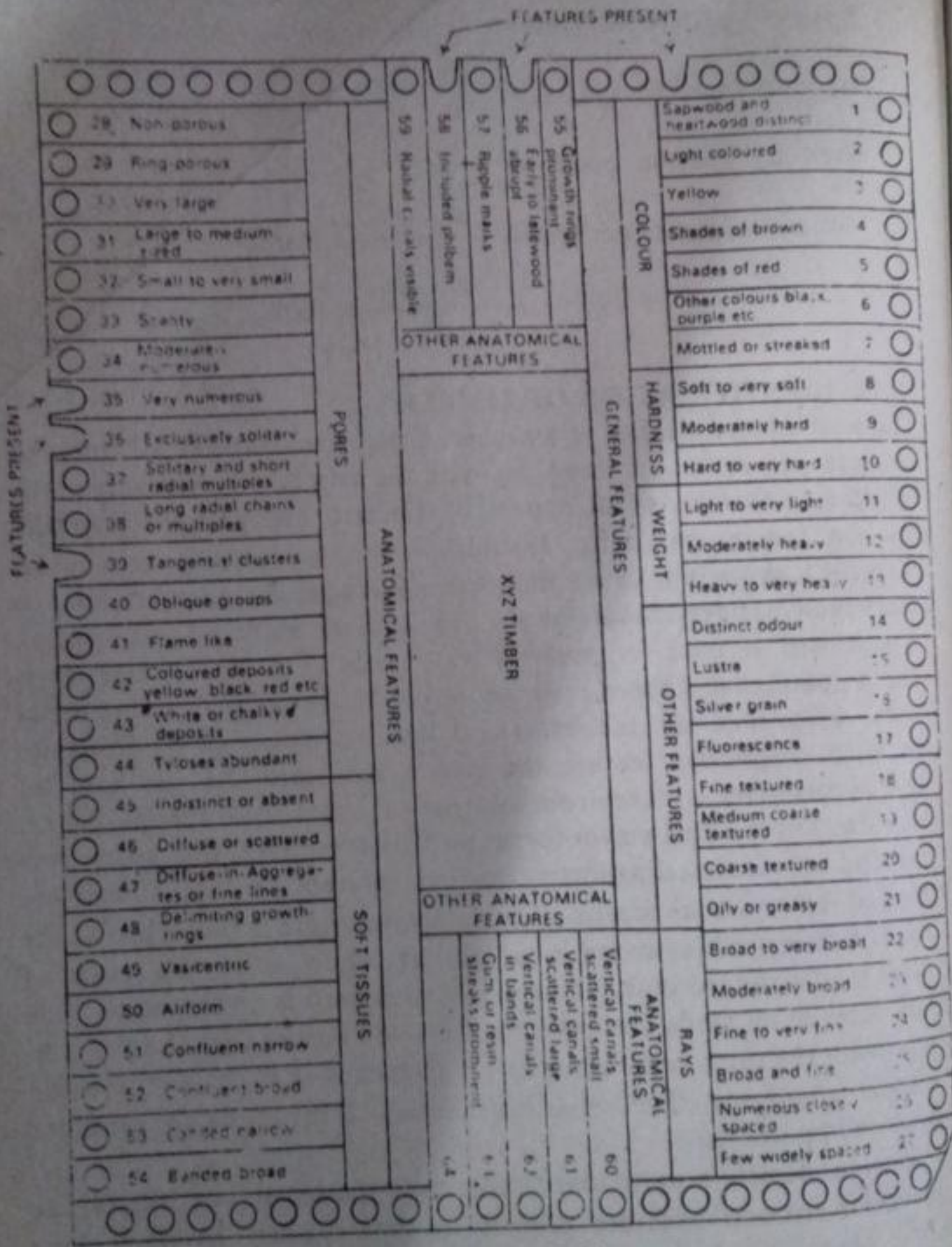


Fig. 9.23. Punch Card

restacked. The process is repeated with regard to other diagonostic features present. Each trial reduces the number of cards till we are finally left with only one card. However, in some cases more than one card are left at the end. In such cases for identification the given piece of timber is actually compared with the test pieces of the timbers corresponding to the cards finally left.

For details refer to IS: 4970-1973

TABLE: 9.1 Diagnostic Features of Commercial Timbers

S. No	*Trade name*	*Botanical name*	*Diagnostic features*
1.	Babul	*Acacia niletica*	1, 4, 5, 10, 13, 19, 23, 27, 31, 34, 37, 42, 49,
2.	Box wood	*Buxus sempervireus*	2, 3, 10, 13, 18, 24, 26, 32, 35, 37, 45
3.	Chir	*Pinus roxburghii*	1, 4, 5, 9, 12, 14, 19, 24, 26, 28, 55, 56, 61, 63
4.	Cypress	*Cupressus torulosa*	1, 2, 4, 8, 9, 11, 12, 14, 18, 24, 26, 28, 46, 55
5.	Deodar	*Cedrus deodara*	1, 2, 4, 9, 12, 14, 18, 21, 24, 26, 28, 55, (62), (2 cards)
6.	Ebony	*Diospyros melanoxylon*	1, 2, 6, 10, 13, 18, 24, 26, 32, 34, 37, 38, 47
7.	Haldu	*Adina cordifolia*	3, 9, 12, 18, 24, 26, 32, 34, 37, 46, 47
8.	Indian oak	*Quercus*	2, 4, 5, 10, 13, 16, 20, 25, 27, (29), 31, 32, 36, 40, 41, 46, 47, (55), (2 cards)
9.	Jamun	*Syzygium cumini*	2, 4, 10, 13, 19, 24, 26, 31, 34, 37, 51, 53
10.	Kail	*Pinus wallichiana*	1, 5, 8, 11, 14, 18, 24, 26, 28, 55, 61, 63
11.	Mango	*Magnifera indica*	2, 4, 9, 12, 20, 24, 26, 31, 34, 37, (48) 50, (2 cards)
12.	Mulberry	*Morus*	1, 3, 4, 9, 12, 15, 19, 23, 27, 29, 39, 44, 48, 49, 51, 52, 55, 56
13.	Rosewood	*Dalbergia latifolia*	1, 6, 7, 10, 13, 14, 19, 24, 26, 31, 34, 37, 42, (48), 50, 51, 53, (57), (4 cards)
14.	Sal	*Shorea robusta*	1, 4, 10, 13, 19, 23, 27, 31, 34, 37, 44, 46, 49, 50, 52, 62
15	Sissoo	*Dalbergia sissoo*	1, 4, 7, 10, 13, 19, 24, 26, 31, 34, 37, 42, (48), 50, 51 53, (57), (4 cards)
16.	Spruce	*Picea smithiana*	2, 8, 11, 18, 24, 26, 28, 55, 60
17.	Teak	Tectona grandis	1, 4, 7, 9, 12, 14, 19, 21, 23, 27, 29, 37, 43, 48, 49, 55
18.	Toon	Toona ciliata	1, 5, 8, 9, 11, 12, 14, 15, 19, 23, 27, 29, 37, 42, 45, 48, 49, 55

9.16 VENEERS

Veneers are those thin sheets of wood that are peeled off, sliced or sawn from a log of wood having attractive and artistic arrangement of grains. Logs of wood are converted into veneers by either rotary veneer cutters or by veneer slicing machines (Fig. 9.24).

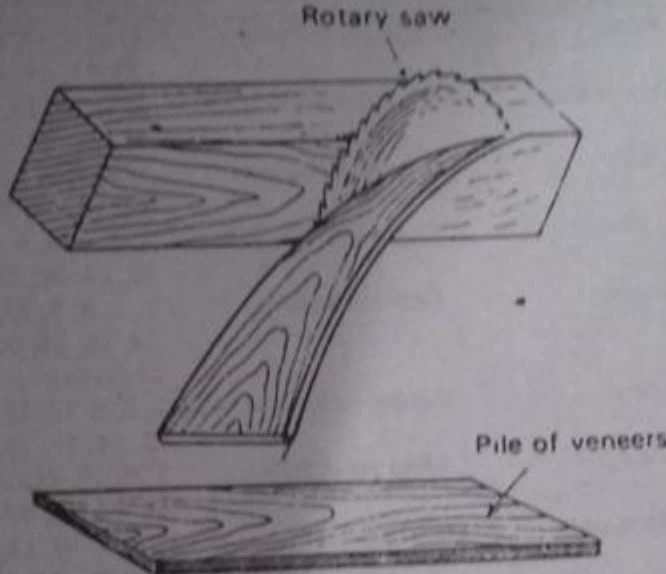


Fig. 9.24

Thickness of these sheets varies from 0.4 mm to 6 mm. These veneers are then glued to inferior timber surfaces to improve the appearance and to form decorative and artistic designs. Veneers should be dried carefully. Veneers are used in the manufacture of plywood, lamin boards and battern boards.

Walnut, teak and rose wood are the timbers commonly used for conversion into veneers.

9.17 PLYWOOD

Veneers used for making plywoods (Fig. 9.25) are known as plies and

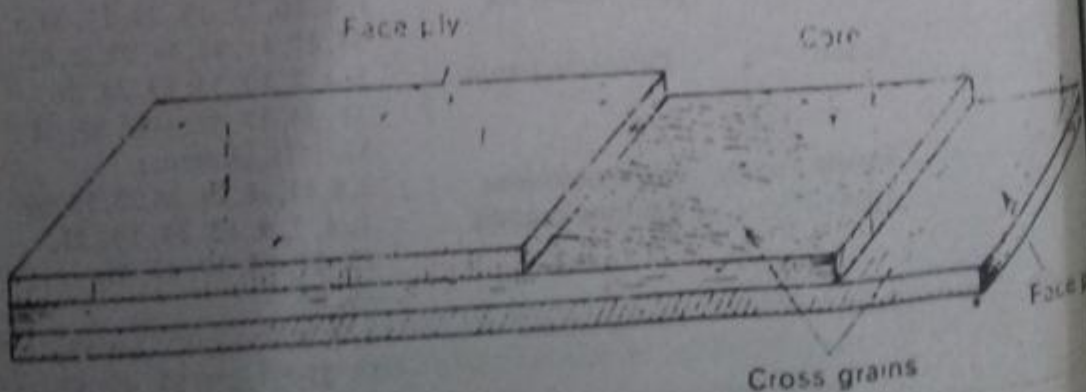
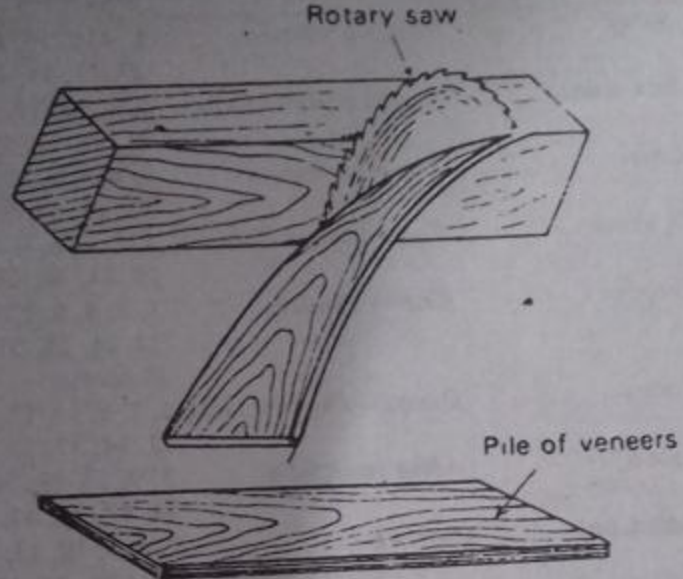


Fig. 9.25. Plywood.

9.16 VENEERS

Veneers are those thin sheets of wood that are peeled off, sliced or sawn from a log of wood having attractive and artistic arrangement of grains. Logs of wood are converted into veneers by either rotary veneer cutters or by veneer slicing machines (Fig. 9.24).



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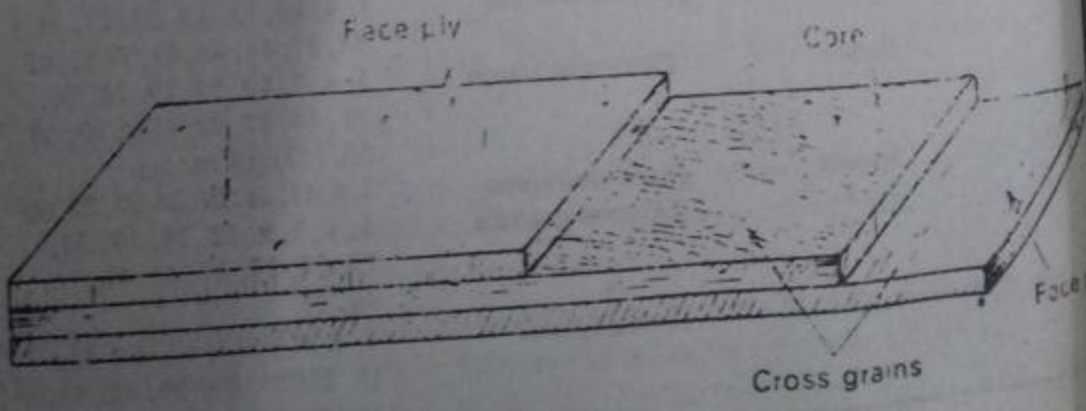

Fig. 9.25. Plywood.

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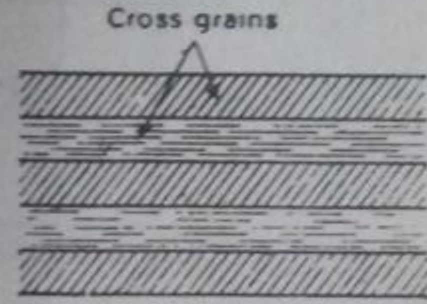
plywoods are made by glueing together plies in *odd numbers*. Glueing is done under pressure. These are usually three ply, five ply (Fig. 9.26) or seven ply depending upon the number of plies used. Plywoods with more than three plies are known as multi-plies. Odd numbe· of plies is used so that shrinkage stresses are symmetric about the middle ply and warping tendency is minimised.



5 Ply

Fig. 9.26

Outside plies are known as *face plies or face*. Plies are arranged so that the grain of one layer is at right angles to the grain of an adjacent layer.

The thinner the plies the more homogeneous the plywood shall be in its elastic properties. Use of better glue increases the strength of plywood. Usually *Blood glue* is found to be the best. Plywoods are generally available up to 1.5 metre in width and 3.4 metre in length. They generally do not crack or split easily if not exposed to rain or to sun. Thickness of plywood varies from 3 mm to 6 mm.

Advantages. Plywood has some advantages in structural usage as detailed below:

(*i*) It gives better appearance.

(*ii*) It is stronger. A three-ply board is three times as strong as a solid board of same thickness.

(*iii*) It can be easily bent to give any shape.

(*iv*) it is an elastic material and is not very much affected by climatic changes.

(*v*) It gives uniform tensible strength in all directions.

(*vi*) It is available in such large sizes that are not possible with solid boards.

(*vii*) Shrinkage and expansion of best grade plywood is almost negligible. *It is due to its cross grained nature*.

(*viii*) Because of its cross grained nature plywood does not split when nailed near edges.

Uses. It is used for covering or panelling walls, for doors, furniture and shuttering in R.C.C.

The cheaper varieties are used for making packages.

9.18 LAMIN BOARDS

Lamin board (Fig. 9.27) consists of a core built up of laminae not more than 8 mm wide and glued between two or more plies. Grains of core laminae should be at right angles to those of outer plies.

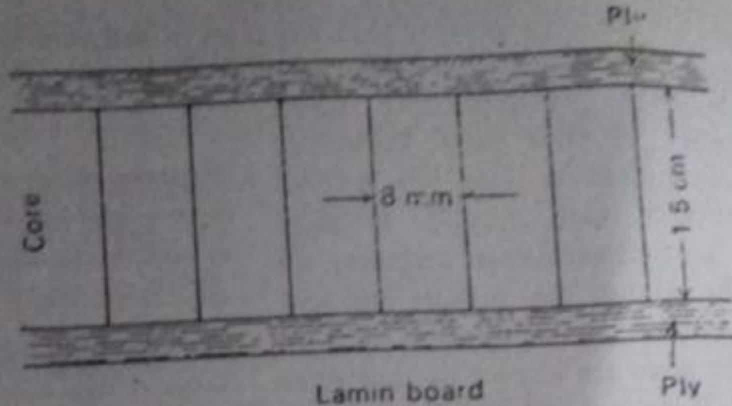


Fig. 9.27

These are pressed into sheets 1 cm to 5 cm thick. These boards are available up to 1.5 metres in width and 2.5 to 3 metres in length. These are light and strong and do not crack or split easily. These are used for the construction of partition walls, packing cases, ceilings, furniture and doors etc.

9.19 BLOCK BOARDS

These are similar to lamin boards. The core is built up of blocks not exceeding 2.5 cm wide (Fig. 9.28) and glued between two or more outer plies. Direction of grains of the core is at right angles to that of outer plies.

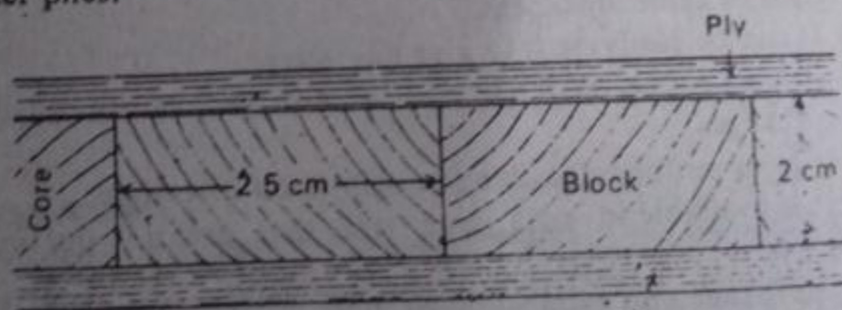


Fig. 9.28

These are cheaper than lamin boards and are used for partition walls and doors etc.

Usual thicknesses are 12 mm to 50 mm; lengths from 1.2 m to 2.4 m and widths from 0.9 m to 1.2 m.

9.20 BATTEN BOARDS

Batten boards (Fig. 9.29) are similar to the block boards. In it the core consists of close grained battens not more than 8 cm in width to 3 cm thick and are edge-glued between two or more outer plies. Direction of the grains of the core battens is at right angles to that of the adjacent outer ply sheets.

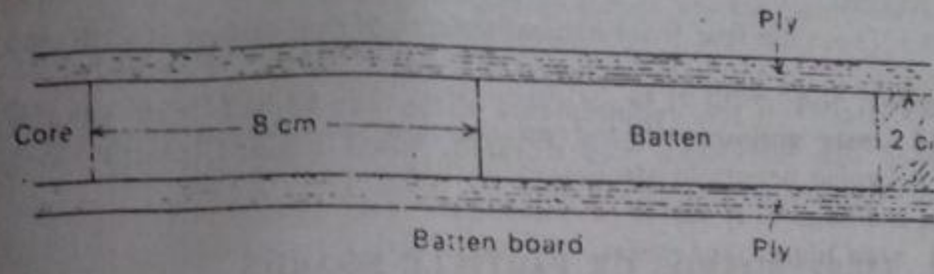


Fig. 9.29

These are light and strong and do not crack or split easily. They are widely used for making partition walls, ceilings, packing cases and leaves of doors and windows etc.

