Bricks
Brick is made by burning clay at high temperature in a kiln
Bricks are used in construction of walls, pillars e.t.c.
The brick might be made from clay, lime-and-sand, concrete, or shaped stone.

Brick Sizes
Modular Size (INDIAN STANDARD) of Bricks are
i) 19 cm x 9 cm x 9 cm
ii) 19 cm x 9 cm x 4 cm
Nominal Size (With mortar Joints of 1 cm), Size of bricks are
i) 20 cm x 10 cm x 10 cm
ii) 20 cm x 10 cm x 5 cm
Bricks available in most part of the country still are
9” x 4 ½” x 3”and are known as field bricks or *traditional bricks.*

Weight of such a brick is about 3.0 kg. (remember by Kids Wt.)

Brick’s Frog
An indent called frog, 1 – 2 cm deep is provided for 9 cm height bricks only.
Frog is not provided in 4 cm high bricks.

Purpose of providing frog :-
1) To form a key for holding the mortar and therefore, the bricks are laid with frogs on top.
2) Manufacturer of bricks also put their logo in frog.

Good Brick Earth
INGREDIENTS to make good brick making earth :- (remember by MALIS~~H~~)
1) Alumina
2) Silica
3) Lime
4) Magnesia
5) Iron Oxide

1) Alumina
This is one of the main Constituents of clay.
It can readily absorb water and provide plasticity to the clay.
It should be present within 20 to 30 % .
If content is more than the limit, then raw bricks are liable to warp and shrink in the process of drying and burning.
2) Silica
Silica may exist in clay as free sand or it may exist as silicate of alumina.
Silica content in brick earth shall be 50 % to 60 %
Excess of silica causes brick to become brittle.
3) Lime
Small quantity of lime (less than 5%) is useful.
Shrinkage of raw bricks is prevented by lime.
Presence of lime helps in fusion of sand at high temperature in the kiln.
The brick particles can bind well by fused sand.
Lime should be added in finely divided form and not in lumps.

4) Magnesia
It is present in very small extent.
Magnesia reduces shrinkage of bricks.
Excess of Magnesia results in decay of bricks.
5) Iron Oxide
5% to 6% of Iron Oxide is desirable in brick earth.
It helps to bind the brick particles making the brick hard and strong.
Red colour of brick shows iron oxide is present at the above limit.

Manufacturing of bricks
Making the Bricks:- (remember by process of making Chapati/roti)

1. Material Procurement:
The clay is mined and stored in the open.
This makes the clay soft and removes unwanted oxides.

2. Tempering:
This clay is then mixed with water to get the right consistency for moulding.
Mixing is done manually with hands and feet. Sometimes and in certain areas, animal driven pug mills are used.

3. Moulding:
A lump of clay mix is taken, rolled in sand and slapped into the mould.
The clay can be moulded in two ways :-
1) Hand moulding.
2) Machine Moulding.

Hand Moulding
Moulding the clay is done by using wooden or steel moulds.
Wooden mould consists of rectangular wooden box opened at top and bottom.
Internal dimensions of mould are made 6 mm greater than required dimensions. This is because the raw bricks shrink in the process of drying and burning.

Bricks made by Hand moulding may be :-
1) Ground moulding bricks
2)Table moulded bricks

Ground moulded Bricks
In case of ground moulded bricks, ground should be leveled and a thin sand is spread over the ground.
The mould is wetted in water and placed on ground firmly.
The tempered clay is now dropped into the mould.
Any surplus clay is removed using steel plate.
Now the mould is lifted up leaving the raw brick on the ground.
In this way, whole prepared ground is covered by raw bricks.
Table moulded Bricks
Same procedure is followed as in case of ground moulded bricks.
In this case, moulding is done over a table 2m x 1m

The brick obtained on the table are moved to a convenient place for drying.

Machine moulding
In case of machine molding, the clay is fed to the moulding machine. As clay moves through it, it is compressed and cut into strips by wires and brick blocks are formed.

4. Drying:
The mould is emptied onto the drying area, where the bricks are arranged in a herring bone pattern to dry in the sun.
Every two days they are turned over to facilitate uniform drying and prevent warping. After two weeks they are ready to be burnt

5. Firing:
The raw bricks are arranged in a kiln and insulation is provided with a mud pack.
Fire holes left to ignite the kiln are later sealed to keep the heat inside. This is maintained for a week.

6. Sorting:
After the kiln is disassembled, the bricks are sorted according to colour.
Colour is an indication of the level of burning.
Over burnt bricks are used for paving or covering the kiln while slightly under burnt bricks are used for building inner walls or burnt once again in the next kiln.

Characteristics of Good Bricks
(i) Colour: Colour should be uniform and bright(red or cherry)
(ii) Shape: Bricks should have plane faces. They should have sharp and true right angled corners.
(iii) Size: Bricks should be of standard sizes as prescribed by codes.
(iv) Texture: They should possess fine, dense and uniform texture. They should not possess, cavities, loose grit and un-burnt lime.
(v) Soundness: When struck with hammer or with another brick, it should produce metallic sound.
(vi) Hardness: Finger scratching should not produce any impression on the brick.
(vii)Strength: Crushing strength of brick should not be less than 3.5 N/mm2.
A field test for strength is that when dropped from a height of 0.9 m to 1.0 m on a hard ground, the brick should not break into pieces.
(viii) Water Absorption: After immersing the brick in water for 24 hours, water absorption should not be more than 20 per cent by weight. For class-I bricks works this limit is 15 per cent.
(ix) Efflorescence: Bricks should not show white patches when soaked in water for 24 hours and then allowed to dry in shade. White patches are due to the presence of sulphate of calcium, magnesium and potassium. They keep the masonry permanently in damp and wet conditions
(x) Sound Insulation: Heavier bricks are poor insulators of sound while light weight and hollow bricks provide good sound insulation.
(xi) Fire Resistance: Fire resistance of bricks is usually good. In fact bricks are used to encase steel columns to protect them from fire.

<u>Testing of Bricks</u>

Laboratory tests may be conducted on the bricks to find their suitability:
(i) Compressive strength / Compression test.
(ii) Absorption
(iii) Shape and size and
(iv) Efflorescence.

