

LECTURE NOTES
ON
BMC&P

UNIT- I:

STONES AND BRICKS

BUILDING STONES: Man requires different types of buildings such as houses, bungalows, flats etc for His living. For his activities man also require Hospitals for his health; Schools, Colleges and Universities for his education; Banks, Shops, Offices and Factories for doing works; Railway buildings, Bus stations and Air terminals for his transportation; Clubs and Theatres for recreation and Temples, Mosques, Churches etc for worship. Each type of the above buildings has its own requirements and needs building stones to construct the same. The period from 1750 A D onwards is known as the period of *Modern Architecture*.

The use of reinforced concrete in construction triggered the rapid development of modern architecture. Structural components such as Columns, RCC slabs became increasingly popular because of the increased speed in construction. Use of plywood, glass, decorative materials etc helped the designers to make the new structures look more elegant in addition to the usage of various building stones.

So, the engineering structures are composed of materials and are known as the *engineering materials (or) building materials*. Hence, Building materials have an important role to play in this modern age of technology. Building stones are obtained from rocks, are derived into three groups viz., *Igneous, Sedimentary and Metamorphic rocks*.

QUARRYING OF STONES: The process of taking out stones from exposed surface of natural rock beds is known as the quarrying. While selecting a quarry site, one should remember that the availability of quantity; desired quality, transportation facilities, cheap local labor, and free from the permanent structures in the vicinity, drainage of rainwater etc..

In case of a quarry, the operations are carried out at ground level (in an exposed condition) whereas in case of mine, the operations are carried out under the ground at greater depths.

SELECTION OF A SITE FOR QUARRYING:

- Availability of Raw material, Tools, Power, Labor
- Space for dumping of refuse material.
- Distance of quarry from roads, railways.
- Proximity to the transportation facilities.
- Easy availability of clean water in sufficient quantity throughout the year.
 - Economy in quarrying
 - Blasting material availability
 - Absence of permanent structures
 - Geological data regarding rock formations.

STONE QUARRYING TOOLS

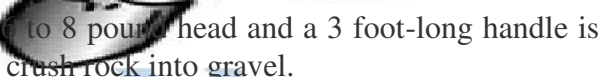
Tamping Bar: A tamping bar has a small blade at one end for loosening compacted or rocky soil and a flattened end for tamping..



Shovels: Shovels are available in various shapes and handle lengths. shovels are most common for trail work and are used to move loosened soil, to dig trenches. They can also be used for cleaning of culvert outlets.



Post Hole Digger: Used for removing soil from holes. Soil should be lifted from the holes.



Sledge hammer: A sledgehammer with a 6 to 8 pound head and a 3 foot-long handle is most useful for trail work. It can be used to crush rock into gravel.



Single Jack Hammer: A single jack (3 to 4 pound head with short handle) hammer can be used with a star drill to punch holes in rock.



Star Drill: Star drills are usually about a foot long and weigh a pound. They are used with single jack hammers to punch holes in rock.

The plug & feather method involves drilling a series of round holes in the rock spaced every six inches or so apart. The typical round hole ranges for 1/2 inch to 1 inch in diameter and 3 to 4 inches deep. These holes are drilled using either a single bladed *plug drill* or a *star drill*. The drill is struck by a *hammer*. The stone dust which accumulates in the holes is removed using a simple tool called a scrapping *spoon*. Once the holes are drilled, two shims called *feathers* or *half-rounds* are placed in the hole and a *wedge* called a *plug* is placed between the two feathers.



Typical Plug Drills - (Top) drill with a round blade (bottom) drill with pointed blade



Scraping spoon



Two feathers (shims) with a plug (wedge) between them



HAND PLUG DRILLS



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FLAT WEDGE PLUG

METHODS OF QUARRYING: The purpose of quarrying is to obtain building stones for various engineering purposes. Depending upon the nature of rocks and the purpose for which stones are needed, quarrying is done by adopting the following methods:

Quarrying is carried out by employing hand tools for digging / excavation, Heating, Wedging and Blasting.

1.Digging / excavation: In this method, the stones are merely excavated with the help of suitable hand tools such as Pick axes, Hammers, Spades, Chisels. This method is useful when soft stones occur in the form of small blocks.

2.Heating: In this method, the surface of rock is heated by placing pieces of wood or by piling a heap of fuel over the surface and fired for a few hours. Due to unequal expansion, the upper layer of rock separates out. The detached portion of rock is then removed by suitable hand tools.

This method is suitable when the rock formation consists of horizontal layers of shallow depth. Sometimes, intermediate layers are to be separated from the top and bottom layers. In such a case, the intermediate layer is heated and the expansion separates it from the other two.

3.Wedging: This method of quarrying is usually adopted for rocks such as Sandstone, Limestone, Marble, Slate, Laterite etc.. About 10 – 15 cm deep holes, at around 10 cm spacing are made vertically in the rock. Steel Pins and Wedges or Plugs are inserted in them. These plugs are then struck simultaneously with sledge hammer. The rock splits along the lines of least resistance through the holes.

large masses of rocks. Explosives such as Gun powder (Blasting powder), Dynamite, (Gelatin), Detonators, Fuse coil etc. are used.

The blasting powder and dynamite are commonly used as the explosives. The blasting powder is also known as the Gun Powder which is a mixture of charcoal, salt petre (KNO_3) and sulphur.

Fuses: It is required to ignite the explosives. It is in the form of a small rope of cotton coated with tar and with a core of continuous thread of fine gun powder. The rate of burning of a good fuse is about 10 mm per second.

Gun cotton: The clean cotton is saturated in a mixture of nitric acid and sulphuric acid. It is pressed into blocks or sticks while it is wet. It is as strong as dynamite. But its shattering power is less.

Liquid Oxygen: It is oxygen in liquid state. It is stored in a special container. It is comparatively cheap and used for blasting on a large scale for mining operations.

COMPARISON OF BLASTING POWDER AND DYNAMITE

Item	Blasting Powder	Dynamite
Action in quarrying	Large blocks of stones are obtained	Small blocks of stones are obtained
Cost	Cheap	High cost and is about 5 times than that of blasting powder
Destructive power	weak	Very strong and 6 times than that of blasting powder.
Efficiency	0.40 m ³	0.60 m ³
Use	Used for ordinary type of quarrying work	Used for tunneling and mining operations

PRECAUTIONS IN BLASTING:

- Blasting should not be carried out in late evening or early morning hours
- A siren should warn the work men and nearby public to maintain a safe distance.
- The danger zone, an area of about 200 mts radius should be marked with red flags.
- First aid should be available
- The number of charges exploded and the misfires should be recorded
- Explosives should be stored and handled carefully.
- Detonators and explosives should not be kept together

STORAGE OF EXPLOSIVES:

- The explosives should be stored in a magazine which should be away from residential areas, petrol depots.
- The magazine should have ventilators at high levels and should have concealed wiring.
- Magazine should be protected from lightning.
- Smoke or fire should not be allowed in the nearby area.
- Explosives should be protected from extreme heat or cold and also from moisture.
- The magazine should be surrounded by a barbed wire and the entry should be

restricted.

Specific gravity; Texture; Toughness Index; Water Absorption; Weathering; Density; Bulk Density; Density Index; Temperature Resistance etc., are to be properly studied before making final selection of any building material for a particular use.

Porosity (α): In simple terms, porosity may be described as the amount of openings (or) interstices (or) empty spaces present in a rock. However, Porosity may be defined as “the ratio of openings or pores or voids (V_i) in the soil/rock to the total volume of the soil / rock (V) expressed as percentage”. If α is the porosity, then $\alpha = V_i / V$ where V_i is the volume of inters tices and V is the total volume. The average porosity values for some common geological formations are as follows:

Ro ck	P o r o s i t y	Rock	P o r o s i t y
Granite, Quartzite	1 · 5 %	Only Gravel	2 5 %
Shale, Slate	4 %	Only Sand	3 5 %
Limestone	5 - 1 0 %	Only Clay	4 5 %
Sand with gravel	2 0 - 3 0 %		

Permeability: The permeability of a rock or soil defines its ability to transmit a fluid or water . Permeability depends on the porosity and interconnected pores character of the rock, thus more porous rocks are more permeable too. (not always). Permeability in a rock is measured in *darcies* ($1 \text{ darcy} = 0.987 \mu \text{ m}^2 \text{ square micrometer}$).

- Eg: 1. Shales are highly porous but less permeable because of fine grained nature which does not allow water to pass through the rock due to less interconnected pores.
- Eg: 2. Vesicular basalts are highly porous but less permeable because the vesicles in them are not interconnected (i.e., the effective porosity is less).

Crushing Strength: For a good stone, the crushing strength should be greater than 100 Newton’s / mm^2 . The approximate value of crushing strength of some of the stones are:

S N o	Roc k type	Buildin g Stone	Crushing Strength (N/mm²)
1	Ign eou s	Basalt	150 – 185
2		Diorite	90 – 150
3		Granite	75 – 127
4		Syenite	90 – 150
5	Sedi ment ary	Limestone	54
6		Sandstone	64
7		Shale	0.20 – 0.60
8	Meta morp hic	Gneiss	206 – 370
9		Slate	75 – 207

Appearance: The stones which are to be used for face work should be decent in appearance and capable of preserving their color uniformly for a long time. It is desirable to prefer light colored stones as compared to dark coloured stones because there are chances of the latter variety to be attacked easily by weathering agents.

Durability: A good building stone should be durable. The various factors such as Chemical composition; Resistance to atmospheric conditions etc... influence the durability of a stone. Following are the important atmospheric agencies which affect the durability of a stone.

- a) Alternate conditions of heat and cold due to differences in temperature
- b) Alternate conditions of wetness & dryness due to rain and sunshine
- c) Chemical agencies such as dissolved gases in rain (eg: NO_x; SO_x)
- d) Growth of trees and Creepers in the joints between the stones.
- e) Wind with high velocity.

Co-efficient of Hardness: The co-efficient of hardness, as worked out in hardness test should be greater than 17 for a stone to be used in road work. If it is between 14 and 17, and < 14, the stone is said to be medium and poor hardness respectively and such stone should not be used in road works.

Specific gravity: For a good building stone, the specific gravity should be greater than 2.7 The heavy varieties of stones with more compact and less porous can be used for various engineering applications such as dams, weirs retaining walls, docks etc.. On the other hand, the lighter varieties of stones are to be used for domes, roof coverings etc.

Texture: A building stone should have compact, fine crystalline nature, free from cavities, cracks, loose material, softness etc.

Toughness Index: In impact test, if the value of toughness index comes below 13, the stone is not tough. If it comes between 13 and 19, the stone is said to be moderately tough. If it exceeds 19, the toughness of stone is said to be high.

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Weathering: A building stone should be capable of with standing adverse effects of various atmospheric and external agencies such as rain, frost, wind etc..

Density (p) is the mass of a unit volume of homogeneous material denoted by: $p = M / V$ (g/cm^3) where $M = mass (g)$ and $V = volume (cm^3)$.

Bulk density (pb) is the mass of a unit volume of material in its natural state (with pores / voids) calculated as $pb = M / V$ (Kg/m^3) where $M = Mass$ of specimen (Kg) and $V = Volume$ of specimen in its natural state (m^3). Density & Bulk density of some building materials are as follows:

Material	Density (g/cm^3)	Bulk density (Kg/m^3)
Brick	2.5 – 2.8	1600 - 1800
Granite	2.6 – 2.9	2500 - 2700
Portland cement	2.9 – 3.1	
Wood	1.5 – 1.6	500 - 60
Steel	7.8 – 7.9	7850
Sand		1450 - 1650

Density Index (po) is the ratio between the bulk density and density ie. $Po = pb / p$

Density index indicates the degree to which the volume of a material is filled with solid matter. For almost all building materials Po is less than 1.0 because there are no absolutely dense bodies in nature.

In addition, Percentage wear, resistance to fire, dressing etc are also to be considered for a good building stone.

