VISVESVARAYA TECHNOLOGICAL UNIVERSITY
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CONCRETE TECHNOLOGY
(Subject Code : 21CV62)

LECTURE NOTES

(MODULE-1)

CEMENT AND AGGREGTES

VI-SEMESTER

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MODULE : 1

Syllabus:

CEMENT AND AGGREGATES: Cement, Chemical composition, Physical and chemical properties, Other Cementitious materials and composition -GGBS, Fly ash rice Husk ash, Silica fume, Hydration of cement, Factors influencing and affecting Hydration of cement, Types of cement.

Fine aggregate - grading, analysis, Specify gravity, bulking, moisture content, deleterious materials.

Coarse aggregate – Importance of size, shape and texture. Grading of aggregates - Sieve analysis, specific gravity, Flakiness and elongation index, crushing, impact and abrasion tests. Codal Provisions.

Cement:

The natural cement is obtained is by burning and crushing the stones containing clay, carbonate of lime and some amount of carbonate of magnesia. The natural cement resembles very closely eminent hydraulic lime. It sets very quickly after addition of water. It is not strong as artificial cement and hence it has limited use of practice.

The artificial cement is obtained by burning at a very high temperature a mixture of calcareous and argillaceous materials. The mixture of ingredients should be intimate and they should be in correct proportion. The calcined product is known as the clinker a small quantity of gypsum is added to clinker and it is then pulverized in to very fine **powder which is known as cement**

Chemical composition:

The ordinary cement contains two basic ingredients namely, 1.Argillaceous and 2.Calcareous.

In Argillaceous materials, the calcium carbonate predominates. A typical analysis of good ordinary cement along with the desired range is given as follows.

Ingredient	Percent	Range
1 Lime	(Cao) 62	62 to 67
2.Silica	(SiO_2) 22	17 to 25
3.Alumina	($Al_2{}^{O}{}_3$) 5	3 to 8
4.Calcium Sulphate	($CaSO_4$) 4	3 to 4
5.Iron Oxide	(Fe_2O_3) 3	3 to 4
6.Magnesia	(MgO) 2	1 to 3
7.Sulphur	(S) 1	1 to 3
8.Alkalies	K_2O &Na_2O 1	0.2 to 1
	TOTAL=100	

1. LIME : (CaO)

This is the important ingredient of cement & its proportion is to be carefully maintained. The lime in excess makes the cement unsound & causes the cement to expand & disintegrate. On the other hand, if lime is in deficiency, the strength of cement is decreased and it causes cement to set quickly.

2. SILICA : (SiO_2)

This is also an important ingredient of cement and it gives or imparts strength to the cement due to the formation of dicalcium (C_2S)&tricalcium (C_3S) silicates. If silica is present in excess quantity, the strength:.of cement increases but at the same time, its setting time is prolonged.

3. ALUMINA(Al_2O_3)

This ingredient imparts quick setting property to the cement. It acts as a flux & it lowers the cleaning temperature. However, the high temperature is essential for the formation of Suitable type of cement and hence the alumina should to be present in excess amount as it weakens the cement.

4. CALCIUM SULPHATE: ($CaSO_4$)

This ingredient is in the form of Gypsum and its function is to increase the initial setting time of cement.

5. **IRON OXIDE; (Fe_2O_3)**

This is ingredient imparts colour, hardness& strength to the cement.

6. **MAGNESIA : (MgO)**

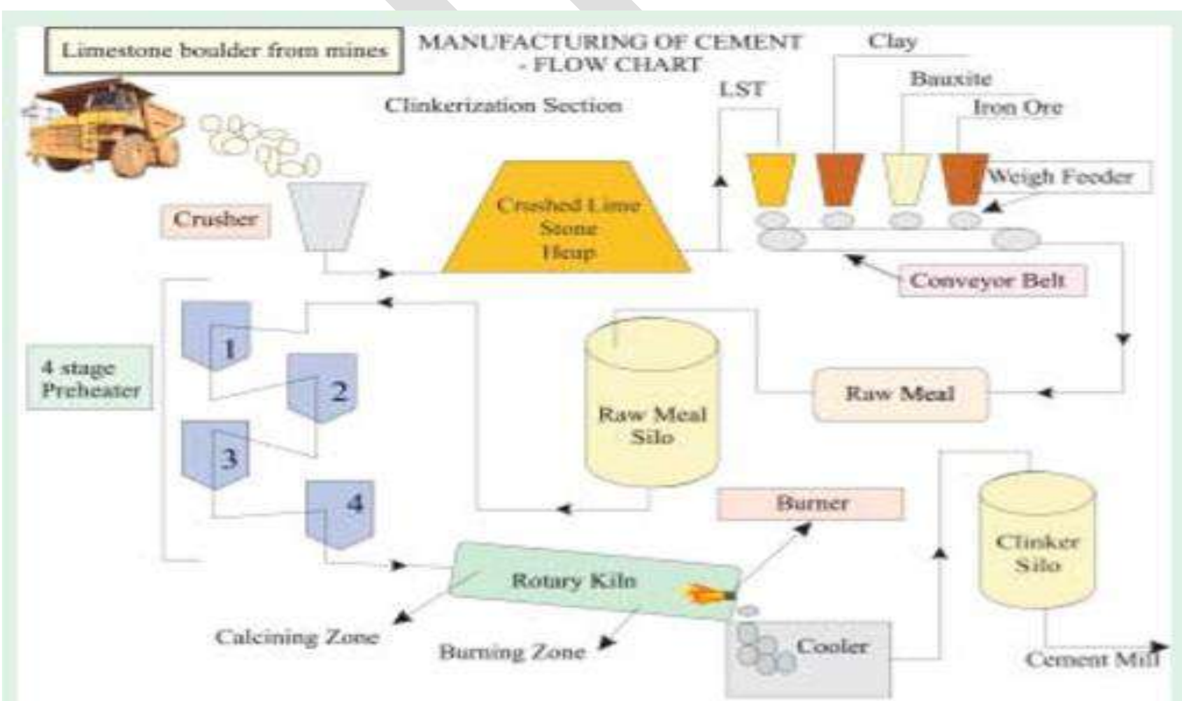
This ingredient if present is small amount imparts hardness and colour to the cement. A high content of Magnesia makes the cement unsound