<u>Compression test</u>

- The brick specimen are immersed in water for 24 hours.
- The frog of the brick is filled flush with 1:3 cement mortar and the specimen is stored in damp jute bag for 24 hours and then immersed in clean water for 24 hours.
- The specimen is placed in compression testing machine with 6 mm plywood on top and bottom of it to get uniform load on the specimen.
- Then load is applied axially at increasing rate of 14 N/mm2 per minute till failure
- The crushing load is noted.
- Then the Compressive strength is the ratio of load at failure to the area of brick loaded.
- .i.e. Compressive Strength = (Max. Load / Loaded area of Brick)
- Average of five specimen is taken as the crushing strength.
- Expected Strength is 105 N/mm2

<u>Water Absorption test</u>

- This is a test to determine the percentage of water absorption which gives degree of burning.
- Brick specimen are weighed dry. Then they are immersed in water for a period of 24 hours.
- The specimen are taken out and wiped with cloth.
- The weight of each specimen in wet condition is determined.
- Water Absorption % = (Wt of water absorbed / Wt of dry specimen) x 100

Types of Bricks

<u>Building Bricks</u> – used for construction of walls
<u>Paving Bricks</u>- These are vitrified bricks used as pavers
<u>Fire Bricks</u> – Specially made to withstand High Temperatures. Example- Silica Bricks used in furnace.
<u>Specially Shaped Bricks</u>- Bricks of special shapes are manufactured to meet the requirements of different situations.

Classification of Bricks Based on their Quality

The bricks used in construction are classified as:
(i) First class bricks
(ii) Second class bricks
(iii) Third class bricks and
(iv) Fourth class bricks

<u>First Class Bricks:</u>

These bricks are of standard shape and size. They are burnt in kilns.
They fulfill all desirable properties of bricks.

Second Class Bricks:

These bricks are ground moulded and burnt in kilns. The edges may not be sharp and uniform. The surface may be some what rough. Such bricks are commonly used for the construction of walls which are going to be plastered.

Third Class Bricks:

These bricks are ground moulded and burnt in clamps.
Their edges are somewhat distorted.
They produce dull sound when struck together.
They are used for temporary and unimportant structures.

Fourth Class Bricks:

These are the over burnt bricks. They are dark in colour.
The shape is irregular.
They are used as aggregates for concrete in foundations, floors and roads.

Aggregates

- Aggregates are the important constituents in concrete.
- They give body to the concrete(70-80% of total volume of concrete), reduce shrinkage and effect economy

Classification based on size:-

1. Fine aggregates – Particles size <4.75 mm
2. Coarse aggregates- particle size >4.75mm

Classification based on availability/Source:

Aggregates can come from either natural or manufactured sources

1) Natural Aggregates (Natural sources)

Natural aggregates come from rock, of which there are three broad geological classifications: aggregates from Igneous, sedimentary and metamorphic rocks.

2) Artificial Aggregates (Man Made)

Manufactured rock typically consists of industrial byproducts such as slag (byproduct of the metallurgical processing typically produced from processing steel, tin and copper) or specialty rock that is produced to have a particular physical characteristic not found in natural rock (such as the low density of lightweight aggregate).

Coarse Aggregates
Characteristics:

- An aggregate to be used in concrete must be clean, hard, strong, properly shapes and well graded.
- The aggregate must posses chemical stability, resistance to abrasion, and to freezing and thawing.
- They should not contain deleterious material which may cause physical or chemical changes, such as cracking, swelling, softening of concrete.
- The toughness of aggregate which is measured as the resistance of the aggregate to failure by impact. It should not exceed 45% by weight for aggregate used for concrete other than those for wearing surfaces & 30% for concrete for wearing surfaces.
- The Hardness of aggregate which is measured as its resistance to wear obtained in terms of aggregate abrasion value is determined by using Los Angeles Machine.

- Abrasion value of not more than 30% for aggregates used for wearing surfaces and 50% for non wearing surfaces,
- Specific gravity of an aggregate is defined as the ratio of the mass of solid in a given volume of sample to the mass of an equal volume of water at same temperature.
- Absolute specific gravity: refers to the volume of solid material excluding voids, and therefore defined as the ratio of the mass of solid to the weight of an equal void free volume of water at stated temperature.
- If the volume of aggregate includes voids, the resulting specific gravity is called the apparent/bulk specific gravity.

<u>Grading of aggregates</u>

- Grading is the particle-size distribution of an aggregate as determined by a sieve analysis using wire mesh sieves with square openings.

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Set of Sieves.

- As per IS:2386(Part-1)
- Fine aggregate-standard sieves with openings from 150 µm to 4.75 mm (4.75mm,2.36mm,1.18mm,600micron,300micron,150micron)
- Coarse aggregate—5 sieves with openings from 4.75mm to 80 mm (4.75mm,10mm,20mm,40mm,80mm)

Necessity of Gradation (grain size analysis)

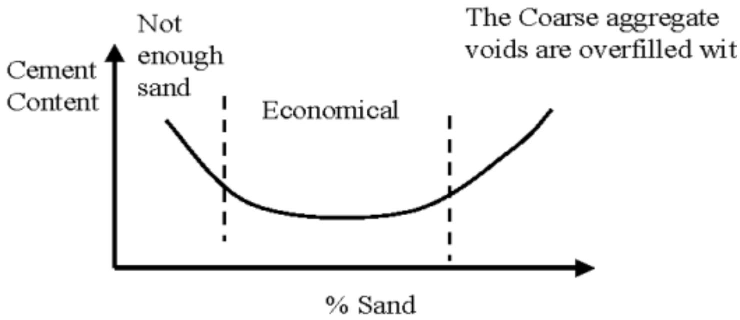
- Grain size distribution for concrete mixes that will provide a dense strong mixture.
- To Ensure that the voids between the larger particles are filled with medium particles. The remaining voids are filled with still smaller particles until the smallest voids are filled with a small amount of fines.
- Ensure maximum density and strength using a maximum density curve