9.21 HARD BOARDS

These are manufactured from wood wastes obtained from saw mills, inferior timber or short logs etc. With machines the raw material is converted into chips which are then softened with steam and converted into fibres. Water repellents and synthetic resins are added to increase the strength. These are then pressed into boards of uniform thickness in hydraulic presses.

Other materials may be added during manufacture to improve certain of its properties. Many species of wood are used, depending upon their availability.

Tempered hard board is made from standard hard board by the addition of certain chemicals and further heat treatment to increase its strength, abrasion resistance and decrease its rate of water absorption.

Hard boards are manufactured with both surfaces smooth or one surface smooth and the other with a screen back, or reverse impression of a screen. It is also available with special finishes such as grooved, embossed, or marked into tiles. The natural colour varies from blond to dark brown.

Width of sheets is usually 1.25 metre but even 1.75 metre wide sheets too are available. The maximum length is 4.75 metres. The thickness varies from 2 mm to 20 mm.

Hard board is used for interior and exterior wall panels; ceilings, siding, table and counter tops and many other purposes.

Trade names are: *Masonite, Celotex, Essex board, Jolly board* etc.

Hard Boards have the following advantages *vis-a-vis* sawn wood:

(*i*) Unlike sawn wood these can be made of any sizes needed.

(*ii*) As these are homogeneous so their strength is uniform in all directions.

(*iii*) These are free from natural defects of timber like shakes and knots etc.

(*iv*) Based on the requirements these can be had with suitable finishes like embossed, preperforated, wood grained, plastic faced, veneer finished or enamelled etc.

9.22 FIBRE BOARDS OR PARTICLE BOARDS

These are made out of wood wastes, small size timber, edging of saw mills, end cuts, stumps and corn stalks etc. and other similar woody materials. All this stuff is converted into small chips with the help of machines which are then dried to a moisture content less than 15 per cent and are then sprayed with synthetic resin adhesives. Resin coated chips are then spread in an even layer. Three such layers are spread to attain the desired thickness of the board. These are then pressed in hydraulic press in the presence of heat and moisture.

Usual sizes are 6 mm to 25 mm thick, 1.2 metre width and 3.5 metre length. The surface is usually fibrous but boards veneered with walnut, mahogany or other woods are also available.

Fibre boards are used for exposed interior wall and ceiling surfaces for outside wall sheeting and for heat and sound insulation. When being used as sheeting these may be coated with asphalt for protection against moisture.

These boards offer advantages similar to those offered by the Hard Boards.

EXERCISES

1. Describe the structure and growth of an exogenous tree.
2. (*a*) What are the characteristics of good timber?

   (*b*) Explain in detail the various defects of timber.
3. Write a short note on seasoning of timber.
4. What are the various methods of seasoning timber? Discuss.
5. What are hard wood and soft wood? Could a soft wood be stronger than hard wood? Name a few species of each.
6. Explain as to why timber used for structural purposes should be properly seasoned? Describe briefly the process of air seasoning and kiln seasoning of timber from green state.

7. Write short notes on common defects in timber.

8. Distinguish between Plywood, Laminated board, Batten board and Fibre board by means of sketches.

9. Write short notes on Plywood and Veneers.

10. (*a*) Describe the factors that lead to decay of timber.

(*b*) What is meant by seasoning of timber? Briefly describe the various methods how the seasoning is carried out.

11. What are the characteristics of good timber? State the usual defects noticed.

12. Explain in details the process of identification of a piece of timber.

10

PAINTS AND VARNISHES

10.1 GENERAL

Paints and varnishes are used to protect metals, timber or plastered surfaces from the corrosive effects of weather, heat, moisture or gases etc. and also to improve their appearance.

10.2 CLASSIFICATION

Paints in common use are classified as oil paints, water paints, cement paints and bituminous paints. There are some "special paints" used for special purposes *e.g.* heat resisting or fireproof paints, chlorinated rubber paints (for protection against acid fumes etc.), luminous paints (for visibility of painted surfaces in the dark) etc., etc.

10.3 COMPOSITION OF OIL PAINTS

Oil paints consist essentially of—(*i*) a base, (*ii*) a vehicle (always an oil, generally raw or boiled linseed oil), and (*iii*) one or more *colouring pigments*. It may also contain one or more of, (*iv*) a solvent or thinner, (*v*) a drier, and (*vi*) an inert filler.

By suitable variation of the type and proportion of the various constituents the paints can be made dry, glossy or flat as desired. Other properties such as permeability to water could also be varied accordingly. All the possible constituents of paints are described in details below:

10.3.1. Base. It provides body to the paint and on it depends the nature of paints to a great extent:

(*i*) It is the solid matter forming the main body of the paint.

(*ii*) It makes the paint film harder and more resistant to abrasion.

(*iii*) It forms an opaque layer to obscure the surface of material to be painted.

(*iv*) It reduces shrinkage cracks formed on drying.

White lead, Red lead, Zinc oxide (or zinc white), Iron Oxide, and metallic powders such as Aluminium, Copper and Bronze etc. are the commonly used bases. Paints are very often named after the bases used *e.g. Lead paints, Zinc paints, Aluminium paints* etc., etc.

Characteristics of the more commonly used bases are discussed below:

White lead. (*i*) It is the cheapest and the most commonly used base for ordinary building works.

(*ii*) It has greater covering power than any other base.

(*iii*) It is dense and has a good body to obscure the painted surface.

(*iv*) It weathers well.

(*v*) Not suitable for delicate work as it gets discoloured on exposure. It may be used for under coat and zinc white for the finishing coat.

(*vi*) Not suitable for painting iron work as it does not stop rusting.

Red Lead. (*i*) With oil it is considered best for first coat for iron and in priming coats for wood work as it sticks well and gives protection against rust.

(*ii*) It is a good drier for linseed oil.

Lead paints are poisonous and as such necessary precautions should be taken while painting with spray machine or while scrapping old paint. These should not be used fresh.

Zinc oxide or Zinc white. (*i*) It is not affected by weather.

(*ii*) It takes a fine polish and is used for decoration work.

(*iii*) It is not poisonous.

(*iv*) It is less durable and more costly than lead bases.

Lead driers should not be used with zinc paints.

Oxide of Iron. (*i*) Used primarily in the finishing coat for painting iron work.

(*ii*) It prevents rust formation.

(*iii*) It is comparatively cheaper.

(*iv*) Tints vary from yellowish brown to black.

10.3.2. Vehicle. (*i*) It is an oily liquid in which the base and pigment are soluble.

(*ii*) It facilitates the paint to be conveniently spread evenly over the surface by means of a brush.

(*iii*) It acts as a binder for the base and causes it to stick to the surface.

(*iv*) On drying it forms a tough and an elastic film. Oils most commonly used as vehicles are: Linseed oil, Poppy oil, Nut oil and Tung oil.

Linseed oil. It is the most widely used vehicle for all ordinary painting works. It is used either raw or boiled.

Raw linseed oil. (*i*) It is thin, pale in colour and transparent.

(*ii*) It has sweet taste and no smell.

(*iii*) It becomes hard and stiff on being exposed to air.

(*iv*) When spread in a thin film it looks like varnish.

(*v*) It dries very slowly but by adding a little white lead and allowing it to settle for a week its drying properties could be improved.

It is used for painting delicate and interior work or wood-work where original colour and grains of wood are to be preserved. It should not be used for work exposed to weather.

Boiled linseed oil. (*i*) It is thicker and darker in colour.

(*ii*) It dries quicker.

(*iii*) Its colour varies from deep amber to rich brown.

(*iv*) On drying it leaves a hard glossy and more durable surface.

(*v*) It has more covering capacity.

It is used for external work.

Double boiled linseed oil. (*i*) It is as light in colour as the raw linseed oil but smells differently.

(*ii*) It dries quicker and gives better results.

(*iii*) It requires a thinning agent like turpentine oil.

It is better suited for painting metals and plastered surfaces.

Tung oil. It is far superior to linseed oil and is used for preparing superior paints.

Poppy oil. Though its drying qualities are inferior to those of linseed oil still it is used for very delicate colours which last longer.

Nut oil. It is almost colourless; dries quicker and is not durable. It is cheap.

10.3.3. Colouring pigments. These are finely ground colouring matters. Their main function is to give colour and opacity to the paint. Pigments are liable to fade because of the bleaching action of sun rays. These are also subjected to change of colour under the influence of moisture, heat or hydrogen sulphide. Commonly used pigments are:

(*i*) ***Blacks:*** Lamp black, vegetable black, ivory black.

(*ii*) ***Blues:*** Indigo, prussian blue.

(*iii*) ***Yellows:*** Chrome yellow, raw siena, yellow ochre.

(*iv*) ***Greens:*** Copper sulphate.

(*v*) ***Browns:*** Raw umber, burnt umber.

(*vi*) ***Red:*** Red lead, vermillion, carmine.

10.3.4. Solvent or thinner. A liquid thinner is added to the prepared paints to increase their fluidity to the desired consistency so as to make them work more smoothly and also to help penetration of porous surfaces. Oil of turpentine is the most commonly used thinner. An excessive use of thinner dulls the colours and the gloss of linseed oil. It reduces the protective value of coating. As such a thinner is generally not used in the finishing coat on exposed surfaces. It is better to use raw linseed oil as thinner except in white paint for which raw linseed oil mixed with turpentine oil is used. For getting a good finish sometimes Copal varnish is also used as a thinner.

10.3.5. Drier. Driers are added to paints to quicken the drying of vehicles. Linseed oil dries by absorbing oxygen and it could be expedited by adding substances rich in oxygen. Some of the commonly used driers are: Litharge, Red lead, Lead acetate, Manganese dioxide and Zinc sulphate.

Litharge. It is the most commonly used drier (its proportion being 25 gms per litre of vehicle). It is especially used for lead paints but is not used for finishing coats.

Red lead. It is less powerful than litharge and is used only when it does not affect the tint.

Lead acetate. When ground in oil it is used for lighter tints.

Manganese dioxide. It gives quick effect but can be used only for deep tints because of its darker colour.

Zinc sulphate. It is more costly and is never used in paints with lead base.

Driers should not be used unnecessarily as they have a tendency to destroy the elasticity and cause flaking of the paint. Drier should not be used in a paint that dries well.

Not more than one drier should be used at a time and it should be added to the paint just before the paint is to be used.

10.3.6. Inert filler. It is an adulterant mixed to replace the base in part and thus reducing the cost of paint. Commonly used fillers are silica, charcoal, powdered chalk, aluminium silicate and barium sulphate etc.

10.4 CHARACTERISTICS OF A GOOD PAINT

(*i*) It should have a good body or spreading power.

(*ii*) It should work smoothly and freely and be capable of being laid in a thin coat with the brush.

(*iii*) It should form durable, tough and resistant to wear film on drying.

(*iv*) Colour of paint should not fade or change.

(*v*) It should become surface dry in about 9 hours and hard enough to take up another coat in 24 hours.

(*vi*) It should not crack on drying.

(*vii*) It should give a smooth and pleasing appearance showing no brush marks on drying.

(*viii*) It should dry quickly.

(*ix*) It should not damage the painted surface.

10.5 PREPARATION OF OIL PAINTS

The base (*white lead*) is thoroughly ground in oil and then mixed with the thinner (*oil of turpentine*) so as to give necessary workability to the paint. The pigment and the drier (if desired) are separately ground in linseed oil and mixed with turpentine oil to make it thin and then intimately mixed with the base that has already been prepared. The paint is then strained through fine cloth or sieve after which it is ready for use.

10.6 REMOVAL OF OLD PAINT

One of the following two methods could be employed to remove old paint from a surface:

(*i*) Burning the paint by directing the flame of a blow lamp on the painted surface and scrapping it. This method is quite suitable, quick and economical in case of iron or steel work but only expert workmen could be depended upon for its use in case of wood work. A little carelessness could leave the wood charred.

(*ii*) Applying any one of the following paint removers:

(*a*) Hot solution of equal parts of soap, potash and quick lime is applied on the surface and kept on it for 24 hours, after which washing with hot water will remove the paint.

(*b*) Two parts of quicklime and one part of washing soda mixed with water to the consistency of cream spread on painted surface is kept for an hour. It is then washed off with clean water to remove the paint.

(*c*) Solution of caustic soda in water is applied to the surface.

While applying caustic soda solution to the surface care should be taken of the hands. On wooden surfaces this solution should not be left long otherwise fibres of wood would be damaged. The surface should be washed well with clean water and neutralized by applying a week solution of acid or vinegar.

(*d*) *Naptha*. Naptha is coated repeatedly on the painted surface till the paint becomes soft. Then it is rubbed down and the surface cleaned.

10.7 PAINTING

Application of paint to a surface either with a brush or by spraying* is known as painting. The surface to be painted should be perfectly smooth, clean and dry. Iron surface to be painted should be free from rust. Presence of moisture between the paint and surface to be painted or between successive coats of paints causes blisters. Painting should as far as possible be carried out in dry weather. Preservative quality of paint depends upon the toughness and impermeability of the film formed by linseed oil in combination with the pigments. Everything added to it like drier, turpentine oil and inferior pigments tend to reduce its life. As such the boiled linseed oil and pigments used should be of the best possible quality and no more turpentine oil and driers should be added than found to be absolutely necessary. No coat should be applied before the previous one has dried. Brush of only good quality, the hair of which do not come off while painting, should be used.

10.8 PAINTING NEW WOOD WORK

Following points should be attended to before painting new wood work:

(*i*) Only well seasoned timber should be painted otherwise not only shall the paint be spoilt, but also due to dry rot the timber is likely to decay early. Also the paint surface will otherwise crack due to uneven shrinkage.

(*ii*) It is advisable not to paint excessively dry wood.

(*iii*) Paint should be applied to only dry surface.

(*iv*) The surface to be painted should be rendered smooth, clean and free from rust or dirt.

(*v*) All nails should be punched in $\frac{1}{2}$ cm below the surface.

(*vi*) Large and loose knots should be cut out and filled tightly with correctly fitting wooden pieces.

(*vii*) The surface should be *knotted*, *primmed* and *stopped* before painting...

10.8.1. Knotting or killing the knot. It consists in rendering knots in resinuous wood incapable of spoiling the paint because of the oil that comes out of them. Knotting should be done before painting. Any one of the following ways may be adopted for knotting:

***Spray Painting.** With a spraying pistol, worked by compressed air, atomised paint is sprayed on the surface in a uniform coat. Beautiful appearance of perfection achieved by spray painting can never be achieved in painting by hand with brushes. All superior class painting work is done by spraying.

(*i*) *Ordinary or size knotting*. First a hot coat of red lead ground with glue size in water is applied on the knot when it has dried then a second coat of red lead ground in boiled linseed oil and thinned with turpentine oil is applied.

(*ii*) *Lime knotting*. In it the knot is left covered with hot lime for 24 hours after which it is scrapped. Then the knot is coated with ordinary or size knotting as explained above. The knot is then rubbed smooth with pumice stone or sand paper.

(*iii*) *Patent knotting*. It consists in the application of two coats of varnish made by dissolving shellac in methylated spirit or naptha. This treatment is applied to cover stains or on tarred surface intended to be painted. In one litre of methylated spirit are dissolved 250 gms of shellac and stirred with 15 gms of red lead to give suitable knotting for ordinary purposes.

10.8.2. Application of priming coat. Priming coat of paint is then applied on the surface. It forms as opaque and hard film filling the pores of wood. It provides a smooth base for the paint. This coat is applied preferably before the wood work is fixed in position. Paint for priming coat consists of one kilogram of red lead and white lead mixed with one litre of oil. When the "priming coat" has dried then the surface is *stopped*.

10.8.3. Stopping. After the *priming coat* has dried, all nail holes, other holes and cracks etc. are filled up with putty.*

When the putty has become sufficiently hard the whole surface is rubbed with pumice stone or sand paper till it gives a smooth surface.

10.8.4. Application of finishing coats. Two or more coats of paint having the desired colour are applied to the surface prepared by knotting, priming and stopping. Each coat should be applied after the previous one, on having fully dried, has been slightly rubbed with fine glass paper. Only good brush held at right angles to the painted surface should be used for painting. Addition of a little Copal varnish to paint for final coat shall enable the paint to withstand weathering

**Ordinary Putty or Glaziers Putty*. It is a paste of very thick consistency used to fill up nail holes, cracks and depression in the wood before applying paint. It is also used for fixing glass panes in doors and windows etc. It is made by mixing 1 kg finely powdered whiting, 65 gms raw linseed oil and 30 gms litharge. All these are mixed well and beaten with wooden mallets, until thoroughly incorporated. After kneading it well it is left for about 12 hours when it is kneaded again to give smooth workable paste. Desired pigment could also be added to it if coloured putty is needed. Holes and cracks etc., *should not be filled up with putty before the application of priming coat* as otherwise the oil in putty shall be absorbed by wood leaving the putty to dry which would ultimately fall off.

better and shall add to the gloss.

When white paint is to be done then white lead should be used for outside work and zinc white for interior works not exposed to weather.

10.9 REPAINTING WOOD-WORK

(*i*) If tne old paint be unsightly, unsound, blistering or flaking off then it should be removed by the application of some paint remover, by scrapping or by burning the paint with a blow lamp.

(*ii*) On surfaces disfigured by smoke a coat of one kilogram glue and 60 gms of unslaked lime in four kilograms of water should first be given.

(*iii*) The surface should be thoroughly cleaned by washing it with soap and water.

All greasy spots should be painted with turpentine oil and washed with soap and water. A solution of washing soda in water is used for cleaning the surface of all greasy spots.

(*iv*) All holes and cracks etc. should be filled up with putty *i.e.* stopping should be done.

(*v*) Before the application of each coat the surface should be rubbed smooth with sand paper or with pumice stone.

(*vi*) Two or three coats of paint having the desired shade are then applied as on new surface (*Priming coat may not be applied*).

10.10 PAINTING PLASTERED SURFACES

(*i*) A plastered surface should be painted only after it has thoroughly dried, otherwise the paint would get spoilt,

(*ii*) To avoid sucking of paint by plaster soak the surface with a pore filling solution which will dry off leaving an impervious surface. A wash of 1 kg of size, 500 gms of soft soap and 9 litres of creamy lime wash is recommended.

(*iii*) Cracks or holes, if any, should be filled in with glaziers putty and the surface sand papered on its drying.

(*iv*) First two coats should consist of white lead and boiled linseed oil.

(*v*) Third coat should consist of white lead, linseed oil, desired pigment and a little turpentine oil. This coat is applied after the surface has been rubbed smooth. Finishing coat having the same composition as the third coat but having more of turpentine oil is applied when the primining coat is still tacky.

In case of new plastered surfaces a solution of one kilogram of zinc sulphate in two kilograms of water should be applied to the surface.

When it has dried then a coat of pure raw linseed oil is applied. It is followed by two coats of paint thinned with turpentine and a little varnish. Third coat consisting of white lead, linseed oil, desired pigment and a little oil of turpentine is then applied. Finishing coat may be the same as third coat but with a little more of turpentine oil.

However, these days paints are available in market that can be applied directly on newly plastered surfaces. These are known as cement paints. *Snowcem* is a popular brand of it. These are mixed in water just before use and applied with brush to clean and wet surface. Normally two coats suffise. The second coat is applied 24 hours after the first one. Painted surfaces are kept wet for 3 days.