DRESSING OF A STONE: The stones, after being quarried, are to be cut into suitable sizes and this process is known as the dressing of stones. The dressing of stones is carried out for the following purposes:

- To obtain a definite and regular shape.
- To make the transport from quarry easy and economical.
- Provides pleasing appearance
- To suite to the requirements of stone masonry.
- At quarry site, it is possible to get cheap labour for the process of dressing of stones.
- It is possible to sort out stones for different works
- The irregular and rough portions of the stones are removed which decrease the weight of stones.

Following are the varieties of finishes obtained by the dressing of stones:

Dragged (or) Combed finish: In this type of finish, a piece of steel which is similar to a comb is rubbed on the surface in all directions and surface of the stone. This finish is suitable for soft stones only.

Punched finish: On the stone surface, the depressions are made by using a punch. The surface of the stone takes the form of a series of hollows and ridges.

Reticulated finish: This type of finish represents anet – like appearance. A margin about 20 mm wide is marked on the edges of stone and irregular sinking's are made on the enclosed space. A pointed tool is used to put the marks on the sunk surface so as to present a pock – marked appearance.

Tooled finish: The stone surface is finished by means of a chisel and parallel continuous marks either horizontal or inclined or vertical are left on the surface.

Rock faced finish: Some stones, as obtained from the quarry, possess smooth surface and they can be directly placed on the work. Such a stone surface is termed as Rock – faced (or) quarry – faced finish.

Vermiculated finish: This finish is similar to reticulated type except that the sinking's are more curved.

ARTIFICIAL STONES: Where durable natural stone is not available at reasonable cost, artificial stone, also known as CAST STONE becomes the choice. Artificial stone is made with cement and natural aggregates (crushed stone) and sand with desired surface finish. Suitable color pigments may be added. Following procedure is generally adopted in making an artificial stone:

- A mixture of 1½ parts of stones of size 3–6 mm; 1½ parts of stones of size < 3mm and 1 part of cement by volume is prepared.
- The necessary pigment is added to produce the desired color effect to the above mixture.
- Required quantity of water is added and thorough mixing is done.
- The mixture thus prepared is transferred to special moulds.
- The mixture is allowed to harden and its surface is kept wet.
- The artificial stone is then ready in block form.
- Polishing can be done if required.

FORMS OF ARTIFICIAL STONES:

Cement Concrete: This is a mixture of cement, fine aggregate, coarse aggregate and water. If steel is used with cement concrete, it is known as the Reinforced Cement Concrete (RCC). Concrete blocks are used in construction of piers, steps, window sills etc...

Mosaic Tiles: The pre-cast concrete tiles with marble chips at top surface are known as the mosaic tiles.

Terrazzo: This is a mixture of marble chips and cement. It is used for bath rooms, residential buildings, temples etc...

Victoria Stones are granite pieces with the surfaces hardened by immersing in soda silicate for about two months.

Ransom Stones are prepared by mixing soda silicate with cement to provide decorative flooring. These are also known as chemical stones. These have compressive strength of about 32 N / mm^2 .

BRICKS

The common brick is one of the oldest building material and it is extensively used at present as a leading material in construction because of its durability, strength, reliability, low cost, easy availability, easy to handle etc.. Bricks are used for building up exterior and interior walls, partitions, footings and other load bearing structures.

The Great Wall of China (210 BC) was built with bricks. The other examples of the use of bricks in early stage of civilization could be in Rome. A number of country farm houses still exist in Great Britain and profess to be the monuments of the excellent hand – made bricks.

A brick is rectangular in shape and of size that can be conveniently handled with one hand. Bricks may be made of burnt clay or mixture of sand and lime (or) of Portland cement concrete.

Size of a standard brick (modular brick) should be $19 \times 9 \times 9 \text{ cm}$. However, the bricks available in most part of the country still are $9'' \times 4 \frac{1}{2}'' \times 3''$ and are known as field bricks. Weight of such a brick is 3.0 kg.

An indent called frog, 1 – 2 cm deep is provided for 9 cm height bricks only. The purpose of providing frog is to form a key for holding the mortar and therefore, the bricks are laid with frogs on top. Frog is not provided in 4 cm high bricks.

COMPARISON OF BRICKSTONE AND STONEMWORK: The brickwork is superior to the stonework in the following respects:

- At places where stones are not easily available but where there is plenty of clay, brickwork becomes cheaper than stonework.
- The cost of construction works out to be less in case of stonework as less skilled labour is required in the construction of brickwork than brickwork.
- No lifting devices are necessary to carry bricks as they can be easily moved by manual labour.
- The bricks resist various atmospheric effects better than stones.
- In case of brickwork, the mortar joints are thin and hence the structure becomes more durable.
- It is easy to construct connections and openings in case of brickwork than stonework.

CHARACTERISTICS OF GOOD BRICK: The essential requirements for building bricks are sufficient strength in crushing, regularity in size, and a pleasing appearance when exposed to view.

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

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

Texture and compactness: The surfaces should not be too smooth to cause slipping of mortar. The brick should have uniform texture and should not show fissures, holes etc..

Hardness and soundness: The brick should be so hard that when scratched by

a finger nail no impression is made. When two bricks are struck together, a metallic sound should be produced.

Water Absorption should not exceed 20% of its dry weight when kept immersed in water for 24 hours to 48 hours.

Crushing Strength should not be less than 10 N / mm².

Brick earth should be free from stones, Kankars, Organic matter, salt petre etc..

COMPOSITION / INGREDIENTS OF GOOD BRICK EARTH:

For the preparation of bricks, clay is usually used. The clay used for brick making consists mainly of silica and alumina mixed in such a proportion that the clay becomes plastic when water is added to it. It also consists of small proportions of lime, iron, magnesium, sulphur etc.. The proportions of various ingredients and functions are as follows:

Silica	50 – 60 %
Alumina	20 – 30 %
Calcium	10 %
Mg	< 1 %
Ferric Oxide	< 7 % < 20 %
Alkalis	< 10 %
SO ₃ ; H ₂ O	< 2 %

Silica: A good brick earth should contain about 50% to 60% of silica. The presence of silica constituent prevents cracking, shrinking in bricks thus imparts uniform shape to the bricks. Excess of silica makes the brick brittle and weak on burning. The durability of bricks depends on the proper proportion of silica in brick earth.

shrink and it produces cracks during drying and burning and become too hard when burnt.

Lime (calcium) : A small quantity of lime not exceeding 10% is desirable in good brick earth. The excess of lime causes the brick to melt and hence its shape is lost and also results in splitting of bricks into pieces.

Magnesia if exceeds 1%, affects the color and makes the brick yellow. Excess of magnesia content leads to the decay of bricks.

Iron – oxide usually constitutes < 7%. If it exceeds 7%, the brick becomes dark blue. When excess of oxygen is available, the bricks become dark brown or black color on burning.

HARMFUL SUBSTANCES IN BRICK EARTH: Following are the ingredients which are undesirable in the brick earth:

LIME: When lime is present in lumps, it absorbs moisture, swells and causes disintegration of the bricks.

PEBBLES, GRAVELS: The presence of pebbles of any kind is undesirable in brick earth because it will not allow the clay to be mixed uniformly and thoroughly which will result in weak and porous bricks. Also the brick containing pebbles will not break regularly as desired.

ALKALIES: These are mainly in the form of soda and potash. When alkalies present in excess, the bricks become unsymmetrical / loose their shape. Further, the presence of excess alkalies content absorb moisture from the atmosphere.

Such moisture, when evaporated, leaves behind grey or white deposits on the wall surface and the appearance of the building as a whole is then seriously spoiled.

ORGANIC MATTER: The presence of organic matter in the brick earth, which is not burnt in case, the bricks become porous and the strength is reduced.

SULPHUR & CARBON: Sulphur is usually found in clay as the sulphates of Calcium (CaSO4); magnesium (MgSO4); Sodium (NaSO4); Potassium (K2SO4) and iron sulphides (FeS2). If, however, there is carbon in the clay and insufficient time is given during burning for proper oxidation of carbon and sulphur, the latter will cause the formation of a spongy, swollen structure in the brick.

MANUFACTURING OF BRICKS

In the process of manufacturing of bricks, the following four distinct operations are involved: 1. Preparation of clay / Brick earth

- 2. Moulding
- 3. Drying
- 4. Burning

1. PREPARATION OF CLAY / BRICK EARTH consists of the following operations:

a) Un-soiling: The soil used for making building bricks should be processed and to be free from gravel, sand (> 2 mm); lime and kankar particles, organic matter etc. About 200 mm of the top layer of the earth, normally containing stones, pebbles, gravels, plant roots etc is removed after clearing the trees and vegetation.

b) Digging: The clay is then dug out from the ground and is spread on the ground. The height of heaps of clay on the ground is about 600 mm to 1200 mm. The digging operation should be done before rains.

c) weathering: The clay/soil is left in heaps and exposed to weather for atleast one month. The soil should be turned over at least twice and it should be ensured that the entire soil is wet throughout the period of weathering.

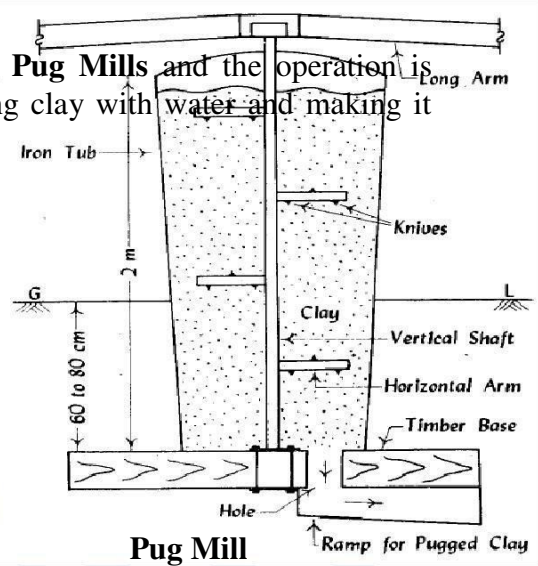
In order to keep it wet, water may be sprayed as often as necessary. The plasticity and strength of the clay are improved by exposing the clay to weather.

d) <u>Blending</u> : The clay / soil is then	mixed	sand and calcareous earth in
suitable proportions to modify the	with composition	of soil uniformly with spades.

Addition of water to the soil at the dumps is necessary for easy mixing and workability. However, the excessive moisture content may affect the size and shape of the finished brick. The blending makes clay fit for the next stage of tempering.

e) Tempering: In the process of tempering, the clay is brought to a proper degree of hardness. The tempering should be done exhaustively to obtain homogeneous mass of clay of uniform character.

For manufacturing good bricks, tempering is done in **Pug Mills** and the operation is called **Pugging**. In other words, the process of grinding clay with water and making it plasticity is known as the Pugging



2. MOULDING: It is a process of giving a required shape to the brick from the prepared clay / soil / brick earth. Moulding may be carried out by hand or by machines.

Hand Moulding: In this process, the bricks are moulded by hand i.e. manually. It is adopted where man power is cheap and for producing a small quantity of bricks. A typical wooden mould should be prepared from well seasoned wood for making bricks.

The longer sides are kept slightly projecting to serve as handles. The strips of brass or steel are sometimes fixed on the edges of wooden moulds to make them more durable.

The steel mould even be prepared from steel angles and plates. The thickness of steel mould is generally 6 mm.

The bricks prepared by **hand moulding** are of two types:

- (a) Ground - moulded bricks
- (b) Table – moulded bricks

Ground – Mould bricks:

In this process, the ground is leveled and sand is sprinkled on it. The mould is dipped in water and placed over the ground. The clay is pressed or forced in the mould in such a way that it fills all the corners of the mould. The extra or surplus clay is removed with a sharp edged metal plate called STRIKE or with a thin wire stretched over the mould. After this process, the moulded bricks are left on the ground for drying.

The bricks prepared by dipping mould in water every time are known as the slop-moulded bricks. The fine sand or ash may be sprinkled on the inside surface of mould,, instead of dipping mould in water is known as Sand – Moulded bricks.