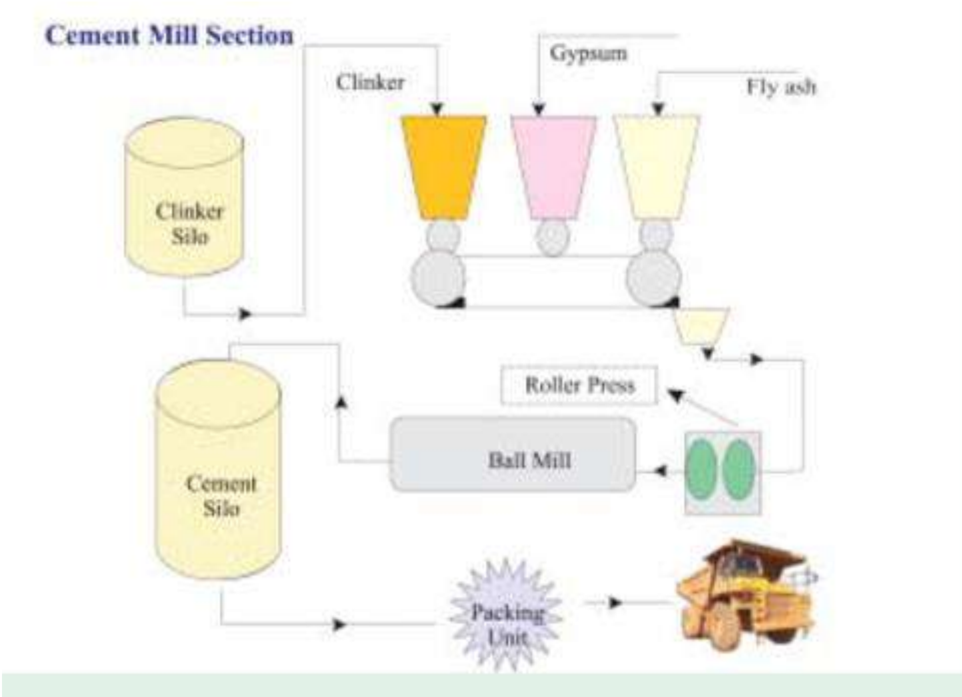
7. **SULPHUR(S)**

A very small amount of sulphur is useful in making sound cement. If it is excess, causes cement to become unsound.

8. **ALKALIES :**

The most of Alkalies present in raw materials are carried away by the flue gases during heating and the cement contains only a small amount of alkalies. If they are in excess in cement, they cause a number of troubles such as alkali-aggregate reaction, efflorescence and staining when used in concrete, brickwork or masonry; mortar.





Diagrammatic representation of the dry process of manufacure of cement.
(Courtesy : Grasim Industries Cement Division)

MANUFACTURE OF OPC (Ordinary Portland Cement)

Following three major operations are involved in the manufacture ordinary Portland cement.

1. **Mixing of raw material**
2. **Burning**
3. **Grinding**

The raw materials required for the manufacture of OPC cement are calcareous materials Such as lime, stone or chalk, and argillaceous material such as shale or clay. Cement factories are established where there raw materials are available in plenty.

The process of manufacture of cement consists of grinding the raw material, mixing them intimately is certain proportions depending upon; their Purity and compositions and burning there in a lain. Temperature of about 1300 ^{o}C to 1500^{o}C, at which temperature, the material sinters and partially fuses to from nodular shaped clinker,the clinker is cooled and ground to fine powder with addition of about 2 to 3% of gypsum. The product formed by using this procedure is called Portland cement.

