# GOVT. POLYTECHNIC, JAGATSINGHPUR

CIVIL ENGINEERING DEPARTMENT

LEARNING MATERIAL OF **BUILDING MATERIAL & CONSTRUCTION TECHNOLOGY**

$3^{RD}$ SEMESTER

FACULTY NAME – ANANTA BISWAL

# Building Material & construction Technology

**Building Material**

1. Stone.
2. Brick.
3. Cement.
4. Mortar.
5. Aggregate.
6. concrete.
7. OCM.
8. Surface Protective materials.

**construction Technology**

1. Foundation.
2. wall.
3. Masonary works.
4. Door.
5. Window.
6. Lintels.
7. Floor.
8. Roof.
9. Stairs.
10. DPC.
11. Plastering.
12. pointing.
13. Painting.
14. White washing.

Ananta Biswal

The building stones are obtained from rocks which are classified in 3 ways.

# Classification of Rocks

1. Geological classification
   - (i) Igneous rocks
     - Plutonic rock.
     - Hypabyssal rock
     - Volcanic rock
   - (ii) Sedimentary rocks
     - Residual deposit
     - Sedimentary deposit
     - Chemical deposit
     - Organic deposit
   - (iii) Metamorphic rocks
     - Thermal
     - Cataclastic
     - Dynamo-thermal
     - Plutonic
2. Physical classification
   - Stratified rocks
   - Unstratified rocks
   - Foliated rocks
3. Chemical classification
   - Siliceous rocks
   - Argillaceous rocks
   - Calcareous rocks

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① Geological classification

(i) Igneous rocks :-

The inside portion of the earth surface has high temprature so as to cause fusion by heat at even ordinary pressure. The molten or pasty rocky material is known as magma and this magma occasionally tries to come out to the earth's surface through cracks (or) weak portions. The rocks which are formed by the cooling of magma are known as the igneous rocks.

(a) Plutonic rocks :-

Such rocks are formed due to cooling of magma at a considerable depth from earth's surface. The cooling is slow and the rock possess coarsely grained crystalline structure. Plutonic type igneous rocks commonly used in building industry. Example : Granite

(b) Hypabyssal rocks :-

Such rocks are formed due to cooling of magma at a relatively shallow depth from the earth's surface. The cooling is quick hence it possess finely grained crystalline structure. Ex : Dolerite

(c) volcanic rocks :-

Such rocks are formed due to the pouring of magma at earth's surface. The cooling is very rapid as compared to the previous two cases. Hence these rocks are extremely finegrained in structure. They frequently contain some quantity of glass which is a non-crystalline material. Ex: Basalt

Note:

* The principal constituents of magma are quartz, mica and feldspar.
* When magma cools rapidly, its mass expands under the pressure of intensively evolving gases. Subsequent rapid cooling of swollen lumps of magma gives rise to glassy porous rock known as pumice used as aggregate for light wt. concrete, as heat insulating material and as active mineral admixture to lime and cements.
* During volcanic eruption ashes, sands are mixed with molten lava to form tuff lava. Cemented tuff lava is called volcanic tuff. Tuffs have a glassy structure due to rapid cooling & are used as aggregate for light wt. concrete & mortar and an an active admixture to air-setting lime or cement.

(ii) Sedimentary rocks:-

Sedimentary rocks are known as aqueous or stratified rocks. The various weathering agencies, e.g. rain, sun, air, frost etc. break up carried away from their place of origin by the agents of transport such as frost, rain, wind, flowing water etc.

Following 4 types of deposite occur.

(a) Residual deposits:-

Some portion of the products, of weathering remain at the site of origin, called as residual deposits. (sedentary deposit)

(b) Sedimentary deposits:-

The insoluble products of weathering are carried away in suspension and when such products are deposited they give rise to the sedimentary deposits.

(c) chemical deposits:-
Some materials that is carried away in solution may be deposited by some physio-chemical process such as evaporation, precipitation etc. It give rise to chemical deposits. ↳ hydrolysis, carbonation.

(d) organic deposits:-
Some portion of the product of weathering gets deposited through the agency of organisms such deposits are known as organic deposits.
Example of sedimentary rocks = Gravel, sand stone, lime stone, gypsum, lignite etc.

(iii) Metamorphic Rocks

→ These rocks are formed by the change in character of the pre-existing rocks. The igneous as well as sedimentary rocks are changed in character when they are subject to great heat and pressure. The process of change is known as metamorphism.

→ There are 3 agents of metamorphism, namely, heat, pressure and chemically acting fluids. The heat may be supplied by the general rise of temprature with depth or by igneous magma. The pressure may be developed due to load of rocks or movement of earth. The chemically acting fluids play a passive role only & they don't take active part in the process of metamorphism.

4 type of metamorphism occur with various combinations of heat & pressure

uniform / direction

a Thermal metamorphism:-
Heat is predominant factor in this type of metamorphism.

b cataclastic metamorphism:-
At the surface of the earth, the temperature are low and metamorphism is brought about by directed pressure only such metamorphism is known as cataclastic metamorphism.

c Dynamo-thermal metamorphism:-
There is a rise in temperature with increase in depth. Hence the heat in combination with stress brings about the changes in rock. Such metamorphism is called Dynamo-thermal metamorphism.

d Plutonic metamorphism:-
Metamorphic changes at great depths are therefore brought about by uniform pressure and heat, such metamorphism is known as the plutonic metamorphism.

3. Physical Classification:-
(i) Stratified rocks:-
Show distinct layers along which the rocks can be split. Ex: sand stone, limestone, slate, shale, marble etc. [i.e. Sedimentary rocks]
(ii) Unstratified rocks:-
do not show any stratification and can't be easily split into thin layers. Ex: Granite, basalt, trap etc.

(iii) Foliated rocks:-

have a tendency to split up only in a definite direction. Most of the metamorphic rocks have a foliated structure except for quartzite, marble which have granulose structure.

3 Chemical classification:-

(i) Siliceous rocks:-

Principal constituent is silica ($SiO_2$) i.e. sand. These rocks are very hard and durable.

Ex - Granite, basalt, trap, quartzite, gneiss, syenite etc.

(ii) Argillaceous rocks:-

Principal constituent is clay or argil ($Al_2O_3$). These rocks are hard & brittle.

Ex: slate,

(iii) Calcareous rocks:-

In these rocks lime is predominates.

Ex:- limestone ($CaCO_3$), marble.

Use of Stones:-

- Stones are extensively used for the construction of foundations, walls, columns and arches in buildings.
- They are ideally suited for the construction of retaining walls, forts, piers of bridges and dams.
- Polished granite and marble are used for the face works of important buildings.
- Stone slabs are used for flooring, damp-proof course, lintles, roofing and pavers round the buildings, as well as for footpaths.

• Crushed stones are used as a basic inert material in concrete, for making artificial building blocks, Such as railway ballast and to provide base course for roads.

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## Natural bed stone:-

→ The building stones which are obtained from rocks, have a distinct plane of division along which stones can easily be split. This plane is known as the natural bed of stone.

Importance: In stone masonry, the general rule to be observed is that the direction of natural bed of all sedimentary stones should be perpendicular (or) nearly Iar to the direction of pressure. Such an arrangement gives maximum strength to the stonework.

✡ The natural bed of stones can be detected by Pouring water and examining the direction of layers. The magnifying glass may also be used for this purpose. The stone breaks easily along these natural beds.

→ The natural beds should be placed in horizontal in walls construction.

→ In stone arches, the stones are placed with their natural beds radial.

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## Qualities of good building stone:

→ Crushing strength > 100MPa.

→ uniform colour, free from clay [illegible] holes, spots of other colour, bands etc.

→ Stones should be durables & for making stones durable, their natural bed should be carefully noted. The stone should be arranged in a structure that the natural bed is ⊥ar. or nearly so to the dirⁿ of pressure.

☆ → For road work, co-eff of hardness > 17

co-eff of hardness 14-17 ⇒ medium hardness

co-eff of hardness < 14 ⇒ Low hardness

☆ → In attrition test, if wear > 3% ⇒ not satisfactory

if wear = 3% ⇒ Tolerable

For good building stone wear ≯ 3% (i.e) wear ≤ 3%

→ About 6 to 12 months is considered to be sufficient for proper seasoning to remove some moisture or quarry sap.

→ specific gravity > 2.7

→ Toughness index < 13 ⇒ Not tough

Toughness index 13-19 ⇒ Moderately tough

Toughness index > 19 ⇒ Highly tough.

☆ % absorption by weight after 24 hrs ≯ 0.6.

Attrition → It is the friction betⁿ same type of material.

Abrasion ⇒ Friction betⁿ different type of material.

1 gallon = 3.78 lit. Bricks

1 foot = 3.17 mm

{A human brain has a capacity to store 5 times as much information as wikipedia

1 Pound = 0.4536 k.g.

Standard size of bricks = (19x9x9) c.m

Modular size of bricks = (20x10x10) c.m ⇒ For high class brick masonary.

Size of Frog = (10x4x1) cm ⟹ To form key for holding the mortar.
↳ 1-2 cm deep

and therefore the bricks are laid with frogs on the top.

non-standardize (or) traditional (or) field bricks = (23 x 11.4 x 7.6) cm

* Bricks are of 2 types ⇒ ① Burnt bricks
② Unburnt bricks (or) Sundried bricks

Burnt bricks are used for construction work & classified into 4 main categories.

| 1st class brick | 2nd class brick | 3rd class brick |
|---|---|---|
| → Table moulded & Burnt in kilns. | → Ground moulded and burnt in kilns. | → Ground moulded and burnt in clamps. |
| → Deep red, cherry (or) copper colour. | → Deep red, cherry (or) copper colour. | → Soft and reddish yellow coloured. |
| → Free from flaws, cracks and stones & smooth rectangular surfaces with straight edges. Uniform texture & no impression when scratch by finger nail | → Small cracks & distortion are permitted. uniform texture and no impression when scratch by finger nail. | → rough surfaces with irregular & distorted edges. |

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| | | |
|---|---|---|
| → Metallic & ringing sound when struck against each other | → Metalic and ringing sound when struck against each other | → Produce dull sound when struck with each other |
| ✱ Water absorption = 12-15% of its dry weight. | ✱ Water absorption = 16-20% of its dry weight | ✱ W.A = 25% of its dry wt. |
| ✱ Crushing strength ≥ 10 MPa or $N/mm^2$ | ✱ Crushing strength ≥ 7 MPa | |
| Use → Pointing, exposed face work in masonary, Flooring. R.B. work. Weight = 3.85 Kg. | Use → For all important or unimportant hiden masory work centering of R.B. work & R.C.C. structure. | Use → For important and temporary structure and at place where rainfall is not heavy. |

R.B. Work → Rain Force Brick work

✱ Percentage of water absorption $= \frac{dw}{Sw} \times 100$

4th class Brick :- over burnt and badly distroted in → Jhama bricks
Shape & size brittle in nature.

Use → Ballast of such brick is used for foundation & floors in lime concrete and road metal, because of fact that over burnt bricks have a compact structure and hence they are sometime found to be stronger the even 1st class bricks.

**Properties of good brick :-**

A good brick should have →

1. uniform size, shape, rectangular surfaces with parallel sides and sharp straight edges.
2. uniform deep red and cherry colour as indicative of uniformity in chemical composition and throughness in the burning of brick.

3. Surface shouldn't be too smooth to cause slipping of mortar. The brick should have precompact and uniform texture. A fractured surface should not show fissures, holes grits (or) lumps of lime. ⇒ Texture & compactness.

4. Brick should so hard that when scratched by a finger nail no impression is made. ⇒ Hardness

5. Water absorption ≤ 20% of its dry wt. when kept immersed in water for 24 hrs.

6. Crushing strength ≥ 10 MPa.

7. Soundness ⇒ Metallic sound be produced when 2 brick struck together

8. Brickearth should be free from stones, grits, organic matter etc.

Composition of good brick earth:

Silica ⟹ 50-60%
Alumina ⟹ 20-30%
Lime ⟹ 10%

Alkalis ⟹ < 10%
Ferric oxide ⟹ < 7%
Magnesia ⟹ < 1%
[< 20%]

$CO_2$, $SO_3$ & $H_2O$ ⇒ Traces

In cement
lime (CaO) ⇒ 60-65
Silica → 17-20%
Alumina ⇒ 3-8%

LSA → cement
SAL ⇒ Brick

Silica:

↳ Exists in clay either as free or combined. As free sand is mechanically mixed with clay and in combined form, it exists in chemical composition with alumina.

★ → It prevents cracking, shrinking and warping of raw bricks. Thus it imparts durability and uniform shape to bricks.

→ Excess of silica destroys the cohesion bet^n particles and the bricks become brittle.

→ A large percentage of sand (or) uncombined

· Silica in clay is undesirable. However it is added to decrease shrinkage in burning and to increase the refractoriness of low alumina clays.

2 Alumina [20-30%]

* Alumina is chief constituent, of every kind of clay.

→ It absorbs water and imparts plasticity to the earth such that it can be moulded.

→ If alumina is present in excess, it causes cracks in bricks on drying and becomes too hard when burnt.

→ Clays having high alumina are found to be very refractory.

Lime [< 10%] [but < 5% most desirable for good brick earth]

→ Prevents the shrinkage on drying.

→ It causes silica in clay to melt on burning and hence helps to bind it. But the excess lime causes the brick to melt and hence its shape is lost.

* The lumps of lime are converted into quicklime after burning and this quick lime slakes and expands in presence of moisture; such an action results in splitting of bricks into pieces.

→ In carbonated form, lime lowers the fusion point.

Oxides of iron [Ferric oxide] [< 7%]

→ It gives red colour on burning when excess of oxygen is available and dark brown (or) even black colour when oxygen available is insufficient but excess of ferric oxide makes the brick dark blue (or) blackish.

→ It improves impermeability and durability.
→ It lowers the fusion point of the clay, especially if present as ferrous oxide.
→ It gives strength and hardness.

Magnesia : [< 1%]
→ decrease shrinkage and gives yellow tint → Excess of magnesia leads to the decay of bricks.

★ Harmful ingredients in Brick earth :-

1. Lime :-
If excess of lime → colour of brick changes from Red to yellow.
→ When lime is present in lumps, it absorbs moisture, swells, cause pieces of brick.

2. Iron pyrites :-
If iron pyrites are present in brick earth, then bricks tend to oxidise and decompose during burning and may split into pieces.
→ Pyrites discolourise the brick.

3. Pebbles, gravels, grits :- It doesn't allows clay to be mixed uniformly and thoroughly, which will result in weak and porous bricks.
→ Bricks containing pebbles will n't break regularly as desired.

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4. Alkalies :-
→ Excess of alkalies causes brick to melt and loose their shape.
→ Alkalies causes efflorescence - when brick come in contact with moisture.
water is absorbed and the alkalies crystallise. on drying, the moisture evaporates, leaving behind grey (or) white powder deposits on the brick which spoil the appearance and this phenomenon is called efflorescence.

5. Organic matter:

→ During burning of bricks, organic matter gets burnt completely, leaving behind pores and hence making bricks porous.

→ It also absorbs water and therefore reduces strength of bricks.

6. Water:- Large amounts of free water causes shrinkage of bricks on drying, whereas combined water causes shrinkage during burning.

7. Sulphur:-

If sulphur is present in brickearth & insufficient time is given (during burning) for oxidation of carbon & sulphur, then sulphur will cause the formation of spongy, swollen structure, in the brick and the brick will be decoloured by white boltches.

Manufacturing of bricks:-

(1) Preparation of brick earth → (2) Moulding → 3. Drying → 4. Burning (1000°C) → Brick

→ Unsoiling ⇒ Top 20 cm depth of soil is rejected because of full impurities.

→ Digging ⇒ Clay is then dugout & make heap of soil of height 60 cm to 120 cm.

→ Cleaning ⇒ If stones, pebbles are excess, then clay is to be washed & screened.

→ Weathering ⇒ Clay is then exposed to atmosphere for softening (or) mellowing from few weeks to full season of monsoon.

→ Blending ⇒ Proper blending done by clay is made loose & turning up & down in vertical dirn.

→ Tempering ⇒ Water in reqd quantity is added to clay and the hole mass is kneaded (or) pressed under the feet of men or cattle.