Good Gradation

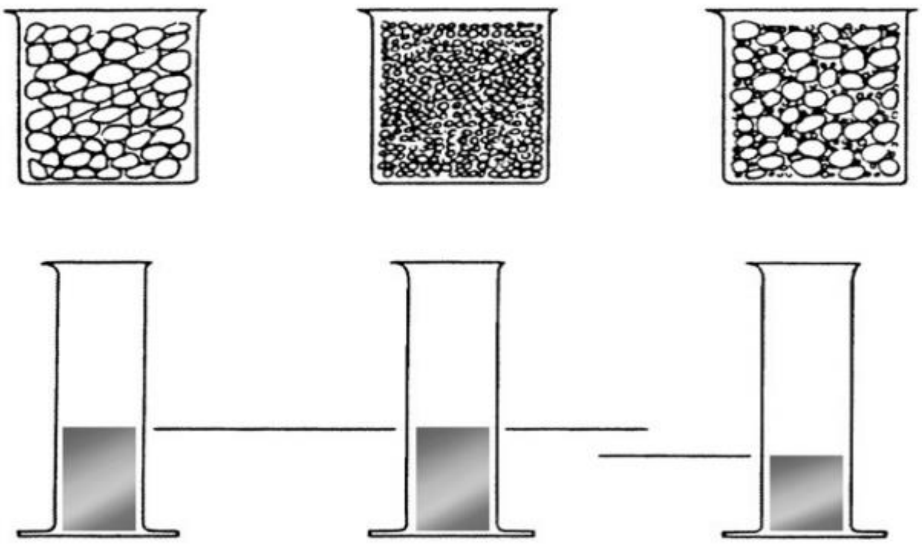
- ✓ Concrete with good gradation will have fewer voids to be filled with cement paste (Increase economical mix)
- ✓ Concrete with good gradation will have fewer voids for water to permeate (increases durability)

Particle size distribution affects:

Workability
Mix proportioning
Freeze-thaw resistance (durability)



Reduction of Voids

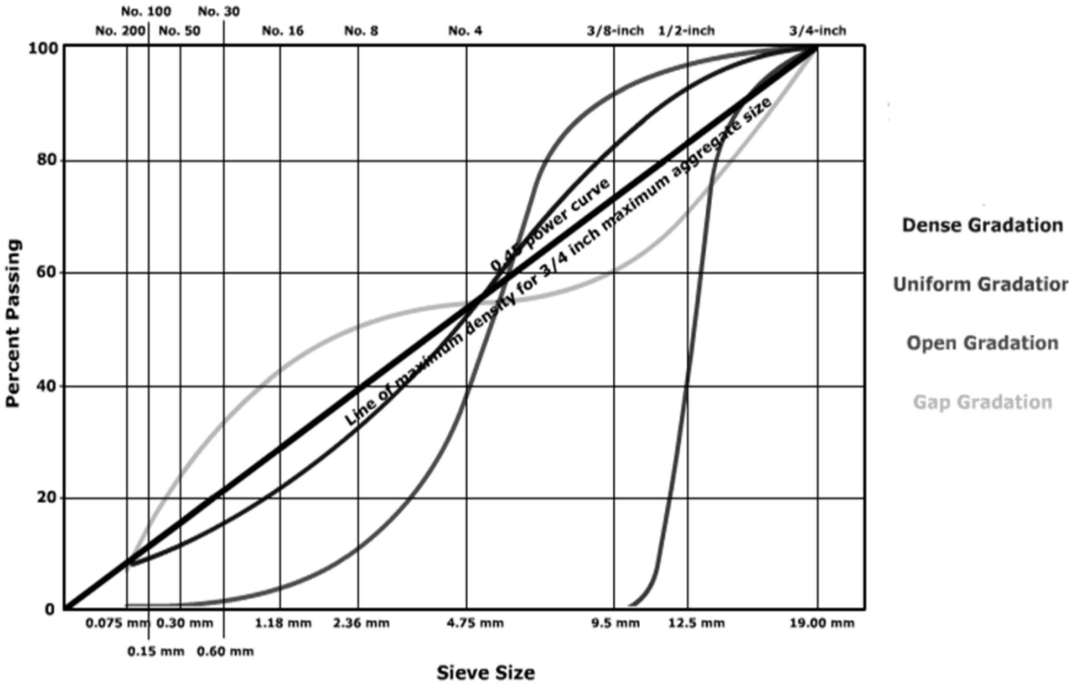


- ✓ If uniform size of aggregates are there, there will be more voids as can be seen from the first two figures.
- ✓ If properly graded aggregates are used which contain suitable percentage of all size then the voids will be minimum which is explained the figure.

Types of Grading

- ✓ Dense or well-graded: Refers to a gradation that is near maximum density.
- ✓ *Gap graded:* Refers to a gradation that contains only a small percentage of aggregate particles in the mid-size range. The curve is flat in the mid-size range. These mixes can be prone to segregation during placement.

- ✓ *Open graded:* Refers to a gradation that contains only a small percentage of aggregate particles in the small range. This results in more air voids because there are not enough small particles to fill in the voids between the larger particles. The curve is flat and near-zero in the small-size range.
- ✓ *Uniformly graded:* Refers to a gradation that contains most of the particles in a very narrow size range. In essence, all the particles are the same size. The curve is steep and only occupies the narrow size range specified.



Fineness modulus

- ✓ The results of aggregate sieve analysis is expressed by a number called Fineness Modulus.
- ✓ It is obtained by adding the sum of the cumulative percentages by mass of a sample aggregate retained on each of a specified series of sieves and dividing the sum by 100.

TABLE 1.8. (*a*) DETERMINATION OF FINENESS MODULUS

IS Sieve	Coarse aggregate (10 kg)			Fine aggregate (1 kg)		
	weight retainded (kg.)	Total wt. retainded (kg.)	% weight retainded	weight retained (kg.)	Total wt. retained (kg.)	% weight retained
80 mm	0.0	0.0	0.0	0.0	0.0	0.0
40 mm	0.0	0.0	0.0	0.0	0.0	0.0
20 mm	3.5	3.5	35.0	0.0	0.0	0.0
10 mm	3.0	6.5	65.0	0.0	0.0	0.0
4.75 mm	2.8	9.3	93.0	0.0	0.0	0.0
2.36 mm	0.7	10.0	100.0	0.1	0.1	10.0
1.18 mm	0.0	10.0	100.0	0.25	0.35	35.0
600 micron	0.0	10.0	100.0	0.35	0.70	70.0
300 micron	0.0	10.0	100.0	0.20	0.90	90.0
150 micron	0.0	10.0	100.0	0.10	1.00	100.0
	Sum : 693.0			Sum : 305.0		
Fineness modulus	$\frac{693.0}{100} = 6.93$			$\frac{305.0}{100} = 3.05$		

- ✓ Index of fineness of an aggregate.
- ✓ The fineness modulus of the fine aggregate is required for mix design since sand gradation has the largest effect on workability.