There are two processes known as WET PROCESS & DRY PROCESS depending upon whether the mixing and grinding of raw material is done in wet or dry conditions.

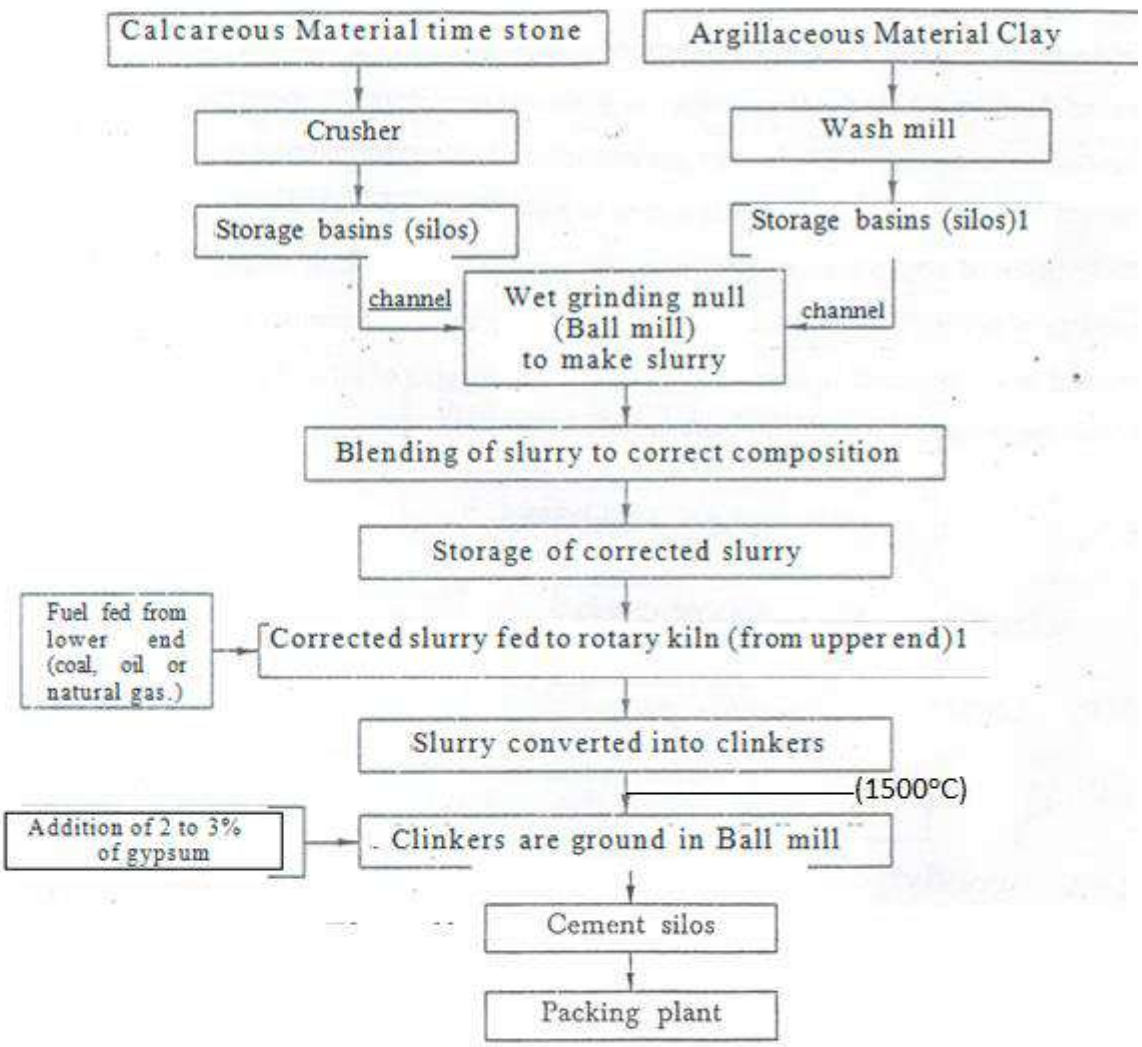
1. WET PROCESS.

In this process, the calcareous materials such as limestone is crushed and store in a silicon storage tanks. The argillaceous materials suchas clay are thoroughly mixed with water (30 to50%water) in a container known as wash mill. This washed clay is stored in basins.

Now, the crushed limestone from soils and wet clay from basins are allowed to fall in a channel in correct proportions. This channel leads the material to grinding mills where they arebrought in to intimate contact to from what is known as slurry. The grinding is carried out either in ball mill or tube mill or both. The slurry is led to correcting basin where it is constantly stirred. At thisstage, the corrected slurry is stored in storage, tanks and kept ready to serve as feed for rotary kiln.