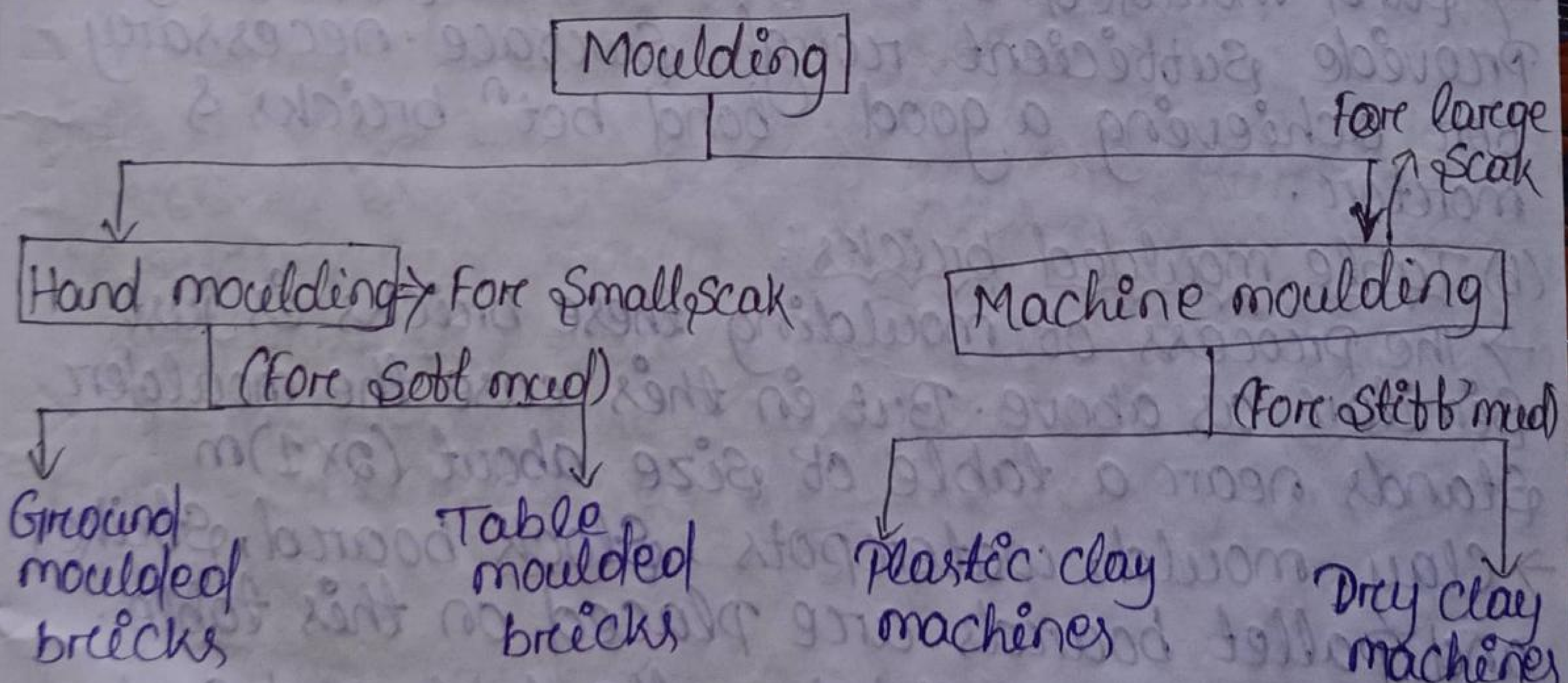
* For manufacturing of good brick, tempering is done in pug mills and operation is called pugging.
* In pug mill, feeding of clay from top and taking out of pugged clay from bottom are done simultaneously.
* Tempering of clay is done such that brick earth can be rolled without breaking in small threads of 3mm diameter.

2. Moulding :-

→ It is the process of giving required shape to the brick from prepared brick earth.

* We know that bricks shrink during drying and burning. therefore, moulds are made 8-12% larger size that of fully burnt bricks.

→ Exact percentage of increase in dimensions of mould is found by experiments on brick earth at site.




(i) Hand moulding :-

→ Adopted, when man power is cheap, & easily available for manufacturing of bricks, usually done on small scale.

→ Moulds are rectangular boxes of wood or steel, open at top & bottom.

(a) Ground moulded bricks :-

→ adopted when a large & level land is available.

→ In this process ground is levelled & sand is sprinkled over it.

→ Extra (or) surplus clay is removed either by a wooden strike (or) metal strike.

→ Now mould is lifted and raw bricks is left on the ground.

→ To prevent the moulded bricks from sticking to the side of the mould, sand is sprinkled on the inner side of mould, (or) mould may be dipped in water every time before moulding is done.

v.v.I. ★ → If sand is sprinkled then bricks are called as Sand - moulded bricks, & in case of mould dipped in water, bricks are called as Slop - moulded bricks.

→ Sand moulded bricks are better since they provide sufficient rough surface necessary for achieving a good bond betⁿ bricks & mortar.

(b) Table moulded bricks :-

→ The process of moulding these bricks is just similar as above. But in this case the moulder stands near a table of size about (2×1)m

→ Clay, mould, waterpots, stock board, strikes and pallet boards are placed on this table.

→ Bricks are moulded on the table and sent for the further drying.

→ cost of brick moulding also increase when table moulding is adopted.

ii) Machine moulding:-

→ Moulding is done with the help of machines when bricks are reqd in a large no. of quantity in a short span of time.

2 ways of classification

(a) plastic clay machine method:-

→ In this method pugged stiff clay is forced through a rectangular opening of brick size by means of an augere.

→ These bricks come out of the opening in the form of a bar and furthure these bricks are cut into strips by wire fixed in frames.

* As the bricks are cut by wire, they are also known as wire-cut bricks.
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(b) Dry clay machine method:-

→ In this method, moist, powdered clay is fed into the mould on a mechanically operated press, where it is subjected to high pressured and the clay in the mould takes the shape of bricks.

→ Such pressed bricks are more dense, smooth and uniform than ordinary bricks. These are burnt carefully as they are likely to crack.

3. Drying :-

→ If Green bricks (containing 7-30% moisture) are burnt, are likely to be cracked and distroted

→ Therefore moulded bricks are dried to remove moisture for controlling of shrinkage and saving of feel during burning.

→ It is a normal practice to dry moulded bricks to approx m.c of 5-7%.

# Drying

- Natural
- Artificial
  - Adopted when bricks are rapedly dried on large scale.
    - Tunnel driers
    - Hot floor driers

**Stage** (Natural)

① 1st bricks are allowed to dry in position as realeased from the mould.

② Then they are turned to stand on edge.

③ Arranged in rows in hacks with spaces of less than 1cm betn the bricks.

Stage ① & ② requires 2 to 3 days and stage ③ about one week.

☆ Tunnel drier are more economical than hot floor driers and they may be periodic (or) continuous.

☆ Temprature maintained by driers is usually less than 120°C and the process of drying of bricks takes about 1 to 3 days.

☆ The bricks in stacks should be arranged in such away that suffecient air space is left betn them for free circulation of air. It is to be seen that bricks are not directly exposed to the wind (or) sun for drying. Suitable screens, if necessary, may be provided to avoid such situation.

## 4. Burning:-

→ It is very important process in manufacturing of bricks as it provides hardness and strength to the bricks and makes them density and durable.

☆ Bricks should be burnt properly. If bricks are over burnt, they will be brittle and hence break easily. If they are underburnt, they will be soft and hence can not carry loads.

Burning of bricks can be divided into 3 stages.

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① Dehydration (400-650°C) ⇒ Also called water smoking stage.

→ The water which has been retained in pores of the clay after drying is driven off and the clay loses its plasticity.

* Some of carbonaceous matter is burnt.
* A portion of sulphur is distilled from pyrites.
* Hydrous minerals like ferric hydroxide are dehydrated.
* carbonate minerals are more (or) less decarbonated.

② Oxidation period (650-900°C)

→ Remained of carbon is elliminated.

→ The ferrous iron is oxidized to the ferric form

* Removal of sulphur is completed only after the carbon has been eliminated.

③ vitrification:

→ Convert the mass into glass like substance - the temp ranges from - 900-1100°C for low melting clay and 1000-1250°C for high melting clay.

* [1000°C reqd for burning of bricks (avg)].
* A special care is required in cooling the bricks below the cherry red heat in order to avoid checking and cracking.

Note:

Too rapid heating causes cracking (or) bursting of the bricks. on the other hand, if alkali is contained in the clay (or) sulphur is present in large amount in the clay, too slow heating of clay produced a scum on the surface of the bricks.

Burning →
- Clamps ⇒ Temporary structure for small scale manufacturing.
- Kilns ⇒ Permanent structure large scale manufacturing.

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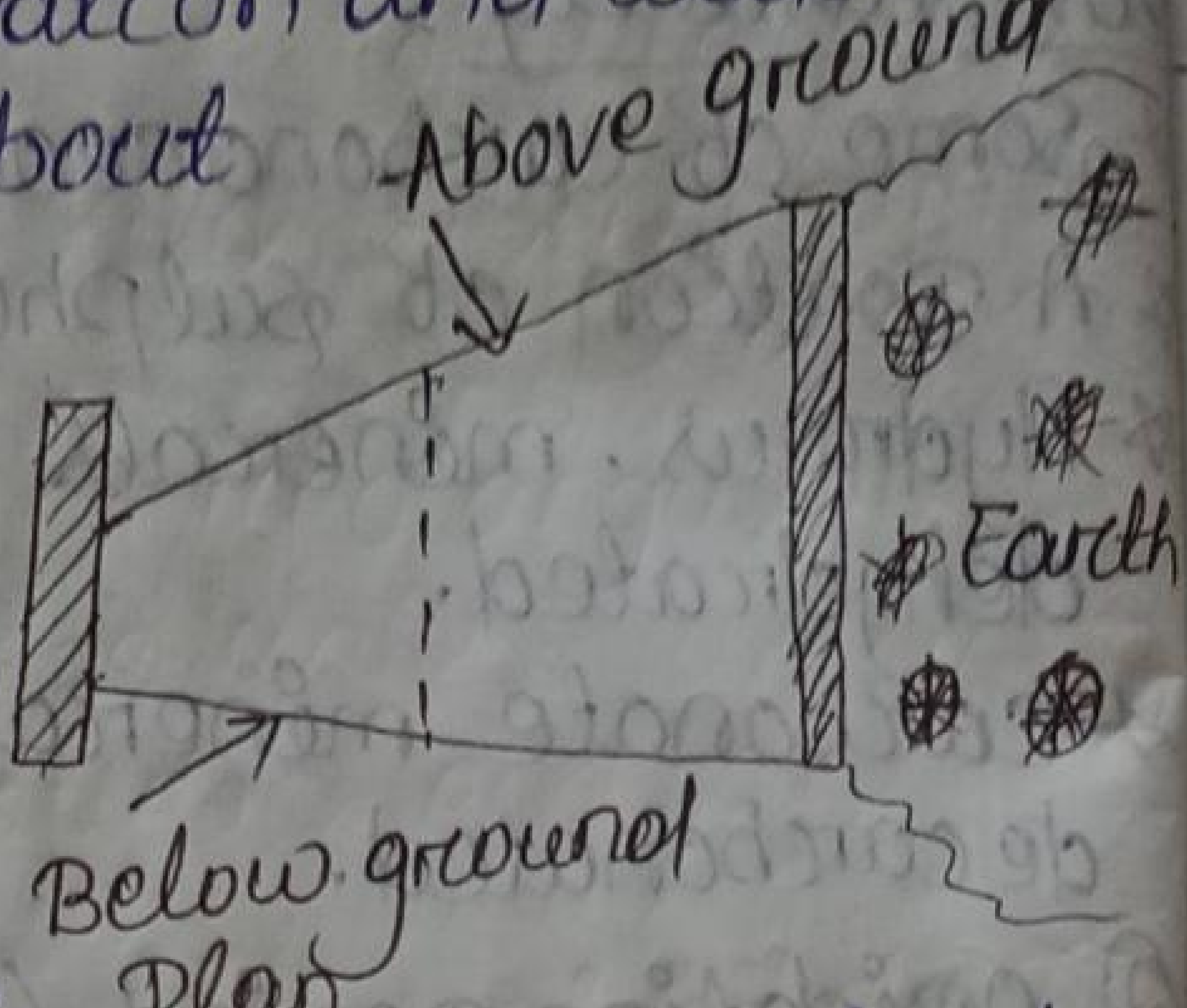
(i) Clamp (or) Pazawah :

→ A peice of land is selected such that its shape in plane is generally trapeziodial land floor of clamp is prepared in such a way that short end is slightly in the excavation and wider end is raised at angle of about 15° from ground level.




→ Brick wall in mud is constructed on the short end and a layer of fuel is laid on the prepared floor.

→ Fuel may consist of grass, cow dung, litter, rice husks, ground nuts etc.

→ Thickness of this layer is about 70 cm to 80 cm.

→ Layer consisting of 4 (or) 5 courses of raw bricks, is then put up. The bricks are laid on edges with small spaces betn them for circuln of air.

→ 2nd layer of fuel is then placed and over it, another layer of raw bricks is put up.

→ Alternate layer of fuel and raw bricks are formed.

⊛ Thickness of fuel layer gradually decreases as the height of clamp increases.

→ Total height of clamp is about 3m to 4m. when nearly $\frac{1}{3}$rd height is reached, the lower portion of the clamp is ignited.

→ when clamp is completely constructed, it is plastered with mud on sides and top and filled with earth to prevent the escape of heat.

→ Clamp is allowed to burn for a period of about one to two months. It is then allowed to cool for more or less the same period as burning.

→ Burnt bricks are then taken out from the clamp.

Advantages of clamp burning :

→ Burning & cooling of bricks are gradual in clamps. Hence the bricks produced are tough & strong.

→ Burning of bricks by clamps proves to be cheap & economical. No skilled labour and supervision is reqd for the construction & working of clamps.

→ Clamp is n't liable to injury from high wind or rain.

→ There is considerable saving of fuel.

Disadvantages of clamp burning :

→ Bricks are not of regular shape. This may be due to the settlement of bricks when fuel near bottom is burnt and turned to ashes.

→ very slow process.

→ It isn't possible to regulate fire in a clamp. once it starts burning and the bricks are liable to uneven burning.

→ Quality of bricks is not uniform.

→ Bricks near the bottom are overburnt and those near sides & top are under burnt.

(ii) Kilns :— → Intermittent
→ continuous

→ A kiln is a large oven used to burn bricks.

→ Bricks prepared by kilns are better than clamps.

(a) Intermittent kilns :

→ These kilns are intermittent in operation which means that they are loaded, fired, cooled and unloaded.

→ These be either rectangular or circular in Pain.

→ They can be overground (or) underground.

→ Intermittent kilns are further divided into 2 groups.

(a) Intermittent up-draught kilns ⇒ not uniform ⇒ Bottom = overburnt, Top = underburnt

(b) Intermittent down-draught kilns ⇒ Evenly burnt bricks.

→ These kilns are in the form of rectangular structure with thick outside walls.

→ Wide doors are provided at each end for loading & unloading of kilns.

→ Fuel channels (or) passages are provided to carry flames (or) hot gasses through the body of kiln.

→ After loading the kiln, it is fired, loaded and unloaded for next loading.

→ Since wall and sides gets cooled during reloading and are to be heated again during next firing, there is a wastage of fuel.

→ Int. up-draught gives non uniform burning bricks, bricks near bottom are overburnt & those near top are underburnt. Int. down draught kiln gives evenly burnt brick.

Continious kiln:

→ These kilns are continious in operation i.e. loading, firing, cooling and unloading are carried out simultaneously in these kilns.

3 types of continuous kilns : ① Bull's trench kiln
② Hoffman's kiln
③ Tunnel kiln

(i) Bull's trench kiln:

→ may be rectangular, circular or oval shape in plan.

As the name suggests, the kiln is constructed in a trench excavated in ground. It may be fully underground or partly projecting above ground.

* This is the most widely used kiln in India and it gives continuous supply of bricks.

(ii) Hoffman's kiln:

→ The kiln is constructed overground and hence it is called flame kiln.

→ Its shape is circular in plan & it is divided into a no. of compartments or chambers. As a permanent roof is provided, the kiln can even function during rainy season.

Qualities of good building bricks:-

Good building bricks have the following main qualities.

① Colour ⇒ Colour should be uniform and bright in colour.

② Shape ⇒ Brick should have plane faces. They should possess sharp and truly right angled corner.

③ Texture ⇒ Bricks should be fine, dense and uniform in texture. A fractured surface should not show fissures, cavities, loose grit and unburnt lime.

④ Size ⇒ Bricks should be of standard size prescribed by the code.

⑤ Sound ⇒ Bricks should give out a metallic sound when struck with a hammer (or) with another brick.

(6) Hardness ⇒ Scratching with fingure should not leave any impression on the brick.

(7) Strength ⇒ Crushing strength should be as high as possible.

(8) Water absorption ⇒ After immersing the bricks in cold water for 24 hrs W.A should n't be more than 20%.

(9) Efflorescence ⇒ Bricks should n't show white patches when soaked in water for 24 hrs. White patches indicate the presence of sulphates of calcium ($CaSO_4$), Mg, Na, K (i.e. all types of salt). They keep the mansorry permanently damp.

(10) Thermal conductivity ⇒ Bricks should have low thermal conductivity so that building built with them are cool in summer and warm in winter.

(11) Sound insulation ⇒ Light weight bricks and hollow bricks provide good sound insulation.

$$\text{Strength} \propto \frac{1}{\text{Sound insulation}}$$

So bricks with unnecessarily high strength (heavy bricks) need not be used.

(12) Fire resistance ⇒ Good bricks are fire resistant.

## Cement by mason Joseph Aspdin of Leeds in England in 1824.

Natural cement is obtained by burning and crushing the stones containing clay, carbonate of lime, and some amount of carbonate of magnesia.

* India's per-capita cement production is 210kg per annum as of Sep 2017.
* cement is a meterial which which has cohesive and adhesive properties in the presence of water.
* For civil Engg work, i.e. construction industry its primary function is to bind the fine aggregates (sand) and coarse aggregate particles together into a hard compact durable mass.

### Cement and lime:

→ cement can be used under conditions and circumstances which are not favourable for lime.

→ The cement, when coverted into a paste form, sets quickly.

→ colour of cement and lime are different.