- ✓ The FM of the coarse aggregate is not required for mix design purposes.
- ✓ The higher the FM, the coarser the aggregate.

The following limits may be taken as guidance:

Fine sand	:	Fineness Modulus	:	2.2 - 2.6
Medium sand	:	F.M.	:	2.6 - 2.9
Coarse sand	:	F.M.	:	2.9 - 3.2

A sand having a fineness modulus more than 3.2 will be unsuitable for making satisfactory concrete.

Building Materials – Cement

- **Cement**
- Cement is a commonly used binding material in the construction.
- The cement is obtained by burning a mixture of calcareous (calcium from Limestone) and argillaceous (Alumina from clay) material at a very high temperature and then grinding the clinker so produced to a fine powder.
- The cement water paste has its characteristic properties of adhesion and cohesion by which it can bond well with aggregates to form strong rock like mass called concrete.
- This concrete is formed as a result of the reaction between cement and water.
- Cement is used in construction of buildings, bridges and culverts. Flooring, plastering, Reinforced concrete etc.

Elements provided by raw materials

Calcium	***Silicon***	***Aluminium***	***Iron***
Limestone	Clay	Clay	Clay
		Shale	Iron ore
Calcite	Sand	Fly ash	
Shale	Shale	Aluminium ore refuse	Shale
Sea Shells	Fly ash		Blast furnace dust
Cement Kiln Dust	Rice husk ash		
	Slag		

- Cement is a complicated mixture of chemical compounds.
- Ordinary Portland cement contains following compounds :
- 1) C3S (Tricalcium Silicate) 40 % - Gives strength
- 2) C2S (Dicalcium Silicate) 30 % - Gives strength
- 3) C3A (Tricalcium Aluminate) 11 % - Results in Flash Set (immediate setting of cement)
- 4) C4AF (Tetra Calcium Alumino Ferrite) – 11 %

When water is added to cement, C3A is the first to react and cause initial set. It generates great amount of heat. C3S hydrates early and develops strength in the first 28 days. It also generates heat. C2Sis the next to hydrate. It hydrates slowly and is responsible for increase in ultimate strength. C4AF is comparatively inactive compound.

- **Raw materials (OPC)**
- Basic Raw materials :- Limestone & Clay, Gypsum(additive)
- Clays are ideal because they are made of fine particles already and thus need little processing prior to use, and are the most common source of silica and alumina.
- Calcium is most often obtained from quarried rock, particularly limestone (calcium carbonate) which must be crushed and ground before entering the kiln

- **<u>Production of Ordinary Portland Cement (OPC)</u>**
- The production of cement takes place with several steps:

1. Quarrying of limestone
2. Digging for clay
3. Grinding
4. Blending of components
5. Fine grinding
6. Burning
7. Finish grinding
8. Packaging and/or shipping

Quarrying and Digging

- Quarrying of limestone accomplished by using explosives to blast the rocks from the ground. After blasting, huge power shovels are used to load dump trucks or small railroad cars for transportation to the cement plant, which is usually nearby.
- Clay are dug out of the ground with power shovels. All of the raw materials are transported to the plant.

Grinding

- After the raw materials have been transported to the plant, the limestone and shale which have been blasted out of the quarry must be crushed into smaller pieces.
- Some of the pieces, when blasted out, are quite large.
- The pieces are then dumped into primary crushers which reduce them to the size of a softball.
- The pieces are carried by conveyors to secondary crushers which crush the rocks into fragments usually no larger than 25 mm across.

Blending

- After the rock is crushed, plant chemists analyse the rock and raw materials to determine their mineral content.
- The chemists also determine the proportions of each raw material to utilize in order to obtain a uniform cement product.
- The various raw materials are then mixed in proper proportions and prepared for fine grinding. This mixing process is called Blending i.e. mixing of two or more raw material .

Fine Grinding

- When the raw materials have been blended, they must be ground into a fine powder. This may be done by one of two methods:
- 1) Wet process (In Course), or
- 2) Dry process (To understand)
- <u>1) Wet process</u>
- In the wet process, the blended raw materials are moved into ball or tube mills which are cylindrical rotating drums which contain steel balls.
- These steel balls grind the raw materials into smaller fragments (up to 200th part of an inch)
- As the grinding is done, water is added until a slurry (thin mud) forms, and the slurry is stored in open tanks where additional mixing is done.
- Some of the water may be removed from the slurry before it is burned, or the slurry may be sent to the kiln as is and the water evaporated during the burning.
- The wet process requires more energy because evaporation of water requires additional energy, has now been rendered obsolete by the development of efficient dry grinding equipment, and all modern cement plants use the dry process.
- <u>2) Dry Process</u>
- The dry process of fine grinding is accomplished with a similar set of ball or tube mills; however, water is not added during the grinding.
- The dry materials are stored in silos where additional mixing and blending may be done.

Burning

- The slurry is burnt in a rotary kiln.
- Rotary kiln consists of a long steel cylinder 50 m to 100 m long support.