10.11 PAINTING IRON OR STEEL WORK

Steel is painted to prevent its deterioration due to rusting and to improve its appearance:

(*i*) The surface should be freed of all dirt, mill scales, or loose rust by scrubbing it with stiff wire brushes and then with amery paper

(*ii*) Greasy spots and other dirt should be removed before painting, if needed, by giving the surface a hot acid bath followed by a wash with a jet of hot water or lime solution or a solution of caustic soda. Lime or caustic soda applications should again be followed by clean water wash.

(*iii*) In case the surface to be painted has an old paint on it the old surface should also be cleaned of dust or greasy spots. If the old paint is unsound then the same should be removed by scrubbing, applying a paint remover or even by burning.

(*iv*) Priming coat consisting of pure linseed oil and red lead in the proportion of one litre of oil to 3.25 kilogram of red lead is applied after the surface has dried.

(*v*) Second and subsequent coats consisting of one litre boiled linseed oil, 800 gms lamp black and 600 gms of red oxide paint is applied after the first coat has dried.

(*vi*) Bituminous, graphite or anticorrosive paints adhere well to surface and give good protection but have black appearance.

(*vii*) White lead, zinc oxide or aluminium paints mixed with varnish, linseed oil and liquid drier may be used with suitable pigment, if desired, in case the paint is desired to have white or coloured appearance. Care should be taken not to apply lead or zinc paint direct on steel or iron surface otherwise the paint would be harmed.

10.12 DEFECTS IN PAINTING

(*i*) *Cracking*. Cracks extending throughout the thickness of paint are caused by improper seasoning of painted wood, excessive use of drier or application of too many coats resulting in an excessive thickness of paint. It results in sealing of paint.

(*ii*) *Crazing and crocodiling*. Use of too much oil, use of impure oil and insufficient drying of undercoat may cause hair cracks in top coat. If these hair cracks enclose small areas then the defect is known as *crazing*, however, if the areas enclosed are large then the defect is known a *crocodiling*.

(*iii*) *Blistering and peeling*. Exposure of paints, rich in oil, to strong sunshine causes blisters. Blisters are also caused if oil or grease is left on surface to be painted. Painting a surface with moisture present on surface or in pores of wood causes peeling.

(*iv*) *Runs and sags*. Application of too thick or slow drying paint, painting over a glossy surface, use of excessive drier or excessive humidity and change of temperatures during drying period are the usual causes of the defect.

(*v*) *Chalking*. Use of insufficient oil in priming coat causes the paint to rub off with hands or clothes (*the defect being known as chalking*).

(*vi*) *Washing off*. Use of pigments soluble in water causes the deposit of dissolved matter at lower edges forming streaks.

(*vii*) *Dull appearance*. It is caused by use of excessive drier or on the paint becoming old.

(*viii*) *Slow drying*. Use of inferior or old oils, painting over damp surfaces or during unfavourable weather conditions causes this defect.

(*ix*) *Yellowing of white paint*. For indoor paintings where gloss is desired white enamel should be used otherwise minimum linseed oil, which has a yellow tint and does not bleach unless exposed to sunshine, should be used.

10.13 ENAMEL PAINTS

Enamels consist of high grade bases like zinc oxide or lead oxide ground in oil or varnish. They dry slowly leaving a hard tough and elastic film which is smooth and durable. Enamel painted surfaces are washable and are not affected by acids, alkalies, gases or steam.

These can be made in any tint, however delicate. Even though they are more costly than ordinary paints yet, because of their durability, they ultimately prove to be more economical. They are equally good for use both on external and internal works.

Enamel made from synthetic resins, known as *Synthetic enamel* dries quickly and is more durable. They are available readymade in many shades.

10.14 LACQUER

It is a solution of natural or synthetic resin in a volatile solvent. It is obtained by dissolving resin and film forming nitro-cellulose or shellac in a solvent. Nitrocellulose is obtained by the action of a mixture of sulphuric and nitric acids on cellulose derived from wood or cotton fibres.

Solvent used is a mixture of ketone alcohol, hydrocarbon and the plasticizer. The solvent evaporates quickly leaving a hard film on the surface.

Lacquers are named after their chief film forming constituent *e.g. shellac lacquer and nitrocellulose enamel*.

Lacquer is used mostly on wood and metal surfaces. If a pigment is added to the lacquer then it is known as lacquer enamel. Lacquers resist mild acids and alkalies, water, oils and alcohol. They are inflammable and hence care has to be taken in their storage and in application. Lacquers leave a glossy, hard, tough and durable film and are extensively used in painting automobile bodies, furniture and other decorative pieces of wood or metal.

Application of lacquer may be done either by hand with a brush or by spraying as in case of paints.

10.15 FIREPROOF PAINT

Fire resisting solution coatings of sodium tungstate and asbestos paints retard the action of fire. As such wherever timber work is intended to be fire resistant it may be coated with either of these solutions.

10.16 CELLULOSE PAINTS

Natural cellulose is chemically treated and converted to nitrate or acetate or to methyl or ethyl cellulose. The resultant derivative of cellulose is dissolved in petroleum or in coaltar hydrocarbon. Plasticizers which are organic compounds of low volatility are added to cellulose paints to improve adherence, toughness, smoothness and elasticity of the paint film. Compared with ordinary oil paints this paint can be easily washed, cleaned, has greater hardness, elasticity and smoothness and stands temperature changes and hot water better. It produces more glossy and durable decorative coat than oil paints with metallic oxide bases. Compared with oil paints, it costs more. *Spray paint* or *Duco* is the trade name given to this type of paint. These are used for painting automobiles, aircrafts and other costly things.

10.17 ALUMINIUM PAINTS

It consists of aluminium powder suspended in varnish.

It has got very good covering power and gives nice protection to iron and steel against corrosion due to sea water and acid fumes. It resists heat. It does not oxidize and fade. It is visible in the dark.

It is commonly used for painting electric and telegraph poles, hot water pipes, marine piers, and oil storage tanks etc.

10.18 ZINC PAINT

It is now being extensively used for indoor and outdoor use for white paints, especially on metallic surfaces. Zinc oxide has a great weathering power. Zinc sulphide gives luminous and fluorescent paints that are used to illuminate maps and aircraft instruments at night. This paint is sometimes known a *luminous paint*.

10.19 DISTEMPERS

These are paints used for the treatment of masonry walls. In them water instead of oil is used as a carrier. These are known as water paints too. It is made by mixing whiting and size with water. Powdered white chalk forms the whiting and glue boiled in water is known as the size. Whiting takes the place of white lead in oil paints as a base. It is usually coloured by mixing with earthy pigments such as ochre, umber, Indian red and lamp black. In market a number of proprietary distempers are available. All prepared distempers are mixed with water only before being used. As the distemper is affected by weather and comes off, if washed, so its use is restricted only to interior works. It forms a cheap, durable and easy finish for interiors. Distempers give a good finish but are likely to flake when subjected to alternate wetting and drying. These should be applied in dry weather after the surface has been cleaned and dried.

10.20 VARNISH

Varnish is a solution of resin in either oil of turpentine or alcohol. It dries after applying leaving a hard, transparent and a glossy film of resin over the varnished surface.

Varnish is applied: (*i*) to the painted surface to increase its brilliance and to protect it from the atmospheric action, (*ii*) to the unpainted wooden surface with a view to brighten the ornamental appearance of the grains of wood.

10.20.1. **Composition.** The ingredients of varnish are: (*i*) Resins, (*ii*) Solvents; and (*iii*) Driers.

(*i*) *Resins*. Commonly used resins are copal,* mastic, amber gum and lac. Quality of varnish depends much upon the quality of resin used. Copal is considered to be the best, toughest, hardest and is very durable for external work.

(*ii*) *Solvents*. These must suit the resin used. Boiled linseed oil is used to dissolve copal or amber; turpentine oil for common resin or mastic; methylated spirit for lac. Wood naptha because of its offensive smell is not suited for superior works, and is used only for cheap varnish.

(*iii*) *Driers*. These should be added only in small quantities as the excess injures varnish and impairs its durability. Litharge or lead acetate are the commonly used driers in varnish, added to accelerate drying process.

10.20.2. The qualities of a good varnish. (*i*) It should dry quickly, (*ii*) On drying it should form a hard, tough and durable film, (*iii*) It should have good weathering properties, resist abrasion and wear well, (*iv*) It should be able to retain its colour and shine, and (*v*) It should be uniform and pleasant looking on drying.

10.20 3. Different kinds of varnishes. Based on the different solvents used varnishes are classified in the following categories:

(*i*) *Oil Varnish*. These are made by dissolving hard resins like amber or copal in oil. They are slow to dry, but are hardest and most durable of all varnishes. These are suited for being used on exposed surfaces requiring polishing or frequent cleanings and for superior works.

(*ii*) *Turpentine varnish*. These are made from soft *resins*. Like mastic common resin dissolved in turpentine oil.

They are cheaper, lighter in colour and dry more quickly than the oil varnish, however, they are less durable and are not so tough.

(*iii*) *Spirit varnish*. Varnishes in which spirit is used as a solvent are known as spirit varnishes or *French Polish*. Shellac is dissolved in spirit and the product is applied in a thin layer. These varnishes give a transparent finish thus showing the grains of the timber. These, however do not weather well and as such are used for polishing wood work not exposed to weather. For details refer to Art. 10.22.

(*iv*) *Water varnish*. They consist of lac dissolved in hot water with borax, ammonia, potash or soda just enough to dissolve the lac. Varnish so made withstands washing. It is used for painting wall paper and for delicate work.

10.20.4. Varnishing. Clean and dry surface of wood work is given a

*Copal is a hard, shining, generally bright yellow or brown coloured resin found embedded in earth.

coat of thin and clear hot solution of glue to which a little brown earth and ochre is added, if the wood is of oily nature and the varnish does not dry on it. It is rubbed down smooth and a second coat of thin clean glue with necessary quantity of burnt umber and burnt sienna is applied. It is rubbed with fine sand paper and a coat of varnish is then applied to the surface. Second coat of varnish should be applied when the first one has dried and rubbed down smooth with sand paper.

10 21 FRENCH POLISH OR SPIRIT VARNISH

It is prepared by dissolving pure shellac, varying from pale orange to lemon yellow in colour and free from resin or dirt, in methylated spirit at the rate of 0.15 kg of shellac per litre of spirit. It may be coloured by adding some pigments. .The solution is then strained through a double thickness of coarse muslim.

It dries quicker and becomes harder and more brilliant than turpentine varnishes but cracks and scales off. It does not withstand weathering and is used only for superior wood work not subjected to the vagaries of weather.

Before applying french polish, the surface is cleaned of dust. It is then coated with a filler made by mixing 250 gms of whiting in one litre of methylated spirit. A suitable pigment like burnt sienna or umber, if required, may be added as otherwise the French polish will get absorbed and a good gloss will be difficult to obtain.

A pad of woollen cloth is wrapped in a fine cloth and used for applying the polish. The pad is moistened with the polish and rubbed hard on the surface to be polished. The polish is used sparingly but uniformally on the surface. Rubbing is done in a series of overlapping circles. A trace of linseed oil on the face of the pad facilitates this operations. Subsequent coats are applied after the previous one has dried. The finishing coat is applied with the pad moistened with methylated spirit and rubbing the surface lightly and quickly to give the surface a uniform texture and high gloss.

10.22 WAX POLISH

Two parts of *bees wax* are mixed in two parts of *boiled linseed* oil over a slow fire. When dissolved then one part of turpentine oil is added .to it. The mixture is rubbed into the pores of wood with cotton wad. On rubbing, wax leaves a dull polish on surface which is far superior, more durable and takes longer to accomplish than the French Polish. Rubbing is continued till the desired finish is obtained. Brisk rubbing will give bright surface. For good finish normally three applications are required. Surface to be polished should be absolutely clean.

10.23 WHITE WASHING

White wash, colour wash or distemper is applied on plastered walls or ceilings with a view not only to improve appearance but also from hygenic considerations.

Preparation of white wash. White wash is prepared by slaking at site quick lime obtained by calcining lime stone or shell lime. Shell lime is to be preferred as it as whiter, slakes more perfectly and makes smoother paste than the one had from lime stone. It is slaked by mixing it with excess of water and allowing it to remain in a tank for at least two days. Lime paste is then drawn off in another drum to which water is added to bring the mixture to the consistency of thin cream. It is then strained through a coarse cloth and to it are added solutions of *gum arabic*, rice (boiled in water) and copper sulphate. The whole is then stirred and intimately mixed.

Preparation of surface. Surface to be white washed should be clean, smooth and dry. In case of rewhite washing, the surface should be thoroughly cleaned and cleared of all foreign matter. Loose white wash should be scrapped. All holes should be made good, nails removed and other repairs done before application of white wash. Nail holes and patches caused by the removal of old white wash scales should be made good with lime putty.* All greasy spots should be coated with rice water and sand before applying white wash. If the old white washed surface is discoloured by smoke then a wash of wood ashes and water should precede white wash. All new patches should be given an extra coat of white wash after they have dried before regular white wash is commenced.

Application. The wash will be laid on the surface with a *moonj* brush made quite soft. A vertical stroke followed by an horizontal stroke shall constitute one coat. Each coat must be allowed to dry before the next one is applied. On new surfaces or where scrapping has been done three coats of white wash would normally suffise. One coat of white wash would suffise on a surface having the old wash in good condition. If the colour wash is to be replaced by white wash then the old colour wash must be scrapped and three coats of white wash applied. A properly applied white wash should when complete form an opaque white coat with a smooth and regular surface through which the plaster or the old work does not show. It should present

*Sediment that settles down at the bottom of tub after the white wash mixture is allowed to stand undisturbed for sometime is known as lime putty.

uniform white colour and should not readily come off on the hand when rubbed.

10.24 COLOUR WASH

To the strained white wash is added the desired pigment and mixed well. Sufficient quantity of colour wash should be prepared at a time to cover a whole room or surface to be covered. Not more than a day's requirement of colour wash should be prepared at a time. New or scrapped surfaces should be given a coat of white wash followed by one or two coats of colour wash as desired. One coat of colour wash would be sufficient on surfaces having already white or colour wash in good condition. In case the old colour wash is to be replaced by a wash of another colour then the old surface should be completely scrapped off and a coat of white wash should precede the new colour wash.

Preparation of surface and the methods of application of colour wash are the same as for white wash. The wash should be stirred continually. The colour washing must be of a uniform tint free from lines or cut shades. The surface must not come off readily on hand when rubbed.

EXERCISES

1. (*a*) What are the ingredients used in oil paints?
(*b*) What are the characteristics of a good paint?
(*c*) Give the composition of a *French polish* and explain how it is applied.
2. Enumerate the various steps involved in the preparation of a paint. What is the function of each ingredient used therein?
3. What is varnish? What are its ingredients and where it is used?
4. Give a short account of varnishes.
5. Explain in details the various operations involved in painting a new wood surface.
6. How would you go ahead with painting an old wooden surface? The old paint is blistering and flaking off..
7. What is Distemper and where is it used?
8. Give brief details of manufacture, properties and uses of paints.
9. Write short notes on:
(*i*) Wax Polish.
(*ii*) Luminous paints.
(*iii*) Glaziers putty:
(*iv*) Cellulose paints.
(*v*) Aluminium paints.
10. What is Lacquer? What is its composition and where is it used?
11. What are the usual defects in painting and what their causes are?
12. Describe the process of white washing a plastered surface.

METALS

11.1 METALS

Metals and their alloys are the backbone of all engineering projects and products. Various metals are used in one form or the other. Metals are found as compounds like oxides, carbonates. phosphates and sulphides etc. in nature. These compounds, known as ores, are treated to remove the impurities and get the metal.

All metals used for engineering purposes are classified into two categories: (*i*) Ferrous metals, wherein iron is the main constituent, and (*ii*) Non-ferrous metals, wherein iron is not the main constituent.

Common ferrous metals in use are—cast iron, wrought iron and different forms of steel.

The non-ferrous metals in common use are—aluminium, copper, zinc, lead and tin etc.

11.2 OCCURRENCE OF IRON

Iron is never available pure in nature. It has to be extracted in the form of *pig iron* from the various iron ores, important one's of which are given below. Pig iron is the crudest and Wrought iron is the purest form of iron. All the various forms of iron and steel are then obtained by suitably purifying and adjusting the composition of pig iron. The ores from which iron is extracted are:

(*i*) ***Magnetite*** : (Fe_3O_4). It contains 70 to 75% iron.

(*ii*) ***Haematite***: (Fe_2O_3). It has about 70% iron.

(*iii*) ***Iron pyrites*** : (FeS_2). It contains 47% iron but is not preferred because of higher sulphur content which makes it brittle.

(*iv*) ***Siderite*** . ($FeCO_3$). It contains 40% iron.

11.3 PIG IRON

To remove impurities from the iron ore carbon and flux are added while melting it. The refined product so obtained is the crudest form of iron and is called *pig iron*. It is cast into rough bars called *pigs*.

Properties. (*i*) It is hard and brittle as such it is neither ductile nor malleable.

(*ii*) It is difficult to bend.

(*iii*) It melts easily. The fusion temperature is 1200°C.

(*iv*) It can be hardened but not tempered.

(*v*) It can not be magnetised.

(*vi*) It has very high compressive strength but is very weak in tension and shear.

(*vii*) It does not rust.

(*viii*) It cannot be welded or riveted.

Uses. Cast iron, Wrought iron and Mild steel are obtained by refining the pig iron. Because of its high compressive strength it is used in columns, base plates, door brackets, wheels and pipe work.

11.4 CAST IRON

Pig iron is remelted with lime stone and coke and poured into moulds of desired shapes and sizes to get purer product known as *cast iron*. Moulding remelted *pig iron* reduces impurities and gives a more uniform product than could be had by directly moulding the pig iron in its initia molten state. Carbon contents in cast iron vary from 2.0% to 4.5%.

Properties. (*i*) Its structure is coarse, crystalline and fibrous.

(*ii*) Freshly fractured surface has grey, white or mottled appearance in case of Grey Cast Iron, White Cast Iron and Mottled Cast Iron respectively.

(*iii*) It is brittle.

(*iv*) It can not withstand shocks and impacts.

(*v*) It can not be welded or riveted.

(*vi*) It can not be magnetised.

(*vii*) It can be hardened but can not be tempered.

(*viii*) It is neither malleable nor ductile.

(*ix*) It does not rust.

(*x*) It becomes soft in saline water.

(*xi*) It is fairly hard and can not be worked with a hand file.

(*xii*) It is strong in compression but weak in tension and in shear.

(*xiii*) It lacks plasticity and as such it is unsuitable for forging work.

(*xiv*) Its melting point is 1200°C.

(*xv*) Its specific gravity is 7.5.

Uses. It is used for castings, rain water pipes, gutters, gratings, railings, cisterns, man hole covers and balustrades. Because of high compressive strength it is used in making columns, supports for heavy machinery, carriage wheels and bed plates etc. It is the basic material for the manufacture of Wrought iron and Mild steel.

11.5 WROUGHT IRON

Nearly all the carbon and other elements in pig iron are oxidised and may be left with 0.25 per cent of carbon to obtain wrought iron. It is by far the purest form of iron in which the total impurities do not exceed 0.5 per cent.