→ when water is added to the cement, no heat is produced and there is no slaking action.

### Note:

* Cement is a product obtained by pulverizing clinker formed by calcinating raw materials primarily consisting of lime (CaO), silicate ($SiO_2$), Alumina ($Al_2O_3$) and ironoxide ($Fe_2O_3$).

Pulverize ⇒ make into a powder form or dust form

* calcination ⇒ The process of heating a substance to a high temprature but below the melting or

fusing point, causing loss of moisture, reduction on oxidation and dissociation into simple substances.

* Cements used in the construction industry can be classified as hydraulic and non-hydraulic.

→ Hydraulic cement set and harden in water and give a product which is stable e.g. port land cement.

→ Non-hydraulic cement doesn't set and harden in water such as non-hydraulic lime (or) which are unstable in water e.g. Plaster of paris.

* Cement can be manufactured either from natural cement stones (or) artificially by using calcareous and argillaceous materials. Examples of natural cements are Roman cement, Puzzolona cement and Medina cement. Ex: of artificial cements are OPC, special cements —

Note :-

Argillaceous (↓ Clay) ⇒ Shale & Clay, cement rock, Blast Furnace slag, marl.

Calcareous (↓ calcium carbonate) ⇒ Limestone, chalk, Marine shells.

* There are various varieties of artificial cement are available in the market at present, we will concentrate on OPC (or) normal setting (or) ordinary cement which has a production of about 2/3rd of the total production of cement.

Portland cement:

→ Most common variety of artificial cement and it is also known as normal setting cement (or) ordinary cement.

→ This cement is called as portland cement, because it has resemblance in its colour after setting to a variety of sand stone which is found in abundance in portland England.

1. Physical properties of cement:

→ Mainly depend upon its chemical composition, throughness of burning and fineness of grinding.

→ gives strength to masonary → an excellent binding material → easily workable.

→ offers good resistant to the moisture → Possesses good plasticity.

→ hardens early ⇒ cement thrown in water should sink and shouldn't float on the surface.

→ Fineness, consistency, initial setting time, final setting time, soundness.

2. Mechanical properties of cement:-

★ compressive strength @ end of 3 days ≮ 11.5 MPa
@ end of 7 days ≮ 17.5 MPa

★ Tensile strength @ end of 3 days ≮ 2 MPa
@ end of 7 days ≮ 2.5 MPa

3. chemical properties of cement:-

→ $\frac{Al_2O_3}{Fe_2O_3}$ (in %) ≮ 0.66 (or $\frac{2}{3}$).

→ $\frac{CaO\ (\%)}{Al_2O_3, Fe_2O_3, SiO_2(\%)}$ = LSF (Lime Saturation Factor)
⇒ ≮ 0.66
≯ 1.02
i.e. It should lie betn
0.66 - 1.02

→ Total loss on ignition ≯ 4%
→ Total sulphur content ≯ 2.75%
→ Wt. of insoluble residue ≯ 1.5%
→ Wt. of magnesia ≯ 5%

As per IS : 10262 has classified the OPC, gradewise from A to F based on 28 days compressive strength as follows:

| category | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| Strength (MPa) | 32.5-37.5 | 37.5-42.5 | 42.5-47.5 | 47.5-52.5 | 52.5-57.5 | 57.5-62.5 |

A ⇓ 33 grades; C ⇓ 43 grade; E ⇓ 53 grade; F: But 43 grade

cement available in market fall in category 'D' and that 53 grade cements in category F.

Composition of ordinary cement:

2 basic ingredients:
- → Argillaceous ⇒ clay predominates
- → calcareous ⇒ $CaCO_3$ predominates

| Ingredients | % composition | Functions |
|---|---|---|
| ① Lime (CaO) → | 62 → | control strength & soundness & its deficiency reduce strength time so set quickly & its excess make cement unsound so cause expand & disintegrate. Excess of it causes slow setting. |

②
③
④
⑤
⑥
⑦
⑧

② Silica → 22 → Gives strength (Formation of $C_2S$, $C_3S$)

③ Alumina → 5 → Responsible for quick setting if, in excess, it lowers the strength.

④ Iron oxide ($Fe_2O_3$) → 3 → Gives colour, hardness and strength to the cement and helps in fusion of different ingredients.

⑤ Magnesia ($MgO$) → 2 → Gives colour, hardness to the cement. If it in excess, causes cracks in mortar & concrete and unsoundness.

⑥ Calcium Sulphate ($CaSO_4$) → 3 → It is in the form of gypsum and its function is to increase the initial setting time of cement (i.e. delayed the setting)

⑦ Sulphur ($SO_3$) → 1 → useful for making the cement sound. If in excess, it causes cement to become unsound.

⑧ Alkalies $\begin{bmatrix} K_2O + Na_2O \\ TiO_2, P_2O_5 \end{bmatrix}$ → 0.2-1 → These are residues and if in excess cause efflorescence & cracking.

Note :

→ An increase in lime content beyond a certain value makes it different to combine completely with other compounds. Consequently, Free lime will exist in the clinker and will result in an unsound cement.

→ An increase in silica content at the expense of alumina and ferric oxide makes the cement difficult to fuse and form clinker.

(ii) Alkali oxides $K_2O$ and $Na_2O$ (ii) Magnesia ($MgO$), are two oxides adversely affects the quality of cement, so treated as harmful constituents of cement.

Note:

→ Rate of setting of cement paste is controlled by regulating the ratio of $\frac{SiO_2}{(Al_2O_3 + Fe_2O_3)}$.

→ When development of heat of hydration is undesirable, the silica content is increased to about 21% and the alumina ($Al_2O_3$) and iron oxide ($Fe_2O_3$) contents are limited to 6% each.

→ Resistance to the action of sulphate waters is increased by raising further the silica content to 24% and reducing the alumina & iron contents in 4% each.

→ The variation in composition depends largely on the ratio of $\frac{CaO}{SiO_2}$ in the raw materials.

→ Alkalis accelerate the setting of cement paste.

Composition of cement clinker:

→ When the raw materials are put in kiln then it fuses and following compounds are formed and they are known as Bogue's compound.

| Principal mineral compounds in OPC | Chemical Formula | Name | Composition | Formation in Kiln | Function | Heat of hydration |
|---|---|---|---|---|---|---|
| 1. Tricalcium silicate ($C_3S$) | $3CaO.SiO_2$ | Alite | 50-60% | IV | Early Strength | 500J/g |
| 2. Dicalcium silicate ($C_2S$) | $2CaO.SiO_2$ | Belite | 25-30% | III | Later Strength (Final or ultimate strength of cement) | 260J/g |
| 3. Tricalcium aluminate ($C_3A$) | $3CaO, Al_2O_3$ | celite | 8-12% | II | Initial setting (Flash set) | 865J/g |
| 4. Tetracalcium alumino Ferrite ($C_4AF$) | $4CaO.Al_2O_3.Fe_2O_3$ | Felite | 6-8% | I | Flash set | 420J/g |

1cal = 4.184J

↑ quality of cement by $C_3S$ / $C_2S$ ↑

$C_3S$ :-

→ It is supposed as the best cementing material and is well burnt cement.

→ It enables clinker easy to grind; increases resistance to freezing & thrawing.

→ It hydrates rapidly generating high heat and develops an early hardness and strength.

→ Raising of $C_3S$ content beyond the specified limits increases heat of hydration and solubility of cement in water.

→ The hydrolysis of $C_3S$ is mainly responsible for 7 days strength & hardness.

→ Rate of hydrolysis of $C_3S$ and the character of gel developed are the main cause of the hardness and early strength of cement.

$C_2S$:-

→ It rapidly hydrates and hardness slowly and takes long time to add to the strength (after a year (or) more). => It imparts resistance to chemical attck.

→ Excess (or) raising of $C_2S$ content, renders clinker harder to grind, reduces early strength, decreases resistance to freezing and throwing at early ages and decreases heat of hydration.

→ The hydrolyses of $C_2S$ proceeds slowly.

→ At early ages, less than a month, $C_2S$ has little influence on strength and hardness. while after 1 year, its contribution to the strength and hardness is proportionality almost equal to $C_3S$.

$C_3A$:

→ It rapidly reacts with water and is responsible for flash set of finely grounded clinker.

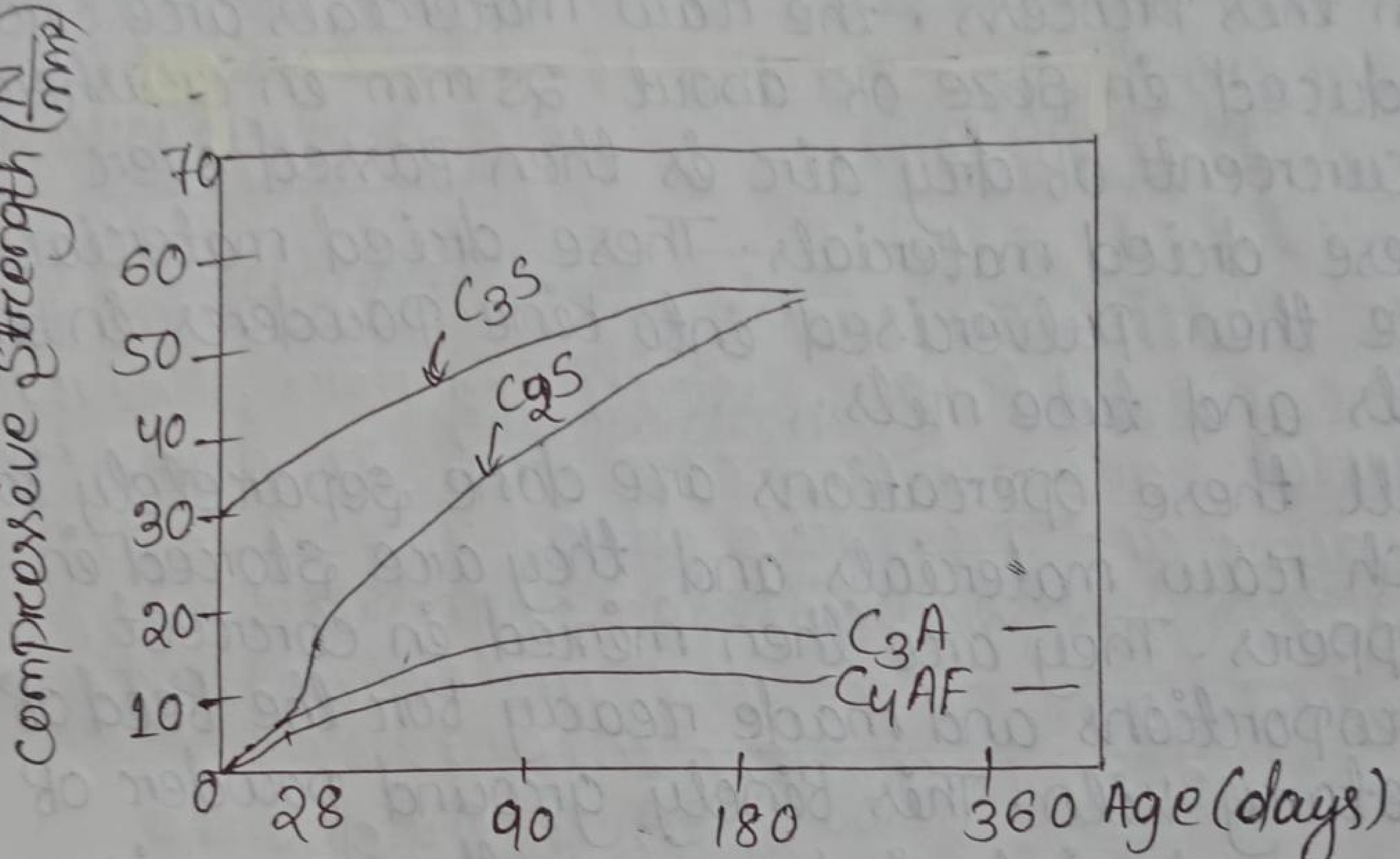
→ Rapidity of action is regulated by the addition of 2-3% gypsm at the time of grinding cement.

→ It is responsible for the initial set, high heat of hydration and has greater tendency to volume changes causing cracking.

→ Excess (or) raising the $C_3A$ content reduces the setting time, weakens resistance to sulphate attack and lowers the ultimate strength, heat of hydration and contraction during air hardening.

## $C_4AF$

→ It is responsible for flash set but generates less heat.
→ It has poorest cementing value.
→ Raising the $C_4AF$ content reduces the strength slightly.




(Contribution of cement compounds to strength of cement)

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## Manufacturing of ordinary cement :

→ 3 distinct operations are involved in the manufacture of OPC.

1. Mining of materials
2. Burning
3. Grinding

### 1. Mining of materials :

raw material
- → Argillaceous ⇒ Shale, Clay, cement rock, Blast Furnace slag, marl.
- → calcareous ⇒ limestone, Chalk, marine Shells.

✯ These raw materials can be mixed either in dry condition (or) in wet condition. The process is accordingly known as dry process or the wet process of mixing.

dry process ⇓ Modern technology

wet process ↳ old technology.

(i) Dry process (or) Modern technology:

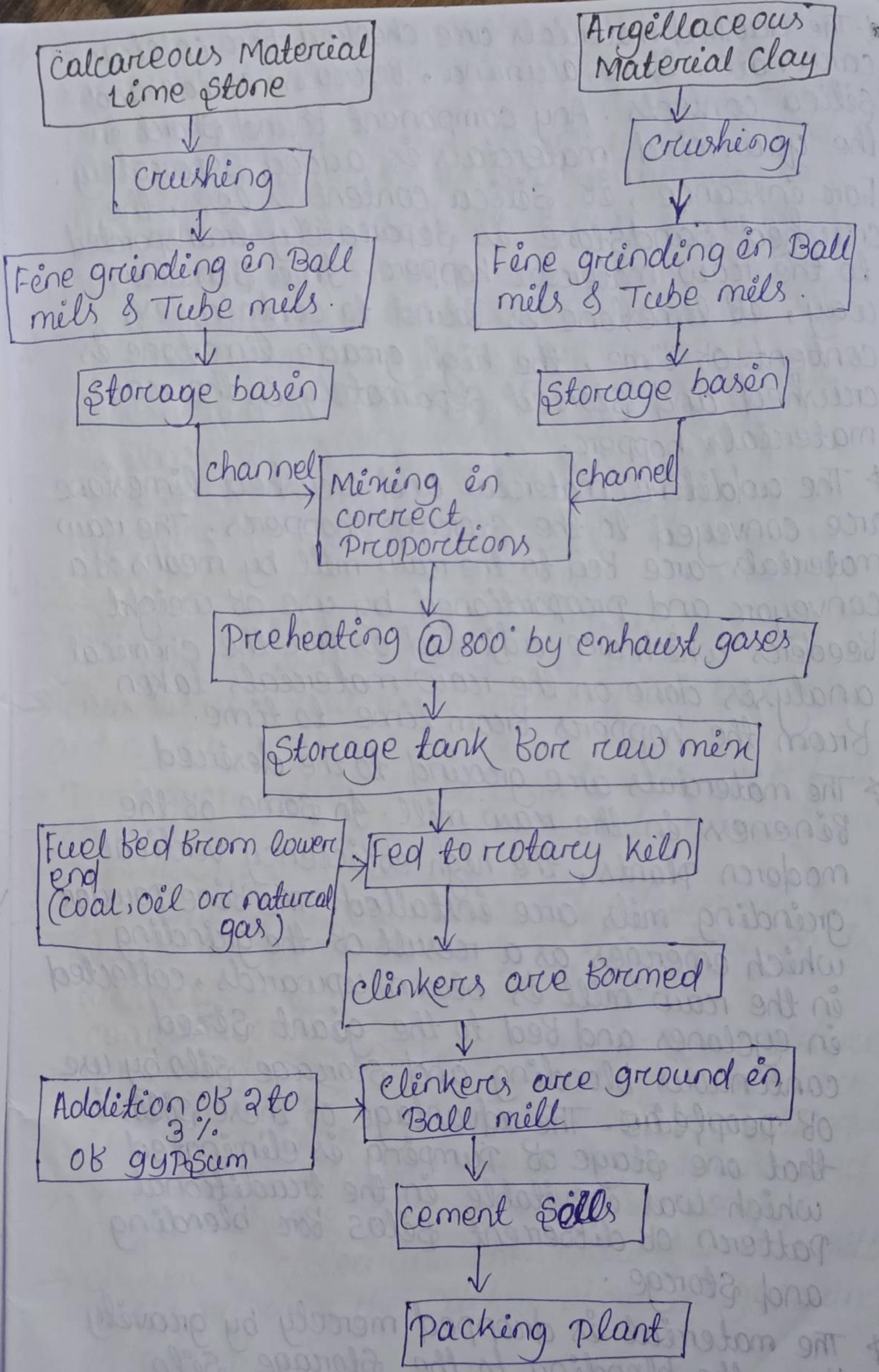
→ In this process, the raw materials are first reduced in size of about 25mm in crushers. A current of dry air is then passed over these dried materials. These dried materials are then pulverised into fine powders in ball mils and tube mils.

→ All these operations are done separetely for each raw materials and they are stored in hoppers. They are then mixed in correct proportions and made ready for the feed of rotary kiln. This finely ground powder of raw materials is known as the raw mix; and it is stored in storage tank.