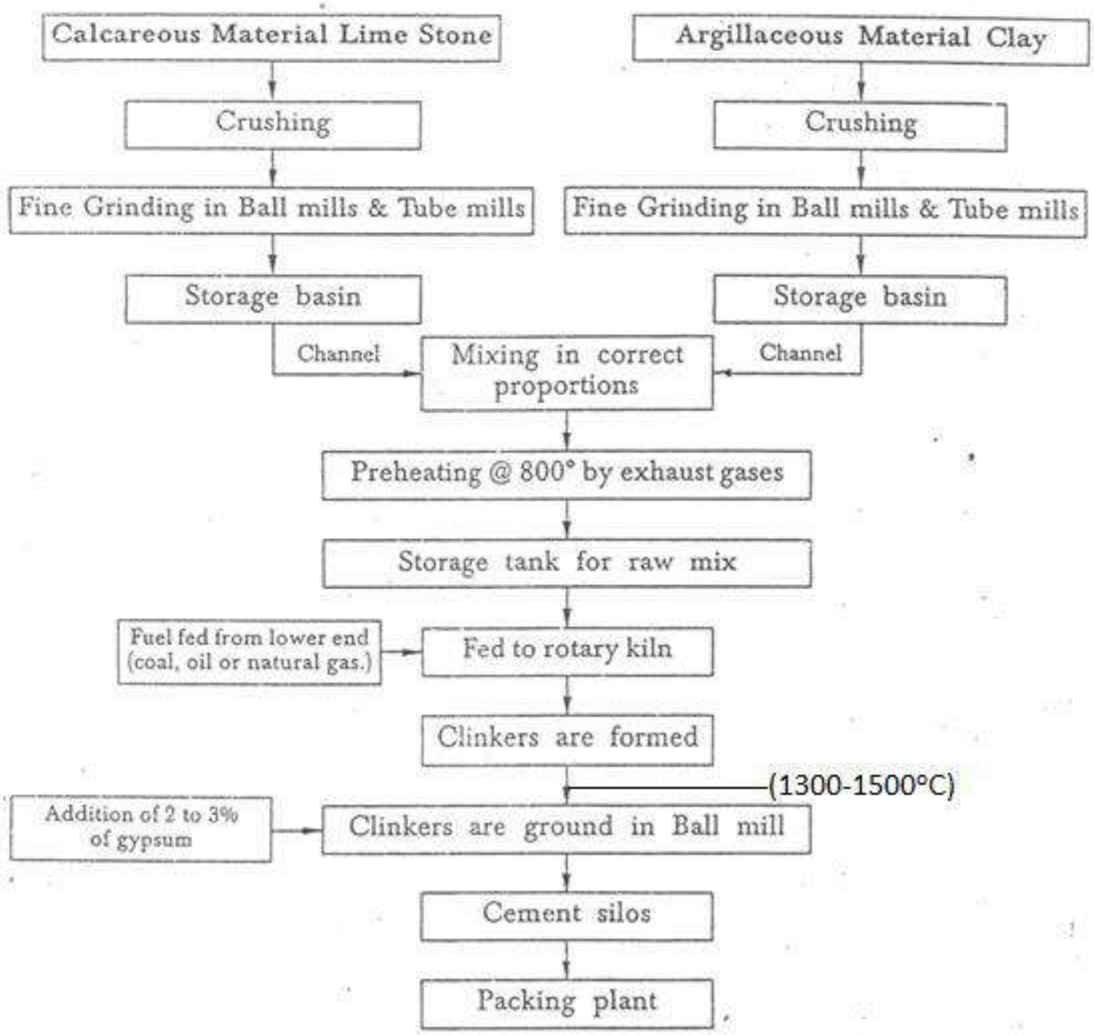
The corrected slurry is sprayed on the upper end of a rotary kiln against hot heavy hanging chains. The rotary kiln is an important component of a cement factory. It is a thick steel cylinder if a diameter anything from 3m to 8m, lined with refractory materials, mounted on roller bearing &capable of rotating about its own axis at specified speed. The length of the rotary kiln may vary anything from 30m to 200m.

The slurry on being sprayed a hot surface of flexible chain loses moisture and become flakes. These flakes peel off and fall on the floor. The rotation of the rotary kiln causes the flakes to move from the upper end towards the lower end. By the time the material rolls down to the lower end of the rotary kiln, the dry material undergoes a series of chemical reactions until finally. In the hottest part of the kiln, where the temperature is in the order of I500°C, about 20 to 30% of materials get fused. The lime, silica and alumina get recombined_ the fused mass turns in to nodular from of size 3mm to 20rnm known as clinker is stored in silos. The cooled clinker is then ground in ball mill with the addition of 3 to 5 percent of gypsum in order to prevent flash setting of cement. A ball mill consists of several compartments charged with progressively smaller hardened fineness are separated crushed to the required fineness are separated by currents of air and taken to storage soils from where the cement is packed for bulk supply.