Table Moulding: the process of moulding these bricks is just similar to ground moulding. But in this process, the clay, mould, water pots, strikes, pallet boards are placed on the table. A thin board called *pallet* is placed over the mould. The bricks are moulded on the table and sent for the further process of drying. The cost of brick moulding also increases slightly when table moulding is adopted.

Machine Moulding: The moulding may also be achieved by machines. It proves to be economical when bricks in huge quantity are to be manufactured at the same spot in a short time. Machine moulding can be done by either of the following process:

Plastic method (Plastic Clay Machine): The pugged clay is placed in the machine through a rectangular opening by means of an auger. Clay comes out of the opening in the form of a bar. The bricks are cut from the bar by a frame consisting of several wires at a distance of brick size and this is a quick and economical process. This process is also known as WIRE CUT BRICKS.

Dry Press Method / Dry Clay Method: In these machines, the strong clay is first converted into powder form. A small quantity of water is added to form a stiff plastic paste. Such paste is placed in mould and pressed by machine to form hard and well shaped bricks. These bricks are also known as PRESSED BRICKS. They can be sent directly for the next process of burning.

3. DRYING: For drying, the bricks are laid longitudinally in stacks. The bricks in stakes should be arranged in such a way that sufficient air space is left between them. The bricks should be allowed to dry till they become hard or the moisture content is brought down to about 3% under exposed conditions within 3 to 4 days.

For the drying purpose, Drying yards should be prepared. The Drying yards should be slightly on a higher level and it is desirable to cover it with sand. Such an arrangement would prevent the accumulation of rain water.

4. BURNING: This is a very important operation in the manufacture of bricks. The burning of clay may be divided into three main stages.

Dehydration stage (400 – 650°C): This is also known as *water smoking stage*. During dehydration :

- The water which has been retained in the pores of the clay after drying is driven off;
- Some of the carbonaceous matter is burnt;
- Carbonated minerals are more or less decarbonated;
- Too rapid heating causes cracking or bursting of the bricks.

Oxidation

period (650 – 900°C):

During the oxidation period, the remaining carbon is eliminated and the ferrous iron is oxidized to the ferric form. Removal of sulphur is completed only after the carbon has been eliminated.

Vitrification

(upto 1100°C):

When the temperature is reached about 1100°C, the two important constituents viz., alumina and sand bind themselves together resulting in the increase of strength and density of bricks. If the temperature is raised beyond 1100°C, a great amount of fusible glassy mass is formed and the bricks are said to be vitrified. The bricks begin to lose their shape beyond a certain limit of vitrification. Burning of bricks is done in a **Clamp or Kiln**. A Clamp is a temporary structure whereas Kiln is a permanent one.

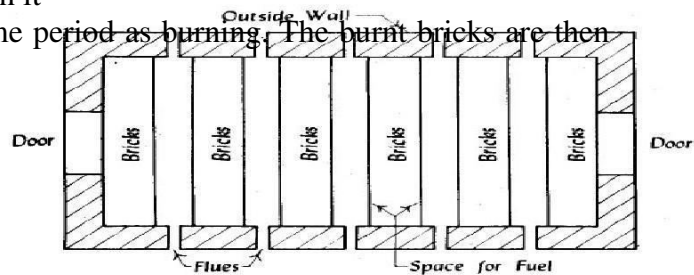
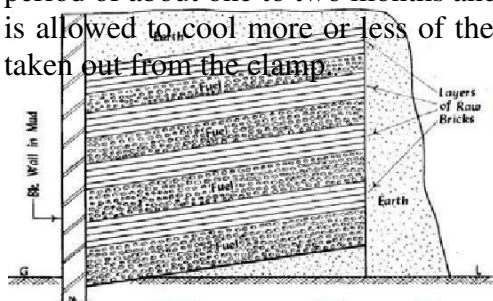
Burning in Clamps (Pazawah): A piece of ground with trapezoidal shape is selected.

The alternate bricks and fuel are placed in layers. The fuel may consist of grass, cow dung, litter, husks of rice or ground nuts etc..

The thickness of this fuel layer is about 700 – 800 mm. The wood or coal dust may also be used as fuel.

Each brick tier consists of 4 – 5 layers of bricks. The total height of a clamp is about 3 – 4 mts. When the Clamp is completely constructed, it is plastered with mud on sides and top and filled with earth to prevent the escape of heat. The Clamp is allowed to burn for a period of about one to two months and then it

is allowed to cool more or less of the same period as burning. The burnt bricks are then taken out from the clamp.



CLAMP

The production of bricks is 2 – 3 lakhs and the process is completed in 6 months. This process yields about 60% first class bricks.

Kiln burning: A large oven kiln is which is used to burn bricks.

used for burning bricks may be underground (Bull's Trench Kiln)

(eg: Hoffman's Kiln). The Kilns may be rectangular, circular or oval

The Kilns are of two types: (i) Intermittent Kilns (ii) Continuous kilns.

INTERMITTENT KILN

completed in 6

The Kiln

or over ground in shape.

fired, cooled and unloaded and then the next loading is done. Since the walls

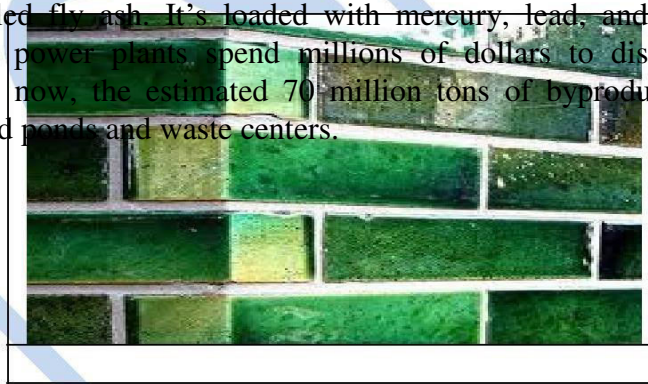
and sides get cooled during reloading and are to be heated again during next firing, there is wastage of fuel. . They may be over ground or underground.

Fly ash Bricks: Fly ash bricks are masonry units that are used in the construction of buildings. They are considered to be a part of good and affordable building materials. They contain Class C fly ash and water.

Fly ash bricks are made by compressing Class C fly ash and water at 4000psi and then curing is carried on for 24 hours at a temperature of 66 degrees Celsius steam bath. Air entrainment agent is used to toughen the bricks.

GREEN BRICKS: The bricks are used like conventional clay bricks – for building things from houses to factories. They're called green because they are built from a toxic byproduct produced from coal-burning power plants. Instead of these toxins being released into the environment, or disposed of through costly means, they're pumped into the bricks.

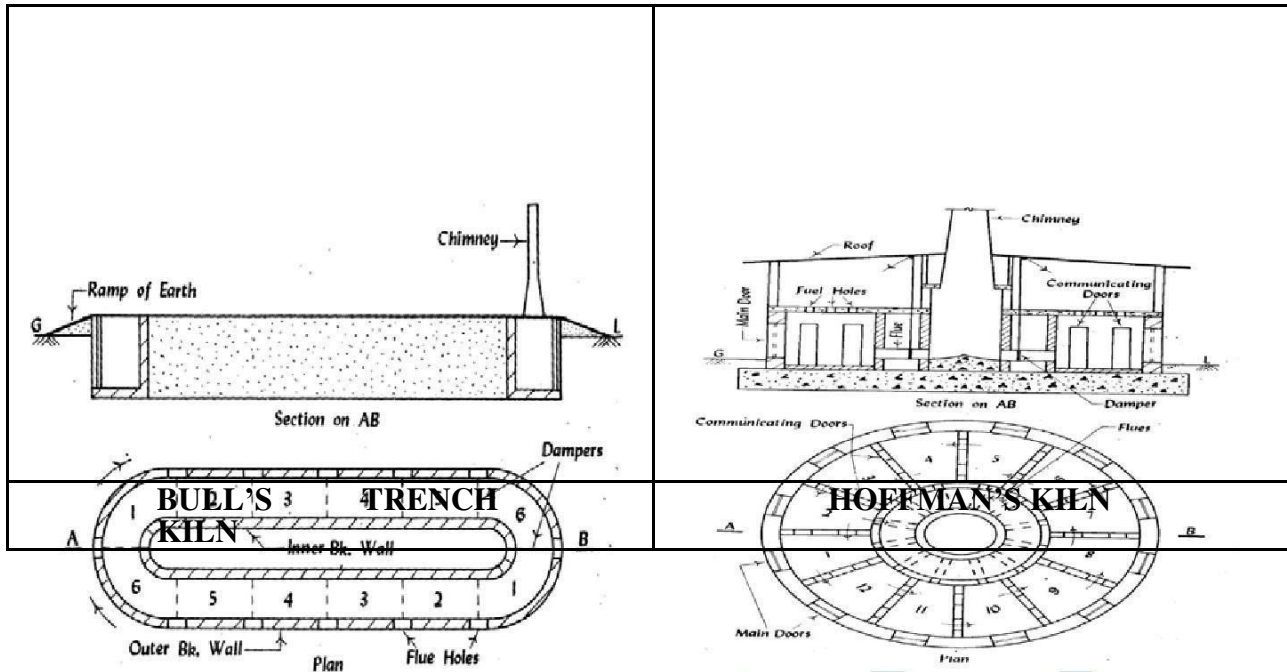
The waste product is called fly ash. It's loaded with mercury, lead, and other toxic chemicals. Coal-burning power plants spend millions of dollars to dispose of the powdery byproduct. Until now, the estimated 70 million tons of byproduct has been buried in specially designed ponds and waste centers.



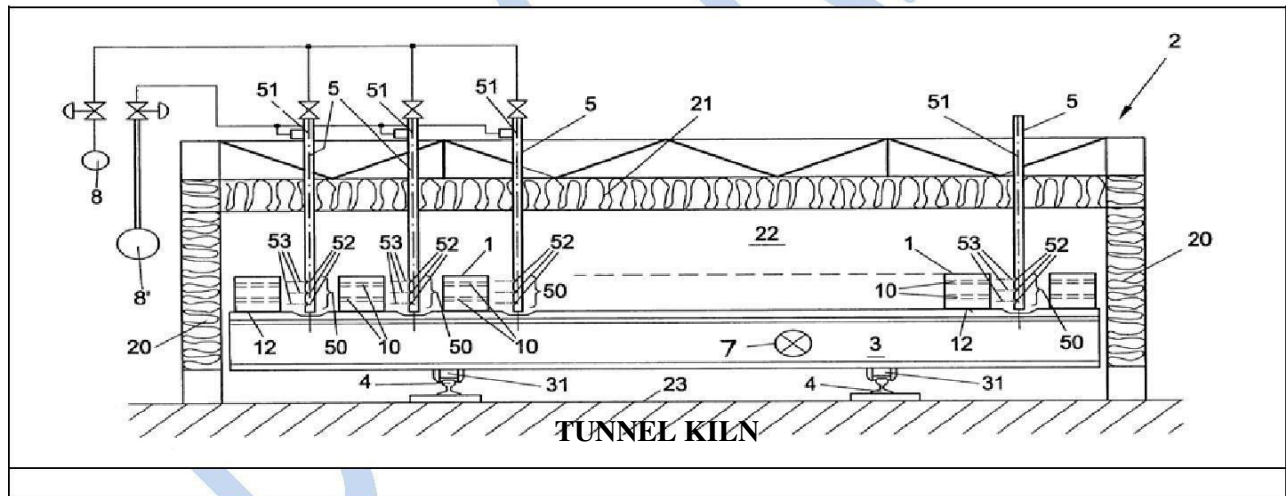
GREEN BRICKS

CONTINUOUS KILNS:

The process of burning bricks is continuous, and hence it is known as continuous kiln (eg: Bull's Trench Kiln and Hoffman's Kiln). In this process, bricks are stacked in various chambers wherein the bricks undergo different treatments at the same time. When the bricks in one of the chambers is fired, the bricks in the next set of chambers are dried and preheated while bricks in the other set of chambers are loaded and in the last are cooled.



TUNNEL KILN: A tunnel kiln useful for burning vertically perforated green bricks, includes a furnace chamber; tubular burners for heating the furnace chamber and a transport device for transporting green bricks in raster-like spaced-apart relationship in a travel direction through the furnace chamber that the perforations of the green bricks are oriented in a common direction.