Following is the procedure of manufacture of cement by the dry process / Modern technology.

→ Most of the cement factories are located very close to the lime stone quarries. The boulders upto 1.2m. size are transported in huge dumpers upto 300kN. capacity & dumped into the hopper of the crusher. After crushing of lime stone about 7.5 cm size is moved from crusher by a series of conveyors for stacking.

→ The argillceous (or) clay materials found in the quarry are also dumped into the crusher and stocked along with the limestone.




Flow diagram of dry process.

* The crushed materials are checked for calcium carbonate, lime, alumina, ferrous oxide and silica contents. Any component found short in the quarried materials is added separately. For instance, if silica content is less, the crushed sandstone is separately transported to the raw material hopper. In a similar way, if limestone is found to contain less content of lime, the high grade limestone is crushed and stored separately in the raw materials hopper.
* The additive material and crushed limestone are conveyed to the storage hoppers. The raw materials are fed to the raw mill by means of a conveyor and proportioned by use of weigh feeders which are adjusted as per the chemical analysis done on the raw materials taken from the hoppers from time to time.
* The materials are ground to the desired fineness in the raw mill. In some of the modern plants, the high efficiency vertical grinding mils are installed. The fine powder which emerges as a result of the grinding in the raw mill is blown upwards, collected in cyclones and fed to the giant sized continuous blending and storage silo by use of aeropole. The advantage of these silos is that one stage of pumping is eliminated which was inevitable in the traditional pattern of different silos for blending and storge.
* The material is dropped merely by gravity from the blending to the storage silo thereby conserving power.

* The material is then once again pumped using an aeropole into the preheater. The most modern preheaters have five stages. The temprature of the material bed from the top is increased in stages from 60°C to 850°C as hot gas at temprature of 1000°C is blown against the falling garoliant.
* The material from the bottom of the preheater is fed to the rotary kiln. Due to the use of multi-stage preheaters in the modern plants, the length of rotary kilns is considerably reduced thereby resulting in saving of maintenance cost and power requirements.

Wet process : [old technology]

→ operations in wet process of cement manufacture are mining, burning and grinding.

→ crushed raw materials are fed into ball mill and a little water is added.

→ During operation of ball mill, the steel ball in it pulverize the raw materials which from a slurry with water.

→ This slurry is passed to silos (Storage tank), where the proportioning of the compounds is adjusted to ensure desired chemical composition.

→ corrected slurry having about 40% moisture content, is then fed into rotary kiln where it uses moisture and forms into lumps/nodules

→ Then it is finally burned at 1500-1600°C and nodules change to clinker at this temp.

→ clinker is cooled and then ground in tube mills. While grinding the clinker, about 3% gypsum is added.

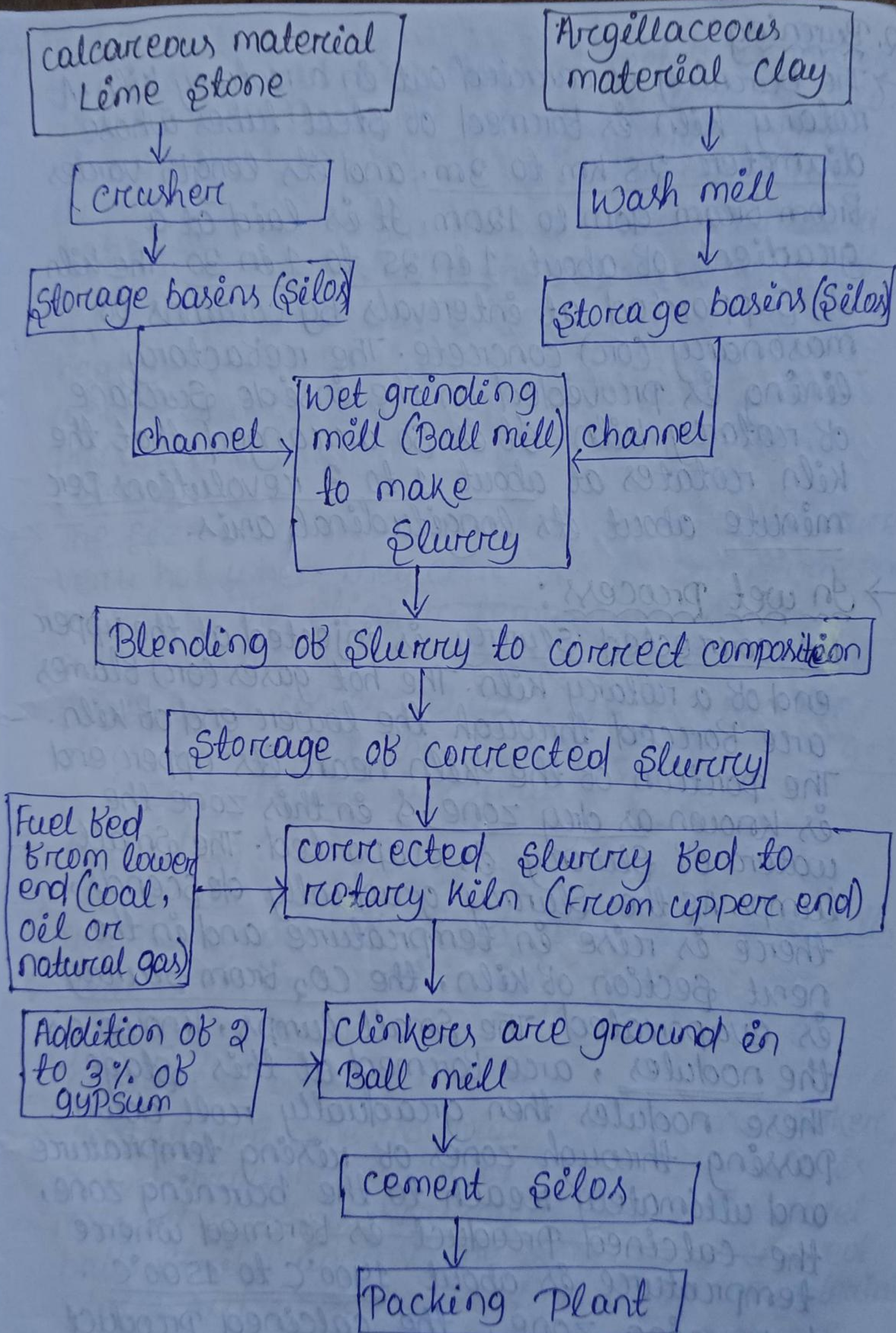
→ The cement is then stored in sides from where it is supplied.

## Comparison of wet and dry process :-

→ Dry process is considered to be economical as compared to wet process because of less consumption of fuel in the kiln.

→ Advantages of wet process are the low cost of excavating and grinding raw materials, the accurate control of composition and homogeneity of the slurry.

→ But longer kilns are reqd in wet process which are more costly and less responsive to a variable clinker demand than the short kiln which can be used in dry process.




Flow diagram of Wet process.

## 2. Burning :-

→ The burning is carried out in a rotary kiln. A rotary kiln is formed of steel tubes whose diameter 2.5 km to 3m. and its length varies from from 90m to 120m. It is laid at a gradient of about 1 in 25 to 1 in 30. The kiln is supported at intervals by columns of masonary (or) concrete. The refactory lining is provided on the inside surface of rotary kiln. It is so arranged that the kiln rotates at about 1 to 3 revolutions per minute about its longitudinal axis.

→ In wet process :

the corrected slurry is injected at the upper end of a rotary kiln. The hot gases (or) flames are forced through the lower end of kiln. The portion of the kiln near its upper end is known as dry zone. & in this zone the water of slurry is evaporated. As the slurry gradually descends, there is rise in temprature and in the next section of kiln, the $CO_2$ from slurry is evaporated. The small lumps, known as the nodules, are formed at this stage. These nodules then gradually roll down passing through zones of rising temprature and ultimately reach to the burning zone, where temprature is about 1400°C to 1500°C. In burning zone, the calcined product is formed and nodules are converted into small hard dark greenish blue balls which are known as clinkers.

→ In dry process:-
the coal brought from the coal fields is pulverised in vertical coal mill & it is stored in silo. It is pumped with required quantity of air through the burners. The pre-heated raw materials roll down the kiln and get heated to such an extent that the $CO_2$ is driven off with combustion gases. The material is then heated to temprature of 1400°C to 1500°C when, it gets fused together. The fused product is known as clinker (or) raw cement.

→ The size of clinker about 3-20 mm & they are very hot when they come out of burning zone of kiln. The clinker temprature at the outlet of the kiln is nearly 1000°C. There shall be a cooler which laid in opposite direction, cool the clinker to temp. of 95°C & then collected in containers.

3. Grinding:

→ The clinker as obtained from the rotary kiln are finely ground in ball mills and tube mills.

★ Ball mills are used to have preliminary grinding and the tube mills are used to carry out final grinding.

→ In ball mill, the material to be ground (Clinker) is fed through the inlet, & when the mill is rotated about its horizontal axis, the steel balls strike against the perforated curved plates and in doing so, they crush the material. This crushed material passes through an inner sieve plates and then through an outer sieve plate. Then it is collected from an outlet.

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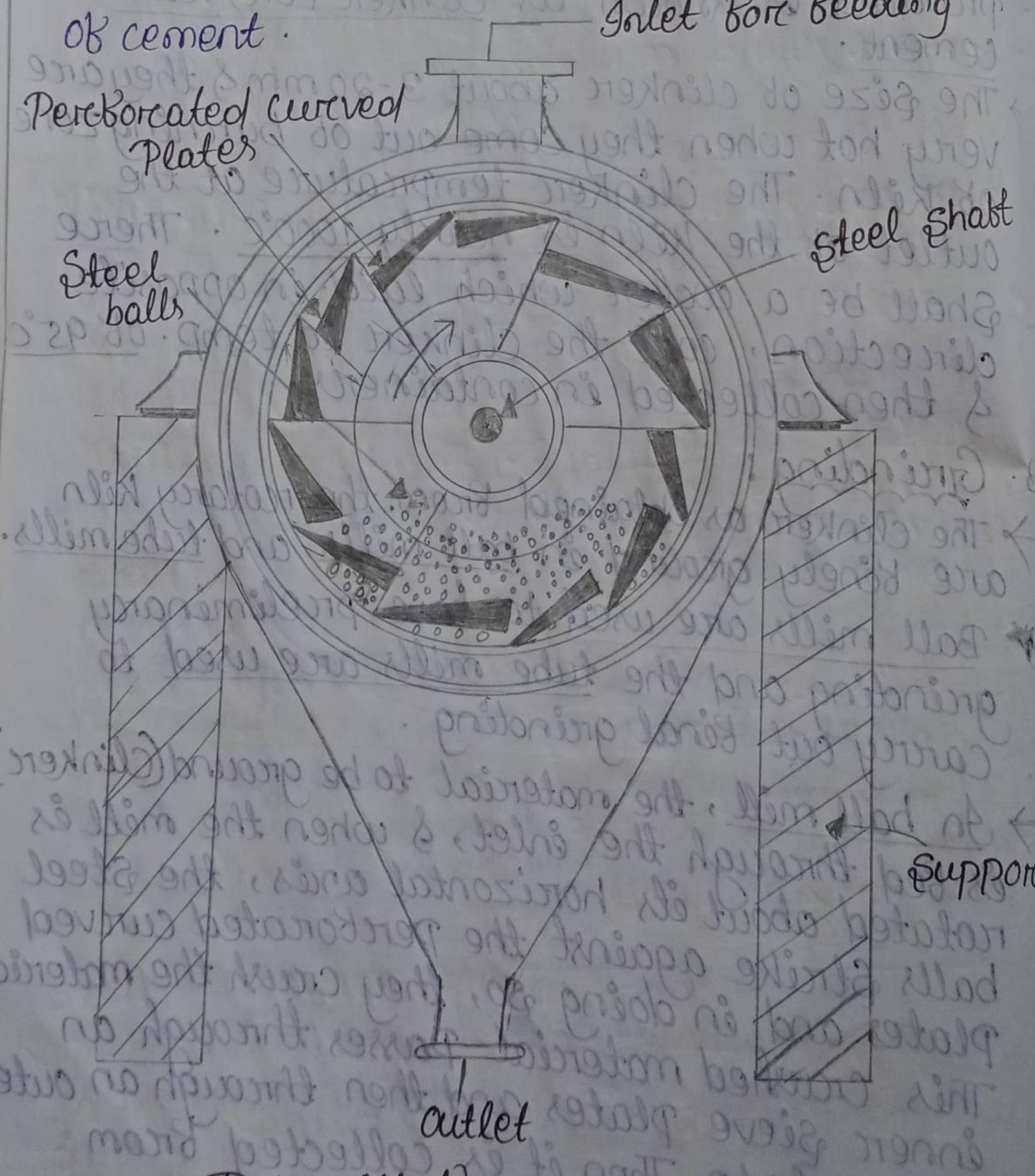
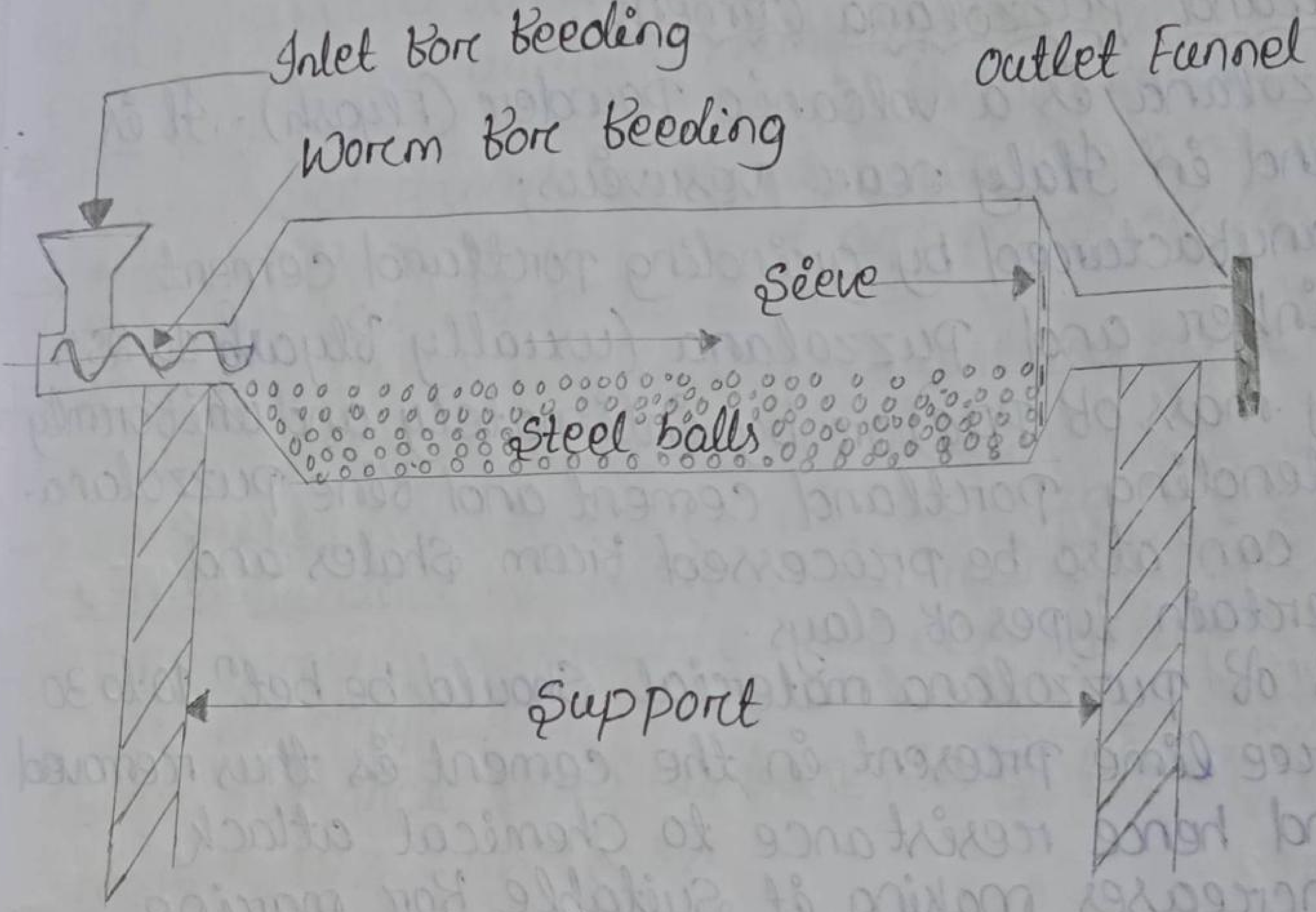
→ In tube mill, fine grinding is achieved due to steel balls of smaller size. A worm is provided to feed the material to the mill. The pulverised material is collected at the outlet funnel.

☆ During the grinding a small quantity about 3 to 4% of gypsum is added. Gypsum controls initial setting time of cement. So gypsum acts as a retarders and delays the action of cement.




Ball mill for grinding cylinders




Tube mill for grinding cylingers

Types of cement :

→ There are various types of cement available in the market. And the different special types of cements are manufactured by alternating the chemical composition of OPC, by using additives (or) by using different raw material.