Flow diagram of wet process

DRY PROCESS:



Flow diagram of dry process

Manufacture of cement by the dry process

In this process the raw materials are first reduced in size in crushers. A current of dry air is then passed over these dried materials. These dried materials are then pulverized in to fine powder in ball mills. All these operations are done separately for each raw material and they are stored in hoppers. They are then mixed in correct proportions and made ready for the feed of rotary kiln. This finally ground powder of raw materials is known as raw mix and it is stored in storage tank.

• Following are the procedures of manufacture of cement by the dry process

1. Most of the cement factories are located very close to the lime stone quarries. They aretransported in huge dumpers and dumped in to the hopper of the crusher.

2. The argillaceous or clay materials found in the quarry are also dumped in to the crusher.
3. 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.

4. The abdicative material and crushed lime stone are conveyed to the storage hoppers. The materials are ground to the desired fineness in the raw mill.

5. The materials is then pumped using an aero pole in to the pre heater. The most modern pre heaters have five stages.

6. The material from the bottom of preheater is stored in storage tank and then it is fed to the rotary kiln. Due to the use of multi- stage pre heater in modern plants, the length of rotary kiln considerably reduced there by resulting in saving of maintenance cast and power requirements.

7. In burning, the coal brought from the coal fields is pulverized in vertical coal mill and 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 carbon dioxide is driven off with combustion gases. The materials are then heated to temperature of nearly 1300 to 1500°C when it gets fused together. The **fused product is known as clinkers or raw cement**. The size of clinkers varies from 3mm to 20mm and they are very hot when they come out of kiln. A rotary kiln of small size is provided to cool down the hot clinkers and they are collected in containers of suitable size.

8. The clinkers as obtained from the rotary kiln are finely ground in ball mills and tube mills. During grinding, a small quantity about 2 to 3 percent. Of gypsum is added. The cement stored in soils and they are fed to the packer machines.

Why Gypsum is added?

When C_3A compound is pure the reaction with water is very rapid which leads to flash set of cement i.e immediate setting of cement after mixing the water to cement which makes concrete mixing work very difficult .To prevent this rapid setting process chemical Gypsum (Calcium sulphate) is added to cement clinker during the grinding process in a required proportion.

BOUGE'S COMPOUND:-

The oxides present in the raw materials when subjected to high temperature combine with each other form complex compounds. The identification of major compounds is largely based on R.H.Bouge's work and hence it is called **"Bogue's Compound".** The four compounds usually regarded as major compounds are.

Name of the compound	**Formula**	**Abbreviated formula**.
Tricalcium silicate	$3CaO.SiO_2$	C_3S(Alite)
Dicalcium Silicate	$2CaO.SiO_2$	C_2S(Belite)
Tricalcium aluminate	$3CaO.A.1_2O_3$	C_3A(Aluminate)
Tetra calcium aluminoferrite	$4CaO.Al_2O_3 .Fe_2O_3$	C_4AF(Ferrite)

ROLE OF Bougue's COMPOUND:-

- Tricalcium silicate and dicalcium silicate are the most important compounds responsible for strength together they constitute 70to 80% of cement C_3S largely governs the strength development at an early stage and C_2S at later stage.
- High percent of C_3S and low percentage of C_2S results in high early strength with high heat generation.
- Low percentage of C_3S and high percentage of C_2S develops strength more slowly and develops less heat.
- The percentage of these compounds can be varied by varying lime content of the raw materials i.e, increase in lime content increase the percentage of C_3S and decrease percentage of C_2S.