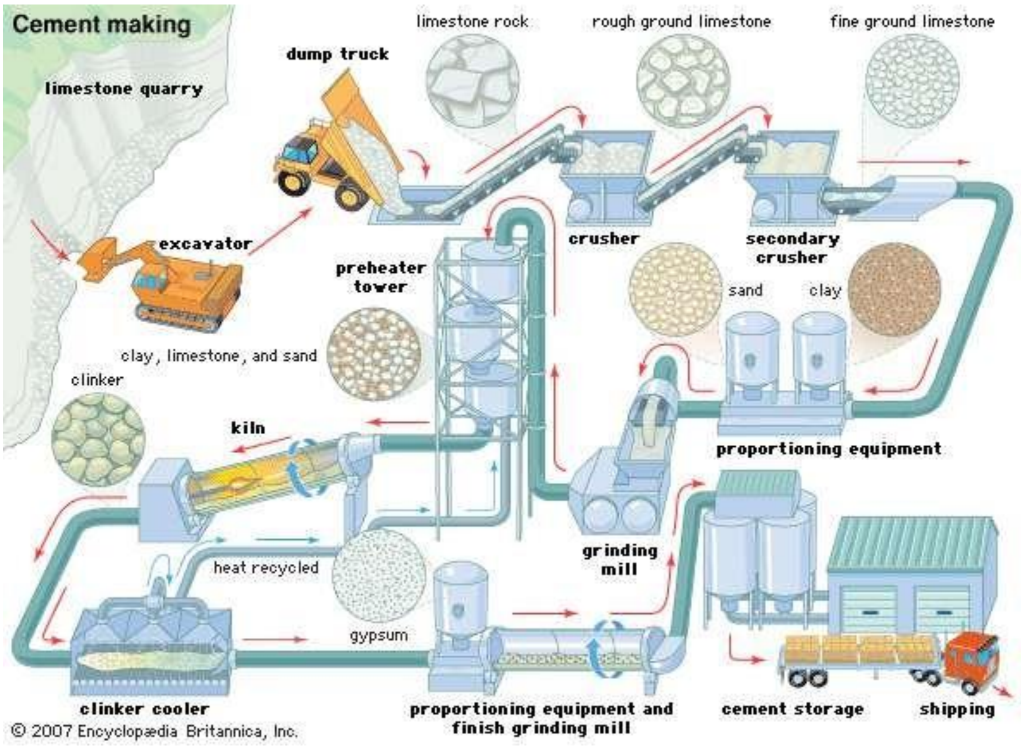
- Inner surface is lined with fire bricks.
- Cylinder rotates at 1 revolution per minute and slope is 1 in 30 m.
- Heating is done by injecting hot air blast from lower end, while slurry is supplied through hopper from the upper end.
- Temperature in the kiln rises to 1600 degree Celsius where slurry changes into hard clinkers.
- This clinkers are cooled down by coolers.

Finish Grinding

- The cooled clinker is mixed with a small amount of gypsum 2 to 4 %, which will help regulate the setting time when the cement is mixed with other materials and becomes concrete. Here again there are primary and secondary grinders.
- The primary grinders leave the clinker , ground to the fineness of sand, and the secondary grinders leave the clinker ground to the fineness of flour, which is the final product ready for marketing

Packaging

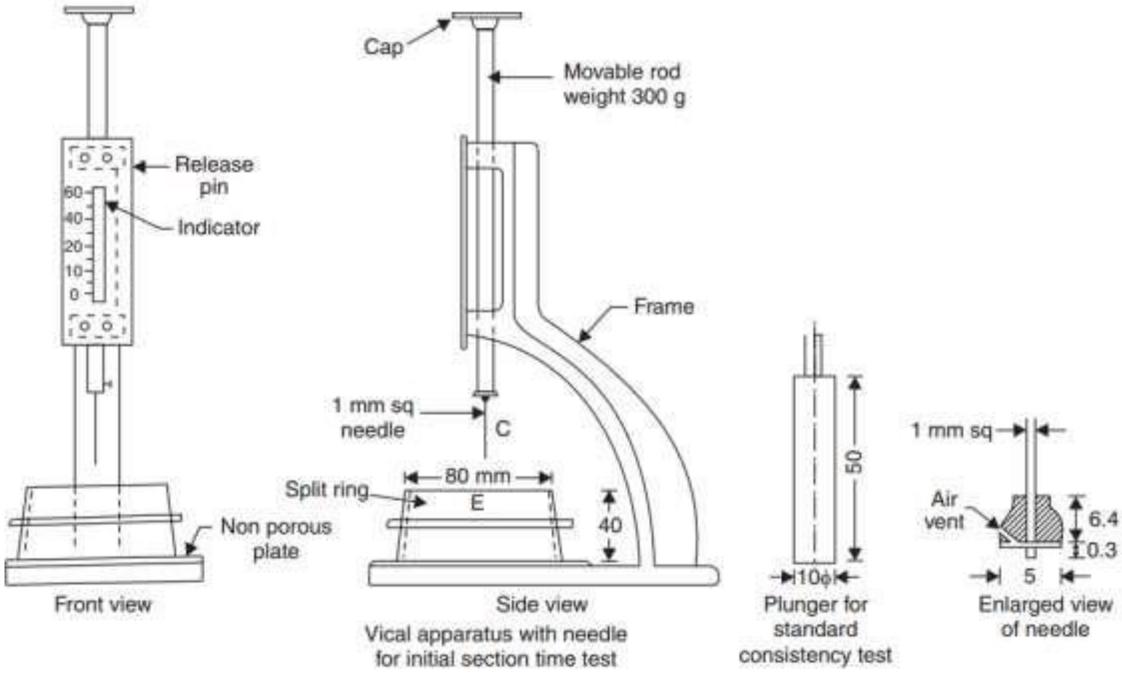
- The final product is shipped either in bulk (ships, barges, tanker trucks, railroad cars, etc.) or in strong paper bags which are filled by machine.
- 50 kg bags of cement in India.



Setting Time of Cement

- Initial setting time and final setting time are the two important physical properties of cement. Initial setting time is the time taken by the cement from adding of water to the starting of losing its plasticity.

Final setting time is the time lapsed from adding of the water to complete loss of plasticity.



Consistency test

Before finding initial and final setting time it is necessary to determine water to be added to get standard consistency.

- For this 300 gms of cement is mixed with about 30% water and cement paste prepared is filled in the mould which rests on non-porous plate.
- The plunger is attached to the movable rod of vicat apparatus and gently lowered to touch the paste in the mould.
- Then the plunger is allowed to move freely.
- If the penetration is 5 mm to 7 mm from the bottom of the mould, then cement is having standard consistency.
- If not, experiment is repeated with different proportion of water fill water required for standard consistency is found.

Then the tests for initial and final setting times can be carried out as explained :

Initial Setting Time:

- 300 gms of cement is thoroughly mixed with 0.85 times the water for standard consistency and vicat mould is completely filled and top surface is levelled.
- 1 mm square needle is fixed to the rod and gently placed over the paste. Then it is freely allowed to penetrate.
- In the beginning the needle penetrates the paste completely.
- As time lapses the paste start losing its plasticity and offers resistance to penetration.
- When needle can penetrate up to 5 to 7 mm above bottom of the paste experiment is stopped and time lapsed between the addition of water and end of the experiment is noted as initial

setting time.