Properties. (*i*) Its structure is fibrous and has silky lustre.

(*ii*) It is ductile and malleable.

(*iii*) It is tough and can withstand shocks and impacts better than cast iron.

(*iv*) It can neither be hardened nor tempered.

(*v*) It can be forged and welded.

(*vi*) At 900°C it becomes so soft that two pieces can be joined by hammering. It melts at 1500°C.

(*vii*) It rusts easily.

(*viii*) It is unaffected by saline water.

(*ix*) It forms temporary magnets but can not be permanently magnetised.

(*x*) It is nearly equally strong in tension, compression and shear.

(*xi*) Its specific gravity is 7.25.

Uses. It is used for making roofing sheets; corrugated sheets; rods; gas and water pipes; boiler tubes; plain and ornamental iron work such as grills, gates and railings; window guards, gratings and electro-magnets.

Use of wrought iron is getting replaced by mild stee .

11.6 STEEL

The essential difference between cast iron and steel is in the amount of their carbon contents. Steel goes on becoming harder and tougher with the increase in its carbon contents. Up to a content of about 1.5 per cent all the carbon gets into chemical combination with iron and none of it exists in its free state. If carbon contents increase beyond 1.5 per cent then it does not combine with iron and is present as free graphite. It is at this stage that the metal falls in the category of cast iron. The carbon contents may be increased to 4.5 per cent for cast iron. *For a material to be classified as steel there should be no free graphite in its composition.* If there is any free graphite in it then it falls in the category of CI.

Depending upon their carbon contents steel is classified as mild *steel* in case the carbon content is from 0.15 to 0.3 per cent. If the carbon content is less than 0.15 per cent then the steel is known as *dead mild steel*. Steel with carbon content from 0.3 to 0.8 per cent known as *medium carbon steel* whereas the one with carbon contents between 0.8 to 1.5 per cent is known as *high carbon steel*. High carbon steel with carbon percentage over one per cent is also known as *cast steel* or *carbon tool steel*.

Steels that owe their properties to carbon are called carbon steels whereas others with distinct properties due to elements other than carbon are termed as alloy steels.

11.6 1. Mild steel. Steel wherein the carbon content is from 0.15 to 0.3 per cent is called the Mild steel, Low Carbon steel or Soft steel.

Properties (*i*) Its structure is fibrous with dark bluish colour.

(*ii*) It is ductile and malleable.

(*iii*) It is more tough and more elastic than cast iron and wrought iron.

(*iv*) It is more prone to rusting than the wrought iron.

(*v*) It corrodes quickly

(*vi*) It can be permanently magnetised.

(*vii*) It can be easily forged, welded and riveted.

(*viii*) It withstands shocks and impacts well.

(*ix*) It is not much affected by saline water.

(*x*) It is equally strong in tension, compression and in shear.

(*xi*) It is difficult to harden and temper.

(*xii*) It's specific gravity is 7.8.

Uses. In construction works it is chiefly used as rolled structural sections like I-section; T-section; channel section; angle Irons..plates; round and square rods. Mild steel round bars (M. S. rounds) are extensively used as reinforcements in reinforced cement concrete. Mild steel tubes are finding extensive use in structures. Plain and corrugated sheets of Mild steel are used as roof coverings.

It is extensively used in the manufacture of various tools and equipments; machine parts; for rail track, transmission towers and industrial buildings.

11.6.2. High carbon steel. These are steels wherein the carbon contents are between 0.55 per cent and 1.5 per cent. Higher percentage of carbon in it renders it harder and tougher.

Properties. (*i*) Its structure is granular.

(*ii*) It is more tough and elastic than Mild steel.

(*iii*) It is easier to harden and to temper.

(*iv*) It is more difficult to forge and to weld.

(*v*) It can be permanently magnetised.

(*vi*) Comparatively it is stronger in compression than in tension or in shear.

(*vii*) It withstands shocks and vibrations better.

Uses. It is used for making tools such as drills, files, chisels. Fine quality of cutlery is made of High Carbon steel. It is used to manufacture those parts of machinery that need a hard, tough, durable material capable of withstanding shocks and vibrations.

11.6.3. High tension steel. It is essentially a low carbon steel and the percentage of carbon is kept lesser than 0.15. It is also termed as *high strength steel*. Because of increased tensile strength, lesser weight of it is used, as compared to Mild steel for the same job. The structure thus becomes lighter. It withstands atmospheric corrosion better, is tougher and more elastic, is more brittle and less ductile than mild steel. High tension steel wires are extensively used in reinforcing prestressed concrete structures.

11.6.4. Reinforcing steel. Plain cement concrete being strong in compression is very weak in tension and in shear. Mild steel or High tension steel is embedded as reinforcement in the concrete to make good that deficiency of the plain concrete. Though *flats* and *square bars* too can be used as reinforcement yet the round bars are extensively used for the purpose. Welded wire mesh and expanded metal too are used as reinforcements in cement concrete. Mechanical properties of the different reinforcing bars are tabulated below:

Properties	*Diameter of the bar (mm)*	*Mild steel*	*Medium tensile steel*
Ultimate tensile stress	All sizes	42	58
Ultimate elongation %	under 10	16	14
	10 to 25	20	18
	over 25	24	22
Yield stress	up to 25	—	36
	25 to 38	—	34.5
	38 to 50	—	33

Note: 1. All stresses are in kg/mm

2. Weight of steel sections may be taken as 0.785 kg/cm^3 of section per metre length.

3. Coefficient of thermal expansion is taken as 11.5×10^{-6} per °C.

11.7 ALLOY STEELS

Besides carbon, other elements that impart distinctive characteristics to steel are added to iron to produce an alloy steel named after the element added. An alloy is generally prepared to increase strength, hardness, toughness, resistance to corrosion and thermal and electrical conductivities.

Alloys are classified into two categories: (*i*) *Ferrous alloys;* and (*ii*) *Non-ferrous alloys.*

11.7.1. Ferrous alloys. Ferrous alloys have iron as the chief constituent. Chromium, nickel, vanadium, tungsten, molybdenum and manganese etc. are the metals that form ferrous alloys with iron. A few important alloys of iron are discussed below.

11.7.2. Stainless steel. Structural steel with a copper content of 0.2 per cent resists atmospheric corrosion better than structural steel with no copper content. Chromium is the most effective ingredient for making steel resistant to corrosion and to heat. It is specially effective if the chromium content is 16 per cent or more. The protection against corrosion is due to the dense tough film of oxide formed over the surface of metal. Steel with a chromium content of over 16 per cent is known as *Stainless steel.*

Various brands of stainless steel in the market may be classified into three groups. Steels in the first group have a chromium content lower than 16 per cent and carbon content lower than 0.4 per cent. These respond to heat treatment and are not excessively brittle. These can be machined by the use of specially designed cutting tools. These can be welded. These are satisfactory for resisting weather and water. These can be used at temperatures up to 800°C.

Steels in the second group have a chromium content higher than 16 per cent and a carbon content not over 0.4 per cent. They do not respond readily to heat treatment and are brittle. They can be forged, rolled or cold drawn and can be machined by use of specially designed tools. They can be welded but some metals are very brittle near the weld. They resist corrosion better than the one's in the first group.

Stainless steels in the third group contain sufficient chromium to make them non-magnetic. They are very tough and do not respond readily to heat treatment. They can be forged, rolled or cold drawn but can be machined with great difficulty. They can be welded. Above 16 per cent of chromium their resistence to corrosion is excellent. The metals under this group are the best for use under high temperatures.

11.7.3. Nickel steel. It contains 0.5 to 1 per cent carbon and about 3.5 per cent nickel. Presence of nickel imparts hardness, toughness, improves strength and reduces rust formation.

It is used in the manufacture of automobile parts, aeroplane parts, cables and propeller shafts. If the percentage of nickel present in steel is from 30-40 per cent, the steel is then known as *invar* which has a very low coefficient of thermal expansion and is used for making delicate instruments.

11.7.4. Vanadium steel. It contains 0.1-2 per cent vanadium and is very strong and ductile. It is capable of resisting shocks. Its elastic limit is high.

11.7.5. Tungsten steel. It contains 14-20 per cent tungsten; 3-8 per cent chromium and very small quantities of carbon, vanadium and molybdenum. It is sometimes known as high speed steel. It hardens at high temperatures and retains the temper. It is used for making drilling machines and high speed cutting tools.

11.7.6. Manganese steel. Addition of 12-15 per cent manganese to steel makes the steel very hard, tough and non-magnetic. It is used for making points and crossings in rail track and machine parts etc.

11.8 RUSTING, CORROSION AND PRESERVATION OF STEEL

Rusting is just the oxidisation of iron at the surface. This process is activated by the presence of moisture and carbon dioxide. On oxidation initially iron changes to ferrous-bicarbonate, then to ferric-bicarbonate and finally to hydrated ferric oxide. Even at the final stage of rust formation certain amounts of ferrous and ferric carbonate are present. Atmospheric pollution too accelerates rust formation.

Corrosion is slow but steady eating away of the metal and is a consequence of rusting.

Rusting and corrosion can be avoided by not letting moist air come in contact with the iron surface. Following methods could gainfully be adopted to minimise rusting and corrosion.

(*i*) *Tarring*. Iron is dipped in hot coal tar so that a film of it sticks to the surface which protects the surface from rusting and corrosion. Pipes or ends of poles to be embedded in earth are usually given this protective treatment.

(*ii*) *Painting*. Paints, usually the lead paints, are applied on the surface to be protected. Exposed metal surfaces as in case of roof trusses and bridge structure are given this treatment which has to be invariably repeated after regular intervals of time.

(*iii*) *Enamelling*. Enamel provides better and long lasting protection as compared to painting. This treatment is given only to smaller surfaces. (For details refer to Chapter 10).

(*iv*) *Galvanising*. Depositing a fine film of zinc on the iron/steel surface is termed as *galvanising*. The surface to be galvanised is first cleared of all foreign matter by giving it an acid wash to be followed by a wash of clean water. The surface is then dried and dipped in mol-

Table: 11.9 COMPOSITION, PROPERTIES AND USES OF CAST IRON, WROUGHT IRON AND STEEL.

Cast iron, wrought iron and different forms of steel differ in their properties just due to variations in the carbon contents of iron. Detailed comparison of the three is tabulated below:

S. No.	*Property*	*Cast Iron*	*Wrought Iron*	*Steel*
1.	Composition	It is crude form of iron containing 2-4% carbon	It is the purest form of iron containing up to 0.25% carbon	It is mid-way between cast iron and wrought iron containing 0.5 to 1.5% carbon
2.	Structure	It has got a crystalline structure	It has fibrous structure with a silky lustre	It has a granular structure
3.	Specific gravity	Its specific gravity varies from 7 to 7.5	Its specific gravity is 7.70	Its specific gravity is 7.85
4.	Melting point	Its melting point is about 1200°C. It contracts on melting	It melts at about 1500°C	Its melting point is between 1300°C and 1400°C
5.	Hardness	It is quite hard and can be hardened by heating and sudden cooling	It cannot be hordened or tempered	It can be hardened and tempered
6.	Strength	Its ultimate compressive strength is 6.3 to 7.1 tonnes/sq cm and ultimate tensile strength 1.26 to 1.57 tonnes/sq cm.	Its ultimate compressive strength is 2.0 tonnes/sq cm and ultimate tensile strength 3.15 to 3.94 tonnes/sq cm.	Its ultimate compressive strength is 4.72 to 25.2 tonnes/sq cm and ultimate tensile strength is 5.51 to 11.02 tonnes/sq cm
7.	Reaction to sudden shock	It does not absorb shocks	It cannot stand sudden heavy shocks	It absorbs shocks

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8.	Magnetisation	It cannot be magnetised	It does not form permanent magnets but can be temporarily magnetised	It can form permanent magnets
9.	Rusting	It does not rust easily	It rusts more than Cast Iron	It rusts easily
10.	Malleability and ductility	It is neither malleable nor ductile	It is tough, malleable, ductile and moderately elastic	It is tough, malleable and ductile
11.	Forging and welding	It is brittle and cannot be welded or rolled into sheets	It can be easily forged or welded	It can be rapidly forged or welded
12.	Uses	Because of its not rusting it is used in the manufacture of parts most likely to rust like water pipes, sewers, drain pipes etc. It is used for making such parts of machines as are not likely to be subjected to shocks or to tension. Lamp posts, columns and railings are usually made of Cast Iron	It being costlier than mild steel in being rapidly replaced by the latter. As it can withstand sudden shocks without permanent injury so it is used for chains, crane hooks and railway couplings etc.	It is used as reinforcement in R.B. and R.C.C. It is used in making structural members, bolts, rivets and sheets (plain and corrugated). High carbon steel is used for those parts of machinery where hard, tough, elastic and durable material is required. It is used for making cutlery, files and machine tools.

ten zinc. The fine film of zinc that gets deposited protects the surface from contact with atmosphere and consequent oxidation. Removal of the zinc film caused by wear or scratches, however, exposes the surface to rust and corrode.

(v) *Sheradising*. Surface to be treated is cleaned of all foreign deposits by washing it with acid solution and then with clean water. It is then dried and covered with zinc dust and enclosed in steel boxes to be heated in a furnace under controlled temperatures. Molten zinc spreads over the whole surface and on cooling forms a thin protective layer.

Sheradising gives better protection than galvaning.

(vi) *Tin plating*. After cleaning the surface with acid wash followed by wash with plain water and drying, it is dipped in a bath of molten tin. A protective covering of tin layer is left on the surface.

(vii) *Electroplating*. By the process of electrolysis a thin film of nickel, chromium, cadmium, copper or zinc is deposited on the surface to be protected. The surface to be protected is made the cathode and the metal to be deposited is made the anode.

11.10. NON-FERROUS METALS

Properties and uses of the more commonly used non-ferrous metals are given below:

11.10.1. Aluminium. It is getting into wider and wider usage in every field of Engineering. Modified metallurgical processes have improved strength and durability of aluminium to an extent that has made it versatile material for use by engineers.

Properties. (*i*) It is of silvery white colour and shows bright lustre on a freshly broken surface.

(*ii*) It is highly ductile and malleable.

(*iii*) It is very light in weight.

(*iv*) It withstands atmospheric corrosion exceedingly well.

(*v*) It is a very good conductor of electricity.

(*vi*) It is very soft.

(*vii*) It can be welded and riveted but can not be soldered.

(*viii*) It is very easy to work upon.

Uses. It is used for making door and windows frames, corrugated sheets for roofing, piping, railings, posts, panels and balustrades in building construction. It is used in powder form in painting. Aircraft and automobile parts are made of aluminium. Because of good conductivity electric wires and cables are made of aluminium. Its alloys with metals like copper, magnesium, manganese and silicon etc. have high tensile strength and hardness still being light and durable.

11.10.2. Copper. It is one of the most widely used metals. High cost is the prohibitive factor in its extensive usage in engineering works.

Properties. (*i*) Its structure is crystalline and the colour is reddish brown.

(*ii*) It is highly ductile and malleable.

(*iii*) It can be welded only at red heat.

(*iv*) It is an excellent conductor of electricity.

(*v*) It withstands corrosion well.

(*vi*) It turns greenish on exposure to atmosphere.

(*vii*) It is soft and highly flexible.

(*viii*) It is tough and withstands wear well.

(*ix*) It is light in weight.

(*x*) Dents in copper can be hammered out without any damage to it.

Uses. Copper wires are used for winding electric motors and generators and for transmission of electricity. It is used for electroplating and electrotyping. It has wide usage in making alloys like brass, bronze and gun metal. In the form of sheets it is used in damp proofing buildings.

11.10.3. Lead. It extensively used metal in building construction and has the drawback of being poisonous.

Properties. (*i*) It is bluish grey metal.

(*ii*) It is so soft that it can be cut with a knife.

(*iii*) Its melting point is 326°C and boiling point is 1150°C.

(*iv*) It is highly ductile and malleable.

(*v*) It is a good conductor of heat and electricity.

(*vi*) It does not corrode.

(*vii*) Its specific gravity is 11.35.

(*viii*) It marks the paper.

Uses. It is used as a base in paints. Lead pipes and lead joints in sanitary fittings are widely used. It is used in lead batteries, cable coverings, making bullet shots and as lining in chemical and metallurgical industries.

11.10.4. Tin. It is one of the most commonly used protective metals used in construction activities.

Properties. (*i*) It is lustrous silvery white metal.

(*ii*) It is highly ductile and malleable.

(*iii*) It is a good conductor of heat and electricity.

(*iv*) Its melting point is 230°C.

(*v*) Its specific gravity is 7.3.

(*vi*) It is soft and has good plasticity.

(*vii*) It withstands corrosion due to acids.

(*viii*) It becomes brittle at 200°C.

Uses. It is used to give protective coatings to iron and steel sheets, as an alloying element in soft solders and for moisture proof packing. It forms alloys.

11.16.5. Zinc. In building construction zinc is commonly used either as a protective covering for metals or as a base for paints.

Properties. (*i*) It is a bluish white crystalline metal.

(*ii*) It is brittle at ordinary temperatures and when heated beyond 150°C.

(*iii*) It becomes ductile and malleable between 100 to 150°C.

(*iv*) It is a good conductor of heat and electricity.

(*v*) It resists corrosion.

(*vi*) Its specific gravity is 7.0.

(*vii*) Its melting point is 420°C.

(*viii*) It forms important alloys like brass and german silver.

Uses. It is used for galvanising iron sheets and pipes, for batteries and printing blocks, for preparing paints and for making important alloys like brass and german silver.

11.11 NON-FERROUS ALLOYS

A few of the important non-ferrous alloys, wherein the non-ferrous metals predominate, are described below.

11.11.1. Brass. It is an alloy of about 60-70 per cent copper and zinc. Hardness of the alloy depends upon the amount of zinc present in it. It is very strong, malleable and ductile. It resists corrosion and it is extensively used for making household utensils, water pumps and certain machine parts.

11.11.2. Bronze is an alloy of 90 per cent copper and ten per cent tin. It can be easily machined and cast. It resists corrosion and takes a fine polish. It is used for the manufacture of household utensils. Phosphorous bronze is used for making radio aerials and certain other instruments.

11.11.3. Duralumin is an alloy of 94 per cent aluminium, four per cent copper and magnesium, manganese, silicon and iron. It is sufficiently strong and resists corrosion. It is a very good conductor of electricity. It is used for making cables, aeroplane parts, automobile parts and surgical instruments.

11.11.4. German silver is an alloy of 20 to 35 per cent zinc, 45-60 per cent copper and of nickel. It resists corrosion and has high tensile strength. It is used for making utensils, resistance coils, valves, plumbing fittings, parts of automobile, type writer and musical instruments.

11.12 JOINING METALS

Metals are joined together by any one of the following methods: (*i*) Soldering; (*ii*) Brazing; and (*iii*) Welding.

11.12.1. Soldering. It is the method of joining two metal surfaces by means of a low melting alloy of lead and tin (usually mixed in the ratio of 1 : 2). This alloy (known as *solder*) melts and adheres to the surfaces to be joined. It has very poor tensile strength and serves only to fill up the joint.