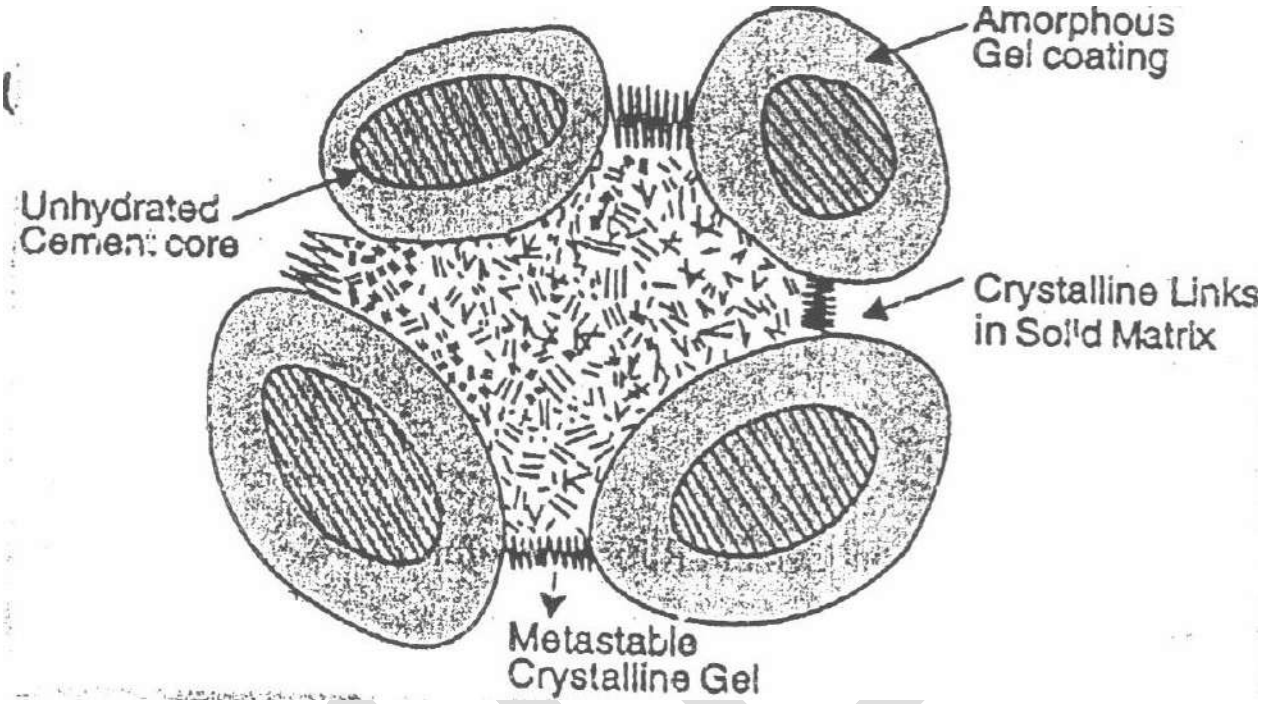
- C_3A contribute very little to the strength of cement this compound hydrates very rapidly and produce considerable amount of heat. It reacts with gypsum to form calcium sulphoferrite which accelerates process of hydration.It causes initial stiffening and less resistant to chemical attack.
- C_4AF is the most undesirable compound in the cement.
- However it cannot be eliminated completely as it facilitates the manufacture of cement by lowering the fusing temperature.

The oxide composition of a typical Portland cement and the corresponding calculated compound composition

Oxide composition percent	**Calculated compound composition using Rogue's equation percent**
CaO 63	C_3S 54.1
SiO_2 20	C_2S 16.6
Al_2O_3 6	C_3A 10.8
FeO_3 3	C_4AF 9.1
MgO 1.5	
SO_2 2	
K_2O 1.0	
Na_2O 1.0	

HYDRATION OF CEMENT

When Portland cement is mixed with water its chemical compound constituents undergo a series of chemical reaction that cause it to harden. This chemical reaction with water is called **Hydration**. Each one of these reaction occurs at a different time and rate. Together, the results of these reactions determine how Portland cement hardens and gains strength.



Microscopic Schematic model representing the structure of hardened cement Paste

OPC (Ordinary Portland cement) HYDRATION

1. Hydration starts as soon *as* the cement and water are mixed.

2. The rate of hydration and heat liberated by the reaction of eachcompound is different.

3. Each compound produces_ different products when it hydrates.

4.**Tricalcium silicate (C_3S):-** hydrates and hardens rapidly and is largely responsible for initial set and early strength. Portland cement with higher percentage of C_3S will exhibit higher early strength.

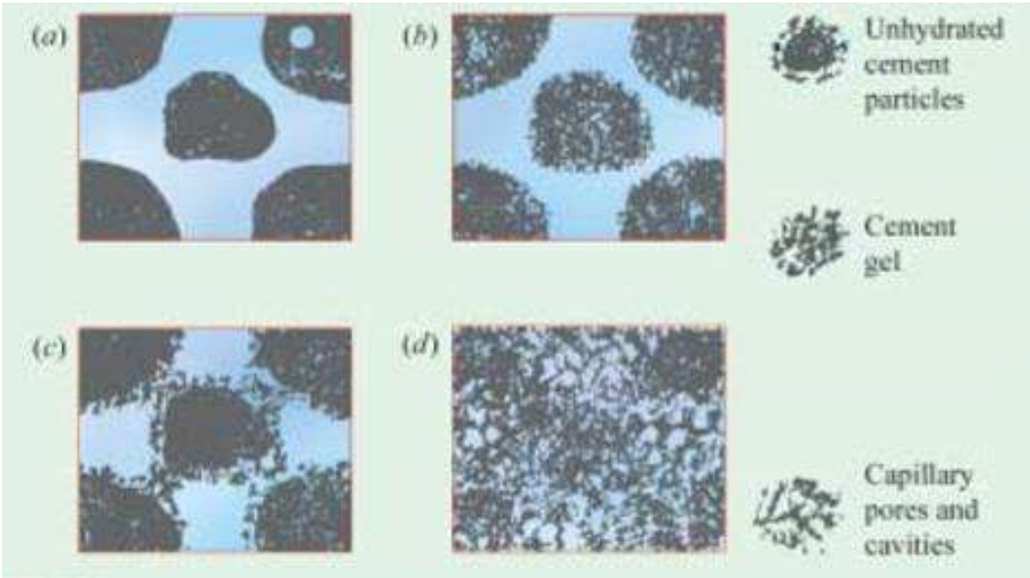
5.**TricalciumAluminate (C_3A):-** hydrates and hardens the quickest. Liberates a large amount of heat almost immediately and contributes somewhat to early strength gypsum is added to Portland cement to retard C3A hydration: Without gypsum, C3A hydration would cause Portland cementto set almost immediately after adding water.