1. PPC (Portland Pozzolana Cement)
2. PSC (Portland Slag cement)
3. RHC (Rapid Hardening cement)
4. HAC (High Alumina cement)
5. SSC (Super Sulphated portland cement)
6. SRC (Sulphate Resisting portland cement)
7. LHC (Low heat cement)
8. Quick setting cement
9. White and coloured cement

10. Hydrophobic cement
11. Air entraining cement

## Portland Puzzolana Cement :

Pozzolana is a volcanic powder (Flyash). It is found in Italy near vesuvius.

→ Manufactured by grinding portland cement clinker and puzzolana (usually flyash 10-25% by mass of PPC) or by intimately and uniformly blending portland cement and fine puzzolana

→ It can also be processed from shales and certain types of clays.
% of puzzolana material should be betⁿ 10 to 30.

→ Free lime present in the cement is thus removed and hence resistance to chemical attack increases making it suitable for marine works.

**Properties:**

→ It has low rate of development of strength but ultimate strength is comparable with OPC.
Addition of puzzolana to cement increases later strength and it offers greater resistance to the attack of aggressive water.

Compressive strength:

| | |
|---|---|
| 72 + 1 hr | ⟹ 16 MPa |
| 168 + 2 hr | ⟹ 22 MPa |
| 672 + 4 hr | ⟹ 33 MPa |

Setting times are same as of OPC.

→ Drying shrinkage ≯ 0.15% ⟶ Fineness ≮ 300 $\frac{m^2}{kg}$

Uses : It has low heat evolution and is used in the places of mass concrete such as dams, and in places of high temprature.

**Portland slag cement: (PSC)** (Slag is a non-metalic product)

Slag is a waste product in the manufacturing process of pig-iron and it contains the basic elements of cement, namely alumina, lime and silica.

✩ For this cement slag is used & the clinkers of cement are ground with about 60-65 % of slag.

→ properties of these cement are more or less the same as those of OPC.

→ Its strength in early days is less and hence it requires longer curing period.

→ It proves to be economical, as slag which is a waste product, is used in its manufacture.

→ This cement is durable, but not suitable for use in dry arid zones.

Blast furnace slag contains $CaO \cong 45\%$, $SiO_2 \simeq 35\%$, $Al_2O_3 \simeq 12\%$, $MgO \simeq 8\%$

**Grades of cement:**

→ It is classified either on the basis of specific surface area (or) crushing strength of concrete.

**Specific surface area (S.S.A.):**

→ defined as total surface area of cement particle in unit mass. units. $\frac{cm^2}{g}$, $\frac{m^2}{kg}$.

① 33 grade cement: If SSA = 225 $\frac{m^2}{kg}$

② 43 grade cement: If S.S.A = 340 $\frac{m^2}{kg}$ ⇒ Mostly used in general construction.

③ 53 grade cement: If S.S.A >>> 340 $\frac{m^2}{kg}$

**Crushing strength:**

→ Defined as the max^m compressive stress, developed in a cube just before failure.

## Mortar:

→ It is the mixture of B.M + F.A + water.

BM → Lime / cement

Lime + F.A + water ⇒ Lime mortar.

Cement + F.A + water ⇒ cement mortar.

Cement + Lime + F.A + water ⇒ Gauged mortar
⇓
[cement + lime mortar]
(or)
[lime + cement mortar]

☆ For 33 grade cement ⇒ If crushing strength $\nless$ 33MPa.

☆ For 43 grade cement ⇒ If crushing strength $\nless$ 43MPa

☆ For 53 grade cement ⇒ If crushing strength $\nless$ 53MPa

## Note:

→ 33 grade cement is outdated.

→ 43 grade cement can be used for general construction.

→ 53 grade cement can be used in high strength concrete.

☆ 53 grade cement cann't be used directly for general construction because shrinkage can occur.
If it is compulsory to be use then add some flyash before use it, it will reduce the strength.

## Mortar & concrete:

### Sand:

Sand is a natural product obtained as sea sand, river sand, nalla sand and pit sand. These days, manufactured sand is prepared by crushing harder varieties of stones. However, sea sand is not used for making mortar because of the following reasons:

- It contains salt and hence, the structure built with such mortar remains damp. After some time, blisters (white patches) appear on the surface.
- It contains shells and other organic matters, which decompose after some time, reducing the life of the mortar.

V.V.I.

### Bulking of Sand:

→ Bulking is increase in the value of given moss of sand caused by the films of water pushing the sand particles apart and exert surface tension force, so by which it keeps the particles away from each other & thus sand particle bulk in volume.

→ However bulk in volume of aggregate, particaly negligible in the case of coarse aggregate. But it is of great importance in case of F.A or sand.

→ Extent of bulking depends upon the percentage of moisture present in the sand and its fineness.

For a moisture content of about 5 to 8% this increase of volume may be as such as 20 to 40%, depending upon grading of sand. The finer the material the more will be the increase in volume for a given moisture content.

→ So bulking increases with moisture content up to a certain Point (4-6%) reaches a maximum, the film of water on the sand surface breaks, and then it starts decreasing till it finally at 25-30% of m.c, the volume of sand returns to its original volume when it is dry.

→ In Preparing concrete mixes if sand is measured by volume and no allowance is made for bulking, the moist sand will occupy considearbly larger volume than that prepared by the dry sand and consequently the mix will be richer.

→ In ordinary sand bulking varies from 15 to 30% for increase in moisture content 5 to 8%. For fine sand this might increase to 40% also.

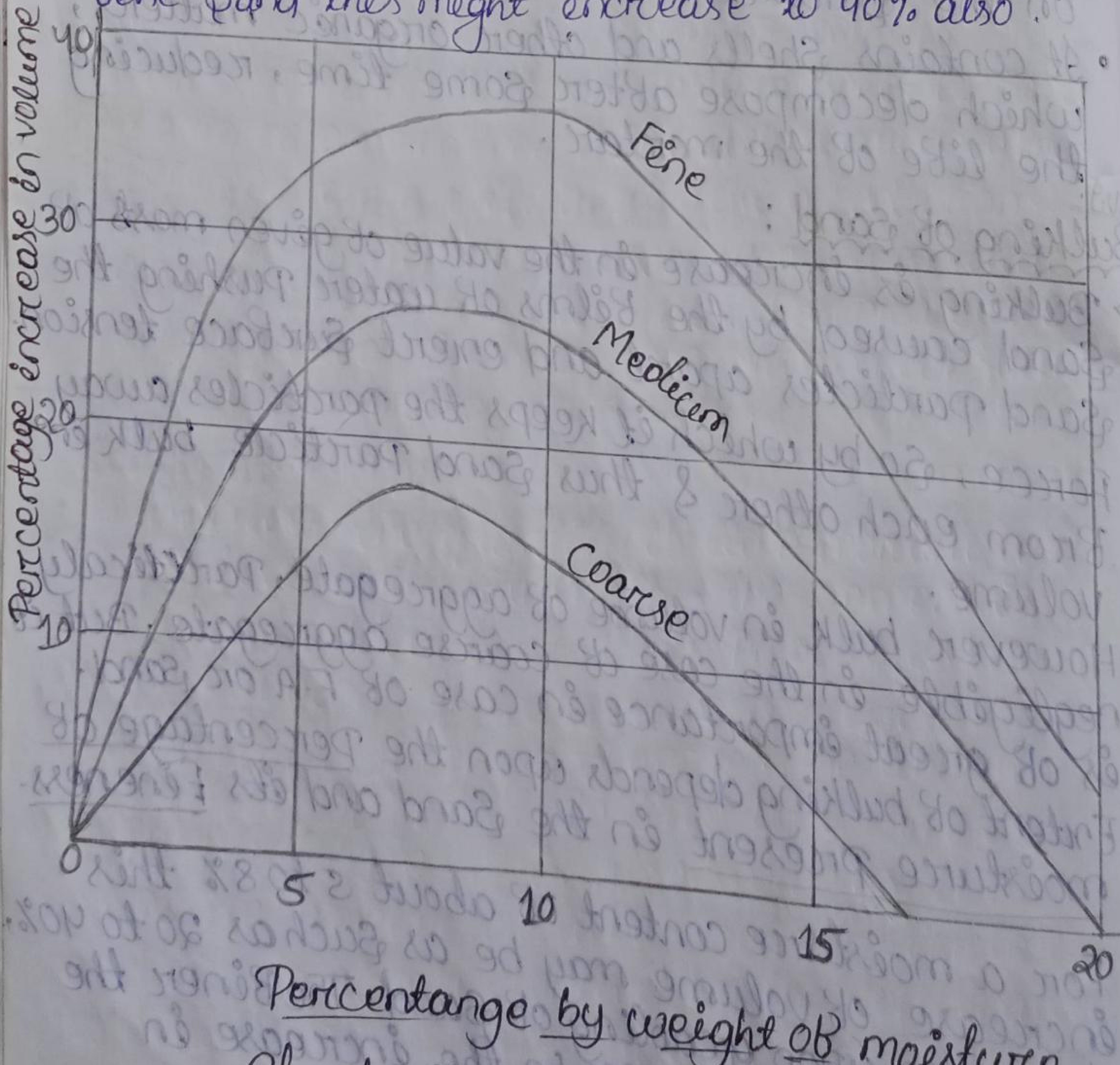



Chart Showing bulking of sand

The mortars are classified into the following five categories.

(i) Lime mortar
(ii) Surkhi mortar.
(iii) cement mortar
(iv) Gauged mortar
(v) Gypsum mortar.

(i) Lime mortar:

In this type of mortar, the lime is used as binding material.

The lime may be fat lime or hydraulic lime.

The fat lime shrinks to a great extent and hence it requires about 2 to 3 times its volume of sand. The lime should be slaked before use. This mortar is unsuitable for water-logged areas or in damp situations.

For hydraulic lime, the proportion of lime to sand by volume is about 1:2 or so. This mortar should be consumed within one hour after mixing. It possesses more strength and can be used in damp situations.

The lime mortar has a high plasticity and it can be placed easily. It possesses good cohesiveness with other surfaces and shrinks very little. It is sufficiently durable, but it hardens slowly. It is generally used for lightly loaded above-ground parts of buildings.

(ii) Surkhi mortar:

This type of mortar is prepared by using fully surkhi instead of sand or by replacing half of sand in case of fat lime mortar. The powder of surkhi should be fine enough to pass BIS No. 9 sieve and the residue should not be more than 10% by weight.

The surkhi mortar is used for ordinary masonary work of all kinds in foundation and

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superstructure. But it cannot be used for plastering or pointing since surkhi is likely to disintegrate after some time.

(iii) cement mortar:

In this type of mortar, the cement is used as binding material. Depending upon the strength required and importance of work, the proportion of cement to sand by volume varies from 1:2 to 1:6 or more. It should be noted that surkhi and cinder are not chemically inert substances and hence they cannot be used as adulterants with matrix as cement. Thus the sand only can be used to form cement motar.

The proportion of cement with respect to sand should be determined with due regard to the specified durability and working conditions. The cement mortar is used where a mortar of high strength water-resisting properties is required such as underground construction water saturated soils, etc.

Gauged mortar:

To improve the qua-lity of lime mortar and to achieve early strength, the cement is sometimes added to it. This process is known as the gauging. It makes lime mortar economical, strong and dense. The usual proportion of cement to lime by volume is about 1:6 to 1:8. It is also known as the composite mortar or lime-cement mortar and it can also be formed by the combination of cement and clay. This mortar may be used for bedding and for thick brick walls.

(V) Gypsum mortar :
These mortars are prepared from gypsum binding materials such as building gypsum and anhydrite binding materials.

Preparation of concrete

M30 = 1:2:2

A. proportioning of concrete ingredient

→ The process of selection of relative proportions of cement, sand, CA & water so as to obtain a concrete of desired quantity is known as the proportioning concrete.

→ It is observed that if a vessel in taken and filled with stones, of equal size, the voids to the extent of about 45% are formed. This result is independent of the size of stones. It is interesting to note that if sand is taken in place of stones, the same result will be obtained. ⇒ The result can be verified by pouring water in the vessel till it is full. The volume of water added in the vessel represents the amount of voids.

→ The theory of formation of concrete is based on this phenomena of formation of voids. When CA is placed, such voids are formed; when F.A i.e. sand is added, it occupies these voids. Further; when finely powdered cement is added, it occupies the voids of sand particles. During the process of setting, a chemical reaction takes place betⁿ water and cement. This results in an absolutely solid substance.

→ In general proportions of CA, F.A cement and water should be such that the resulting concrete has the following properties.

(i) When concrete is fresh, it should have enough workability so that it can be placed in the formwork economically.

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(ii) The concrete must possess max^m density i.e. it should be the strongest and most watertight.
(iii) The cost of materials and labour req^d to form the concrete should be minimum.

Different methods of proportioning concrete:

1. Arbitary method.
2. Fineness modulus method.
3. Minimum voids method.
4. Maximum density method.
5. Water - cement ratio method.

5. Water - cement ratio method:

According to Abram, if concrete is assumed to be fully compacted, then the lower water cement produces stiff paste having greater binding property and hence the lowering of w/c ratio within certain limits results in increased strength.

→ Similarly the higher water content increases the workability. But it is not useful for the the chemical action. The excess water evaporates leaving pores in the concrete. Thus the increased water - cement ratio lowers the strength of concrete.

(B) Measurement of materials:

(i) mass batching: 1 bag cement contains 50 k.g. mass of cement.

(ii) volume batching: volume of 50 kg cement = 34.7 lit. For volume boxes of size (30×30×38) cm are used. Size is in cubical shape

$V = \frac{M}{\rho} = \frac{500\,kg}{1440\,\frac{kg}{m^3}} = 0.0347\,m^3 = 35\ lit.$

C. Mixing and placing of concrete:

→ The ingredients of concrete should be throughly mixed such that the cement paste is coated to the surface of all aggregates and a uniform mass is obtained.

This can be done by —
→ concrete mixer for large work.
→ Hand mixing for small work.

→ The mixed concrete should be transported to the place of laying as early as possible.

→ During transport care should be taken to see that segregation doesn't take place and the concrete should be placed before it starts setting.

→ If segregation does occur during unloading the concrete should be remixed before placing.

D. compaction:

After concrete is placed at the desired location, the next step in the process of concrete production is its compaction.

compaction consolidates fresh concrete within the moulds or frameworks and around embedded parts and reinforcement steel.

→ compaction of the concrete is the process to get rid of the entrapped air and voids.

→ (imp) compaction is extremely important as 1% of voids can give a loss of 5% to 6% of strength, 5% of void can give a loss of 30% of strength, 10% of void can give a loss of 60% in strength, 25% of voids can give a loss of 90% in strength.

✡ Other properties of concrete like durability, impermeability etc. also greatly depends on the compaction of concrete.

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Compaction may be done by

- Hand tool
- Vibrator

## Hand tool:

→ This method of compaction is used for small and unimportant jobs. However this method is extremely useful for thin elements such as slabs and for members with congested reinforcements.

→ This method can be used for mixes with any workability except for very fluid or very plastic mix.

Hand compaction is achieved by rodding ramming or tamping.

## Compaction by vibration:

→ This is the most common and widely used method of compacting concrete for any structural element.

→ The vibration imparted to the fresh concrete reduce the internal friction betn the particles of concrete by setting the particles in motion and thus produce a dense and compact mass.

→ On vibration, the concrete mix gets fluidize and the internal friction betn the aggregate particles reduces, resulting in entrapped air to rise to the surface.

→ On losing entrapped air the concrete gets denser.

The various types of vibrators in use are needle, formwork, table or platform and surface vibrator.

(i) Needle vibrator:

→ These are also known as immersion, internal or Poker vibrator.

Needle vibrator can be used for any type of concrete work.

(ii) Formwork vibrator:

→ Also known as external or shutter vibrator. Generally used under the following circumstances.

- → compaction of concrete is reqd to be done in a very thin or very densely congested reinforced section.
- → In addition to internal vibration, compaction is reqd to be done specially in the cover area where at times needle vibrator is unable to do satisfactory compaction.
- → compaction of very stiff concrete is reqd to be done because such concrete can't be compacted by internal vibrator.

✡ Formwork vibrators are used for concreting columns, thin walls and precast units. These are rigidly clamped to the formwork, causing it to vibrate and consequently transfer the vibrations to concrete.

(iii) Surface vibrators:

→ These are also known as screed board vibrators. Surface vibrator are used for floor and roof slabs and pavement surfaces

✡ These are effective only upto a thickness of 150 mm (15 c.m) of concrete but can be used upto 25 cm.

→ Surface vibrators cause movement of fine particles to the top and hence aid the finishing operation. The operating frequency is 4000 cycles/min.

Note: compaction of concrete through vibrator is very useful. However over-vibration makes the concrete non-homogeneous.

E. Curr-ing:

→ The process by which the lost of water from concrete is prevented is known as curr-ing.
(or) The process by which keeping the concrete surface wet is known as curing.

Different methods of curing.

(i) Moist curing. — Spraying, Pondage.
(ii) Membrance curing.
(iii) Steam curing.

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Segregation

It is the separation of coarse aggregate from the concrete mass generally occurs because of non-reactive aggregate.

Bleeding

It is the separation of cement particles from the concrete mass in which cement floats on water.

# Test on concrete

- Test on freshly mixed concrete
  (To know the workability)
  - Slump test
  - Compaction factor test
  - Vee-bee test
- Test on hardened concrete
  - Destructive test
    - Comp. Strength
    - Tensile Strength
  - Non-destructive test
    - Rebound hammer test
    - Pulse velocity test.