11.12.2. Brazing. It is similar to the operation of soldering but is done at a much higher temperature (from 650°C to 1100°C). It consists of a mixture of one part of tin, three parts of zinc and four parts of copper. The brazing solder is applied to the joint in the presence of borax which acts as a flux. The surfaces to be joined are held pressed firmly together until the brazing solder applied has solidified. It is used in joining together iron, copper, brass and gun metal etc.

11.12.3. Welding. Metals may be joined together by any one of the following two methods:

(*i*) *By pressure welding*. To mild steel and wrought iron with low carbon and silicon content may be applied this method of joining together. In it the surfaces to be joined are heated to such a temperature as to render them plastic and then pressure is applied to join the surfaces.

(*ii*) *By fusion welding*. In welding by fusion the surfaces to be joined are brought near to each other and then locally heated either by gas or by an electric spark until the surfaces melt. Molten matter to fill the joint is supplied by the welding rods. Different welding rods are used to weld surfaces of different natures. Fusion of surfaces may be caused by (*a*) gas welding, (*b*) arc welding, (*c*) flash welding, and (*d*) thermit welding.

In gas welding a combination of oxygen and acetylene gases supplied from gas cylinders under pressure is lighted at the tip of a welding torch. By controlling the supply of gases the length of flame and its nature (oxidizing or reducing) can be adjusted. Suitable welding rod, depending upon the nature of surfaces to be welded, are coated with fluxes. Welding rods provide the molten metal necessary to fill the joint.

In electric arc welding a spark is produced between the welding rod and the surface to be welded. The heat of spark is enough to heat the surfaces to be welded and also to melt the welding rod. To help fusion the welding rod is often coated with a suitable flux.

In flash welding electric arc is utilised to cause fusion of the surfaces to be welded and then pressure is applied to join the fused surfaces. Heavy pieces like rails are welded by this method.

In thermit welding, molten thermit is poured over the joint of surfaces to be welded. Thermit consists of a mixture of aluminium and iron oxide in the ratio of 1 : 3 by weight. This method is used in welding large damaged steel pieces.

11.13 HEAT TREATMENT

Steel is subjected to heat treatment so as to develop in it specific properties. It involves not only heating but also cooling steel. Some of the usual treatments and effects thereof are discussed below:

11.13.1. Annealing. Steel is annealed to soften it to enable it to be easily machined and to release internal stresses that might have been caused by working of the metal or by unequal contraction in its casting.

For annealing it is heated slowly to a temperature of 800°C to 1000°C. It is then held at the temperature for sufficient time so as to enable the internal changes to take place. It is then cooled *slowly*. For slow cooling, which is very essential, the heated steel is taken out of the furnace and embedded in sand, ash, lime or some other non-conducting material.

11.13.2. Normalising. This treatment is done to refine the structure and to remove strains that might have been caused by cold working. When steel is cold worked its crystalline structure may get upset and the metal may become brittle and even crack. Also when the metal is heated to very high temperatures as for forging then it may loose its toughness. To remedy these defects steel is slowly heated to about 1000°C and allowed to cool in air.

11.13.3. Hardening: This treatment of steel consists in heating the steel to red heat and then suddenly cooling it by dipping it in a bath of cold water or oil. This way of cooling hot steel is known as *quenching* or hardening. The steel after quenching is known as quenched steel which becomes hard and brittle. The hardness of quenched steel depends upon the medium used for quenching and the rate of cooling.

11.13.4. Tempering. Hardened steel is heated below the critical temperature which causes a partial transformation thereby reducing its hardness but making the steel tougher. The temperature at which the hardening should be done depends upon the purpose for which it is being done. When the metal has been heated to the tempering temperature then it may be cooled by quenching it or allowing it to cool off.

11.13.5. Case hardening. It is the method whereby only the surface of metal is hardened to a depth of about 1.5 mm. Case hardening consists of two operations:

(*i*) Converting the outer skin to high carbon steel.

(*ii*) **Hardening the case and refining the core.** To increase the carbon content steel is encased in cast iron or steel boxes together with a substance rich in carbon like charcoal granules, bone dust etc. and the boxes are heated in furnaces to a temperature of 900°C to 950°C. At this temperature carbon infuses into the surface of steel and converts it to high carbon steel. The depth to which this effect takes place depends upon the time of heating. Usually 3-4 hours are sufficient. The steel when taken out of boxes that have been allowed to cool has a soft core and a casing of high carbon steel.

11.14 COMMERCIAL FORMS OF STEEL

Steel is rolled/extruded into different sections to suit different needs. Basic features of each section are explained below:

(*i*) **Bars.** Steel bars are available in the following three shapes:

(*a*) *Round bars.* These are of circular sections designated by Indian Standards Institution as ISRO followed by bar diameter varying from 5 mm to 250 mm. Commonly used sections are of 5 mm to 50 mm diameters. Usual lengths are from 10 m to 12 m. These are widely used as reinforcement in R.C.C. work and in R.B. work (reinforced brick work) and for fabricating Grills and Railings.

Bars of less than 5 mm diameters are termed as wires.

(*b*) *Square bars.* These are of square sections, designated by Indian Standards Institution as ISSQ followed by side width of the section in mm. Sizes vary from 5mm square to 250 mm square.

These are commonly used for Grill work and Railings in buildings.

(*c*) *Deformed bars.* These bars have projections on their surfaces that increase their bond with Concrete in RCC. Permissible tensile stress in these bars is about 50 per cent more than in MS bars. Deformed bars could be *cold twisted* or *hot rolled*. Hot rolled twisted bars are ribbed type and its common trade name is *Tor steel*.

Note: Rounds and squares above 12 mm size are available in lengths of 6.5 m to 13.5 m rising by 250 mm. Below 12 mm sizes, they are available up to 27 m length.

(*ii*) **Flats.** Commonly termed as M.S. flats are available from 5 mm × 12 mm to 25 mm × 250 mm in section and 6.5 m long. In structures these are used for fabricating grills and railings.

(*iii*) **Angle sections.** The section has two legs, one vertical and the other horizontal. Both the legs are of same thickness. If both the legs are of same length then it is termed as *Equal Angle* and if the lengths of each of the two legs differ then it is termed as *Unequal Angle*. According to Indian Standards Institution these are designated as ISA followed by lengths of both the legs in *mm* (length of longer leg, in case of unequal angles being placed first). Equal angles (Fig. 11.1a) are from ISA 5050 (the two legs being 50 mm each) to ISA 200200 (each leg being 200 mm long). The unequal angles (Fig. 11.1 b) are from ISA 5030 (the longer leg being 50 mm long and the shorter one being 30 mm long) to ISA 200150 (the longer leg being 200 mm and the shorter one 150 mm long).

These are extensively used in the fabrication of roof trusses, steel frames for doors and in fabrication of other built up structural sections.

(*iv*) **Tee-sections.** The section resembles the Roman alphabet T in shape (Fig. 11.1 c). The top horizontal portion is called the flange and the vertical portion meeting the flange at its midpoint is termed as web. According to the Indian Standards Institution these are designated as ISNT; ISHT; ISST; ISLT and ISJT followed by the depth of the section in mm.

These are extensively used in roof trusses and in fabricating built up sections.

(*v*) **I-sections.** The sections resemble the Roman alphabet I in shape (Fig. 11.1 d). The top and the bottom horizontal portions are termed as flanges and the vertical portion joining the mid points of the two flanges is termed as web. According to the Indian Standards Institution these are designated as. ISJB; ISLB; ISMB and ISHB followed by the depth in mm. These sections are termed as Rolled Steel Joists (RSJ) too.

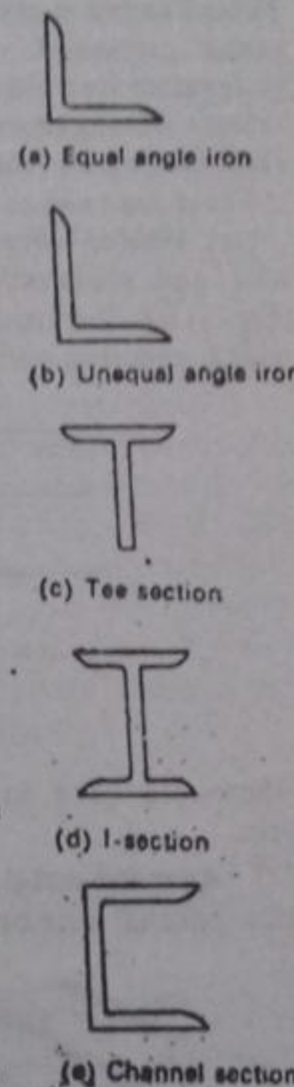

Fig. 11.1

These are extensively used as floor beams, as columns and in fabricating built up sections like stanchions.

(*vi*) **Channel sections.** These sections (Fig. 11.1e) have two horizontal portions, termed as flanges, connected to each other at ends by a vertical member termed as web. According to the Indian Standards Institution these are designated as ISJC, ISLC and ISMC followed by its depth in mm.

These are mainly used to build up different structural sections.

(*vii*) **Plates.** Steel plates are rolled to thickness varying from 5 mm to 63 mm, width 900 mm to 2500 mm and length 2200 mm to 12500 mm.

These are used for fabricating built up structural sections.

(*viii*) **Corrugated sheets**. Iron sheets are strengthened by providing *corrugations* that have the cross-section of trigonometric sine curve. These sheets are protected against corrosion by galvanising and are called *galvanised corrugated iron sheets* abbreviated as G.C.I. sheets. Galvanised iron sheets without corrugations are abbreviated as G.I. sheets. Corrugated G.I. sheets are 66 cm wide and up to 3 m long. Thickness varies from 24 gauge to 16 gauge.

These are used as roof coverings.

(*ix*) **Welded wire fabrics**. There are manufactured in sheets or rolls and are available in rectangular or square mesh of steel wires (Fig. 11.2). The cross wires which make the fabric are electrically welded, ensuring correct spacing of cross wires and rigidity of welds.

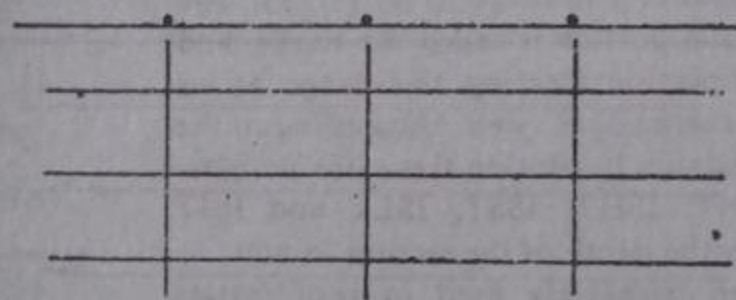

Fig. 11.2

These are used in fencing, grills and as reinforcement in R.C.C. work.

(*x*) **Expanded metal.** It is manufactured from mild steel sheets or plates. Parallel cuts or slits, a few centimetres long, are made in sheets

Fig. 11.3

which are then firmly gripped and pulled. The material then opens out along the slits forming diamond shaped mesh (Fig. 11.3). It is manufactured in various mesh sizes and plate thicknesses. Diagonal lengths of each mesh give the mesh size. Expanded metals made out of brass and copper sheets also are available.

Expanded metal is used as reinforcement in R.C.C. work, as lath (ground for plaster) in plaster for ceilings, as grills and for fencing.

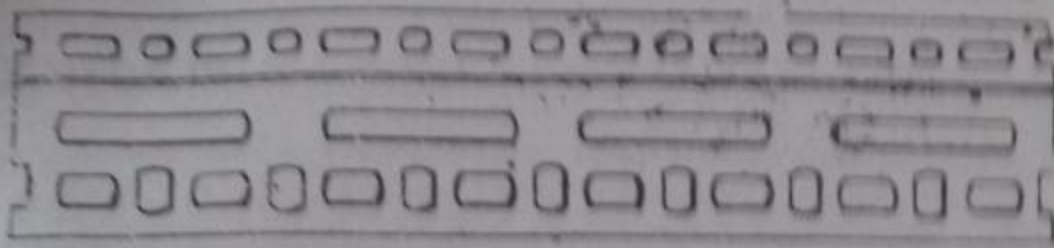

Fig. 11.4

(*xi*) **Slotted angles.** Angles with slots at regular intervals (Fig. 11.4) are marketed by different firms in different sizes. Length of each slotted angle is 3 m and the three commonly available sizes are 75 $\times$ 40 $\times$ 2.5 mm, 60 $\times$ 40 $\times$ 3.0 mm and 35 $\times$ 35 $\times$ 1.8 mm. Punched steel straps 38 $\times$ 2 mm are available in 3 m lengths. Two pieces of it are joined by tightening nuts and bolts. These are good for assembly of structural components, scaffolds, bench or storage racks. These may be used in combination with plywood, hard board, asbestos or wire mesh etc. It helps in cutting costs and saving time.

EXERCISES

1. Describe briefly the composition, properties and uses of the following:
   (*i*) Cast iron, (*ii*) Wrought iron, (*iii*) Mild steel.
2. Describe different uses of the following:
   (*i*) Mild steel, (*ii*) High carbon steel, (*iii*) High tension steel.
3. Give the properties and uses of stainless steel.
4. In the construction of buildings give the uses of the following:
   (*i*) Lead, (*ii*) Copper, (*iii*) Brass, (*iv*) Zinc, (*v*) Tin.
5. Write short notes on:
   (*i*) Brazing, (*ii*) Nickel steel, (*iii*) Soldering, (*iv*) Annealing, (*v*) Case Hardening, (*vi*) Tempering.
6. What is Alloy? Describe the properties and uses of some of the important non-ferrous alloys.

12

PLASTICS

12.1 GENERAL

Plastics, mostly being synthetic materials, are available in market in a variety of forms to suit varied requirements. It is finding newer and newer usages in building construction and is fast replacing many convential materials like timber and steel etc. It is being used for making fittings and fixtures to meet aesthetic requirements and structural components to withstand wear and tear.

Shortage of conventional materials of construction during the 2nd world war gave impetus to the use of plastics in electric and sanitary fittings like electric points,. switches, holders, insulators, cisterns, cistern floats, W.C. seats and domestic furniture etc.

12.2 PLASTICS

These are generally taken to imply a group of organic materials that become plastic on heating and then they could be moulded to required shapes. On cooling down to normal temperatures these regain rigidity.

These are natural or synthetic in origin. Natural plastics like *shellac* and *resin* have since long been in use. Plastics are weighed or filled with fibres or granular substances as needed. Technically plastics are classified into two categories as Thermoplastics and Thermosets.

12.2.1. Thermoplastics. (*i*) *Acrylic* (*polymethyl methacrylate*). Methyl methacrylate is an important constituent of this class of plastics having very wide application. It is more transparent than even glass and transmits light far better. It is tough and strong and does not shatter under impact. It is unaffected by moisture and light acids. Its compressive strength is 1600 to 2400 kg/cm² and the tensile strength is 450 kg/cm² to 700 kg/cm². It does not soften up to 80°C.

It is used in place of glass in doors and windows where shatter risk is high. It is used as safety glass in cars and aircrafts.

(*ii*) *Cellulose acetate*. These are made from the short stubby fibres (termed as linters) left on the cotton seed after spinnable fibres have been removed.

Cellulose acetate is brittle at low temperatures and is attacked by strong acids. Dilute acids, alkalies, ether and hydrocarbons do not affect it. It swells on absorbing water and looses the shape.

It is extensively used for insulating electric cables, for lighting fittings, for door plates and for hand rails.

(*iii*) *Cellulose nitrate*. To obtain it cotton is treated with sulphuric acid and nitric acid by a process called "*Nitration*". Excess acids are then removed, the product washed with hot water mixed with camphor, a plasticizer, and the desired colouring pigment. These are then kneaded, rolled into sheets and seasoned for weeks.

Cellulose nitrates are tough and durable. These are unaffected by moisture or solvents other than alcohol, ketone and ether. Letters can be etched on it. Continued exposure to heat and light makes them brittle. These are used in making set squares, slide rules and fountain pens etc.

(*iv*) *Polythene*. It is transparent, chemically inert and unaffected by moisture or temperature. It is used in making pipes for cold water services, cistern ball floats, covers to cement concrete for curing and sheets for moisture proof packings.

(*v*) *Perspex*. It is a proprietory thermoplastic resin that gives light and tough sheets which does not break easily. The sheets that are exceptionally transparent, can be cut, nailed and sawn without difficulty. It is used for lamp shades and in electric fittings and put to various other building usages.

(*vi*) *Polyvinyl chloride* (*PVC*). It is a product obtained from vinyl chloride and acetates. It resists attacks of acids and alkalies and is unaffected by moisture. It is light in weight and can be cut easily. It is a bad conductor of electricity. It withstands wear and tear well.

It is used in the manufacture of drainage pipes for sanitation, as insulation for electric wires,. as flooring finish, as emulsion paint etc. etc.

(*vii*) *Polyvinyl acetate* (*PVA*). It is a product obtained by the polymerisation of vinyl acetate. Its properties and uses are very much similar to those of polyvinyl chloride (PVC).

12.2.2. **Thermosetting.** These undergo chemical changes on moulding and the product obtained after moulding is chemically changed. In these phenol-formaldehyde or other resin is the binder and powdered wood is the filler. Both the constituents are intimately mixed, heated and moulded under pressure. Resin can not be had on reheating, just as cement cannot be obtained back from cement concrete after it has set.

The plastics are durable and fairly strong.

12.3 MANUFACTURE OF COMMERCIAL GOODS

Depending upon the shape, size and thickness of the finished product and the quality of resin used, one of the following methods may be used in fabricating commercial articles from plastic:

(*i*) Casting (*ii*) Moulding (*iii*) Extrusion (*iv*) Lamination

12.3.1. Casting. Molten raw material is cast into moulds exactly in the same manner as cast iron castings are had. Zinc, wooden or plaster of paris moulds are used for the purpose. At times steel moulds are also used. Products obtained on polishing have to be smoothened by polishing. Cellulose acetates and cellulose nitrates are generally cast.

12.3.2. Moulding. Plastic can be moulded into finished products by adopting any one of the following procedures, depending upon the peculiarities of the particular product.

(*a*) *Compression moulding.* In this process the raw material is placed in the mould cavity (4) (Fig 12.1) and both parts of the mould (1) and (2) are subjected to high pressure along with the simultaneous heating of the mould. Pin (3) in upper part (1) of the mould when inserted in corresponding holes in lower part of the mould (2) helps the two parts of the die to take the correct relative position.

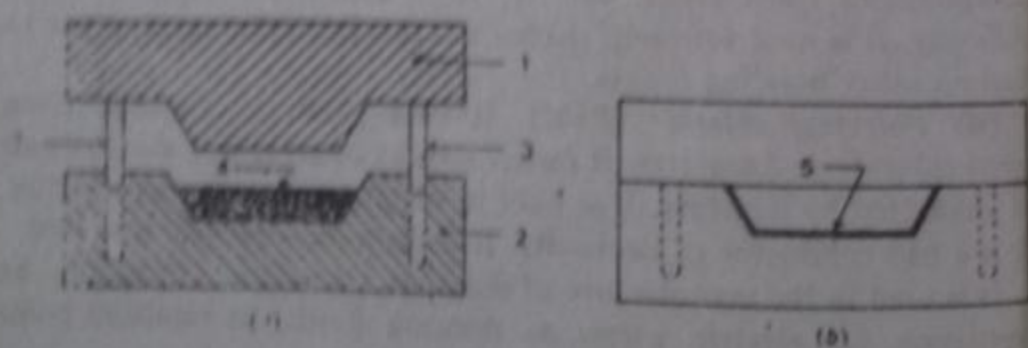

Fig. 12.1

The raw material on becoming soft due to heat forces into all areas of the cavity because of applied pressure. The temperature and the pressure are continued to be applied till the chemical changes have taken place. The two parts of the die are then separated and the moulded article (5) is taken out for cooling.