Bull's Trench Kilns: In India, brick making is typically a manual process. The most common type of brick kiln in use there are **Bull's Trench Kiln (BTK)**, based on a design developed by British engineer W. Bull in the late 19th century. An oval or circular trench, 6–9 meters wide, 2–2.5 meters deep, and 100–150 meters in circumference, is dug. A tall exhaust chimney is constructed in the centre. Half or more of the trench is filled with "green" (unfired) bricks which are stacked in an open lattice pattern to allow airflow. The lattice is capped with a roofing layer of finished brick.

In operation, new green bricks, along with roofing bricks, are stacked at one end of the brick pile; cooled finished bricks are removed from the other end for transport. In the middle the brick workers create a firing zone by dropping fuel (coal, wood, oil, debris, and so on.) through access holes in the roof above the trench.

The advantage of the BTK design is a much greater energy efficiency compared with clamp or scove kilns. Sheet metal or boards are used to route the airflow through the brick lattice so that fresh air flows first through the recently burned bricks, heating the air, then through the active burning zone. The air continues through the green brick zone (pre-heating and drying them), and finally out the chimney where the rising gases create suction which pulls air through the system. The reuse of heated air yields savings in fuel cost.

A half dozen laborers working around the clock can fire approximately 15,000-25,000 bricks a day. In the BTK process the bricks do not move. Instead, the locations at which the bricks are loaded, fired, and unloaded gradually rotate through the trench.

TESTS FOR BRICKS: A brick is generally subjected to the following tests to find out its suitability for the construction work:


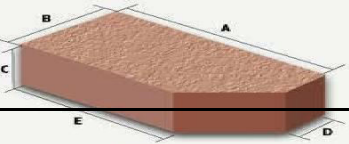
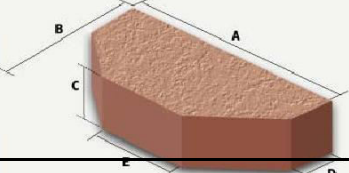
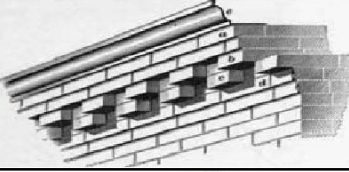



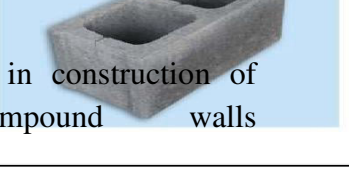
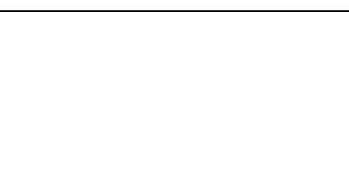
Water Absorption Test (US 3495):: A brick is taken and it is weighed dry. It is then immersed in water for a period of 24 to 48 hours. It is weighed again and the difference in weight indicates the amount of water absorbed by the brick. It should not, in any case, exceed 5%-20% of weight of dry brick.

Compressive Strength Test (IS: 3495): The crushing strength of a brick is find out by placing in a compression testing machine. It is pressed till it breaks. The minimum crushing or compressive strength of bricks is 3.50 N / mm^2 .

Efflorescence Test: The brick is immersed in water for 24 hours. It is then taken out and allowed to dry in shade. The absence of grey or white deposits on its surface indicates the absence of soluble salts. If the white deposits cover about 10% surface, the efflorescence is said to be slight and it is considered as moderate when the white deposits cover about 50 % of surface. If grey or white deposits are found on more than 50 % of surface, the efflorescence becomes heavy and it is treated as serious.

Soundness: In this test, the two bricks are taken and they are struck with each other. The bricks should not break and a clear ringing sound should be produced.

DIFFERENT FORMS OF BRICKS: Various forms of bricks are used depending upon the places of use. For eg:

Round ended bricks	Used to construct open drains	
Bull nosed bricks	A brick moulded with a rounded angle. A connection which is formed when a wall takes a turn is known as Quoin.	
Cant (splay) brick	Used in case of doors and windows	
Double cant bricks	Used for Octagonal pillars	
Cornice brick	Used for architectural point of view	
Fire / refractory brick	It is used in lining furnaces, kilns, fireboxes, and fireplaces. A refractory brick is built primarily to withstand high temperature.	
Coping bricks	Used for parapets. These bricks are made to suit the thickness of walls on which coping is to be provided.	
Perforated bricks	The perforated bricks are used in roadways in order to drain of the rain water from the streets	
Hollow bricks	Hollow bricks which are highly used in construction of houses, buildings and compound walls	

	the bricks
Gun powder	A mixture of charcoal, salt petre (KNO ₃) and sulphur and the proportions by weight are 15, 75 and 10 respectively.
Magazine	A special type of building meant for storing the explosives.
Masonry	Masonry may be defined as the construction of building units (such as stones, bricks / precast blocks of concrete) bonded together with mortar.
Metamorphism	The process by which the changes are brought in solid rocks by the agencies of temperature, pressure and chemical active solutions which in turn establish a new equilibrium.
Mortar	Mortar is a homogeneous mixture produced by uniform mixing of cement or lime or combination of these two in addition to sand and water to make a paste of required consistency.
Pallet	A thin board called <i>pallet</i> is placed over the mould
Pugging	the process of grinding clay with water and making it plastic is known as the Pugging.
Strike	The extra or surplus clay is removed with a sharp edged metal plate called <u>STRIKE</u>
Weathering	which is a natural process of disintegration and decomposition

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UNIT- 2:

CEMENT & ADMIXTURES

Babylonians were perhaps the first to use clay as cementing material. In ancient times stones have been invariably used as a construction material with lime as the binder for construction of forts and defense structures. Egyptians have used lime and gypsum as cementing materials in the famous Pyramids. The calcareous rocks used by the Romans were either composed of limestone's burned in Kilns or mixtures of limestone and puzzolanic materials (volcanic ash, tuff) combining into a hard concrete. The natural cement is obtained by burning and crushing the stones containing clay, carbonate of lime (CaCO_3) and a little quantity of magnesia (CaMgCO_3)₂. The natural cement is brown in color and is also known as Roman cement.

Ingredient	Oxide / composition	%	Range	Function
Lime	CaO	6-2	60 – 65	Controls strength and soundness. Its deficiency reduces strength & setting time
Silica	SiO_2	2-2	17 – 25	Imparts strength. Excess cause slow setting
Alumina	Al_2O_3	5	3 – 8	Responsible for quick setting, it lowers the strength / weakness the cement if in excess
Calcium sulphate	CaSO_4	4	3 – 4	A small amount of sulphur is useful in making sound cement. If it is in excess , it causes cement to become unsound.
Iron oxide	Fe_2O_3	3	0.5 – 6	Gives colour, hardness & strength to the cement
Magnesia	MgO	2	0.5 – 4	Gives color, hardness. If in excess, it causes cracks in mortar.
Alkalies	$(\text{Na}_2\text{O} + \text{K}_2\text{O})$	1	0.1 – 0.4	These are residues and if in excess cause efflorescence and cracking

USES OF CEMENT: Cement is widely used in construction of various engineering structures.

Following are various possible uses of cement:

- Cement mortar for masonry works
- Cement Concrete for laying floors, roofs, lintels, beams, stairs, pillars etc
- Construction of important engineering structures such as Bridges, Culverts, Dams, Tunnels, storage Reservoirs; Docks etc
- Making Cement Pipes
- Manufacture of precast pipes, dust bins, fencing posts etc..

ORDINARY PORTLAND CEMENT: The artificial cement is obtained by burning at a very high temperature of a mixture of calcareous (limestone) and argillaceous (clay) materials. The calcined product is known as the CLINKER. A small quantity of gypsum is added to the clinker and it is then pulverized into very fine powder which is known as the CEMENT. This cement is also known as the normal setting cement or ordinary cement.

The Ordinary Portland Cement has been classified as 33 Grade (IS269: 1989); 43 Grade (IS 8112:1989) and 53 Grade (IS 12669:1987). The physical requirements of all these three types of cement are almost same except for compressive strength and are as follows:

S.No	Physical requirement	Grade		
		33	43	53
1	Fineness (m ² /Kg)	225	225	225
2	Soundness	10mm	10mm	10mm
3	Setting time (minimum)	30 minutes	30	30
	Setting time (maximum)	600 minutes	600	600
4	Compressive Strength (MPa)/n/mm ²			
	72 hours (3 days)	16	23	27
	168 hours (7 days)	22	33	37
	672 hours (28 days)	33	43	53

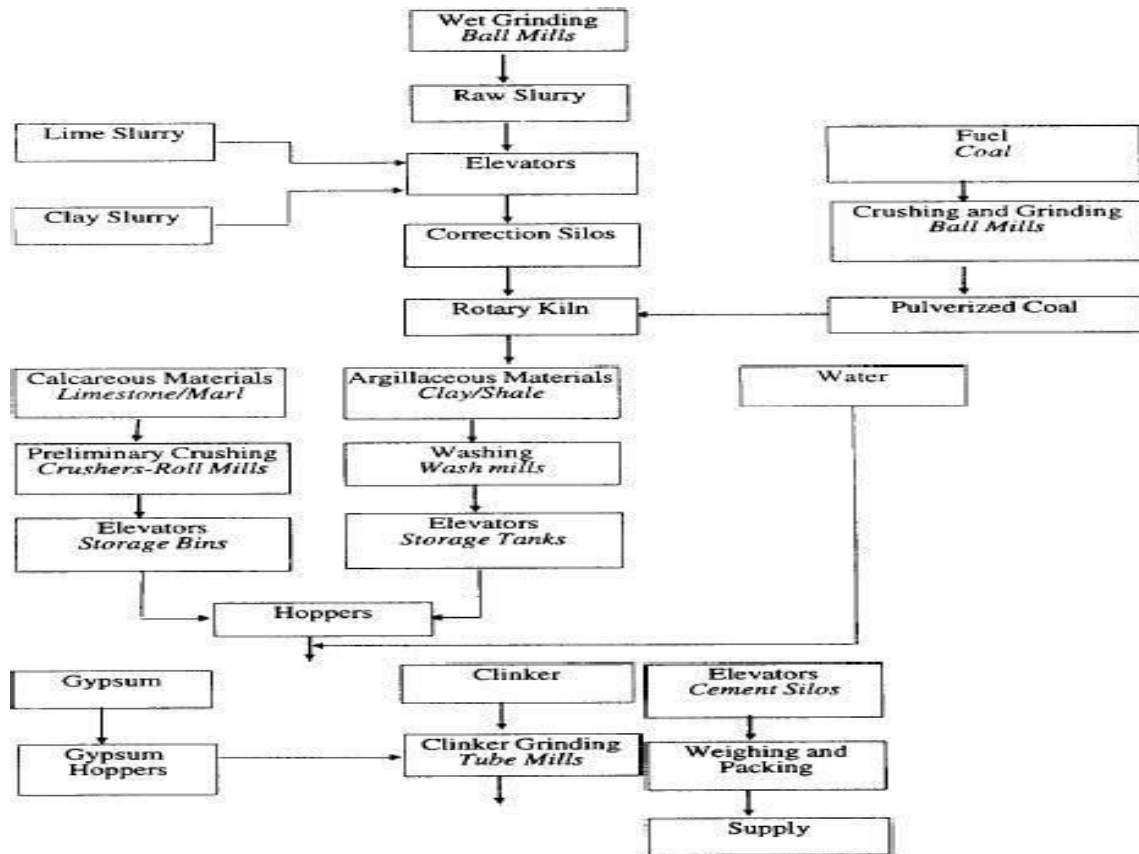
MANUFACTURE OF CEMENT: Calcareous (limestone, marl, chalk, marine shell) and argillaceous (clay, shale, slate etc) materials are used in the manufacture of Ordinary or Portland cement. From these materials, like silica, iron-oxide, and small quantities of other chemicals such as Na, K, S are obtained during the process of manufacturing of cement. Cement can be manufactured either by dry process or wet process.