Final Setting Time

- The square needle is replaced by needle with an annular attachment (needle for Final setting time) . Experiment is continued by allowing this needle to freely move after gently touching the surface of the paste.
- The cement shall be considered as finally set, when upon applying the needle gently to the test block, the needle makes an impression thereon while the attachment fails to do so.
- The final setting time is the interval between the addition of water to the cement and the time at which the needle makes an impression while the attachment fails to make an impression on the surface of the test block.

Table 4.2 The Initial and Final Setting Time of Various Grades of Cements

Type of cement	Initial setting time	Final setting time
1. Ordinary	It shall not be less than 30 minutes.	It shall not be more than 10 hours.
2. Rapid hardening	It shall not be less than 30 minutes.	It shall not be more than 10 hours.
3. Low heat	It shall not be less than 60 minutes.	It shall not be more than 10 hours.

Time of setting Influenced by :

1) Temperature at which cement is allowed to set.
2) The percentage of water mixed to cement in making the paste.
3) The humidity at which the setting is allowed.

Grades of cement

OPC (ordinary portland cement) is classified into 3 grades of cement :-

1) 33 grade cement (28^{th} Day Compressive Strength– 33 N/mm2 or 33 MPa (Mega Pascal))
2) 43 grade cement(28^{th} Day Compressive Strength– 43 N/mm2)
3) 53 grade cement(28^{th} Day Compressive Strength– – 53 N/mm2)

Sl. No.	Type of cement	Compressive strength 1 day min. MPa	3 days min. MPa	7 days min. MPa	28 days min. MPa
1	33 grade OPC (IS 269-1989)	N.S.	16	22	33
2	43 grade OPC (IS 269-1989)	N.S.	23	33	43
3	53 grade OPC (IS 269-1989)	N.S.	27	37	53

N.S. – Not specified

Types of Cement :-

(i) White Cement:

RAW MATERIAL:- this cement is manufactured from China clay and white chalk in place of limestone and clay.

The White colouring effect is due to absence of iron oxide.

In the manufacture of this cement, the oil fuel is used instead of coal for burning.

USES: -White cement is used for the floor finishes, plastering, ornamental works etc. In swimming pools white cement is used to replace glazed tiles. It is used for fixing marbles and glazed tiles.

(ii) Portland Slag Cement (PSC) / Blast furnace Slag Cement :-

RAW MATERIAL:- Cement Clinker + Slag (60 to 70 % by weight)

Iron and steel industry produces large quantities of blast furnace slag as by-product. The slag is waste product in the manufacturing of pig iron and it contains the basic elements of cement, namely alumina, lime, and Silica.

The clinkers of cement are ground/Grinded with 60 to 70 % of slag. This cement has a slow rate of hardening and less heat of hydration.

Mortar

- ✓ Mortar is an mixture of binding material, fine aggregate and water.
- ✓ When water is added to the dry mixture of binding material and the inert(non reacting) material, binding material develops the property that binds not only the inert material but also the surrounding stones and bricks.
- ✓ If the cement is the binding material, then the mortar is known as cement mortar.
- ✓ Other mortars commonly used are lime mortar and mud mortar.
- ✓ The inert material used is sand.

Cement Mortar

- ✓ Binding material is cement. Inert material is sand.
- ✓ For preparing mortar, first a mixture of cement and sand is made thoroughly mixing them in dry condition.
- ✓ Water is gradually added and mixed with shovels.

Cement to sand proportions for various works: (C:S)

- ✓ Masonry works 1:6 to 1:8
- ✓ Plastering masonry 1:3 to 1:4
- ✓ Plastering concrete 1:3
- ✓ Pointing 1:2 to 1:3

Proportion	Uses
1:2	Damp proof course Pointing etc.
1:3	Internal wall plastering Construction of partition wall Arch work
1:6 to 1:8	Generally for plastering Construction of ordinary works Brick masonry. Masonry work in foundation up to plinth.

Properties of cement mortar

- ✓ When water is added to the dry mixture of cement and sand, hydration of cement starts and it binds sand particles and also the surrounding surfaces of masonry and concrete.

- ✓ Leaner mix is not capable of closing the voids in sand and hence the plastered surface is porous.

- ✓ **A mortar used in masonry should have following properties:**

1. It should be easily workable.
2. It should retain water against suction by bricks.
3. It should be plastic and work well into the joints and depres•sions in bricks.

4. It should be easily trowelable.
5. It should have good adhesive strength and adequate compressive strength.
6. It should stiffen quickly enough to ensure a reasonable speed of construction.
7. It should not shrink excessively and the first shrinkage should take place during the early hardening of the mortar.

- ✓ The strength of mortar depends upon the proportion of cement and sand.
- ✓ Strengths obtained with various proportion of cement and sand is :-

1. 1:3 -10 N/mm2
2. 1:4 -7.5 N/mm2
3. 1:5 -5.0 N/mm2
4. 1:6 -3.0 N/mm2
5. 1:8 -0.7 N/mm2

Uses of cement mortar

1. to bind masonry units like stone, bricks, cement blocks.
2. to plaster slab and walls make them impervious.
3. to give neat finishing to walls and concrete works.
4. for pointing masonry joints.
5. for preparing building blocks
6. to fill joints and cracks in walls.
7. as a filler material in stone masonry.

Curing of mortar

- ✓ Cement gains the strength gradually with hydration.
- ✓ Hence it is necessary to see that mortar is wet till hydration has taken place.
- ✓ <u>The process to ensure sufficient moisture for hydration after laying mortar/concrete is called curing</u>.
- ✓ Curing is ensured by spraying water.
- ✓ Curing normally starts 6–24 hours after mortar is used.
- ✓ It may be noted that in the initial period water requirement is more for hydration and gradually it reduces.
- ✓ Curing is recommended for 28 days.

For Detailed Study
B.C.Punmia Book Shall be referred.

Stone

Stone is a ‘naturally available building material’ .
It is available in the form of rocks, which is cut to required size and shape and used as building block. It has been used to construct small residential buildings to large palaces and temples all over the world.
Stone form an important source of aggregate of both fine and coarse aggregate. Example: Red Fort, Taj Mahal are famous stone buildings.