(*b*) *Transfer moulding.* It consists in passing the molten material into the moulds and there it is subjected to pressure so that it reaches all recesses in the mould. The pressure is continued till the chemical changes have taken place. The moulded article is then taken out of the mould. Intricate machine parts made of thermosetting plastics are moulded by this process.

(c) *Injection moulding*. The raw material (2) (Fig 12.2) is fed into a tube (1) which is heated by a heating element (4) surrounding the tube when the plastic has liquified then the same is pushed out of a nozzle (5) by pushing the plunger (3) down with force. The liquified raw material passes from the nozzle into the entire cavity provided for in the cold mould. The moulded article is removed out of the mould and the process repeated.

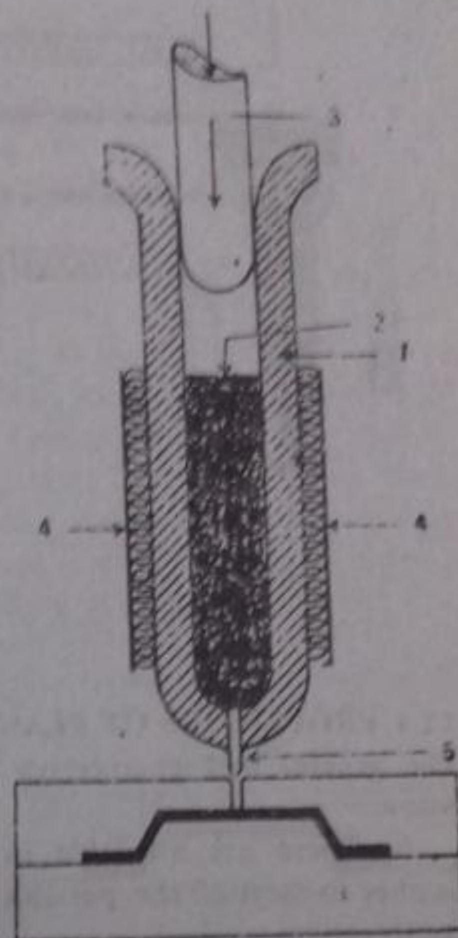

Fig. 12.2

It is a quick method used for moulding thermoplastics.

12.3.3. **Extrusion** The raw material is fed into a hopper (1) (Fig. 12.3) which is then propelled onwards by a rotating screw (2). The tube wherein the screw rotates is covered with a heating element (3) because of the heat of which the raw material melts. The molten raw material is forced out of a notch having the shape of the finished product needed. Thermoplastic rods and tubes are extruded through dies. If, however, something is to be provided with the plastic covering like insulation of electric wires and cables then the same is drawn through a die (4) as shown in Fig. 12.3.

12.3.4. **Lamination**. If thin sheets of paper, cloth, wood, glass fibre or asbestos are impregnated with thermosetting resin and passed through rollers, thereby subjecting them to heavy pressures. These sheets, under the effect of pressure and temperature are bonded together and form sheets of thicknesses varying from 0.12 mm to 15 mm. The laminates are extensively used for ornamental and decorative purposes.

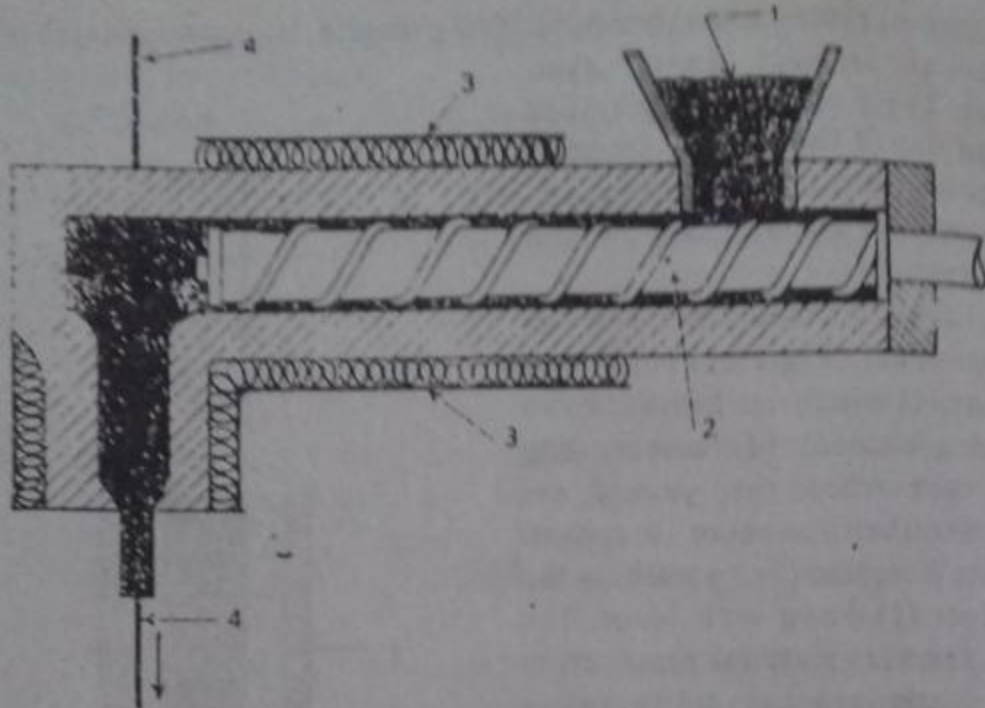

Fig. 12.3

12.4 PROPERTIES OF PLASTICS

The general and engineering properties of plastics are enumerated below:

(*i*) These are available in a variety of shades, textures and finishes to meet all the possible aesthetic requirements in building construction.

(*ii*) These can be moulded to any shape or size.

(*iii*) These are easy to work upon.

(*iv*) These offer high resistance to weathering and to corrosion.

(*v*) These are quite light in weight.

(*vi*) These are not attacked by insects or fungi.

(*vii*) These require little maintenance care.

(*viii*) These have good electrical insulation properties.

(*ix*) Some varieties of plastics have good optical properties.

(*x*) These have good sound and heat absorption properties.

(*xi*) These withstand moisture, oils and greases well;

(*xii*) These are easy to install.

12.5 USE IN BUILDING CONSTRUCTION

Plastic is a versatile material whose properties can be changed to suit varying requirements when used at different places and in different situations in a building. Its more important usages are discussed below:

12.5.1 Flooring. For flooring either Thermoplastics or Polyvinyl (PVC or PVA) are used in the form of sheets or tiles. Polyvinyl chloride (PVC) is resistant to abrasion and is unaffected by many chemicals.

(a) *Thermoplastic vinyl tiles.* These tiles are cut or punched out of rolls of masticated hot mixture of plasticised PVC, lime stone, asbestos and required pigments passed through hot rollers.

These tiles are unaffected by water oils or grease and withstand wear well. These tiles are laid on dry floor free from dust, grease or loose scales. The tiles are laid on cut back bitumen adhesive spread on the sub-base hot and rolled with light rollers.

(b) *PVC sheets or tiles.* Masticated PVC, its compounding ingredients and the required pigments are passed through hot rollers. The rolls are annealed and cooled before cutting them into tiles. Usual thickness of sheets is 1 mm. These sheets are provided with cheaper backing material so as to cut the cost and yet have a reasonally thick sheet that could be laid on normal floors. To ensure better adhesion to substrate, the underside of these sheets (to be cut into tiles if required) are roughened or patterned. Sheets with Hessian or felt as Backing too are produced.

These flooring tiles have excellent wearing properties and are unaffected by greasy or oily stuff. Inferior qualities become brittle after sometime.

These tiles expand on wetting and as such curl at the wet face.

Fabric based tiles are additionally liable to decay due to fungi attack.

These tiles should, as such, be laid on a dry sub-base free from all dirt, oil, grease or any loose scales.

The floor sub-base and the underside of tiles are coated with adhesive. When the adhesive becomes tacky, the tiles are laid in position and rolled with a light roller.

(c) *Polyvinyl acetate floors.* Floors laid with Polyvinyl Acetate are jointless in-situ finishes and are also termed as *plastic.*

(d) *Emulsion floor finishes* Cold mix of Polyvinyl Acetate emulsion, fillers and pigments is spread evenly on a smooth sub-base to provide a tough floor finish on drying. To have a thick finishing layer, successive thin layers are spread.

These floor finishes fairly wear resistant, dampen noise, are non-slippery and comfortable to walk. Though these floors can be washed without any damage yet these should not be allowed to get saturated as then they soften and have poorer resistance to wear.

12.5.2 Roofing. Corrugated sheets of phenolic-resin-bonded paper laminates manufactured in rather darker shades provide light, strong and corrosion resistant opaque roofing material.

Corrugated plain or curved sheets in glass reinforced polyester resin, or of Acrylic resin are translucent and when used for roofing they provide ample day light.

These sheets are resistant to weathering, are strong and light in weight.

12.5.3. Pipes. Plastic pipes are finding more and more usage in water supply, sanitation and in specialized industrial applications. Polythylene and PVC pipes are the most extensively used ones.

Polythylene pipes owe their popularity to their light weight flexibility, resistance to breakage from mechanical shocks and chemical inertness.

Acrylo-mitrile copolymer blends give rigid plastic pipes used as wall pipes. The pipes can be threaded and so are its fittings and fixtures. These pipes resist corrosion exceedingly well and can profitably be used for sewerage and for carrying industrial products.

PVC pipes withstand sewage erosion well and can as such be used in drainage, sanitation and in water supply schemes. These pipes are ductile, can be threaded and can be welded with hot gas stream and a PVC rod.

Plastic pipes are excellent in use at low temperatures, particularly when there is fear of metal pipe bursting due to freezing but they become soft at temperatures higher than 65°C.

12.5.4 Decorative laminated plastics veneer. These are versatile sheets marketed under trade names of *Formica, Sunmica, Sungloss Decolam* etc. Veneers of 1.6 mm thickness and panels of 3.2 mm thickness are available in sheets of sizes 244 cm × 122 cm and 274 cm × 122 cm of various shades and patterns.

It is a surface material, a smooth ready finished decorative veneer or board of exceptional toughness and durability. It is made from sheets of paper impregnated with selected resins. The impregnated papers are assembled into packs (A) (Fig 12.4). The tough core laminae (B). The last layer but one carries the colour-printed pattern. These visible laminae are coloured and patterned in a wide range, some to simulate decorative wood grains. This is protected by a transparent top sheet (C) which is impregnated with a colourless resin of extreme toughness. The assembly is then subjected to very great pressure and accurately controlled high temperatures. In the closely compacted paper layers a chemical reaction, polymerisation occurs. This fuses the combination into one homogeneous whole. The result is a superb decorative material possessing physical and chemical properties that ensure a uniformity in durability and finish unobtainable in any other material.

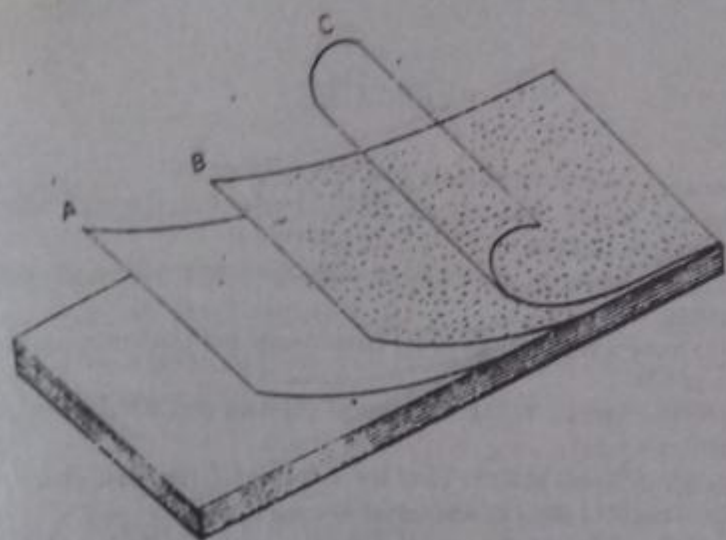

Fig. 12.4

It looks best and remains unblemished longer when bonded as flat as practically possible. Plywood supported on strong underframe or block boards offer an acceptable base for the laminate. Plain timber panels, no matter how well matured, are unsuitable and unreliable base for sound work.

It can be cut and sawn as ordinary plysheets. It can be bonded to any other material provided suitable adhesive is used. Synthetic resins are the most commonly used adhesives for bonding it with a wooden base like plywood, block board, chipboard etc. These provide a rigid waterproof, heat resistant joint. Light pressure of about 2.5 kg/cm² is required while the adhesive cures and though it is best provided by pressing at 100°C but even improvised cold pressing is quite adequate.

Its resistance to hard wear and rough usage are unrivalled. It withstands extremes of temperatures, light acids and alkalies, water (cold or hot). It is not stained by common dyes and common kitchen preparations. It can be bent to large curves and withstands minor scratches. Razor sharp scratches do damage it and should be avoided. It can be wiped clean with damp cloth with or without detergent powder or soap solution. It does not need polishing or any other maintenance.

It is as such used where elegance, durability and hygiene are the main considerations.

It is extensively used for table tops, wall panels, counters in kitchens and bathrooms, interior of bodies of trains, buses, aircrafts and ships etc. It is put to numerous industrial and commercial uses too.

EXERCISES

1. Differentiate between thermosets and thermoplastics.
2. Describe the salient features of PVC, PVA, Polythene cellulose acetate, Acrylic and Polythene plastics.
3. What are the different methods of manufacturing plastic goods? Describe injection moulding.
4. What is extrusion method? Give its advantages over other methods used for making plastic goods.
5. What are the salient characteristics of plastics and what is their scope for use in construction works?
6. What are the different plastics used for flooring? Give their characteristics.
7. What are laminated plastics and what are their uses?
8. What are the different types of plastics used for flooring? Discuss the peculiarities of each.
9. Write short notes on:
   (*i*) Injection moulding.
   (*ii*) PVC pipes.
   (*iii*) Polythene.
   (*iv*) Perspex.
   (*v*) Lamination.

Chapter 13

GLASS

13.1 GENERAL

Glass has been extensively used in building construction since long for glazing doors and windows, for insulation and for decoration. Rapid advances in glass technology have opened up newer avenues of its use in the construction industry. In this chapter we propose to study its composition, properties of its various commercial forms and their uses.

13.2 PRINCIPAL CONSTITUENTS

The glass is obtained by fusion of silica, chalk (lime) and potash or soda at over 1000°C. In order to modify its properties of hardness, brilliance and colour other ingredients like iron oxide, lead oxide, borax etc. are added in varying proportions. Functions of the various important constituents of glass are discussed below:

(*i*) *Silica*. It is the main constituent of all kinds of glass. Since it fuses at very high temperatures some alkaline admixture like sodium carbonate or potassium carbonate is added to it so as to make it fuse at lower temperatures. The admixtures added to lower the fusion temperature also make the liquid silica more viscous and better workabie.

(*ii*) *Potash*. This renders glass infusible and gives fire resisting properties to it.

(*iii*) *Soda*. It quickens fusion of glass and as such excess of it is harmful.

(*iv*) *Lime*. It imparts durability and toughness to glass.

(*v*) *Lead oxide*. It gives colour to glass and therefore its presence in glass is not much desirable.

(*vi*) *Cullet*. It is broken glass of the type desired to be manufactured that is added to the raw materials to bring down cost of production.

13.3 MANUFACTURE

All the constituents of glass discussed in Art. 13.2 are separately ground, sieved and mixed in definite proportions. The mix is then fused in a *tank furnace* or in a *pot furnace*. The former is used for large scale productions and the latter for smaller productions of superior quality. The charge that is fed at one end of the furnace is continuously taped in molten state at the other end. The molten glass is given the desired shape by any one of the following methods:

(*i*) *Blowing*. The operator dips one end of a blow pipe, 12 mm in diameter and 2 m long, in the molten glass and takes it out. The blow pipe is held vertically on taking it out after a dip The sticking molten glass lengthens. The operator then blows vigorously in the pipe which results in the sticking molten glass taking the shape of a hollow ball. When the blown ball cools down then it is reheated and blowing operation repeated. The process is repeated till the articles are ready.

(*ii*) *Flat drawing*. Iron rod is dipped into molten glass and moved sideways to form a plate of glass which is then passed between rollers to form glass sheet.

(*iii*) *Rolling*. Molten glass is poured over flat iron table which has rollers fitted at one edge. The molten glass is rolled into glass plate.

(*iv*) *Compression moulding*. Articles of irregular shape are moulded by pressing molten glass into moulds. This gives glass of better quality.

(*v*) *Spinning*. A machine is used to spin the molten glass. This gives very fine glass fibres. These glass fibres are extremely thin and very strong, do not shrink or expand, are unaffected by water, fire or insects and are used for heat, sound and electricity insulation.

13.4 CLASSIFICATION

Glass is usually classified into three categories: (*i*) Soda lime glass; (*ii*) Lead glass; (*iii*) Boro-silicate glass.

13.4.1 Soda lime glass. It is obtained from the fusion of a mixture of silica, lime, soda and alumina. Powdered glass too may be added. This glass is also termed as *Soda-ash glass*, *Soda glass* or *Soft glass*.

It is used for glazing doors, windows, and for making ordinary glass wares.

13.4.2. Lead glass. It is obtained from the fusion of a mixture of silica, lead and potash. Powdered glass too may be added. This glass is also termed as *flint glass*.

Lead glass has highly shining appearance and takes good polish. It is not affected by temperature. Cut glass work, electric bulbs and optical glass are made from it.

13.4.3. Boro-silicate glass. It is obtained from the fusion of silica, borax, lime and felspar. Powdered glass too may be added. This glass withstands high temperatures and as such laboratory equipment and cooking utensils are made out of it.

13.5 COMMERCIAL FORMS

Glass is marketed in various commercial forms to suit varying field requirements. Some important commercial forms of glass are discussed below:

13.5.1 Sheet glass. This is the variety most extensively used in engineering works. It is available in thicknesses of 2.0, 2.5, 3.0, 4.0, 5.0, 5.5 and 6.5 mm. Sheets up to 175 cm × 110 cm sizes are also available.

Following three classes of it are produced:

(*i*) *Ordinary Glazing Quality* (*O.Q*). It is used for general glazing.

(*ii*) *Selected Glazing Quality* (*S.Q*). It is better than O.Q and is used for better quality work.

(*iii*) *Special Selected Quality* (*S.S.Q*). It is used for superior quality work as for show cases and cabinet making.

It is used for glazing of doors, windows and for partitions.

13.5.2. Plate glass. It is made in thicknesses varying from 3 mm to 32 mm and sizes up to 275 cm × 90 cm. It is stronger and more transparent than the sheet glass. It is ground and polished.

Following three classes of it are produced :

(*i*) *G.G. Quality*. Used for cabinets, show cases, shop fronts, counters and shelves.

(*ii*) *S.G. Quality*. Mostly used in making mirrors.

(*iii*) *S.Q. Quality*. Superior quality for high class work.