DRY PROCESS (Modern Technology) : This process is adopted when the raw materials are quite hard. The raw materials of limestone and clay are first reduced in size of about 25 mm in crushers. A dry air is then passed over these materials. These dried materials are then pulverized into fine powder separately in the ball mills.

Ball mill is a key equipment to grind the crushed materials, and the ball mill is widely used in powder-making production All these materials are stored in hoppers / bins / silos and they are then mixed in correct proportions.

The clinker is cooled rapidly to preserve the metastable compounds and then ground in Tube Mills where 2 – 3 % of gypsum is added. The purpose of adding gypsum is to retard the setting of cement. Generally, cement is stored in bags of 50 kg. The dry process has been modernized and it is widely used at present because of competition in production; lesser consumption of power; automatic proper temperature control ; advancement of instrumentation; computerization and quality.

Flow diagram of manufacturing of cement



WET PROCESS (old technology)_Wet process was used for the manufacture of cement started from 1913 onwards and till early 1980. The operations involved in the wet process of cement manufacture are mixing; burning and grinding.

The crushed raw materials are fed into ball mill and a little water is added to make thick paste. This paste, usually contain about 14% of moisture is dried and made ready for the feed of rotary kiln where it loses moisture and forms into lumps or nodules.. These are finally burned at 1500 – 1600°C where the nodules change to clinker at this temperature. Clinker is cooled and then ground in tube mills. While grinding the clinker, about 3% of gypsum is added. The cement is then stored in silos from where it is supplied. During the operation of ball mill; the steel balls in it pulverize the raw materials which form a slurry with water. This slurry is passed to silos (storage tanks), where the proportioning of the compounds is adjusted to ensure desired chemical composition.

Physical characteristics of various types of cement

S no	Type of cement	Grade	Soundness by		Compressive strength (MPa) or N/mm ²			Fineness (m ² /Kg)
			Le Chatelier (mm)	Autoclave (%)	3 days	7 days	28 days	
								225
1	OPC	33	10	0.8	16	22	33	225
2	OPC	43	10	0.8	23	33	43	225
3	OPC	53	10	0.8	27	37	53	225
4	SRC		10	0.8	10	16	33	225
5	PPC		10	0.8	16	22	33	300
6	RHC		10	0.8	27	NS	NS	325
7	HAC		5	NS	35	NS	NS	225
8	SSC		5	NS	15	22	30	400
9	LHC		10	0.8	10	16	35	320

+NS = NOT SPECIFIED

1-3) OPC = ORDINARY PORTLAND CEMENT

4) SRC = SULPHATE RESISTANCE CEMENT

5) PPC = PUZZOLONA PORTLAND CEMENT

7) HAC = HIGH ALUMINA CEMENT

8) SSC = SUPER SULPHATE CEMENT

9) LHC = LOW HEAT CEMENT

Why gypsum is to be added during the manufacture of cement???

The gypsum is the hydrated sulphate of calcium and its chemical composition is CaSO₄ 2H₂O. It contains 79.1% calcium sulphate and 20.9% water. When gypsum is added to 205°C, its specific gravity increases from 2.3 to 2.95 due to loss of water. As a binding material, the gypsum quickly sets and hardens. It is soluble in HCl but insoluble in H₂SO₄.

Gypsum has a number of valuable properties like bulk density, incombustibility, good absorbing capacity, good fire resistance, rapid drying etc. Because of all these properties, gypsum is used in the manufacture of cement to increase its setting time.

PLASTER OF PARIS: Plaster of Paris is a calcium sulfate hemi-hydrate (CaSO₄, ½ H₂O) derived from gypsum by firing this mineral at relatively low temperature of 160 – 170°C and then reducing it to powder. In ancient times, in Paris, all the walls of wooden houses were covered with plaster as protection against fire. Since then the plaster was named as Plaster of Paris.

POP powder is mixed with water to form a paste which releases heat and then hardens once dried under normal temperature. Unlike mortar and cement, plaster remains quite soft after drying, and can be easily rubbed or scratched with metal tools or even sandpaper. On heating, further upto a temperature of about 20°C, the entire water is driven off and the resulting product is known as the Gypsum Anhydrite.

FIELD TESTS & LAB TESTS FOR CEMENT: In engineering construction, the main qualifications of a cement are permanency of structure; strength and a rate of setting. To determine these qualifications, both physical and chemical tests are made, the former on account of importance more often than the other. However, following field tests are to be carried out to ascertain the quality of cement:

- The cement should feel smooth when touched in between fingers.
- If it is felt rough, it indicates adulteration with sand.
- If hand is inserted in a bag of cement, one should feel cool and not warm.
- If a small quantity of cement is thrown in a bucket of water, it should sink and should not float on the surface.
- The color of cement should be uniform and the typical cement color is grey.

The cement should be free from any hard lumps. Such lumps are formed by the absorption of moisture from the atmosphere.

As a result of long experience the physical tests which have come into general use in determining the acceptability of cement are:

- Soundness
- Strength:
- Consistency Test and
- Fineness.

SOUNDNESS: Soundness refers to the ability of a hardened cement paste to retain its volume after setting without delayed destructive expansion. This destructive expansion is caused by excessive amount of CaO or MgO. In other words, the purpose of this test is to detect the presence of uncombined lime in cement. This may happen due to over burning of ingredients of cement in kilns. So it is an important test to assure the quality of cement since an unsound cement produces cracks, disintegration and leading to failure finally.

Soundness of cement may be tested by Le-Chatelier method or by autoclave method.

STRENGTH: Cement is tested for Compressive and Tensile strength because the cement hydrates when water is added to it. So, the strength of mortar and concrete depends upon the type and nature of cement.

Hydration of cement: The chemical reaction between cement and water is known as hydration of cement

Conditions affecting strength:

- Cement is very strong at early stages if a high lime or high alumina content is present.
- Gypsum and Plaster of Paris in small percentages also tend to increase the strength slightly but when present in quantities more than 3%, these substances provide variable effects.
- The strength of cement is greatly also influenced by the degree of burning, the fineness of grinding.
- An under burnt cement is likely to be deficient in strength.

Compressive Strength.: Compressive Strength is the basic data required for mix design. By this test, the quality and quantity of concrete can be controlled and the degree of **adulteration** is checked.

The compressive strength at the end of 3 days, 7 days and 28 days are given in table and the results are expressed in N/mm^2

Tensile Strength.: Tensile Strength may be determined by Briquette Test method or by Split Tensile Strength Test.

The Tensile strength of cement affords quicker indications of defects in the cement. However, the test is also used for the determination of rapid hardening cement. The tensile strength at the end of 3 days and 7 days for OPC is 2.0 N/mm^2 and 2.5 N/mm^2 respectively.

$$(2.0 \text{ N/mm}^2 = 20 \text{ kg/cm}^2) (2.5 \text{ N/mm}^2 = 25 \text{ Kg/cm}^2)$$

consistency Test: This is a test to estimate the quantity of mixing water to form a paste of normal consistency.



Vicat apparatus is used to determine the consistency test. 300 gms of cement is mixed with 25% water. The paste is filled in the mould of Vicat's apparatus and the surface of the filled paste is smoothed and leveled. A square needle 10 mm x 10 mm attached to the plunger is then lowered gently over the cement paste surface and is released quickly. The plunger pierces the cement paste. The reading on the attached scale is recorded. When the reading is 5 – 7 mm from the bottom of the mould, the amount of water added is considered to be the correct percentage of water for normal consistency

FINENESS: This test is carried out to check proper grinding of cement. In other words, the degree of fineness of cement is the measure of the mean size of the grains in it.

There are 3 methods for testing fineness:

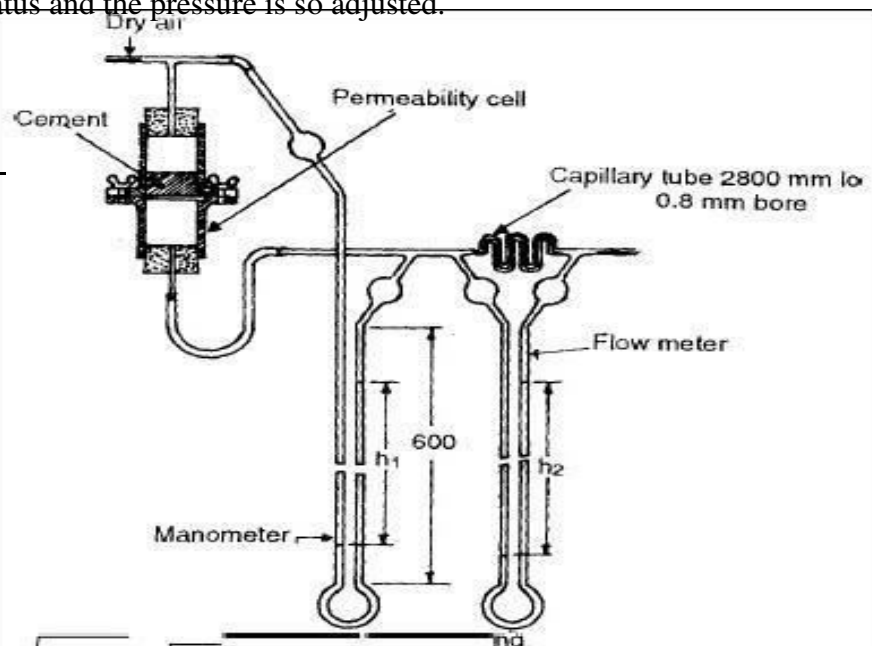
- The Sieve method -- using 90 micron sieve
- The air permeability method (Lea Nurse and Blains method)
- The sedimentation method (Wagner Turbidimetre)

SIEVE METHOD: 100 gms of cement sample is taken and air set lumps if any, in the sample are broken with fingers. The sample is placed on a 90 micron sieve and continuously sieved for 15 minutes. The residue should not exceed the limits specified below:

O P C	1 0 %	of residue by weight
R H C	5 %	of residue by weight
P P C	5 %	of residue by weight

Air Permeability method: In this process, a cement sample of 20 mm height is placed in the Lea and Nurse apparatus and air pressure is applied. A manometer is connected to the top and bottom of the permeability apparatus and the pressure is so adjusted.

Type of cement	Specific surface not less than cm^2/gms
OPC	2250
RHC	3250
LHC	3250
PPC	3000
HAC	2250
SSC	4000



Wagner Turbidimetre method: This method is to be adopted to estimate the surface area of one gram of cement. The cement is dispersed uniformly in a rectangular glass tank filled with kerosene. Then, parallel light rays are passed through the solution which strike the sensitivity plate of photoelectric cell. The turbidity of the solution at a given instant is measured by taking readings of the current generated by the cell. By recording the readings at regular intervals while the particles are falling in the solution, it is possible to secure information regarding the grading in surface area and in size of particle. Readings are expressed in sq cm per gms.

ADMIXTURES: Admixture is defined as a material, other than water, aggregates, cement, that is added to the concrete immediately before or during mixing. Admixtures change properties of the concrete in colour, curing time, temperature range and setting time.

Concrete is being used for wide varieties of purposes to make it suitable in different conditions. Ordinary concrete may fail to exhibit the required quality performance or durability under different conditions. In such cases, admixture is used to modify the properties of ordinary concrete so as to make it more suitable for any situation.

Classification of admixtures as given by MR Rixom is:

- Plasticizers (Water Reducers)
- Superplasticizers (High Range Water Reducers)
- Retarders
- Accelerators
- Air entraining Admixtures
- Mineral Admixtures / Puzzolanic Admixtures
- Chemical Admixtures

Plasticizers and Superplasticizers specifically developed in Japan and Germany around 1950 and later on they were made popular in USA, Europe and Middle East. Unfortunately, the use of plasticizers and Superplasticizers have not become popular in India till recently (1985).

Plasticizers (Water Reducers): Concrete in different situations requires different degree of workability. A high degree of workability is required in case of beams, columns, beam junctions, pumping of concrete for considerable distances. One must remember that addition of excess water, will only improve the fluidity or the consistency but not the workability of concrete.