Classification of stones/rocks based on:

1) Geological features

2) Physical Features

3) Chemical Features

Geological Classification of rocks

1) Igneous Rocks :-

- ✓ They are formed by cooling of molten lava (Magma) released during a volcanic activity.
- ✓ These stones are very strong and durable.
- ✓ **Plutonic rocks:-** They are formed by cooling of magma at a considerable depth from the earth surface. These rocks are crystalline in nature. Ex-Granite.
- ✓ **Volcanic rocks:-** They are formed when solidification of magma takes place on or near the surface of the earth. These rocks are non-crystalline in nature. Examples are Basalt & Trap.
- ✓ Many Temples of south are made up of Igneous rocks.

2) Sedimentary Rocks :-

- ✓ Due to weathering action of water, wind and frost existing rocks disintegrates.
- ✓ The disintegrated material is carried by wind and water; the water being most powerful medium. Flowing water deposits its suspended materials at some points of obstacles to its flow.
- ✓ These deposited layers of materials get consolidated under pressure and by heat.
- ✓ Chemical agents also contribute to the cementing of the deposits.
- ✓ The rocks thus formed are more uniform, fine grained and compact in their nature.
- ✓ They represent a bedded or stratified structure in general.
- ✓ Examples: - Sand stones, lime stones, mud stones etc. belong to this class of rock.

3) Metamorphic Rocks:

- ✓ Previously formed igneous and sedimentary rocks undergo changes due to metamorphic action of pressure, internal heat.
- ✓ Heat may be provided by the general rise of temperature with depth or by igneous magma.
- ✓ Pressure due to the load of rocks or movement of earth.
- ✓ For example due to metamorphic action granite becomes gneisses, trap and basalt change to schist and laterite, lime stone changes to marble, sand stone becomes quartzite and mud stone becomes slate.

Physical Classification of rocks:

Stratified rocks :-

- ✓ These rocks are having layered structure.
- ✓ They possess planes of stratification or cleavage.
- ✓ They can be easily split along these planes.
- ✓ Sand stones, lime stones, slate etc. are the examples of this class of stones.

2) Un-stratified rocks:-

- ✓ These rocks are not stratified.
- ✓ They possess crystalline and compact grains.

- ✓ They cannot be split in to thin slab.
- ✓ Granite, trap, marble etc. are the examples of this type of rocks.

3) Foliated Rocks:

- ✓ These rocks have a tendency to split along a definite direction only.
- ✓ The direction need not be parallel to each other as in case of stratified rocks.
- ✓ This type of structure is very common in case of metamorphic rocks
- ✓ Example- Gneiss.

Classification based on chemical composition (i)Siliceous rocks:

- ✓ The main content of these rocks is silica. They are hard and durable.
- ✓ Examples of such rocks are granite, Quartzite, trap, sand stones etc.

2) Argillaceous Rocks:

- ✓ The main constituent of these rocks is argil i.e., clay.
- ✓ These stones are hard and durable but they are brittle.
- ✓ They cannot withstand shock. Slates and laterites are examples of this type of rocks.

3) Calcareous Rocks

- ✓ The main constituent of these rocks is calcium carbonate.
- ✓ Limestone is a calcareous rock of sedimentary origin while marble is a calcareous rock of metamorphic origin.

Classification of Rocks According to Their Structure

Physical classification	Characteristics	Typical name
1. Stratified rock	Has many strata	Slate
2. Unstratified rock	Does not have strata	Granite
3. Foliated rocks	Has foliated structure	Gneiss

Classification of Rocks According to Their Chemical Composition

Chemical classification	Composition	Name of the rock
1. Silicious rock	Predominance of silica	Granite, sandstone, basalt
2. Argillaceous rock	Predominance of clay	Slate, laterite, schist
3. Calcareous rock	Predominance of lime	Limestone, marbles, dolomite

Table 1.1 Various Types of Metamorphic Rock and Its Origin

Name of the original rock: Igneous	Sedimentary	Name of the metamorphic rock
		Gneiss
Granite	Limestone	Marble
	Sandstone	Quartzite
	Clay	Slate

Properties of stone (not given in syllabus / may not be remembered)

- 1. Strength is an important property to be looked into before selecting stone as building block. Indian standard code recommends, a minimum crushing strength of 3.5 N/mm2 for any building block.
  - Trap 300 to 350 N/mm2
  - Basalt 153 to 189 N/mm2

- Granite 104 to 140 N/mm2
- 2. Hardness: It is an important property to be considered when stone is used for flooring and pavement. Coefficient of hardness is to be found by conducting test on standard specimen in Dory's testing machine. For road works coefficient of hardness should be at least 17. For building works stones with coefficient of hardness less than 14 should not be used.
- 3. Percentage wear: It is measured by attrition test. It is an important property to be considered in selecting aggregate for road works and railway ballast. A good stone should not show wear of more than 2%.
  - 4. Toughness: The resistance to impact is called toughness. It is determined by impact test.

Stones with toughness index more than 19 are preferred for road works.

- 5. Resistance to fire, Texture, Durability etc.

Quarrying of stones (not given in syllabus / may not be remembered)

- A place where exposed surfaces of good quality natural rocks are abundantly available is known as 'Quarry'.
  - The process of taking out stones from natural bed is known as 'Quarrying'/
  - 1) Quarrying with hand tools
  - 2) Quarrying by use of machines
  - 3) Quarrying by blasting with explosives

Dressing of stones (not given in syllabus / may not be remembered)

- The stones after being quarried are to be cut into suitable sizes and with suitable surfaces.

This is known as dressing of stones.

Important Building stones and their uses : (in syllabus)

1. **Granite (igneous rock):**
   - ✓ It is hard, durable and available in different colours.
   - ✓ It is highly resistant to weathering and has good crushing strength

- It is used for heavy engineering works for bridge piers, retaining walls, random rubble masonry, foundation, and for coarse aggregates in concrete.
  - They can also be cut into slabs and polished to be used as floor slabs.

2. **Basalt and trap (Igneous rocks)**
   - ✓ These are hard, tough and durable and available in different colours.
   - They have the same use as granite.

- It is used for heavy engineering works for bridge piers, retaining walls, random rubble masonry, foundation, and for coarse aggregates in concrete. They can also be cut into slabs and polished to be used as floor slabs.
  - Ornamental and decorative works and as road metal (Aggregate)

3. Gneiss (Metamorphic rock)

- It is easy to work and splits into thin slabs.
- They have the same use as granite.
- It is used for heavy engineering works for bridge piers, retaining walls, random rubble masonry, foundation, and for coarse aggregates in concrete. They can also be cut into slabs and polished to be used as floor slabs.
- It can be identified by its elongated platy minerals often mixed with mica.