6. **Dicalcium silicate (C_2S):-** hydrates and hardens slowly and is largely responsible for strength increase beyond one week.

7.Tetracalciumaluminoferrite(C_4AF):- hydrates rapidly but contributes very little to strength. Itsuse allows lower kiln temperature in Portland cement manufacturing. Most Portland cement effects are due to C**4**AF.

Water Requirements for Hydration

1. It has been brought out earlier that C_3S requires 24% of water by weight of cement and C_2S requires 21%. It has also been estimated that on an average 23% of water by weight of cement is required for chemical reaction with Portland cement compounds.
2. This 23% of water chemically combines with cement and, therefore, it is called **bound water.**
3. A certain quantity of water is imbibed within the gel-pores. This water is known as gel-water. It can be said that bound water and gel-water are complimentary to each other. If the quantity of water is inadequate to fill up the gel-pores.
4. The formations of gel itself will stop and if the formation of gel stops there is no question of gel-pores being present. It has been further estimated that about 15 per cent by weight of cement is required to fill up the gel-pores.
5. Therefore, a total 38 per cent of water by weight of cement is required for the complete chemical reactions and to occupy the space within gel-pores. If water equal to 38 per cent by weight of cement is only used it can be noticed that the resultant paste will undergo full hydration and no extra water will be available for the formation of undesirable capillary cavities.



Diagrammatic representation of the Hydration process and formation of cement gel.

6. It can be seen that the capillary cavities become larger with increased water / cement ratio With Lower w/c ratio the cement particles are closer together

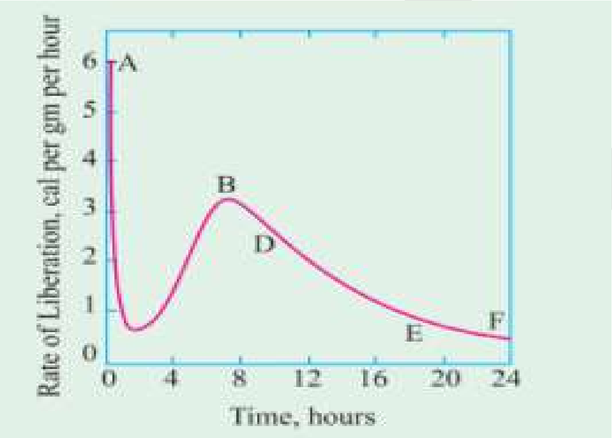
7. With the progress of hydration, when the volume of anhydrous cement increases, the product of hydration also increases.

Heat of Hydration

- The reaction of cement with water is exothermic the reaction liberates a considerable quantity of heat. The Liberation of heat is called heat of hydration.
- The quantity of heat in Joules/gm of hydrated cement involved upon complete hydration of high temperature is called 'Heat of Hydration'
- During the mass mixing of concrete it can be seen that lot of heat evolved in the concrete which is quite noticeable. The generation of heat continues for long say one year and helps to build the strength. Different compounds hydrates at different rates and liberates different quantities of heat.
- Early heat of hydration is mainly because of hydration of C_3S. The total quantity of heat generated in the complete hydration will depend upon relative quantities of major compounds present in the cement.
- Portland cement produces 90-100 calories per gram of heat in 28 days.
- The hydration process is not an instantaneous one. The reaction is fastened in the early periods and continuous at a decreasing rate can be seen in the graph.

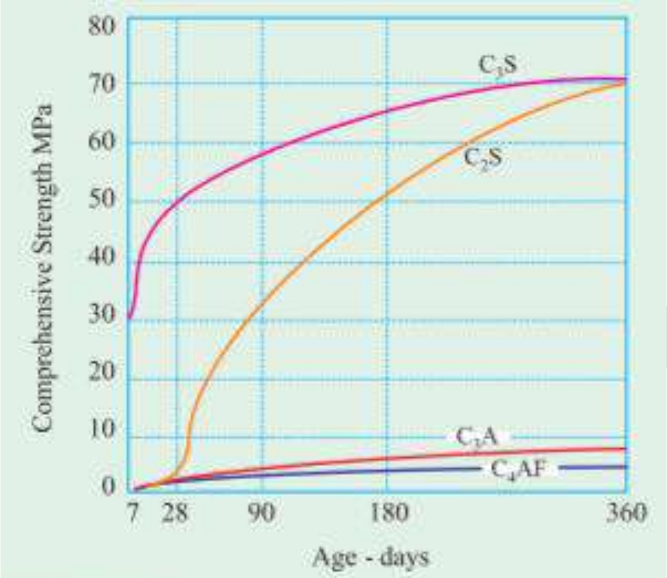
Heat evolution is mainly due to reaction of solution of Aluminates & Sulphates (Ascending peak A).This initial heat evolution ceases quickly when the solubility of aluminates is depressed by gypsum (descending peak A).