The easy method generally followed at the site in most of the conditions is to use extra water to overcome different situations which is unengineering practice. Today, the use of plasticizers helps the difficult conditions obtaining higher workability without using excess of water.

Superplasticizers (High Range Water Reducers): Superplasticizers constitute a relatively new category and improved version of plasticizer, the use of which was developed in Japan and Germany during 1960 and 1970 respectively.

Use of Super plasticizers permits the reduction of water to the extent up to 30% without reducing the workability. The use of superplasticizer is practiced for the production of high strength and

high performance concrete. Superplasticizers can produce same w/c (water cement ratio); same workability;

increased strength, homogeneous character etc.

Retarders: A retarder is an admixture that slows down the chemical process of hydration so that concrete remains plasticity and workable for a longer time. The retarders are used in casting purposes. These are also used in grouting oil wells. Oil wells are sometimes taken upto a depth of about 6000 meter deep where the temperature may be about 200°C. The spacing between the steel tube and the wall of the well are to be sealed with cement grout and to prevent the entry of gas or oil into other rock

formations. For all these works cement grout is required to be in mobile condition for about 3 to 4 hours even at that high temperature without getting set.

Accelerators: These admixtures are added to increase the rate of strength of concrete and to reduce the required period of curing. In the past one of the commonly used materials as an accelerator was calcium chloride. The recent studies have shown that calcium chloride is harmful for reinforced concrete.

Air entraining Admixtures: Air entrained concrete is made by mixing a small quantity of air entraining agents. These agents modify the properties of concrete regarding workability, segregation, finishing quality of concrete. Air entraining admixture is used to prevent frost scaling in concrete.

The following types of air entraining agents are used for making concrete:

- Natural wood resins
- Animal or vegetable fats and oils such as olive oil, stearic acid; oleic acid.
- Various wetting agents such as alkali salts
- Miscellaneous materials such as the sodium salts of petroleum sulphonc acids, hydrogen peroxide and aluminium powder

The common air entraining agents are Vinsol resin, Darex, Airalon, Orvus, Teepol, Petrosan, Cheecol etc.. Air entrained concrete was used in the construction of Hirakud dam, Koyna dam, etc.

Chemical admixtures: Chemical admixtures are added to concrete in very small amounts mainly for reduction of water content or control of setting time.

Mineral admixtures: Mineral admixtures (puzzolanic materials) are usually added to concrete in larger amounts to enhance the workability of fresh concrete; to improve resistance of concrete.

The term Puzzolana is derived from Pozzuoli, a town in Italy. The sand (volcanic dust) around this town, when mixed with hydrated lime was found to possess cementitious properties. Puzzolanic materials can be divided into two groups such as:

Natural Puzzolanas viz clay, shales, cherts, volcanic tuff which needs further grinding and sometimes needs calcining to activate them to show puzzolanic properties.

Artificial Puzzolanas include Fly ash, Blast Furnace Slag, Silica fumes.

USES: A proper use of admixtures offers certain beneficial effects to concrete, including improved quality, acceleration or retardation of setting time, enhanced frost and sulfate resistance, control of strength development, improved workability, and enhanced finishability.

Blast Furnace Slag consisting essentially of silicates and aluminates of calcium. The granulated material when further ground to less than 45 microns will have specific surface of about 400-600

m²/kg. The chemical composition of BFS is similar to that of cement clinker.

UNIT- 3

BUILDING COMPONENTS

LINTELS and ARCHES: Openings are invariably left in the wall for the provision of doors, windows, cupboards, almirahs etc... These openings are bridged by the provision of either a lintel or an arch. Thus, both lintel as well as arch are structural members designed to support the loads..

A *lintel* is a sort of beam, which is placed across the opening. The width of a lintel is equal to the width of the wall and the ends of which are built into the wall. Lintels are simple and easy to construct. Lintels are classified into the following types according to the materials of the construction:

Timber Lintels: These are relatively costlier, structurally weak and vulnerable to fire. Sometimes timber lintels are strengthened by the provision of mild steel plates at their top and bottom, such lintels are called *Flitched Lintels*.

Stone Lintels: These are common in usage where stone is abundantly available. Dressed stone lintels give good architectural appearance. Stone is very weak in tension and cracks develop if subjected to vibratory loads.

Brick Lintels: These are not structurally strong and they are used only when the opening is small and loads are light.

Steel Lintels: These are provided where the opening is large and the loads are heavy. It consists of steel channels either used singly or in combination of two or three units.

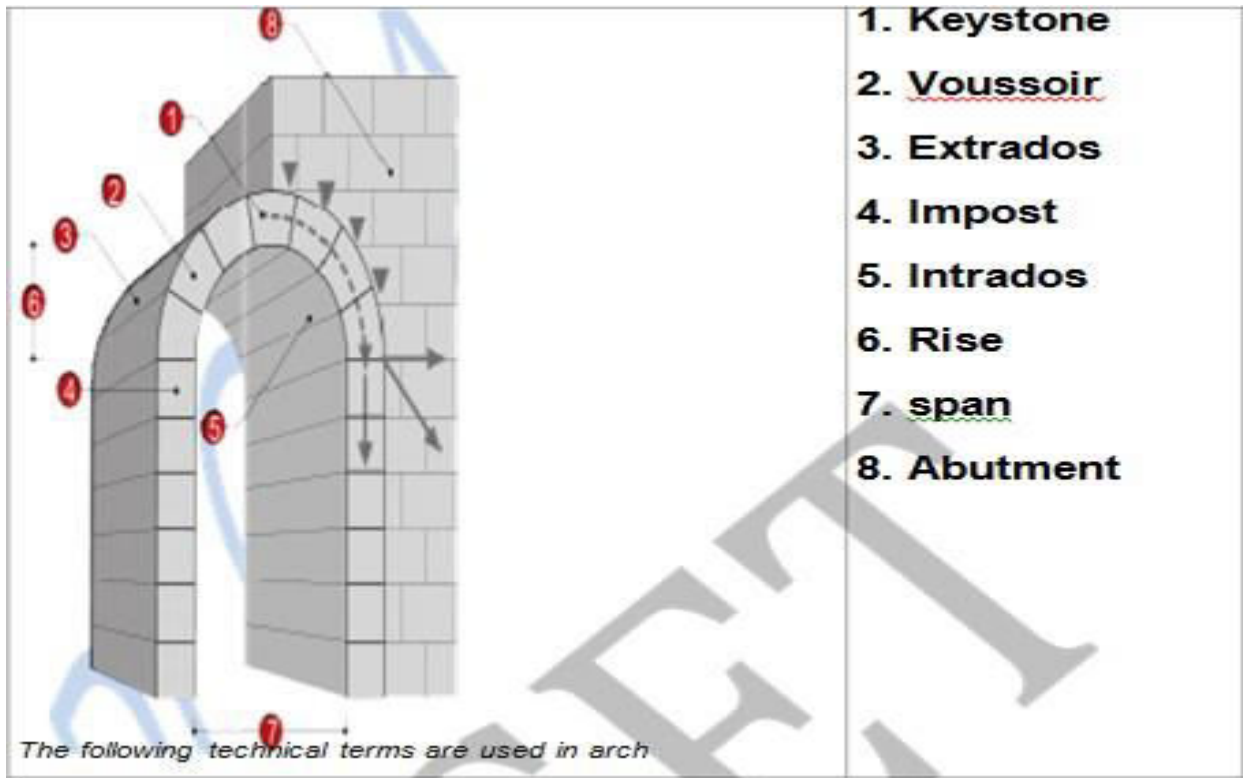
Reinforced Cement Concrete Lintels: Because of their strength, rigidity, fire resistance, economy and ease of construction, the RCC lintels are widely used. These can be used on any span. It is kept equal to the width of the wall. RCC lintels are also available as precast units.

Arches appeared as early as the 2nd millennium BC in Mesopotamian brick architecture and their systematic use started with the Ancient Romans who were the first to apply the technique to a wide range of structures.

An arch is an opening to support the weight of the wall or a load above it along with other superimposed loads.

A structure, especially one of masonry, forming the curved (an inverted U) pointed, or flat upper edge of an open space and supporting the weight above it, as in a bridge or doorway. However, arches are constructed where

1. Loads are heavy
 2. Span is more
 3. Strong abutment is available
- Special architectural appearance is required.

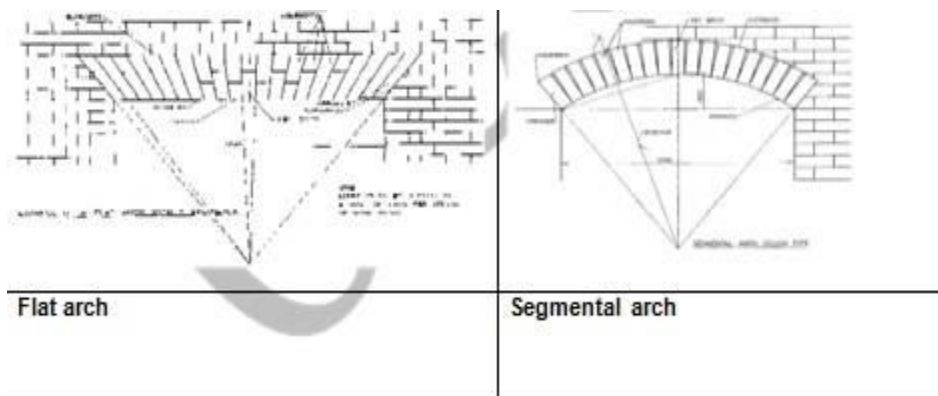


1. **Keystone**
2. **Voussoir**
3. **Extrados**
4. **Impost**
5. **Intrados**
6. **Rise**
7. **span**
8. **Abutment**

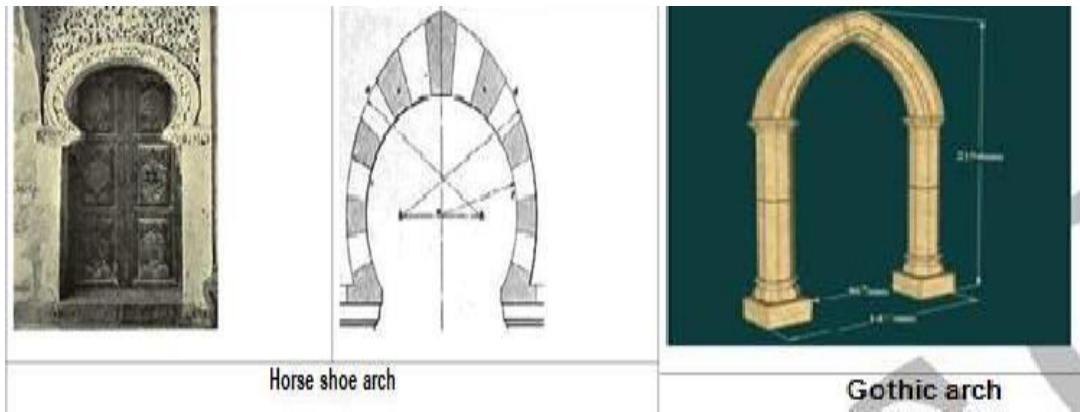
Classification of Arches: An arch can be classified as
 According to Shape
 Based on Number of Centres
 Based on material and workmanship

Classification according to shape:

Flat Arch: A flat arch has usually the angle formed by skewbacks as 60° , thus forming an equilateral triangle with intrados as the base. The extrados is kept horizontal & flat. Flat arches are used for light loads and for spans up to 1.5 mts. **Segmental Arch:** The centre of arch lies below the springing line or lies on the springing line.



Horse shoe arch: The arch has the shape of a horse shoe, which is more than a semi circle. Such type of arch is provided mainly from architectural considerations



Pointed arch: It consists of two arcs of circles meeting at the apex. The triangle formed may be either equilateral (all sides equal ie $ab = bc = ca$) which is also known as **GOTHIC arch** or isosceles (any two sides equal ie $ab=bc$ or $bc=ca$ or $ca=ab$) which is also called as **LANCET arch**.

Venetian arch: This is another form of pointed arch which has deeper depth at crown. It has four centers, all located on the springing line.