Imp

## Test on freshly mixed concrete:

Workability :- Property of concrete (ability to work)

→ Workability is the ease with which a concrete can be mixed, placed and compacted so that a dense concrete is obtained (full compaction).

→ In wide sense workability is defined as the amount of useful internal work necessary to produce full compaction.

→ The workable concrete shouldn't show any Segregation & bleeding of concrete.

→ It should be noted that workability is different from consistency. consistency indicates fluidity or mobility.

→ concrete with high consistency may not be workable for a particular job and concrete having same consistency may vary in workability.

→ For example : concrete workable for foundation may not be workable for slab. Even for slab different workabilites will be required for compaction by hand and that by vibration. It is because the requirement of workability is less.

## Segregation:

Segregation is said to occur when the constituent material of concrete try to separate out from each other, producing concentration of coarser material at one place and finer material at other place in concrete. Such concrete contains large voids and is less durable.

→ Segregation occurs due to poor grading of aggregat (i.e. large difference, in size of particles) over vibration and dropping the concrete from above a certain height, which should be avoided & also due to concrete carried over long distance.

→ To reduce segregation, well graded aggregates are used and concrete is placed with enough compaction. The concrete shouldn't be dropped from a height of more than 1.5 meters, increasing small size of C.A, air entertainment, using dispersing agents and puzzolona.

## Bleeding:

Bleeding of concrete is said to occur when unreacted water in the mix tends to rise to the surface of freshly placed concrete due to sedimentation of constituents of concrete.

→ This produces continuous capillary pores which provides a clear straight acess to chemicals and deleterious materials in concrete and lowers the strength & durability of concrete

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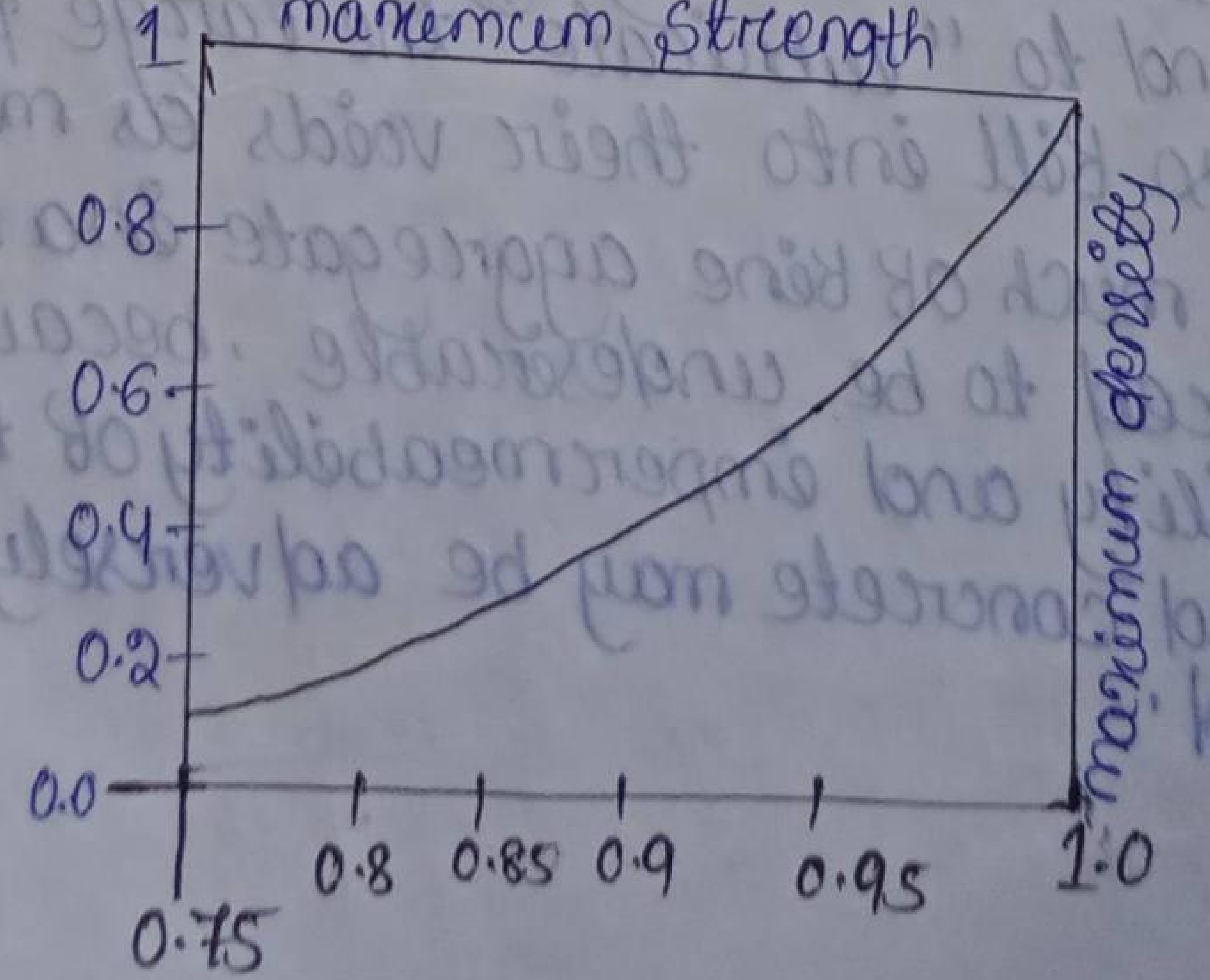
## Grading requirements of aggregate:-

→ Grading is the size distribution of aggregate. It is measured by sieve analysis and is generally described by means of a grading curve, which shows the 'cumulative percentage passing' against the standard IS sieve sizes.

→ The grading (as well as the type & size) of aggregate is a major factor which influences the workability of fresh concrete and its consequent degree of compaction.

→ It is of extreme importance with regard to the quality of hardened concrete, because incomplete compaction results in voids, thereby lowering the density of concrete and preventing it from attaining its full compressive strength capability also the impermeability and durability characteristics get adversely affected.

☆ It is observed that as little as 5% of voids can lower the strength by as much as 32%




(Relⁿ betⁿ density ratio and strength ratio)

→ From an economic view point, it is desired to aim for maximum density by a proper grading of aggregate alone - with the smaller particles filling, as much as possible, into the voids of the larger particles in the drystate, there by limiting the use of the (more expensive) cement paste to filling in the voids in the fine aggregate. Unfortunately such a concrete mix is prone to be "harsh" and "unworkable". Moreover, it is very likely to segregate, with the coarse particles separating out or setting - more than the finer particles.

→ The cement paste must be in sufficient quantity to be able to coat properly all the aggregate surfaces, to achieve the reqd workability, and to ensure that the particles sizes are distributed as homogeneously as possible without segregation.

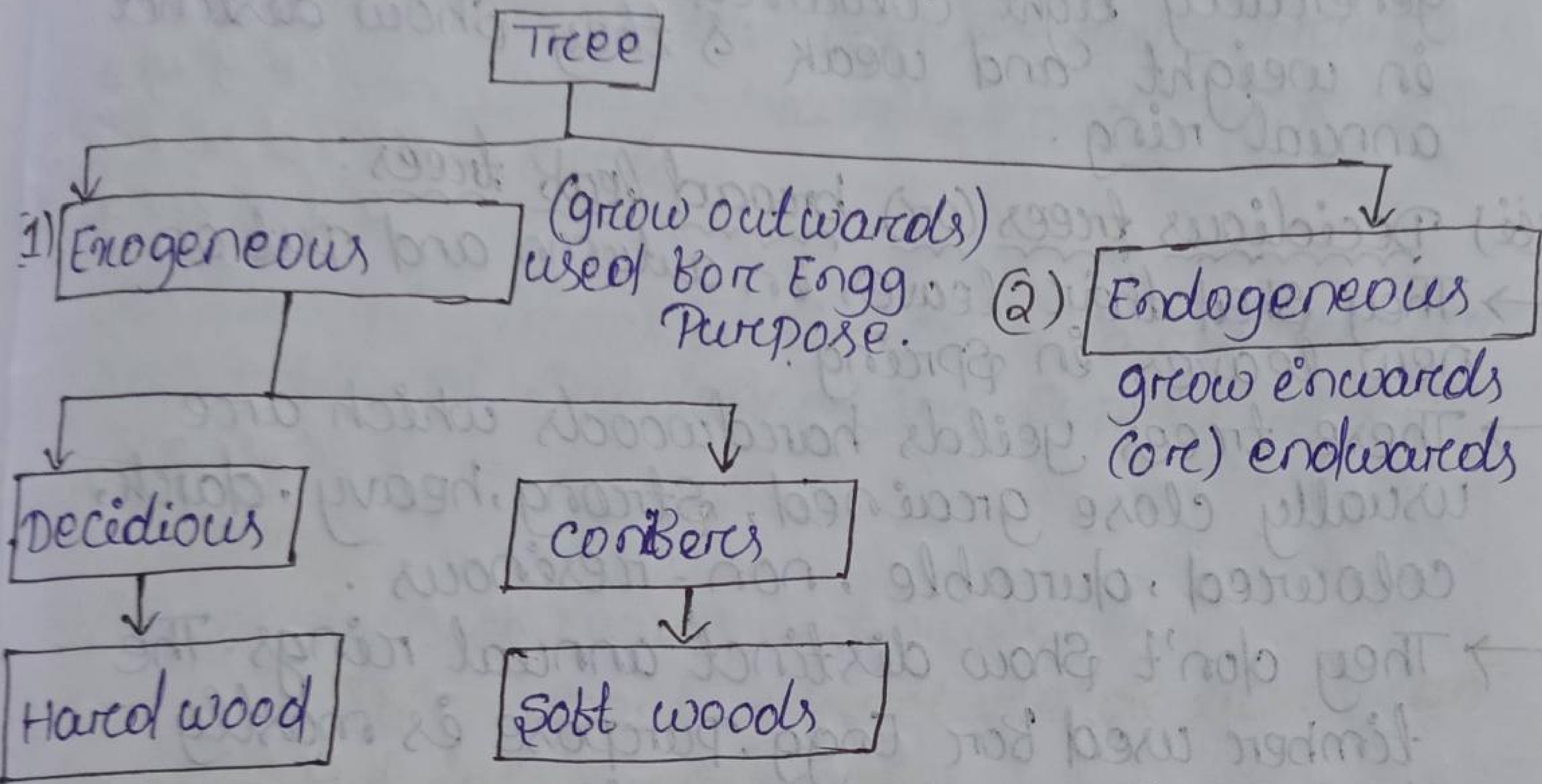
→ presence of more fines (sand & cement) in a mix is bound to improve both workability and resistance to segregation, because the fines tend to "lubricate" the large particles, and also fill into their voids as mortar.

→ But too much of fine aggregate in a mix is considered to be undesirable, because the durability and impermeability of the hardened concrete may be adversely affected.

# Timber

## classification of timber :

→ classified 2 types according to their manner of growth.




## Endogeneous trees :

→ grows inward or endwards.

→ Stems of these trees are too flexible, so not much suitable for Engg. Purpose.

→ Found in tropical countries & limited application for tempoprary construction.

Ex: cain, Bamboo, Palm etc.

## Exogeneous trees :

→ grows outwards & increase in bulk by the formation of successive annular rings on the outside under the bark.

→ These rings are known as annual rings because one such ring is added every year and these rings are useful in predicting the age of a tree.

→ Exogeneous trees are used for Engg. Purposes

Exogeneous trees are of 2 types.

(i) coniBers (or) evergreen trees:

→ They remain evergreen and bear Bruits in conoBorm with needle pointed leaves.

→ These trees yeild SoBtwoods which are generally light coloured, resinous, light in weight and weak & they show distinct annual ring.

(ii) Decidious trees (or) broad leaB trees:

→ They shed their leaves in autumn and put on new leaves in spring.

→ These trees yeilds hardwoods which are usually close grained, strong, heavy, dark coloured, durable, non-resinous.

→ They don't show distinct annual rings. The timber used Bor Engg. Purpose is mostly derived Brom decidious trees.

| Aspects | SoBt woods | Hard woods |
|---|---|---|
| 1. Trees Brom which obtained | ConiBers trees | Decidious trees. |
| 2. Annual rings → | Distincts → | Indistincts |
| 3. Medullary rays → | Indistincts → | Distincts. |
| 4. Structure → | Resinous and split easily → | Nonresinous and close grained |
| 5. Density → | low → | High |
| 6. Fire resistance → | Poor → | More |
| 7. Weight → | Light → | Heavy |
| 8. Strength → | Strong Bor direct Pull and weak Bor resisting trust and shear also strong along the grain.<br>Ex: Kail, Deodar, chir, Bir, pine sp ruce etc. | Equally strong Bor resisting tension, compression & shear. Also strong along and across the grain.<br>Ex: Babul, Mohogany, Sal, oak, teak etc. coconut. |

## Structure of timber:

⇒ Tree basically 3 parts:

1. Trunk (or) Stem ⇒
It support crown and supply water and nutrient from the roots to the leaves through branches ~~and leaves through branches~~ and from leaves back to the roots.

2. Roots ⇒
It implants trees in the soil, to absorb water and mineral substances and supply it to stem.

3. Crown ⇒
It consists of leaves and branches.

⇒ From visible aspect, structure of tree can be divided into 2 categories.

1. Macrostructure.
2. Microstructure.

1. Macrostructure can be study by cutting the trunk in 3 direction.

(a) crosssectional
(b) Longitudinal
(c) Radial.

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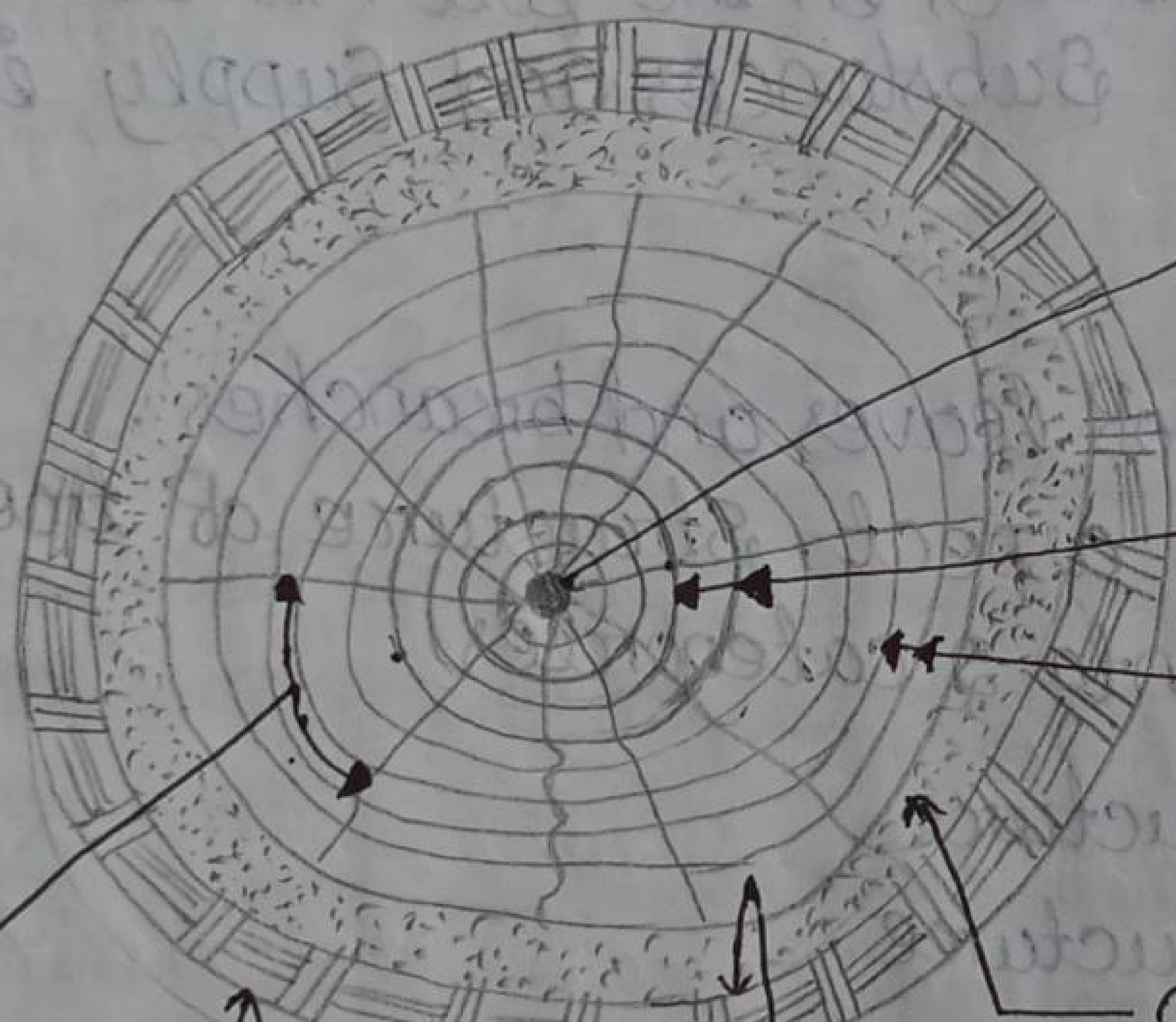
Cross-sectional view of trunk of an exogenous trees:-

Barks → cambium layer → Sapwood → Heartwood → Pith

Food supplied

not in young age
→ will be hole after long age




Annual ring or growth ring:

→ concentric layers of wood known as growth rings (or) annual rings.