13.5.3. Tempered plate glass. Glass plate is heated and then suddenly cooled to temper it. Tempered glass is much stronger than ordinary glass and is used for glazing entrance doors or in making table tops, shelves, counters etc. etc.

13.5.4. Laminated glass. Two or more glass plates, with intervening layers of transparent plastics, are bound under effects of heat and pressure.

This type of glass does not fly off in splinters when it breaks. It thus ensures safety at places where glass is liable to shatter.

Laminated safety glass used in glazing windows and doors of buildings and land transport available in 4 to 20 mm thickness. IS: 2553-1971.

13.5.5. Wired glass. It is a rough cast translucent glass with special steel wire mesh of 0.46 to 0.56 mm diameter completely embedded between the layers of the glass during the process of its manufacture.

It is fire retardant and provides safety in the event of any breakage, wire pieces holding the broken pieces from flying and causing injury. A special annealing process gives the wired glass additional resistance to breakage.

It is extensively used for *north light* glazing, sky lights, glazed partitions, door and windows in buildings. It is used at places where both light and safety are simultaneously required. It is available in 6.4 mm thickness.

For details refer to IS: 5437-1969.

13.5.6. Insulating glass. Two layers of glass separated by 6 mm to 12 mm of dehydrated air are hermetically sealed to provide heat insulation and to ensure transmission of light.

It is used in glazing doors and windows.

13.5.7. Coloured glass. By adding oxides of metals to molten glass, the finished product gets coloured. Coloured glasses are used for decoration work in building construction. Glasses with light tints are used to cut off sun.

13.5.8. Heat absorbing glass. It has bluish green tinge and cuts off ultra violet rays of sun. It is used in glazing windows of railway carriages and in buildings where heat of sun is desired to be cut. *Calorex* is a patent product available in market.

13.5.9. Flint glass. It is lead glass which shines and takes up good polish. It is used for cut glass work, as optical glass, for making electric bulbs and valves etc.

13.5.10. Ground glass. One face of plate of sheet glass is made rough by grinding. The idea is to render it translucent so that it transmits light but provides privacy by obstructing vision. It is used for glazing doors and windows of toilets and bed rooms etc.

13.5.11. Block glass. These are hollow sealed glass blocks made by fastening together two halves of pressed glass. They are made 10 cm thick and 15 cm, 20 cm and 30 cm square in sizes. Their edges are sealed with grit bearing plastic material so that a good bond is provided with mortar.

Ribs, flutes or prisms are cast on one or both their faces so as to render them translucent and free from glare. These blocks provide heat and sound proof partitions.

EXERCISES

1. What are the principal constituents of glass? Give the characteristics of each one of them.
2. Give different classifications of glass. Describe the properties of Lead glass.
3. Describe the uses of the following:
(*i*) Wired glass, (*ii*) Flint glass, (*iii*) Tempered plate glass, (*iv*) Ground glass, and (*v*) Laminated glass.
4. What type of glass shall you recommend for the following use:
(*i*) Outer door of a house, (*ii*) Toilet windows, (*iii*) Sky lights, (*iv*) Table tops, (*v*) Shelves in show cases, and (*vi*) Partition walls.
5. Give details of the various methods of fabrication of glass.

Chapter 14

TAR, BITUMEN AND ASPHALT

14.1 GENERAL

Tar, Bitumen and Asphalts form a group of interrelated materials widely used in the field of Civil Engineering in damp proofing buildings, water proofing basements, water proofing roofs, painting timber and steel and for constructing metalled roads. These materials are being put to more and more use. In this chapter we propose to study their origin, properties, uses and a few tests as laid down by the Indian Standards Institution.

14.2 TAR

It is a dark black viscous liquid. Depending upon its source of origin tar is classified into the following three categories:

(*i*) *Coal tar*. It is obtained as a byproduct in the destructive distillation of coal or as a byproduct in the manufacture of coal gas.

It is used for multifareous purposes such as coating of wooden poles and sleepers, iron poles and laterine walls etc.

For details refer to IS: 212-1961.

(*ii*) *Wood tar*. It is obtained by the distillation of resinous wood. Wood tar contains creosote and as such it has strong preservative properties.

(*iii*) *Mineral tar*. It is obtained by distillation of bituminous shales.

Tar is used as a preservative for wood work and metals embedded in earth. Tar felts are used for water proofing.

14.3 ROAD TAR

It shall be prepared entirely from crude tar as a byproduct of high temperature carbonization of coal in coke ovens or in retorts.

As per IS: 215-1961 there shall be five grades of road tar as follows:

RT 1—For surface painting under exceptionally cold weather conditions and for use on hill roads at high elevations.

RT 2—For standard surface painting under normal Indian climatic conditions.

RT 3—(*a*) For surface painting and renewal costs, and

(*b*) For premixing chips (top course and light carpets),

RT 4—For premixing tar macadam (base course), and
RT 5—For grouting.

14.4 CRUDE COAL TAR

It is a product of the destructive distillation of coal free from adulterants. Composition of the crude coal tar varies with the source that it is obtained from. It is used for coating of wooden poles and sleepers, iron poles, laterine walls, fishing nets etc.

For details refer to IS: 212-1961.

14.5 COAL TAR PITCH

It is either the residue of the direct distillation of crude tar produced by the high temperature carbonization of coal or is obtained by fluxing back such pitch residues with high boiling coal tar distillates to give products of the desired softening point.

It is a valuable ingredient in the product of a number of water proofing protective and binding compounds employed in masonry, steel and timber structures. It is also used for water proofing concrete structures, caulking of decks, as a saturant for roofing felts for damp proof courses, flooring mastics and as a base for coal tar paints.

Based on IS: 216-1961 coal tar pitch is classified into the following four grades: (*i*) Soft pitch; (*ii*) Soft medium pitch; (*iii*) Hard medium pitch; and (*iv*) Hard pitch.

14.6 BITUMEN

As per IS: 334-1965 Bitumen is defined as a non-crystalline solid or viscous material, having adhesive properties derived from petroleum either by natural or refinery process, and substantially soluble in carbon disulphide. These are brown or black in colour and may occur naturally, but are usually made as end products from distillation of or as extracts from selected petroleum oils.

Bitumen, the properties of which have been modified by blowing air through it under pressure at a high temperature, is termed as ***Blown Bitumen***.

Bitumen, the viscosity of which has been reduced by a volatile diluent, is termed as ***Bitumen cut back***. It is obtained by fluxing bitumen with distillates of petroleum or coal tar and is primarily used in road construction. It is of three types:

(*i*) Rapid curing (RC), (*ii*) Medium curing (MC), and (*iii*) Slow curing (SC).

Bitumen when suspended in a finely divided condition in an aqueous medium is termed as ***Bitumen emulsion***.

Bitumen that has been distilled (vacuum and steam refined) to a definite viscosity or penetration without further treatment is termed as *Straight run bitumen*.

It is dark brown in colour, sticky and soluble in carbon disulphide. It is extensively used in road construction, in making water proofing felts, filling and packing construction joints etc.

14.7 ASPHALT

As per IS : 334-1965 Asphalt is a natural or an artificial mixture in which Bitumen is associated with inert mineral matter. The word "Asphalt" should always be qualified by indication of its origin or nature. Natural Asphalt is also termed as *Native Asphalt*. Natural Asphalt obtained from lakes is termed as *Lake Asphalt*. A naturally occurring rock formation, usually lime stone or sandstone, intimately impregnated throughout its mass with bitumen is termed as *Rock Asphalt*. Asphalt is used in road making and in water proofing.

A few tests for Tar and Bitumen are discussed below:

14.8 TESTS FOR TAR AND BITUMEN

Samples, for putting tar and bitumen to different tests, are collected as per IS : 1201-1958.

Types of samples. (*a*) *Top sample*. It is the one taken at a level of one-sixth of the depth of the material below the top surface and in the centre of the container.

(*b*) *Middle sample*. It is the one taken at a level of one-half of the depth of the material below the top surface in the centre of the container.

(*c*) *Lower sample*. It is the one taken at a level of five-sixths of the depth of material below the top surface in the centre of the container.

(*d*) *Average sample*. True average or representative sample is such that its composition would be the same as that of any part of the quantity sampled if the whole were mixed to ensure homogeneity. It is usually made up by combining equal parts of samples drawn from levels at one-sixth, one-half and five-sixths of the depth of the liquid below the top surface.

(*e*) *Composite sample*. It is a mixture of the representative samples drawn from a number of containers in proportion to the contents of each container sampled.

While sampling and storing the samples care should be taken to see that neither any extraneous matter enters the sample nor anything is lost out of it by way of evaporation etc.

14.8.1. Penetration test. Below is discussed the detailed procedure in performing penetration test on Asphaltic Bitumen, Fluxed Native Asphalt and Blown type Bitumen. The procedure is as per IS : 1203-1958.

Definition. Penetration is the measure of hardness or consistency and is the vertical distance (expressed in hundreths of a centimetre) traversed by a standard needle entering the material under specified conditions of standard load, time and temperature.

Test. Soften the test sample to a pouring consistency between 75° and 100°C above the approximate softening point and stir it thoroughly so as to make it homogeneous and free it of air bubbles and water. Now pour the melt into a container* (a flat bottomed cylindrical metallic dish 55 mm diameter and 35 mm or 57 mm in depth) to a depth at least 15 mm more than the expected penetration. Cool the sample at 18°C for one hour and not letting the dust in the sample.

Now place it along with the transfer dish** in the water bath at 25°±0.1°C and allow it to remain for one hour.

Fill the transfer dish with water from the water bath. The water should be enough to cover the container completely. Now place the test sample in the transfer dish and place it on the stand of the penetration apparatus.

Wash the needle clean with benzene, dry, load with the specified load and adjust it to make contact with the surface of the sample. The superimposed load should be so adjusted that it added to the weight of the needle and the carrier comes to 100±0.25 gm. After bringing the pointer to zero release the needle for exactly five seconds and measure the penetration. At least three penetration observations should be made, for each the needle is dried after it is cleaned with benzene. Each observation is made at not less than 10 mm apart from the point of previous observation and not less than 10 mm from the edge of the dish. The sample and the transfer dish is transferred to the water bath after each observation. The value of penetration for the sample shall be the average of the observations taken.

14.8.2. Determination of flash point and fire point. The following definitions are based on IS : 334-1965.

Flash point. It is the lowest temperature at which the vapour of a substance can be ignited in air by a flame under specified conditions of test. The substance itself does not continue to burn.

*For materials having penetration of 225 or more the deeper dish is used.

**A small dish provided with some means which ensure a firm bearing and prevent the rocking of the container. It is of such capacity as to ensure complete immersion of the container during the test.

Fire point. It is the lowest temperature at which the material gets ignited and burn under specified conditions of test.

Tests. On IS: 1209-1958 are based the following details of the test:

(*a*) **Method A (Pensky-Martens—Closed), for determination of flash point for bitumen other than cut back bitumen.**

Apparatus. Following are the major parts of Pensky-Martens Closed Tester:

(*i*) *Cup*. It is made of brass and all its dimensions are standardized as per table 1 of IS: 1209-1958.

(*ii*) *Lid*. It includes the stirring device, the flame exposure device, cover proper and the shutter. All these conform to the specifications laid down in IS: 1209-1958.

Before the test is commenced, all parts of the cup and its accessories are thoroughly cleaned and dried. The cup is then filled upto the filling mark with the material to be tested. Insert the proper thermometers, ensure that all the locating devices are properly located, place the lid on the cup and set it in the stove. Light and adjust the test flame so that it is of 4 mm diameter. Adjust the head applied in such a way that the rise in temperature is between 5°C and 6°C per minute. Turn the stirrer at approximately 60 rpm.

Apply the test flame at each temperature reading which is a multiple of 1°C up to 140°C. At temperature ranges above 104°C apply the test flame at each temperature reading that is a multiple of 3°C. First application of test-flame is made at 17°C below the actual flash point. In applying the test flame the test flame burner and the shutter are so operated as to lower the flame in 0.5 seconds, left in its lowered position for one second and then suddenly raised to its high position. Stirring is discontinued during the application of the test flame.

Normally flash point shall be taken as the temperature read on the thermometer at the time of the flame application that causes a distinct flash in the interior of the cup. To the observed flash point a correction of 1°C is made for each variation of 25 mm in the atmospheric pressure from the average of 760 mm. The correction is positive if the recorded pressure is below and negative if it is above 760 mm.

(*b*) **Method B (Pensky-Martens—Closed) for determination of flash point for cut back bitumen.**

Apparatus for this test is the same as for method A above except that the stirrer is mechanically operated to stir in the downward direction at a speed of 70 to 80 rpm.

Head the tester and the material to be tested to a temperature 17°C lower than the expected flash point. Fill the space between the cup and the interior of the air bath with water heated to the temperature of the tester and the test material. Raise the temperature throughout the test at a rate of 1°C to 1.5°C per minute. Perform the test as explained in Method A above and apply the test flame at every 0.5°C rise in temperature.

(*c*) **Method C (Pensky-Martens—Open) for determination of open flash point and fire point.**

Apparatus used for method A above shall be modified for this test as under:

A clip encircling the upper rim of the cup and carrying the thermometer and test flame replaces the cover of the cub. The thermometer carrying tube shall have its centre on a radius at 90° (approximately) to the radius passing through the point of attachment of the test flame and shall be at such a height that when the thermometer is in position, its bulb shall be in the vertical axis of the cup and 12 mm below the filling line. The test flame shall be fixed at the vertical axis of the cup and in level with the upper edge of the cup.

To perform the test, the cup and its acccessories are thoroughly cleaned, dried and the cup filled with the test material up to the filling mark. The cup fitted with the clip carrying the thermometer and the test flame is placed in the stove. The test flame shall be lighted and adjusted so that it is of the size of a bead 4 mm in diameter. Application of heat shall be so adjusted as to cause a raise in temperature of 5°C to 6°C per minute.

Open flash point shall be taken as the temperature at which the flash first appears at any point on the surface of the material.

Fire point is the temperature at which the oil ignites and continues to burn for 5 seconds.

For details refer to IS: 1209-1958.

14.9 BITUMINOUS FELTS

Felts woven with vegetable fibres, cellulose or animal hair are treated with ordinary bituminous materials and given special surface finish with bitumen of higher melting point. This treatment imparts strength, durability, imperviousness, toughness with flexibility and resistance to wear and tear. These felts are commonly used in building construction. Common varieties of bituminous felts are :

14.9.1. **Bitumen impregnated felts.** The felts are prepared by thoro-

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ughly impregnating (not coating) under heavy pressure felts of fibre or hessian with bituminous compounds. These felts are available in rolls and are laid on dry surfaces, free from grease or oil, coated over with a glueing layer of mastic. After laying these layers are protected by a layer of suitable covering material. These felts are used for water proofing roofs and basements in buildings.

14.9.2. **Surface finished bituminous felts**. Bitumen impregnated felts are given a special treatment by spreading fine sand over it while the bitumen is still hot. This treatment enables use of these felts in exposed conditions.

For use in interior works the surfaces of felts are given fine finish with talcum powder or with mica Roofing felts after impregnation with bitumen of low melting point are alternatively coated with layers of bitumen, having higher melting point, on both sides. The surface is finally finished with fine sand, talcum powder or with mica.

14.9.3. **Reinforced bitumen felts**. The felts are strengthened to take up more wear and tear by reinforcing these with hessian or jute fabric. These are extensively used in water proofing roofs and basements.

EXERCISES

1. What is the difference between Tar, Asphalt and Bitumen?
2. What is coal tar pitch and what are its uses?
3. What are the various kinds of Bitumen and what are their uses?
4. Define Asphalt and give its uses.
5. Describe penetration test for Bitumen Asphalt.
6. Describe flash point/fire point test for Bitumen.

Chapter 15

MISCELLANEOUS MATERIALS

15.1 ASBESTOS

Asbestos is available in nature as a mineral in Marwar, Garhwal (in UP); Bhandara (in MP) and Mysore. It is a silicate of calcium and magnesium found in the form of very thin fibres in veins of metamorphic rocks.

It has low water permeability, is vermin proof and resists rot.

It is brown, grey and white in colour.

It is good for heat sound and electric insulation.

It is resistant to acids and alkalies.

Its fibres are capable of being woven into fabrics.

It is highly durable and is strong.

Its specific gravity is 3.10

Its melting point is 1200-1 50°C.

It acts as reinforcing material when mixed with ordinary Portland Cement.

Uses. Asbestos is used extensively for heat insulation. It is used for making fire proof padding, packing sheets and clothes for firemen and electricians. In the form of paper and mill boards asbestos is used for low voltage insulation.

Various products for use in buildings are made with a mixture of 8 to 20 per cent of asbestos with Portland cement. These products are called *asbestos* cement products.

Asbestos cement products are light in weight, strong, durable, water proof and resist corrosion. These can be sawn, drilled and drilled, nailed and screwed. It is rolled into various forms such as sheets, tiles and pipes for drainage etc. Everest Asbestos Cement Ltd. manufacture a variety of quality products made with asbestos.

Asbestos cement sheets. Asbestos cement paste obtained by mixing 15% asbestos fibres with cement and mixed with water is pressed under grooved or toothed rollers so as to give a series of waves or corrugations. Corrugations are given to increase strength and rigidity of sheets and ensure quick flow of rain water.

These are light, durable, impervious and fire resisting commonly used for roofing big halls, factories, workshops. These provide a reasonably priced roof covering which is a non-conductor of heat and is durable. A.C. sheets require no maintenance.

There are three types of A.C. sheets.

1. Everite 'Big Six'.

2. Everite standard: Sheets 0.76 m wide, 6.5 m thick and 1.1 m to 3 m in length. Overall depth of corrugations is 2.56 to 2.85 m. There are 10½ corrugations per sheet at a pitch of 5.4 cm.

3. Turnal-trafford sheets: 1.12 m wide, 1.3 to 3 m long and 6.5 mm thick. Every sheet has 4-5 cm deep corrugations alternating with flat portions. Pitch of corrugations is 34 cm. Excellent roof covering specially for large spans.

15.1.1. **Asbestos cement flat sheets.** These may be compressed or uncompressed and are intended for interior and exterior use. The compressed sheets are stronger than the uncompressed one's. Nominal thicknesses of these sheets are: 5, 6, 8, 10 and 15 mm with ±5 per cent tolerance. Their nominal lengths are 2400, 1800 and 1200 mm; and the width is 1200 mm with tolerance of ±5 mm in each case.

For details refer to IS : 2096-1966.

15.1.2. **Unreinforced corrugated asbestos cement sheets.** These are designed for roof coverings and walls of different types of buildings and for decorative and other purposes.

TABLE 15.1: Dimensions and Tolerances of Corrugated Sheets

All Dimensions in millimetres

S. No.	*Type of Sheets*	*Depth of Corrugations*	*Pitch of Corrugations*	*Overall width*	*Effective width*	*Nominal Thickness*	*Length of sheet*
(i)	Corrugated Sheets	48	146	1050	1010	6	1750 2000 2500 or 3000
(ii)	Semi-Corrugated Sheets	45	338	1100	1014	6	1750 2000 2500 or 3000
(iii)	Tolerances on Dimensions	+3 −5	+6 −2	+10 −5	+10 −5	+ Free −0.5	+5 −10

For details refer to IS : 459-1970.