BUILDING SERVICES

PLUMBING SERVICES (WATER DISTRIBUTION, SANITARY)

Buried underground by arranging elbows, nipples, clamps, sockets, bends, bib-taps, check nut/ unions, gate valves/ball valves etc.. and finally connected to bath rooms, kitchens, wash basins, sinks. A water meter is also provided to the municipal mains at the entry level of water mains to a building.

Sanitary lines & fittings:

For collection of water, various types of sanitary fittings are required and to be fitted in the building. All these fittings should be as far as possible be fitted against an external wall. Following are some of the examples for sanitary fittings:

Wash basins: These are used for washing hands, tooth brushing, face washing etc and usually fixed that the height from the floor to the top of the basin is 78.5 cm.

SINKS: These are used cleaning of utensils in kitchens or glassware items in laboratories. Sinks are rectangular basins made from glazed earthen ware or stone-ware with flat bottom and all their internal angles are made round for easy cleaning.. Sinks are fixed in such a way that height of the top of the sink from floor is 90 cm.

Bath tubs: These are made from enameled iron, plastic, Cast Iron, porcelain, marble. Normal dimensions of bath tubs are as follows:

Length..... 1.7 - 1.85 mts

Width..... 70 – 75 cms Overall height 58 – 60 cm

The bath tub is provided with a tap to fill it with water and an outlet to drain the water. In some tubs two taps are provided, one for hot and another for cold water supply. Bath tub should also be provided with one over-flow pipe to take away excessive spilling water.

DRAINAGE SYSTEM: Drainage of a locality can be divided into public drainage and private drainage systems.

Under public drainage category, municipal sewers/drains are laid along the roads and are properly maintained by municipal / corporation authorities. Houses and buildings are constructed along both the sides of the roads

by laying own sewer lines inside the house / building premises under the category of private drainage system. These sewer lines collect sewage / waste water from bathrooms, kitchens, water closets etc fitted in the building and convey it to the municipal sewers.

So, the system of sewer lines or drains laid in the premises of a building is called the house drainage.

Principles of house drainage:

- House sewers / drains should be laid as far as possible by the side of a building rather than below the building.
- The size of drain should be adequate for maximum discharge from the house.
- Drains should be laid at proper gradient so that the lowest level of the building may drain in it.
- Drain should be laid on good foundation and protected against external loads.
- As far as possible, drains should be laid in straight lines with successive inspection chambers.

The house drain should be connected to the public sewer line which is always lower than the level of house sewer else, the flow in reverse direction may take place.

SYSTEMS OF VENTILLATION:

following requirements:

□□ It should admit required amount of fresh air in the room. All the corners of the room should get proper ventilation. Desired humidity should be maintained.

□ Effective temperature should be maintained

□□□ The ventilating air should be free from impurities such as dust, odour etc The systems of ventilation may be divided into two categories:

NATURAL VENTILATION: Natural system of ventilation is considered suitable for small houses and not for big buildings such as government offices, assembly halls, theatres, auditoriums and factories.

This natural ventilation system largely depends upon the scientific location of doors, windows, ventilators and other openings. Fresh air inside the building is cool and heavy. After sometime, the air becomes hot and lifted up in due course of time. The heated air is driven out through ventilators provided near the ceiling. For proper ventilation the top of this opening area should be not more than 45 cm below the ceiling.

Fresh air again comes in the building gets lifted up by heating and again escapes through openings provided near the ceiling. This effect cause flow of wind in upward direction and is known as ***stack effect***.

General considerations for natural ventilation:

- Inlet openings should be located that all parts of the room are uniformly ventilated.
- Inlet openings should not be obstructed by trees, partitions, adjoining buildings etc.
- Outlet openings (ventilators) should be located near the ceiling. Outlet openings should be just opposite to inlets. This ensures better cross-ventilation.
- More height of the room gives better ventilation due to stack effect. If wind direction is variable , then openings should be provided in all the walls.\

Types of air-conditionings:

- Comfort air-conditioning creates such conditions of the air inside the room, as would give maximum human comfort.
- Industrial air-conditioning creates and maintains the air to the needs of the industry during the material processing, manufacturing process, storage etc.
- Summer air-conditioning cools and control the inside temperature of the room.
- Winter air-conditioning is just the reverse of summer air-conditioning.
- Composite air-conditioning required to be done for the whole year irrespective of the temperature variation.

Principles of air-conditioning:

The temperature range which is liked by majority of the people is called the comfortable zone. A temperature of 21oC to 22.5oC is regarded as most likely comfort temperature in a room the air movement or velocity of air is important factor in air-conditioning. The velocity of air should be between 6 to 9 mts per minutue. It is remembered that the increase in air velocity decreases the inside effective temperature.

Humidity control of air is also important. An average value of relative humidity between 40 – 60% is considered desirable.

ROOM AIR-CONDITIONERS: These are self-contained air-conditioning units comprising a compressor, evaporator fan, and air-cooled condenser.

This unit is used for single rooms having limited occupancy. These are suited for bed rooms, office cabins, hotel rooms and hospitals. Room air-conditioners are available in the normal range of 1.0; 1.5; 3.0, 4.5 tons capacity.

CENTRAL SYSTEM OF AIR-conditioning:

In this system, various processes such as filtering; cooling or heating; humidification etc are all installed at a central place and conditioned air is distributed in all the parts of the building through system of ducts. This system is economical than other systems and better control on conditions inside the hall can be maintained.. However, this system requires an elaborate system of ducts which occupy considerable space.

UNIT – IV

FORM WORK (SHUTTERING)

Formwork is the term given to either temporary or permanent moulds into which concrete is poured till it get sufficient strength for self-supporting.

The form work involves various materials such as timber (wood), plywood, steel, aluminium, combined wood–steel etc... used as moulds in civil structures, in which concrete is poured. The construction of form work involves considerable materials. The cost of form work may be upto 20 – 25 % of the cost of the structure in building works and even higher in bridges. In order to reduce this expenditure, it is necessary to design economical types of form work.

When the concrete reach a certain required strength, the form work is no longer needed and is removed. The operation of removing the form work is commonly known as Stripping. Similarly, when the components of form work are removed and then reused for other parts of the civil structure for several times are known as Panel forms.

FORMWORK MATERIALS:

Timber is the most common material used for form work. When the form work is to be used for small works only a few times, then timber proves to be more economical than steel or aluminium.

Advantages: Formwork material of timber is

- easily available
- formwork material can be made to desired shape
- can be made to required size
- easy to carry
- economically viable and cheap
- convenient for small works

- possibility of warping, swelling and shrinkage of timber. However, those effects can be overcome by applying shuttering oil as coating. This coating prevents the material from adhering to concrete and hence the stripping (removing of formwork material) makes easier.

Steel/Aluminium formwork: If the formwork is desired to be re-used several times, then the use of steel or aluminium is preferred. Though the initial cost of steel is very high but for large works with many repetitions, the steel form work proves to be economical. In case of specific structures, such as round columns, curved surfaces, tunnels etc the use of steel form work should be made.

Steel form work has many advantages such as

- Can be used a number of times
- It provides ease stripping
- It ensures an even and smooth concrete surface.
- It is not liable to shrinkage/ swelling.

Requirements for a Form work: A good form work should satisfy the following requirements:

- The material of the formwork should be cheap and it should be suitable for re-use several times.
- It should be water proof so that it doesn't absorb water from concrete.
- Shrinkage and swelling of material should be minimum.
- It should be strong enough to withstand all loads coming on it such as dead load of

concrete, live load of concrete during its pouring, compaction and curing of concrete.

- The surface of the form work material should be smooth and should afford easy stripping.
- All joints of the form work should be stiff so that lateral deformation under loads is minimized.

Indian Standards on form work (IS 456 – 2000)

General: The formwork shall conform to the shape, dimensions etc as shown on the plans and so constructed as to remain the rigidity during the placing of the concrete and the form work shall be sufficiently tight to prevent loss of liquid from the concrete.

Cleaning and treatment of forms: All rubbish particularly chippings, saw dust shall be removed from the interior of the form work material before the concrete is placed.

Procedure to be adopted for removing the form work: All form work materials are to be removed without creating vibrations as would damage the reinforced concrete. Before the form work materials are removed, the concrete surface should be checked thoroughly.

Tolerances: Form work shall be so constructed that the internal dimensions are within the permissible tolerance specified by the designer.



Formwork material (PLYWOOD) and Modular steel frame work



SCAFFOLDING

The Scaffolding is a temporary frame work of timber or steel components having platforms at different levels, to enable the masons to work at different heights of a buildings. When the height of wall or column or other structure of a building exceeds about 1.5 mts (4'), temporary structures are used to support the platform over which the work men can sit and carry the activities. These temporary

structures constructed are very close to the wall, is in the form of timber or steel frame work, commonly called scaffolding.

Scaffolding materials is needed for the repairs or even demolition of a building. In addition, surface finishing such as plastering, pointing, white washing or distempering of walls, columns etc at higher levels can also be carried out. The scaffolding should be stable and be strong enough to support work men and other construction material placed on the platform. The height of the scaffolding goes on increasing as the height of construction increases.

Components of Scaffolding:

Standards: These are the vertical members of the frame work supported on the ground or embedded into the ground.

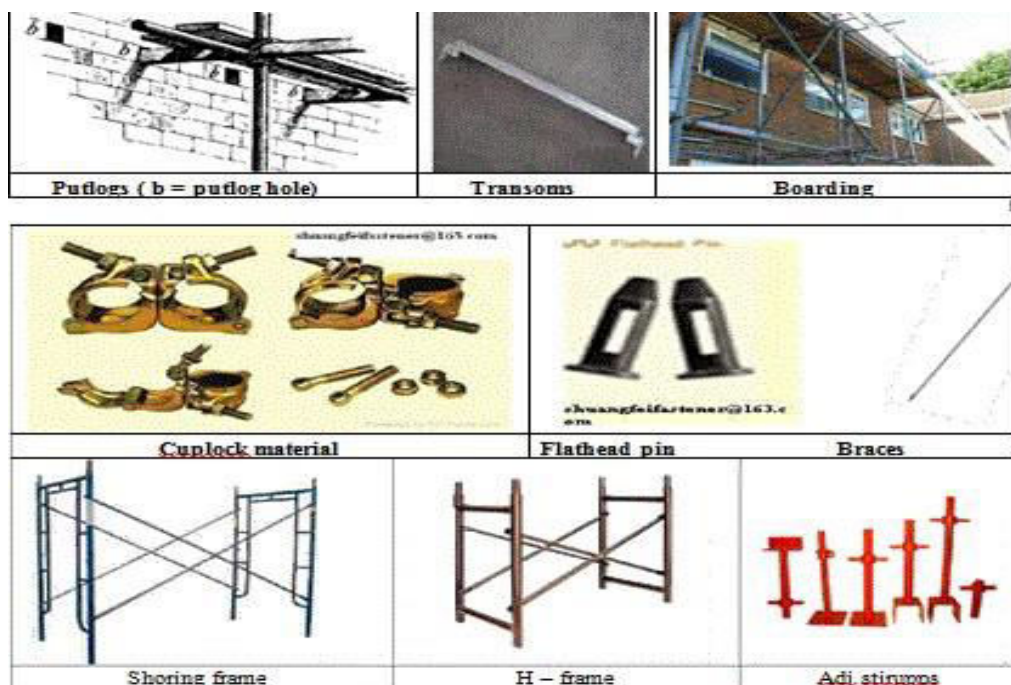
Ledgers: These are horizontal members, running parallel to the wall,

Braces: These are diagonal members fixed on standards.

Putlogs: These are transverse members, placed at right angles to the wall with one end supported on ledgers and other end on the wall.

Transoms: These are those putlogs whose both ends are supported on ledgers.

Boardings: These are horizontal platform to support workmen and material and are supported on the putlogs. Various components or members of the scaffolding are secured by means of rope lashings, nails, bolts etc.....