4. Quartzite (Metamorphic rock)

- It is hard, durable, brittle and crystalline.
- It is difficult to work.
- They have the same use as granite.
- It is used for heavy engineering works for bridge piers, retaining walls, random rubble masonry, foundation, and for coarse aggregates in concrete. They can also be cut into slabs and polished to be used as floor slabs.
- It cannot be used for ornamental work as it is brittle.

5. Marble(metamorphic rock)

- It can be easily cut with saw and carved.
- It is available in different colours.
- flooring in the form of slabs, wall linings, steps, columns etc.
- It is used for ornamentation, flooring and stone facing slabs.
- Taj Mahal is built fully of white marbles.

6. Slate (Metamorphic rock)

- It is black in colour and can be split easily.
- It is used for damp proofing flooring and roofing tiles.

7. Limestone(Sedimentary rocks) :

- It is easy to work. It consists of high percentage of calcium carbonate.
- It is used for walls as coarse aggregates for concrete and also as a base material for cement.

8. Sandstones (Sedimentary rocks):

- Its structure shows sandy grains.
- It is easy to work and dress.
- It is available in different colours.
- Its strength is low.
- They are used for ornamental work and paving

Advantages & Uses:

- The properties of this cement are more or less same as ordinary cement, but it is cheap, since it utilises waste product.
- PSC can be used for all purpose for which Ordinary portland cement is used.
- In view of Low heat evolution, It can be used in mass concrete structures such as dams, retaining walls , foundation and bridge abutment.
- It is not affected by sea water and, hence, is used for marine structures. Its strength is less in the early days and, hence, requires longer curing period.

(iii) Pozzolana Portland Cement(PPC):-

RAW MATERIALS:- OPC Clinker + Pozzolana Material (10 to 30 %) = PPC Cement.
Fly ash is a by-product in thermal stations. The particles of fly ash are very minute and they fly in the air, creating air pollution problems.

PPC is manufactured either by intergrinding Portland cement clinker and pozzolana (Fly Ash/ Silica Fumes) or by intimately and uniformly blending Portland cement and fine pozzolana. In this cement pozzolana material is 10 to 30 per cent.

Advantages :

1. Cheaper than OPC Cement.
2. Higher resistance to chemical agencies and sea water attack.
3. It releases less heat during setting. So, It is used for mass concrete works.

USES : The Portland Pozzolana Cement is ideally suited for the following construction:
1) Hydraulic structures 2) Mass concreting works 3) Marine structures 4) Masonry mortars and 5) plastering under aggressive conditions. 6) All other application where OPC is used.

CIVIL ENGINEERING STUDENT MUST KNOW THAT:

The pozzolanic material reacts with calcium hydroxide liberated by the hydrating Portland Cement and forms cementitious compounds generally known as C-S-H gel. The reaction can be given as under:

C3S + 6H (from water) ---------> CSH GEL+ 3 Ca(OH)2
2C2S + 4 H (from water) ------> CSH GEL + Ca (OH)2
Ca(OH)2 + (SiO2 + Al2O3) (From Pozzolana) ------> CSH GEL + Other components

The flyash converts Ca(OH)2 in to useful cementitious compound (C3S2H3) thereby increasing the properties of hardened concrete.

(iii) Ordinary Portland Cement(OPC):-

RAW MATERIAL :- Limestone, Clay and Gypsum
USES: - It is the most commonly used building material in mortar for masonry work, in mortar for plastering and as a binding medium in cement concrete, Reinforced concrete.

HEAT OF HYDRATION :
It is the heat produced during the chemical action between cement and water. In mass concreting like construction of dams, this heat produced will be high and will affect the stability of the structure, So, there is a necessity to control the amount of heat produced and it is in these situations that the use of PPC, PSC comes into play.

Ferrous Material

- ✓ A ferrous material is the one in which iron is a main constituent.
- ✓ Iron ore is first converted into pig iron and then pig iron is subjected to various metallurgical processes to mix different percentage of carbon and to get the following three useful ferrous materials:

1. Cast Iron
2. Wrought Iron
3. Steel

- ✓ All ferrous materials contain about 0.5 to 3% silica, less than 2% manganese, 0.15% sulphur and 0.6% phosphorous**. (Can be remembered by SU-PER MAN – Su- Sulphur/Silica, Per – Phosphorus, Man – Manganese)**

Cast iron

- ✓ Carbon content 1.7% to 4.5%
- ✓ Important properties of cast iron are:
- ✓ (a) Compression strength is 700 N/mm2 and tensile strength is 150 N/mm2
- ✓ (b) It is brittle and does not absorb shocks.
- ✓ (c) Its specific gravity is 7.5.
- ✓ (d) Its structure is coarse, crystalline and fibrous.
- ✓ (e) It cannot be magnetised.
- ✓ (f) It does not rust-easily.
- ✓ (g) It has low melting point of about

1200°C. Uses of Cast iron

- ✓ 1. It is used for making rain water and sanitary pipes, sanitary fittings and manhole covers.
- ✓ 2. It is used for making railings and spiral stair cases.
- ✓ 3. Fire gratings, cover for pumps and motors and brackets are made with cast irons.

Wrought iron

- ✓ Carbon content <0.15 %
- ✓ 1. Its ultimate compressive strength is 200 N/mm2and ultimate tensile strength is 375 N/mm2.
- ✓ 2. It is ductile and brittle.
- ✓ 3. Its unit weight is 77 kN/m3.
- ✓ 4. It melts at about 1500°C. It becomes so soft at 900°C that two pieces can be joined by hammering.
- ✓ 5. It can absorb shocks very well.
- ✓ 6. It forms temporary magnets but it cannot be magnetised permanently.
- ✓ 7. It rusts more easily.

Uses Wrought iron

- ✓ 1. It is used for making nails nuts and bolts, wires and chains.
- ✓ 2. It is used for making roofing sheets, grills, fences, window guards etc.

Steel

- ✓ Steel—carbon content 0.25% to 1.5%.
- ✓ It is extensively used building material. The following three varieties of steel are extensively used:
- ✓ (a) Mild steel – 0.25 % Carbon
- ✓ (b) High carbon steel – 0.7 – 1.5 % Carbon
- ✓ (c) High tensile steel- 0.8 % carbon & 0.6 % manganese.