15.1.3. **Asbestos cement boards.** These are made by moulding under pressure a mix of ordinary Portland cement and asbestos fibre. The boards are usually 1.22 metre wide 3 mm to 6 mm in thickness and up to 2.44 metre long. It has dense hard surfaces. The exposed surface is finished smooth. The sheets may be in the colour of plain cement or any other colour, with plain finish or with tiles cut on its surface or with marble finish. The sheets can be sawed and nailed with ease. These provide a nice wall covering with fire resistant properties. Asbestos is used for electric insulation and heat insulation.

Bakelite. It is a thermosetting plastic obtained by polymerisation of phenol (obtained from coal tar) and formaldehyde. It is of three categories:

An amber coloured substance called Bakelite *A* is obtained in the form of a liquid. Mixed with inert materials called *fillers* it is used for forming different materials. It is soluble in alcohol and acetone. On cooling Bakelite *A* solidifies to form Bakelite *B*. Further heat treatment of Bakelite *B* gives the final product called Bakelite *C*. It is dark brown in colour and melts at a temperature 50°C and is soluble in spirit. It is widely put to use in various electrical insulation, decorative fittings and for bearings in roller mills, propeller shafts, pumps and machines.

15.2 LINOLEUM

In it linseed oil is oxidized by exposure to air into a tough, rubber like substance which is then mixed with ground cork, wood flour, colouring matter and other ingredients. The resulting plastic material is pressed upon a backing of burlap. It is then thoroughly cured and seasoned by passing it through drying ovens to get linoleum which is used as floor covering for wood and concrete floors. After drying the whole surface is applied with transparent oil varnish.

Linoleum is of three types; *plain*, *printed* or *stamped* and *inlaid*. It is available in the form of tiles or as rolls 2.0 metre wide. Length of rolls is not less than 5.5 metre. Overall thickness is 4.5, 3.2, 2.0 and 1.6 mm. Tiles are 228, 305, 457 mm square.

Plain linoleum is of a uniform colour throughout its thickness which varies from 2 mm to 4.5 mm. It is available in a variety of shades. Thicker varieties of it known as *battleship linoleum* are well suited for heavy traffic.

Stamped or printed linoleum has a pattern printed on it in oil paints. Its thickness varies from 1.25 mm to 2 mm. It is fit for use in case of light traffic only. The pattern wears off in time even though it is still serviceable but unattractive.

Inlaid linoleum has small units of linoleum of various colours and shapes arranged in patterns and pressed on a burlap back. Each unit has a constant colour throughout the entire thickness. As such the pattern lasts as long as the linoleum lasts. These are of 2 mm to 3 mm thickness and are used extensively to give satisfactory services.

Suitable linoleum when properly laid lasts for many years.

Linoleum floors are durable and resist wearing.

Linoleum floors are resilient, quiet and comfortable.

Linoleum floors are hygienic and easy to maintain. These can be easily cleaned with soap. Excessive use of water or of strong soaps is injurious to linoleum floors. It swells due to moisture and is attacked by fungi. It is polished with wax polish.

Linoleum provides non-slippery floors.

These floors are economical and easy to install.

The following thicknesses are recommended for usage in the places noted against each:

4.5 mm Magazines, Canteens, Corridors, Hotels, Restaurants, Departmental Stores, Public Buildings, Hospitals, Ships, Railway Coaches, etc. etc.

3.2 mm Offices, Hotels, Restaurants, Cafes, Shops, Public Transport.

2.0 mm Offices (small), Domestic rooms etc.

1.60 mm Domestic rooms.

Linoleum is available both in tiles and full length rolls of about 15 to 30 metres.

15.3 THERMOCOLE

It is the trade name of a very light and cellular plastic material. Initially it is obtained in liquid form and then moulded into desired forms. It is an excellent insulating material of heat, sound and electricity.

It is very light, strong and durable.

It resists dampness.

Its compressive strength is 117 to 144 kg/cm^2.

It can be manufactured in any colour, though it is mostly white in colour.

It is very soft, can be easily sawn, cut, broken and scratched with nails.

Uses. It is used for heat and sound insulation in refrigerators and air conditioning buildings.

It is used in acoustic treatment and lining of ceilings and walls.

Thermocole is available in slabs 50 × 50, 60 × 60, 100 × 100, 50 × 100 cm and 15 to 25 mm thick.

15.4 REXIN

Molten PVC is applied to cotton cloth coming out of calendering machine and the treated cloth is then subjected to pressure between steel rollers. The rexin is then printed in desired colours and patterns. It is finally polished with varnish and dried. It is available in rolls. It is mostly used in upholstery work.

Leatheroid is synthetic leather used in making coverings for furniture and for interior decoration work.

15.5 WOOD WOOL

Generally it is bye-product of big timber industries in the form of shavings of light weight timbers like chir, deodar and kail etc. At times it may be specially prepared with the help of special planning machines.

It is an effective heat and sound insulating material. It is fairly cheap and flexible.

Generally it is used in packaging of delicate materials for transportation and in the manufacture of fibre boards.

15.6 RUBBER

It is essentially an elastic material and is obtained both as *natural* and as *synthetic* material.

15.6.1. **Natural rubber (India Rubber).** It is present as an emulsion in the latex of certain plants growing in Ceylon, Singapore, Malaya and Mexico etc. Latex is the milky colloidal fluid oozing from vertical grooves having an upward inclination cut around the trunk of the rubber trees. Pots are tied to the trunk of trees for collection of latex. Crude rubber is obtained from the latex by its coagulation with acetic acid, alcohol, alum or lime etc. Coagulation of latex is achieved even by heating. In certain cases the latex is mixed with appropriate compounding materials and then precipitated directly from the solution to the shapes required. More modern methods are used these days for obtaining rubber from the latex.

Crude rubber becomes hard and brittle in winter and soft and sticky in summer. It is therefore subjected to following treatments to improve and modify its properties.

(*i*) **Compounding.** To crude rubber are added certain compounds to modify its properties. The compounds that are added are vulcanizing agents, plasticizers, accelerators, fillers, hardners, reinforcing agents and pigments.

Vulcanizing agents are substances like sulphur which when added to crude rubber reduce its plasticity while maintaining its elasticity.

These are essential for vulcanization of rubber.

Plasticizers are materials like vegetable oils, rosin and wax etc. that soften the crude rubber.

Accelerators are substances like white lead, lime, magnesia etc. which when added hasten the process of vulcanization and reduce the requirements of sulphur.

Fillers are substances like lamp black, oxide of iron or zinc, china clay, magnesia, and silica etc. that modify the properties of rubber and at the same time reduce its cost. Substances that increase tensile strength of rubber are called *reinforcing agents*. Lamp black and zinc oxide are both fillers and reinforcing agents.

Hardners are substances like barium sulphate, calcium carbonate and sealing wax that give hardness to rubber and increase its tensile strength. Hard rubber withstands high temperature better.

Pigments are substances like ferric oxide, lithophone and lead chromate etc. that are added to give desired colour to rubber. Compounded rubber is hard, tough, weather and water resistant.

(*ii*) *Calendering* is the operation of passing rubber between large steel rollers kept at controlled temperatures and pressures. The rollers press rubber into sheets of desired thicknesses and sizes.

(*iii*) *Vulcanization* treatment of rubber with sulphur or compounds resulting in a change in the properties of rubber is known as *Vulcanization*. Vulcanization renders it useful for all seasons. Vulcanization with 1 to 5 per cent sulphur produces soft rubber whereas with 30 per cent sulphur produces hard rubber. Increasing sulphur gives harder and less flexible product. Full vulcanization requiring about 45 per cent sulphur will give rise to a fully rigid product known as *Ebonite*.

Sulphur is absorbed by rubber when they are heated together at 135°C to 160°C. To accelerate the process of vulcanization accelerators may be used. Vulcanization makes natural rubber much less sensitive to changes of temperature, more elastic and strong, more durable and resistant to action of water, base and dilute acids. It is a bad conductor of heat, resistant to abrasion, tough and shock absorbent. It can be moulded to any shape.

15.6.2. Reclaimed Rubber. Rubber waste and worn out rubber articles are treated for reuse and the rubber so obtained is called *reclaimed rubber*. Worn out rubber and rubber waste is cleared of all metal or other matter and heated with alkali solution in closed steel vessels. Separate fabric contents and free sulphur. The treated rubber is washed with clean water and then dried to get what is called the reclaimed rubber. Reclaimed rubber may be mixed with some raw rubber. Reclaimed rubber is cheaper, is of uniform composition, more durable, more easily compounded, vulcanized and moulded. However it has low elasticity, low tensile strength and poor resistance to friction.

15.6.3. Sponge Rubber. It is had by adding sodium-bicarbonate during vulcanization. Small pores are left on evaporation of moisture from within the rubber. This rubber has better heat and sound insulating properties.

15.6.4. Synthetic Rubber. Important varieties of synthetic rubber are obtained from petroleum, coal tar and alcohol. Properties of synthetic rubber, though similar to those of natural rubber can have wider variations. Synthetic rubber has better resistance to light rays, weather, acids, oils and greases etc. Synthetic rubbers are getting more popular than natural rubbers and has wider uses.

15.6.5. Rubber flooring materials for general purposes. Rubber flooring material is well suited for covering floors of domestic and public buildings, cinemas, hospitals, large stores, ships, transport vehicles etc. Toppings of these floors may be plain or marbled and ribbed or fluted. Backings may be fabric backing or fabric insert, sponge rubber backing or plain rubber backing. The flooring should be satisfactorily vulcanized, free from sulphur bloom and objectionable odour and blisters, cracks and embedded foreign matter. The colour of flooring should not be affected by cleaning with water and washing soap or floor polish.

Sizes of tiles are 200 × 200 mm, 300 × 300 mm and 500 × 500 mm. Sheets are 900 mm wide and of lengths 5, 3.5 or 2.5 m. Thickness varies for 2.5 to 6.5 mm.

The rubber floor coverings are used in the public and industrial buildings, buses and ships because of their fair weather resistance quality, resiliency and reduction in noise.

For details refer to IS: 809-1970.

15.7 WIRE ROPES

Seven or more steel wires of specific composition and each of a specific diameter are twisted helically into strands. Three or more of these strands are then twisted helically around a wire core. Ordinarily the wires and the strands are twisted in opposite directions. However, if the ropes are likely to be subjected to abrasive action then the wires and the strands are twisted in the same direction.

Two methods for twisting or laying of wire ropes are:

(*i*) *Lang Lay*. This is the most commonly used method. In it the wires in the strands and the strands in the rope are all twisted in the same direction.

(ii) *Regular Lay*. In this method the strands in the rope are twisted in a direction opposite to the one in which the strands are twisted in the rope.

6. The number of strands in the rope and the number of wires in each strand designate the type of the rope. A 6 × 19 rope stands for a wire rope having 6 strands and each strand having 19 wires. The most common ropes are 6×7; 6×19; 6×39 and 8×19. However, to meet specific requirements wire ropes of desired specifications are made. While specifying the rope in addition to number of strands in the wire and the number of wires in a strand, the method of twisting/laying the rope too is specified.

Wire ropes are stiff, strong, flexible and resistant to wear. Lang layed wires are more flexible than the regular layed ones but are relatively weaker. Actual properties of a rope, however depend upon the chemical composition of wires, the number of wires in a strand, the numbers of strand in the rope and the method used in twisting.

Wire ropes are used in elevators, arial cable ways and suspension bridges.

Nominal diameters of steel wire suspension ropes are : 6, 7, 8, 9, 10, 11, 12, 13, 14, 16, 18, 19, 20 mm.

For details refer to IS : 2365-1977.

15.8 PLASTER OF PARIS

Gypsum found as hydrous sulphate of calcium in amorphous mineral or in crystalline form when heated turns into a fine white powder called *plaster of paris*. It sets quickly on mixing with water. While setting it gives out heat. Because of its property of slight expansion on setting it is excellent for filling of cracks/holes in plastered surfaces. It is also used for filling cracks and knots in wooden surfaces before painting/polishing.

15.9 GYPSUM PLASTER BOARDS

They are used for lining walls and ceilings of buildings. Decoration may be applied direct to the face of gypsum wall boards. If, however, gypsum plaster is to be applied on the face of the board then *gypsum plaster* base board, which is provided with perforations at manufacturing stage, is used. Strengthened variety of it called *Fibrous Gypsum Plaster Boards*, wherein gypsum plaster is mixed with sisal, coconut or other fibre forming body, are preferred for lining ceilings, covering walls and for partitions in normal dry environments in buildings. Gypsum boards are comparatively light and have high fire resisting properties. Widths of these boards are 400, 600, 800, 900 and

1200 mm, lengths 1200, 1500 and 1800 to 3600 mm in steps of 100 mm. Thicknesses vary from 9.5 to 15 mm.

For details about Gypsum Plaster Boards refer to IS : 2095-1982 and for Fibrous Gypsum Plaster Boards refer to IS: 8273-1976.

15.10 ADHESIVES

It is a substance that binds two or more surfaces together. At times it can be a better substitute for welding/riveting. Adhesive may be applied by brushing, spraying or roller coating over surfaces to be joined. Before applying the adhesive the surfaces should be cleared of all oils, greases, dirt or any other matter adhering to the surfaces.

Adhesives can join a variety of surfaces like wood, glass, metals and plastic etc. Adhesives give quick and easily formed joints impervious to gases and liquids. However, adhesives cannot be used to join all materials and the choice of adhesive to be used depends upon nature of materials to be joined. It takes time for adhesives to set and gain strength. Joints made with adhesives loose their stability at high temperatures.

Adhesives are either *glues* or *resins*.

(*i*) **Glues.** Glues are derived from animals or from vegetables. *Animal glues* are derived from different parts like hides or bones of animals. These are prepared by boiling in water horns, hoofs, bones and skins of animals. Animal glues are prepared from blood and eggs too. It is available in the form of flakes, granules, cakes and jelly.

Animal glues are easy to apply and are stronger than vegetable glues, but are not resistant to moisture and fungus. These glues are primarily used in wood work.

Vegetable glues. These are primarily used in wood based and allied industries. *Casein glues* obtained milk, curd and lime gives strong waterproof wooden joints which withstand weathering well. These glues are mostly used in plywoods.

Starch. Starch is derived from corn, wheat and potatoes etc. and is used in laminated boards and paper etc.

Gum Arabic is a glue derived from acacia tree. It is soluble in water. It is recommended for use in packaging exposed to tropical conditions, joining paper and wood.

Soyabean protein is derived from soya seed. It is reasonably good for use with plywoods.

Zein is a product of corn, is cheap and may be used with other adhesives.

(*ii*) **Resins.** Glues may be from *natural resins* or from *synthetic resins*.

Glues from natural resins are like *rosin*, *shellac* and *asphalt*.

Synthetic resins are either *thermosetting resins* or *thermoplastic resins*. Synthetic resins are more commonly used ones.

Thermosetting resins include those resins that are formed from phenol formaldehyde, polyesters, epioxides and silicon resins. These give high strength and stability adhesives at high temperatures and resist moisture.

These are used in plywood, laminate glass, ceramic bonding and for bonding metallic components.

Thermoplastic resins do not resist moisture or heat. These become soft on heating. Most commonly used thermoplastic resin are vinyls e.g. polyvinyl acetate and acrylics.

15.11 CORK

It is made from the bark of a tree. It is highly elastic and compressible. It is light and is unaffected by moisture.

Cork carpet and *Cork tiles* are used for flooring. Wood or concrete floors may be coverd with cork carpet which is a covering similar to linoleum but is more resilient, porous and less durable. Cork carpet is available in the form of rolls 6 mm thick and 1.83 metre wide. It is available in many colours. It is particularly suitable as a floor covering in churches, theatres and public places where a noiseless floor covering is essential.

Cork tiles are obtained by compressing cork shavings in moulds to thickness of 12 mm. The moulded tiles are then baked. Cork tiles are elastic, noiseless, fairly durable and quite absorbent and are used for wall covering as well as for flooring.

15.12 GLASS WOOL

Thin fibres of glass are spun out of molten glass. These fibres are fairly flexible and have high tensile strength as such these can be woven into mats.

Glass Wool is available in loose fibres, quilts, mats, rigid or semi-rigid slabs. It is chemically inert, durable and waterproof.

Glass Wool is used as filter in air conditioners, for electric insulation, for heat insulation and for filtration of corrosive liquids.

15.13 EBONITE

It is obtained by vulcanising rubber with large amount of sulphur. Ebonite becomes soft on heating and can be moulded to any shape, takes good polish, is unaffected by moisture or light acid is durable. Its colour varies from grey to dark.

It is extensively used in electric insulation.

15.14 MICA

It is a natural mineral found as thin sheets whose colour and composition varies. It is an excellent insulator of electricity and is fairly good insulator of heat.

It is used for electric and heat insulation.

15.15 CEMENT CONCRETE FLOORING TILES

Cement concrete flooring tiles may be:

Plain Cement Concrete Tiles. In these no pigment or stone chips are used in the wearing surface.

Plain Coloured Tiles. These have plain wearing surface wherein pigments but no stone chips are used.

Terrazo Tiles. In these at least 25 per cent of the wearing surface is composed of stone chips in a matrix of ordinary or Coloured Portland Cement mixed with or without pigments and mechanically ground and filled. Standard sizes available are 200×200×20 mm; 250×250×22 mm and 300×300×25 mm. Half tiles rectangular in shape too are available.

Colour and texture of wearing layer shall be uniform throughout its thickness.

For details refer to IS: 1237-1980.

15.16 CEMENT CONCRETE PIPES

Pipes of upto 100 mm diameter are cast into moulds. Pipes of larger diameters and especially those that have to carry water at high pressure are cast by pouring cement concrete in moulds rotating at high speeds around its vertical axis. The cement concrete is reinforced with hard-drawn steel wire rings held in position by longitudinal binders welded to them. These spun cement concrete pipes are capable of withstanding high internal pressures and are extensively used in water supply and in sewerage. Popularly these pipes are called *Hume Pipes* and are manufactured by "Indian Hume Pipe Company".

EXERCISES

1. What is Asbestos? Give its properties and uses.
2. Write short notes on:
   (i) A.C. corrugated sheets.

(*ii*) A.C. flat sheets.
(*iii*) Unreinforced corrugated A.C. sheets.
(*iv*) A.C. boards.

3. What is Bakelite? Give its properties and uses.
4. What is Linoleum? Give its anvantages and disadvantges as a flooring material.
5. Write short notes on:
   (*i*) Thermocole.
   (*ii*) Rexin.
   (*iii*) Wood Wool.
6. Explain vulcanization of rubber.
7. Write short notes on:
   (*i*) Reclaimed rubber.
   (*ii*) Sponge rubber.
   (*iii*) Synthetic rubber.
   (*iv*) Rubber flooring.
8. How are steel wire ropes designated ? What are the properties and uses of wire ropes.
9. Write short notes on:
   (*i*) Plaster of Paris.
   (*ii*) Gypsum plaster boards.
   (*iii*) Cork.
   (*iv*) Glass Wool.
   (*v*) Concrete flooring tiles.
   (*vi*) Hume pipes.
10. What are adhesives? What are it different types?
11. Write short notes on:
   (*i*) Animal glue.
   (*ii*) Vegetable glue.
   (*iii*) Thermosetting resin.
   (*iv*) Thermoplastic resin.