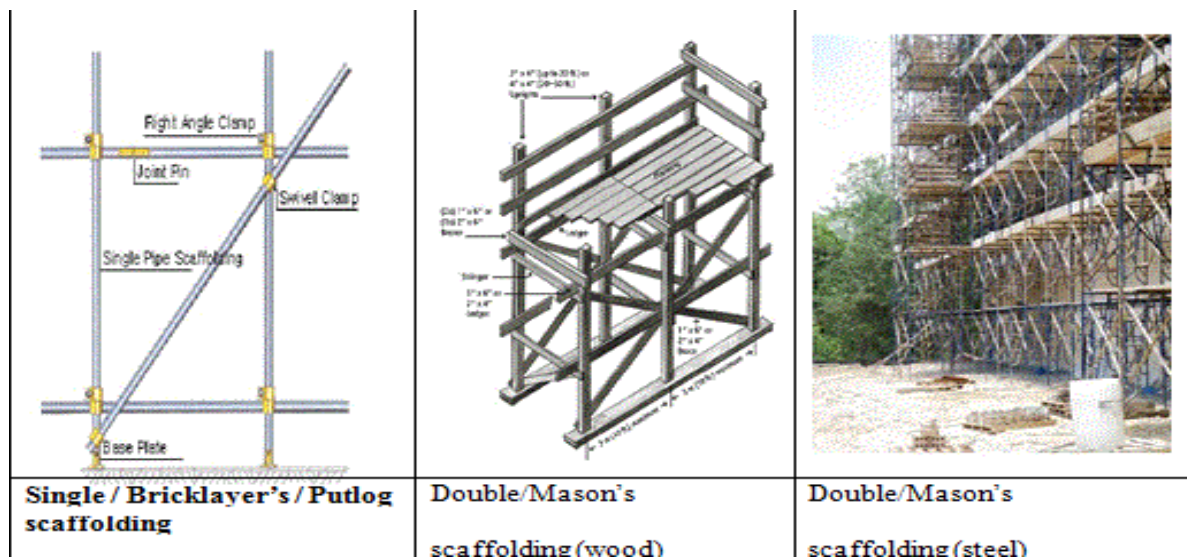
TYPES OF SCAFFODING:

- **Single / Bricklayer's / Putlog scaffolding:** It consists of a single row of standards (vertical members) which are driven into the ground. Standards are to be arranged parallel to the wall at distance of 1.20 mts. The standards are then connected to each other by ledgers (horizontal members)

placed at right angles. They are secured in position by rope lashings or cuplock materials. The put logs are fastened to ledgers by rope lashings. The cross braces are used for strengthening of the structure.

Double scaffolding/ Mason's Scaffolding: This type of scaffolding is stronger than the single scaffolding and is used in the constructions of stone work. The form work is similar to the single scaffolding except two rows of standards are used, one row close to the wall within 15 cm and the other at

1.2 to 1.5 m away from the face of the wall. The put logs are supported at both ends on ledgers. Sometimes, in addition to the diagonal braces, inclined supports called Racking shores are provided to prevent the slipping of scaffold away from the wall.



3. Cantilever Scaffolding / Needle Scaffolding: This type of scaffolding is needed under the following circumstances:

- Where it is not possible to fix the standards in to the ground
- Where the scaffolding is to be provided on the side of a busy street without obstructing the traffic on road.
- Where the scaffolding is required in case of tall buildings. In this work, single scaffolding or double scaffolding components are supported by a series of cantilevers or needle beams (timber beams projecting from wall) passing through window openings or through holes in the wall.

4. Suspended scaffolding: This type of scaffolding is suitable for maintenance works such as painting, pointing, distemping etc. The working platform is suspended from the roofs by means of wire ropes or chains.. The mechanical arrangements are provided to raise or lower the platform to attain the optimum level for working.

• **Trestle scaffolding:** The working platform is supported on the top of mobile devices such as tripods, ladders etc mounted on wheels. Trestle scaffolding is suitable for minor repairs or painting work upto a maximum height of 5 mts from the supporting level.

• **Steel scaffolding/Centering:** It is practically similar to timber scaffolding except that wooden members are replaced by steel tubes and rope lashings are substituted by special couplings and set-screws at junctions. Though its initial cost is more but its salvage (The property so saved) value is higher.

- **Ladder Scaffolding / Patented scaffolding:** The working platforms are supported on brackets (with inner row of standards) which can be adjusted at any suitable height. The various components of the scaffold are
- fastened to each other by means of bolts and screws.

UNIT V:

BUILDING PLANNING

Plan of a typical floor: The plan of a typical floor (ground floor plan at ground floor level , first floor plan at first floor level) is represented by a Plan cut at the window sill level so that all the windows, cup boards, almirahs etc are also represented on the plan.

Foundation plan: Foundation is immediate beneath the lowest part of the structure, near to the ground level is known as shallow foundations. Such foundations are mostly placed on the hard strata available below the ground level.

Shallow foundations are further classified into the following types: 1.Open trench foundations:.

The open-trench foundations were common whenever the terrain was sufficiently compact and the trench did not require much depth. In other situations it was necessary to reinforce the walls of the trench to prevent them from collapsing during digging

2. Grillage foundations: Grillage foundation is used when heavy structural loads from columns, piers or stanchions are required to be transferred to a soil of low bearing capacity. Grillage foundation is often found to be lighter and more economical. This avoids deep excavation. Depending upon the material used in construction of grillage foundation can be broadly divided in the following two categories.

- Steel grillage foundation
- Timber grillage foundation Raft foundations:

a foundation (usually on soft ground) consisting of an extended layer of reinforced concrete.

4.Stepped foundations:

A foundation constructed in a series of steps that approximate the slope of the bearing stratum.

The purpose is to avoid horizontal force vectors that might cause sliding. 5.Inverted arch foundations/ Footing .

It is used to be provided for multi-storeyed buildings in olden times. However, with the advent of reinforced cement concrete construction practice, inverted arch footing is rarely done these days. One of the drawbacks in this type of construction is that the end piles have to be specially strengthened by buttresses to avoid the arch thrust tending to rupture the pier junction. However, the advantage of inverted arch construction is that in soft soils the depth of foundation is greatly reduced

Structural plan of a typical floor: A structural plan of a typical floor contains location, nomenclature and details of various structural elements at that floor level.

Terrace plan. The terrace plan is the plan at the roof level showing the stair cabin, lift cabin, overhead water tanks alongwith roof drainage pattern, parapet walls etc.

Classification of buildings: According to National Building code of India 1970, different classification of buildings on the basis of occupancy are:

Group A – Residential Buildings: All those buildings in which sleeping accommodation is provided for residing permanently or temporarily with or without cooking or dining or both facilities are termed as residential buildings, for example Apartments, Flats, Bungalows, Dormitories, Private Houses, Hotels,

Hostels, Cottages, Holiday Campus, Clubs, outhouses, Inns, etc., These buildings are further sub-divided in to 5 groups, namely; A- 1 Lodging Houses; A- 2 Family Private Dwellings; A- 3 Dormitories; A- 4 Flats; and A- 5 Hot

Group B – Educational Buildings: All those buildings which are meant for education from a nursery to the university, are included in this group, for example, schools, colleges, Universities, Training Institutes, etc. These buildings provide facilities like class – rooms, staff cabins, drawing rooms, laboratories, admin blocks, seminar halls; recreation halls, library, playfields, gymnasium etc.

Group C – Institutional Buildings: This group includes any building which is used for the purposes such as medical, health, physical or mental disease, care of infants or aged persons, etc. These buildings normally meant for healthcare for the occupants.

These buildings are further sub–divided into three groups viz, C–1 Hospitals; C-2 Custodian Institutions (a financial institution that has the legal responsibility for a customer's securities) and C-3 panel Institutions (a group of persons selected for some services).

Group D – Assembly Buildings: This group includes any building where groups of people assemble or gather for amusement / entertainment. For eg: theatres, cinema halls, assembly halls, auditoriums, exhibition halls, museums, restaurants, places of worship (temple, mosque, church, etc.), club rooms, passenger stations, public transportation services; open air theatres, sports pavilions(i.e., stadium), swimming pools, etc.

Group E – Business Buildings : A commercial building is a building that is used for commercial use. Types can include office buildings, warehouses, shopping malls, etc

Group F – Mercantile Buildings: This group includes any building or part of a building which is used as shops, stores, market for sale and display of products or wares either wholesale or retail.

Group G – Industrial Buildings: This group includes any building in which products of different kinds and properties, are fabricated, assembled or processed. For example, laboratories, assembling plants, laundries, gas plants, power plants, refineries, dairies...

Group H – Storage Buildings: This group includes to store materials such as cement, iron/steel; home appliances etc. eg: godowns

Group I – Hazardous Buildings: This group includes those building structures which are used for the storage, handling, manufacture/ processing of materials which are liable to burn and prove hazardous to building contents. Hazards may be due to fire, poisonous fumes or gases , explosions, ignition, etc., from materials subjected to various operations. Buildings used for storage of explosive materials, manufacture of synthetic leather, explosives, fire works

BASIC PRINCIPLES OF BUILDING PLANNING: The basic principles of building planning in respect of residential buildings are:

(1) **FLOOR AREA RATIO (FAR)** is the ratio of the total covered area of all floors in a building on a certain plot and to the area of the plot.

The Floor Area Ratio, describes the relationship between the size of a plot and the amount of floor space it contains. For example, a 50' x 100' lot (5,000 sft) with a single-story 50' x 50' building (2,500 sft) has a floor area ration of 0.5. If a building with the same size footprint had 4 stories, the FAR would

increase to 2. Higher FARs tend to indicate more urban (dense) construction and is used by local governments in zoning codes

(2) **FLOOR SPACE INDEX (FSI):** It is the ratio of builtup area inclusive of walls of all the floors and to the area of the land on which the building stands.

Total floor area including walls of all floors Floor Space Index = Plot Area / Building Unit

Thus, an FSI of 2.0 would indicate that the total floor area of a building is two times the gross area of the plot on which it is constructed, as would be found in a multiple-story building. FSI for residential buildings in the city area is 4.

The value of FSI is fixed by local authority and it is different for different areas and for different buildings of the town.

Use	Area	FSI	Remarks
Residential	Scheme 1		Only Ground floor is allowed.
Residential	City area	4	Facing street of > 12 mts width
Residential	City are3		Facing street of < 12 mts width

(4) **THE AREA OF ROOMS:**

Bed rooms, living rooms, drawing room, dining room (min)9.4 sq mts Kitchen and store rooms (min) 5.45 sq mts

Bathrooms and dressing rooms ... 1.85 – 4.5 sq mts Water Closet (WC); Urinal rooms . 0.89 – 1.1 sq mts

(5) **HEIGHT OF ROOF:** Roof height on each floor is 2.7 mts (min) and for bath room and WC is 2.1 mts (min)

(6) **AREA OF DOORS, WINDOWS & VENTILATORS:** This shall be 1/6th to 1/10th of the floor area of the room. In addition, every room should have ventilator .

(7) **STAIR CASE:** The stair case shall have area not more than 12 sq

mts. The pitch shall be in the range of 30o to 45o and flight shall have steps neither < 3 nor > 12. Minimum width of stair shall be 900 mm.

(8) LIFT: This shall be provided for buildings having more than 3 floors excluding the ground floor.

(9) SEPTIC TANK: shall be provided as per number of floors / rooms .

(10) HEIGHT OF COMPOUND WALL: The maximum height of compound wall on road side shall not be more than 1.5 mts and the gates shall open inwards. On other sides, the height of compound wall shall be 1.8 mts.

(11) OPEN SPACE: The open space width shall be 1.8 mts (min) and 3 mts (max) for front, rear and sides .

(12) PARKING SPACE: Parking spaces for cars required for cinemas, shopping areas and offices located in central areas are to be allocated as per National Building Code.

BUILDING BYE-LAWS: Every locality has its own peculiarities in respect of weather conditions, availability of material and labour and thus adopts its own method of construction. In addition, every locality has certain rules and regulations which help in controlling the development of locality. The rules and regulations covering the requirements and ensure the safety of the public, minimum use of rooms , area limitations are known as “Building bye-laws”.