→ It consist of cellular tissue and woody fibre. These are formed due to the deposition of sap below bark. The no. of annual rings indicates the age of tree in a tropical climate.

1. Pith (or) Medulla.

→ Innermost central portion (or) core of tree.
→ It varies in size & shape for different types of trees.
→ It consists entirely of cellular tissues & it nourishes the plant in its young age.
* → It is larger in young trees than that in matured trees.
→ Usually 12.5 mm dia. Sometimes barely visible.
→ As the plant becomes old, the pith dies up and decays and the sap is then transmitted by the woody Fibers deposited round the pith.
→ The pith of branches is nothing but merely a prolongation of the pith of stem.

2. Heartwood:-

→ Inner annual rings surrounding the pith constitute the heartwood.
→ Dark in colour generally & it is non porouse & dense.
→ It indicates dead portion of tree and as such, it doesn't take active part in the growth of tree.
* → It imparts rigidity to tree & hence it provides strong and durable timber for various engineering purpose.

3. Sap wood (or) Alburnum:

→ It outer annual rings betn heart wood and cambium layer is known as Sapwood.
→ It is light in colour and weight. It shows recent growth and contains sap.
* → The annual rings of Sap wood are less sharply

defined than those of heartwood. It takes active part in the growth of tree and the sap moves in an upward direction through it.

4. cambium layer:

→ The thin layer of sap betⁿ sap wood and innerbark is known as cambium layer.

→ It indicates sap which has yet not been converted into sapwood.

→ If the bark is removed for any reason the cambium layer gets exposed and the cells cease to be active resulting in death of tree.

[Bark is like our skin]

5. Innerbark:

→ The inner skin or layer covering the cambium layer is known as the inner bark. It gives protection to the cambium layer from any injury.

Outer bark: [Cortex]

→ The outer skin (or) cover of the tree is known as outerbark.

→ It is outermost protective layer & sometime contains crack & fissure.

→ It consists of cells of wood fibre & is also known as the cortex.

Medullary rays:

→ The thin radial fibers extending from pith to cambium layer are known as the medullary rays.

→ The function of these rays is to hold together the annual rings of heartwood and sapwood.

## 2. Microstructure

→ The structure of wood apparent only at great magnification is called the microstructure.
→ When studied under a microscope, it becomes evident that wood consists of living and dead cells of various shape & sizes.

* Living cell consists of 4 parts.

i. Membrance ⇒ consists of cellular tissue and cellulose.

ii. protoplasm ⇒ It is granular, transparent, viscous vegetable protein composed of carbon, hydrogen, oxygen, nitrogen & sulphur (CHONS).

(iii) Sap ⇒

(iv) core ⇒ core of cell differs from protoplasm merely by the presence of phosphorus and it is generally oval.

The cells according to the functions they perform, are classified into 3 types.

1. conductive cells: These cells serve mainly to transmit nutrients from roots to the branches and leaves.

2. Mechanical cells: These cells are elongated, thick-walled and have tightly interconnected narrow interior cavities. These cells imparts strength to the woods.

3. Storage cells: These cells serve to store & transmit nutrients to the living cells in the horizontal dir^n and they are usually located in medullary rays.

## Seasoning of timber:

→ Newly felled timber contains about 50% or more of its own dry weight as water. This water is in the form of sap and moisture. This water is to be removed before the timber can be used for any engineering purpose.

→ In other words the process of drying of timber is called seasoning.

→ If timber is used without seasoning, it is liable to shrink, warp and cracked, if used may even rot and decay occurs.

∴ Seasoning should be the first step for the efficient utilization of timber.

Imp

## Objects of Seasoning:

See properties *

→ To chock/minimise the tendency of timber to shrink, warp & split.

→ To increase the strength, durability and electrical resisting power of the timber (& also to increase hardness, stiffness).

→ To increasing the resisting power of timber as most of the causes of decay of timber are more or less related to timber seasoning.

→ To maintain the shape and size of the timber articles which are expected to remain unchanged in form.

→ To decrease the weight, so as to lower the cost of transport & handing.

→ To make timber easily workable and to facilitate operations during conversion.

→ To make timber suitable for gluing (i.e. effective Joining of 2 member by glue).

→ To make timber safe from attack of fungi and insects.

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→ To make timber fit for receiving treatment of Paints, Preservaties, varnishes etc.

→ To allows timber to burn readily, it used as fuel.

## Method of Seasoning

(1) Natural Seasoning ⇓ Air Seasoning

(2) Artificial Seasoning ⇓ (i) Boiling (ii) Chemical (iii) electrical (iv) kiln (v) water.

## Properties of Good Timber:

Good quality timber has the following properties:

Colour: It should be uniform and dark.

Odour: It should be pleasant when freshly cut.

Sound: A clear ringing sound when stuck, indicates the timber is good.

Texture: In good timber, the texture is fine and even.

Grains: close grains indicate good timber.

Density: Higher the density, better is the timber.

Hardness: Harder timber is strong and durable.

Warpage: Good timber retains its shape under changing environmental conditions.

Toughness: Timber should be capable of resisting shock loads.

Abrasion: Timber should be capable of resisting wear. This property is especially required if the timber is used for flooring.

Strength : Timber should have high strength in bending, shear and direct compression tension.

Modulus of elasticity : Timber with a high modulus of elasticity is preferred in constructing buildings

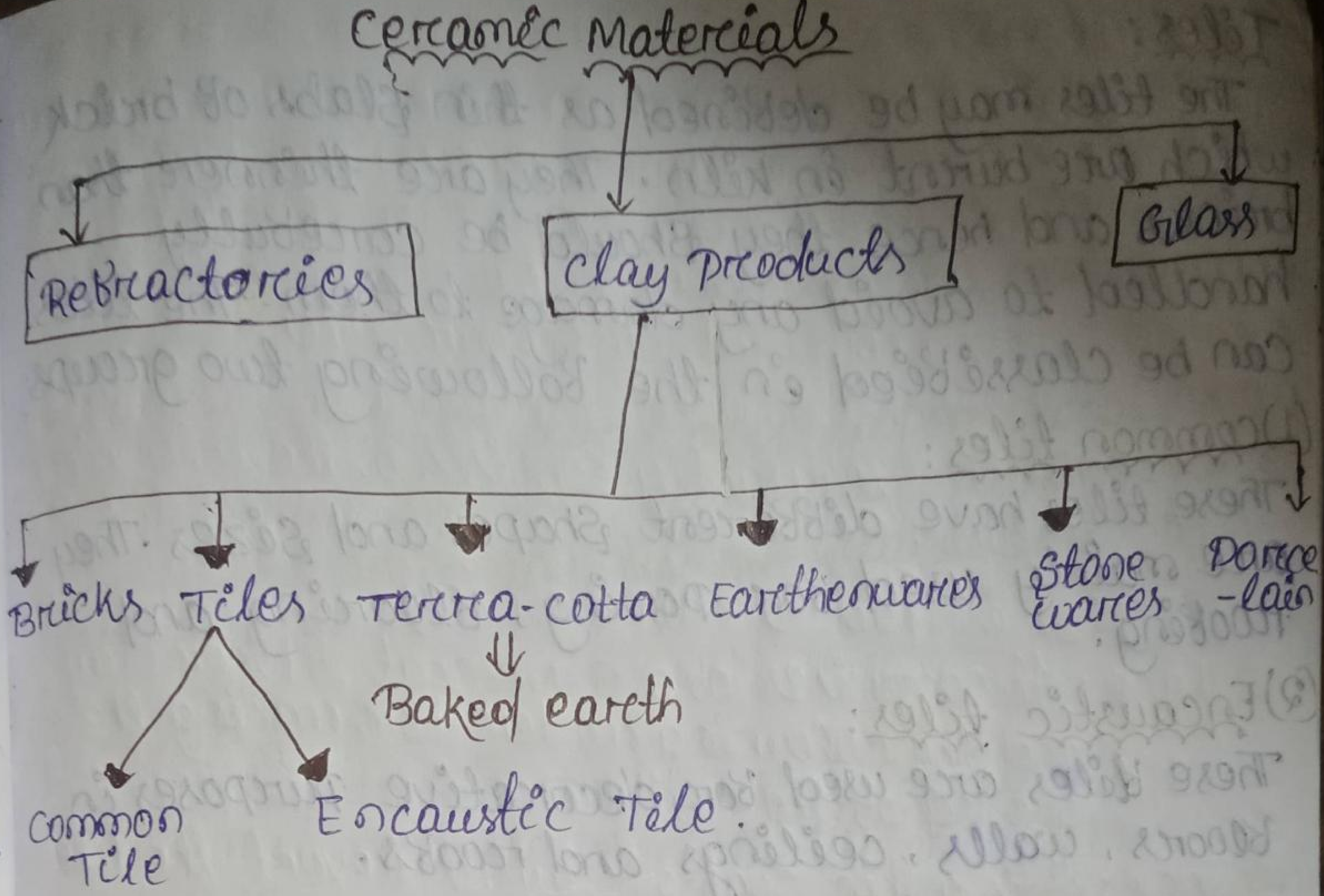
Fire resistance : Good timber has high resistance to fire.

Permeability : Good timber has low water permeability. This is measured by the quantity of water filtered through a unit surface area of a specified thickness of wood.

Workability : Timber should be easily workable. It should not clog the saw and should be capable of being planed.

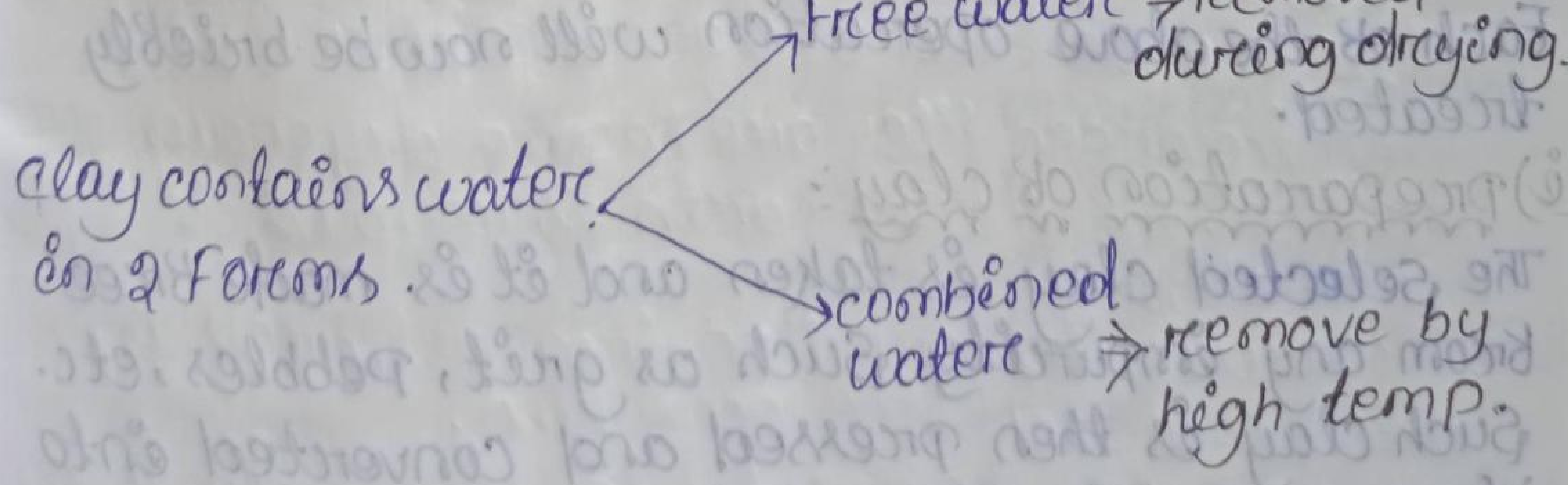
Durability : Good timber is capable of resisting the action of fungi, insects, chemicals and changing weather conditions. By seasoning and treating with preservatives, durability can be increased.

Defects : Good timber is free from serious defects like dead knots, shakes and cracks.




**Clay products :**

Clay is a distinct product of chemical weathering of igneous rocks. Clay occurs plenty in nature. Orthoclase felspar is mainly responsible for the production of clays in nature. This mineral, on decomposition, gives kaolinite which is free from ironoxide and alkalis.



Tiles:

The tiles may be defined as thin slabs of brick which are burnt in kiln. They are thinner than bricks and hence they should be carefully handled to avoid any damage to them. The tiles can be classified in the following two groups

(1) common tiles:

These tiles have different shapes and sizes. They are mainly used for paving, flooring and roofing.

(2) Encaustic tiles:

These tiles are used for decorative purposes in floors, walls, ceilings and roofs.

Common Tiles:

(1) Manufacture of common tiles:

Following four distinct operations are involved in the general process of manufacturing the common tiles.

(i) preparation of clay
(ii) Moulding
(iii) Drying
(iv) Burning.

Each of the above operation will now be briefly treated.

(i) Preparation of clay:

The selected clay is taken and it is made free from any impurity such as grit, pebbles, etc. Such clay is then pressed and converted into fine powder in pug mills.

For tiles of superior quality, a large quantity of pure water is added to the powered clay and it is well mixed in a tank. The mixture is then allowed to stand quietly. The coarse heavy particles settle at the bottom of tank. The fine particles are taken into other tanks and the water is then allowed to dry off. The fine clay left after such process is used for the manufacture of tiles.

To make the tiles hard and impervious, a mixture of ground glass and potterywarre may be added in required quantity to the clay of tiles.

(ii) Moulding:

The clay is placed in moulds which represent the pattern or shape in which the tile is to be formed. The moulding may be done either with the help of wooden moulds or mechanical means or potter's wheel.

The wooden moulds should be prepared from well seasoned timber. The clay is pressed into such moulds and tiles are ready for drying when clay is taken out of moulds. The care should be taken to preserve the shape of tiles during the removal of moulds. The tiles which do not have a uniform section throughout their length are moulded with the help of wooden moulds.

The moulding with the help of mechanical means includes the provision of machines and the clay is pressed into such machines to get tiles of

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## Encaustic Tiles :-

The encaustic tiles are manufactured from carefully prepared ordinary clays, colouring materials and sometimes with finer clays. Depending upon the colouring pigment added in the clay, these tiles obtain the desired print or colour after manufacture.

An encaustic tile usually consists of the following three layers.

(1) Body : It is made a coarser clay.

(2) Face : It comprises of a 6 mm coat of finer clay and the colouring matter for making the ground of the pattern.

(3) Back : It is a thin coat of clay to prevent the tile from warping.

The manufacturing process of these tiles is as follow

(i) The face is moulded to the desired pattern.

(ii) The coarser clay body is put on the back of the face and also a thin coat to form the back.

(iii) The maker's name is stamped on the back.

(iv) A few holes are kept for joining with cement during laying.

(v) The clay with different colours is poured into the different portions of the pattern so as to obtain the desired design of colours.

(vi) When the green tiles ~~are~~ become dry enough for handling, the excess earth is removed or scraped off.

(vii) The green tiles are then trimmed, dressed, dried and burnt in the dome kiln.

(viii) If required, the burnt tiles may be glazed by dipping them into a mixture of powdered glass and water and then reheating them.

Terra-cotta :-

(1) General : The terra means earth and cotta means baked. Hence the terra-cotta means the baked earth. It is thus a type of earthenware or porous pottery made from local clays and glazed with glazes containing galena. It is soft enough to be scratched by a knife.

(2) Manufacture of terra-cotta:

Following four distinct operations are involved in the manufacture of terra-cotta :-

(i) Preparation of clay
(ii) Moulding
(iii) Drying
(iv) Burning

Each of the above operation will now be briefly described.

(i) Preparation of clay: For terra-cotta, the selected clay is taken. The clay should contain a slightly higher percentage of iron oxide, about 5% to 8% and proportion of lime should be less, about 1 percent or so. Sometimes several varieties of clay with high alumina content are taken and then to this mixture is added sand, ground glass, old terra-cotta or pottery. The addition of Such materials gives strength and rigidity to the terra-cotta products and it prevents shrinking while drying.
Such clay is made free from any impurity such as grit, pebbles, organic matter, etc. It is then finely crushed and pulverized. The water is added in required quantity and the ingredients are thoroughly mixed with spades. Such wet clay is kept for several days in a damp condition for weathering and temperings. It is then pressed

or kneaded in a pug mill and it is made ready for the next operation of moulding. The required quantity of colouring substance is added at this stage to obtain the desired shade of colour in the final product of terra-cotta.

(ii) Moulding:

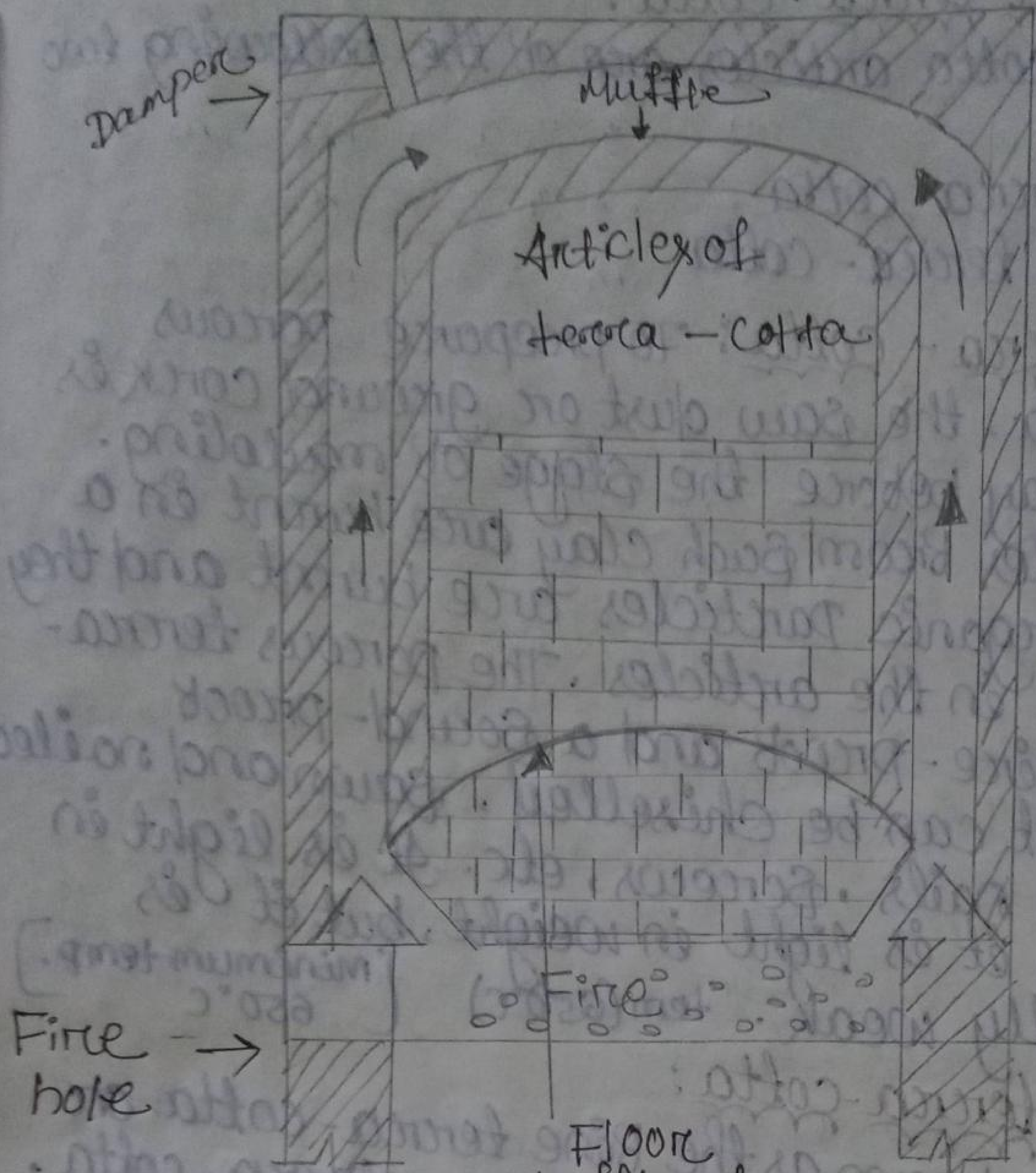
The clay is placed in moulds which represent the pattern or shape in which the product is to be formed. For terra-cotta work, special moulds of plaster of paris or templates of zinc are used. The size of moulds is determined by keeping due allowance for shrinkage. The fine sand is sprinkled on the inside surface of moulds and clay is then pressed in moulds with hand.

(iii) Drying:

The moulds filled in with clay are kept for some days for drying. After this period, the articles of the terra-cotta are taken out from the mould and they are allowed to dry further in a room or under a shed. The drying should be done carefully and slowly with proper control of temprature. The gradual drying helps in retaining the correct shape and size of the blocks.

(iv) Burning:

The dried products are then burnt in special muffle furnaces. temp (650-1200°C). 4 day burn & 5 days cooling down.



Muffle furnace

A muffle indicates a box or a compartment of a furnace in which things can be heated without contact with the fuel and its products. A damper indicates a metal plate which is provided in an opening to regulate the draught. The dried articles are arranged in muffle and temprature of kiln is raised to about 1200°C. This temprature is maintained for about four days and the burnt products are then allowed to cool down in kiln for a period of about five days. For getting the glazed products, the glazed materials should be applied by brush on terra-cotta products before they are burnt.

(3) varieties of terra-cotta:

The terra-cotta articles are of the following two types:

(i) porous terra-cotta
(ii) polished terra-cotta

(i) porous terra-cotta: To prepare porous terra-cotta, the saw dust or ground cork is added in clay before the stage of moulding. when articles from such clay are burnt in a kiln, the organic particles are burnt and they leave pores in the articles. The porous terra-cotta is a fire-proof and a sound-proof material. It can be chiselled, sawn and nailed easily with nails, screws, etc. It is light in weight, but it is light in weight, but it is structurally weak. tem (650°C) [Minimum temp. 650°C]

(ii) polished terra-cotta:

This is also known as the fine terra-cotta or faience. To obtain this variety of terra-cotta, the articles are burnt at a lower temprature of about 650°C. The first burning is known as the biscuiting. The articles brought to biscuit stage are removed from kiln and are allowed to cool down. They are then coated with glazing compound and burnt again in the kiln at a temprature of about 1200°C. The finance is available in a variety of colours and it indicates superior quantity of terra-cotta. It is used for ornamental purpose and in industrial areas since it is ordinarily unaffected by the adverse atmospheric conditions.

(4) Advantages of terra-cotta:
Following are the advantages of terra-cotta:
(i) It is strong and durable material.
(ii) It is available in different colours.
(iii) It is cheaper than ordinary finely dressed stones.
(iv) It is easily cleaned.
(v) It is easily moulded in desired shapes.
(vi) It is fire-proof and can therefore be conveniently used with R.C.C. work.
(vii) It is light in weight.
(viii) It is not affected by atmospheric agencies and acids and is capable of withstanding weathering actions better than most kinds of stone.

(5) Disadvantages of terra-cotta:
(i) It cannot be fixed during the progress of work. But it is to be fixed when the work is in final stage of completion.
(ii) It is twisted due to unequal shrinkage in drying and burning.

(6) Uses of terra-cotta:
(i) The hollow terra-cotta blocks are used for various ornamental purposes such as facing work, arches, cornices, casing for columns, etc.
(ii) It is adopted for all sorts of ornamental work.
(iii) It is used as a decorative material in place of stones for ornamental parts of buildings such as cornices, string courses, sills, copings, bases of pillars, fire places, etc.

Earthenware:
The term earthenware is used to indicate wares or articles prepared from clay which is burnt at low temprature and cooled down slowly. The clay

is mixed with required quantity of sand, crushed pottery, etc. The addition of such materials prevents the ~~during~~ shrinkage during drying and burning. The earthenwares are generally soft and porous. When glazed, the earthenwares become impervious to the water and they are not affected by acids or atmospheric agencies. The terra-cotta is a kind of earthenware. The earthenware is used for making ordinary drain pipes, electrical cable conduits, partition blocks, etc.

Stoneware:

The term stoneware is used to indicate the wares or articles prepared from refractory clays which are mixed with stone and crushed pottery. Such a mixture is then burnt at a high temperature and cooled down slowly.

The stoneware is more compact and dense than earthenware. When glazed, the stonewares become impervious to the water and they are not affected by acids or atmospheric agencies. The sound stonewares give clear ringing sound when struck with each other.

The stonewares are strong, impervious, durable and resistant to corrosive fluids and they resemble fire bricks. The stonewares can be kept clean easily and hence they have become very popular as the sanitary articles such as wash basins, sewer pipes, glazzed tiles, water closets, gully traps etc. They are also used as jars to store the chemicals.

Porcelain:

The term porcelain is used to indicate fine earthenware which is white, thin and semi-transparent. Since the colour of porcelain is white, it is also refferred to as the whiteware.

# High voltage porcelain

| Name | Properties | Uses |
|---|---|---|
| 1. carbon and graphite | It is a refractory material of high quantity. But it is oxidized at high temprature. | It is used for making electrodes & in the construction of atomic reactor rockets. |
| 2. carbon brick | It is prepared from powder coke and tar. It can resist high temprature. | It is used as lining material ~~refractory bricks, etc~~ for electric furnace. |
| 3. cordierite porcelain | It contains 22% alumina, 35% clay and 43% silicate of magnesia. It is available in porous, partly porous and glassy form. | It is used for electric furnace, refractory bricks, etc. |
| 4. steatic porcelain | It contains 70 to 90% silicate of magnesia. | It is used as electrical insulator, for high intensity electric current, vacuum tubes, etc. |
| 5. zircon porcelain | It contains 45 to 60% zircon, 15 to 30% clay and 15 to 30% silicate of zircon. Its dielectric constant at high temprature is good. | It is used in the manufacture of spark plugs. |

The clay of sufficient purity and possessing high degree of tenacity and plasticity is used in preparing porcelains. It is hard, brittle and non-porous. It is prepared from clay, felspar, quartz and minerals. The constituents are finely ground and then they are thoroughly mixed in liquid state. The mixture is given the desired shape and it is burnt at high temprature.

(1) General:

The surface of clay products are sometimes glazed. A glaze is a glassy coat of thickness about 0.1 to 0.2 mm applied on the surface of an item and then fused into place by burning at high temprature.

(2) Purpose:

Following are the purposes for which the glazing is done:

(i) To improve the appearance.
(ii) To make the articles durable and impervious.
(iii) To produce the decorative effects.
(iv) To protect the articles from action of atmospheric agencies, chemicals, sewage, etc.
(v) To provide smooth surface.

(3) Methods of glazing:

The glazing may be transparent like glass or it may be opaque like enamels. For obtaining coloured glazes, the oxides and salts of various metals or special refractory colouring agents are added. For instance, the addition of copper oxides will impart green colour and addition for iron oxide will impart red and brown colours.

(i) Transparent glazing:

This type of glazing may be given by the following two methods:

(a) Salt glazing
(b) Lead glazing

(a) Salt glazing: In this method, a small quantity of wet sodium chloride or salt is added in the kiln at a high temprature of about 1300°C. The salt is vaporized at a high temprature and a glass like glaze is formed on the surface of articles due to sticking of vapour of salt. This method is useful for sanitary pipes and chemical stonewares. The quantity of wet salt and throwing it at proper time should be done with extreme care. The colour of articles glazed by this method is brownish.

(b) Lead glazing:

For getting articles of better quality, the lead glazing is preferred to the salt glazing. In this method, the article is once burnt and it is then dipped in a bath containing oxide of lead and tin. The article is taken out from the bath and it is reburnt at a high temprature. The particles of oxide of lead and tin melt and they form a film of glass over the exposed surfaces of the article. In this method of glazing, the glaze does not penetrate into the body of ware and as a matter of fact, it can easily be detached from the ware surface. This method is used for terra-cotta, fire-clay wares and earthenwares.

(ii) Opaque glazing:

This type of glazing is adopted to give better appearance than that given by the burnt material. The superior clay is finely powdered and dried. The sufficient quantity of water is added to such clay to make a plastic cream like substance, known as the slip.
The articles to be glazed are dipped in the slip before burning and they are subsequently heated. The burning of articles results into the flow of clay particle and an opaque glaze surface is formed. The sanitary articles are glazed by this

Process:

Properties of cast-iron:

Following are the properties of cast-iron:

(i) If placed in salt water, it becomes soft.

(ii) It can be hardened by heating and sudden cooling, but it cannot be tempered.

(iii) It cannot be magnetised.

(iv) It does not rust easily.

(v) It is fusible.

(vi) It is hard, but it is brittle also.

(vii) It is not ductile and hence it cannot be adopted to absorb shocks and impacts.

(viii) Its melting temprature is about 1250°C.

(ix) It shrinks on cooling. This fact is to be considered while making patterns or moulds for foundry work.

(x) Its structure is granular and crystalline with whitish or greyish tinge.

(xi) Its specific gravity is 7.5.

(xii) It lacks plasticity and hence it is unsuitable for the forging work.

(xiii) It is weak in tension and strong in compression. The tensile and compressive strengths of cast-iron of average quality are respectively 150 N/mm² (Tensile) and 600 N/mm² (compression)

(xiv) The two pieces of cast-iron cannot be connected by the process of riveting or welding. They are to be connected by nuts and bolts which are fixed to the flanges. The holes for bolts, etc. are either drilled out or cast in the casting.

Uses of cast-Iron:

The use of cast-iron is not recommended in horizontal direction either for heavy or variable loads or at places where there are chances for the slightest shock to exist. The cast-iron cracks and snaps suddenly when subjected to the cracks, overloading or force without giving any warning of approaching failure under such stresses. The cast iron to be used on the works should be tough, close grained grey metal, free from air holes, sand holes, flaws and with an even surface. It should be sufficiently soft to admit of being easily cut either by a chisel or a drill.

Following are the important uses of cast-iron:

i) For making cisterns, water pipes, gas pipes and sewers, manhole covers and sanitary fittings.
ii) For making ornamental casting such as brackets, gets, lamp posts, spiral staircase, etc.
iii) For making parts of machinery which are not subjected to heavy shocks.
iv) For manufacturing compression members like columns in building, bases of columns, etc.
v) For preparing agricultural implements.
vi) For preparing rail chairs, carriage wheels, etc.

Properties of wrought-iron:

Following are the properties of wrought-iron.

i) It becomes soft at white heat and it can be easily forged and welded.
ii) It can be used to form temporary magnets, but cannot be magnetised permanently.
iii) It fuses with difficulty. It cannot therefore be adopted for making castings.
iv) It is ductile, malleable and tough.
v) It is moderately elastic.
vi) It is unaffected by saline water.
vii) It resists corrosion in a better way.
viii) Its fresh fracture shows clear bluish colour with a high silky luster and fibrous appearance.

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(ix) Its melting point is about 1500°C.
(x) Its specific gravity is about 7.8.
(xi) Its ultimate compressive strength is about 200N/mm².
(xii) Its ultimate tensile strength is about 400N/mm².

Defects in wrought-iron:
The wrought-iron which has become defective may either be cold short or red short. The cold short wrought-iron is very brittle when it is cold. It cracks, if bent. It may however be worked at high temprature. This defect occurs when phosphorus is present in excess quantity.

The red short wrought-iron possesses sufficient tenacity when cold. But it cracks when bent or finished at a red heat. It is therefore useless for welding purpose. This defect occurs when ~~St~~ sulphur is present in excess quantity.

Use of wrought-iron:
The wrought iron is replaced at present to a very great extent by mild steel. It is therefore produced to a very small extent at present. It is used where a tough material is required.

The wrought-iron, at present, is used for rivets, chains, ornamental iron work, railway couplings, water and steam pipes, raw material for manufacturing, steel, bolts and nuts, horse shoe bars, handrails, straps for timber roof trusses, boiler tubes, roofing sheets, armatures, electro-magnets etc.

# Uses of Steel

| Name of steel | Carbon content | Uses |
|---|---|---|
| Mild steel | up to 0.10% | Motor body, Sheet metal, tinplate etc. Boiler plates, structural steel etc. |
| Medium carbon steel | up to 0.25% | Rails, tyres, etc. |
| | up to 0.45% | Hammers, large stamping |
| | up to 0.60% | and pressing dies, etc. |
| High carbon steel or hard steel | up to 0.75% | Sledge hammers, springs, stampping dies, etc. |
| | up to 0.90% | Miner's drills, smith's tools, etc. stone mason's tools, etc. |
| | up to 1.00% | chisels, hammers, saws, wood working tools, etc. |
| | up to 1.10% | Axes, cutlery, drills, knives, Picks, punches etc. |

**Properties of Mild-steel:**

Following are the properties of mild steel:

(i) It can be magnetised permanently.
(ii) It can be readily forged and welded.
(iii) It cannot be easily hardened and tempered.
(iv) It has fibrous structure.
(v) It is malleable and ductile.
(vi) It is not easily attacked by salt water.
(vii) It is tougher and more elastic than wrought iron.
(viii) It is used for all types of structural work.
(ix) It rusts easily and rapidly.
(x) Its melting point is about 1400°c.
(xi) Its specific gravity is 7.80.
(xii) Its ultimate compressive strength is about 80 to 120kN per $cm^2$ or (800 - 1200 $N/mm^2$)
(xiii) Its ultimate tensile and shear strengths are

about 60 to 80 KN per cm$^2$.

Properties of Hard Steel:

(i) It can be easily hardened and tempered.
(ii) It can be magnetised permanently.
(iii) It cannot be readily forged and welded.
(iv) It has granular structure.
(v) It is not easily attacked by salt water.
(vi) It is tougher and more elastic than mild steel.
(vii) It is used for finest cutlery, edge tools and for parts which are to be subjected to shocks and vibrations.
(viii) It rusts easily and rapidly.
(ix) Its melting point is about 1300°C.
(x) Its specific gravity is 7.90.
(xi) Its ultimate compressive strength is about 140 to 200 KN per cm$^2$.
(xii) Its ultimate shear strength is about 110 KN per cm$^2$.
(xiii) Its ultimate tensile strength is about 80 to 110 KN per cm$^2$.