Next heat of evolution is on account of formation of ettringite& also may be due to reaction of C_3S (Ascending peak B)



Heat Liberation from a Setting Cement.[1]

<u>Development of strength in concrete by different compounds or development of strength of pure compounds</u>



Development of Strength of Pure Compounds

Schematic Representation of Cement & Hydration of Portland cement

Raw material for Cement	Limestone, clay, shale (calcareous & Argillaceous material).

↓

Component element in raw materials	O2,Si,Ca,Al,Fe

↓

Oxide Composition in raw materials	CaO,SiO2,Al2O3,Fe2O3

On burning ↓ clinker

Compound Composition	C_3S,C_2S,C_3A,C_4AF

On grinding ↓ clinker

Portland Cements	Various types

On ↓ Hydration.

Porducts of Hydraton	C-S-H gel+Ca $(OH)_2$

Where CSH represents hydrated compounds and it is called gel because of its crystal structure.

<u>Difference between Major & Minor Compounds</u>:

Major compounds are formed during the process of formation of clinker in the kiln at high temperature. They have major role to play such as imparting strength, deciding properties etc. Usually C_3S,C_2S, C_3A,$C_4AF$are called **Major Compounds**.

Minor compounds which are formed during this process such as K_2O & Na_2O are called minor compounds. They are less significant in determining the property of cement.

Characteristics of hydration of the cement compound:

compounds	Reaction time	Amount of heat liberated	Strength
C_3S	Moderate	High	High
C_2S	Slow	Low	Low initially, high later
C_3A	Fast	Very high	Low
C_4AF	Moderate	Moderate	Low

Calcium SilicateHydratesOr(C-S-H) gel

During the course of reaction of C_3S and C_2S with water, calcium silicate hydrates (C-S-H), calcium hydroxide and $Ca(OH)_2$ are formed. C-S-H is the most important products. It is the essence that determines the good properties of concrete. It makes up to 50-60 percent of volume of solids in completely hydrated cement paste,

The following are the approximate equations showing the reactions of C_3S and C_2S with water

$2(3CaO.SiO_2) + 6H_2O$---------- $3CaO.2SiO_2.3H_20 + 3Ca\ (0H)_2$

Or2 C_36H------------------------ $C_3S_2H_3+3Ca(OH)_2$

$2(CaO.Si0_2) + 4H_2O$------------- $3CaO.2Si0_2.3H_20 + Ca\ (OH)_2$

Or C_2S+4H------------------------- $C_3S_2H_3+Ca(OH)_2$

It can be seen that C_3S produces a comparatively lesser quantity of calcium silicate hydrates and more quantity of $Ca(OH)_2$ than that formed in the hydration of C_2S.

C_3S readily reacts with water and produces more heat of hydration. It is responsible for early strength of concrete.

C_2S hydrates rather slowly. It is responsible for the later strength of concrete. It produces less heat of hydration.

CALCIUM HYDROXIDE:-

The other product of hydration of C_3S and C_2S is calcium hydroxide. It constitutes 20-25% of the volume of solids in the hydrated paste.

Advantages

- Alkaline in nature maintain pH value around 13 in the concrete which resists corrosion in reinforcement
- Use of fly ash, silica fume and such other pozzolanic materials reduces the bad effects of $Ca(OH)_2$ in concrete.

Disadvantages:

- The lack of durability of concrete is an account of the presence of calcium hydroxide.
- It reacts with sulphates present in soils or water to form calcium sulphate, which further reacts with C_3S and cause deterioration of concrete. This is known as **sulphate attack**

CALCIUM ALUMINATE HYDRATES: (C-AH)

Due to the hydration of C_3A a calcium aluminate system, $CaO\text{-}Al_2O_3\text{-}H_2O$ is formed. The reaction of pure C_3A with water is very fast and this may lead to the flash set, gypsum is added at the time of grinding the cement clinker. The quantity of gypsum added has a bearing on the quantity of C_3A present

The hydration aluminates do not contribute anything to the strength of concrete. On the other hand, their presence is harm full to the durability of concrete particularly where the concrete is likely to be attacked by sulphates. As it, hydrates very fast it may contribute a little to the early strength.

Depending upon the concentration of aluminate and sulphate ions in solution, the precipitating crystalline product is either the calcium aluminate are trisulphate hydrate ($C_6AS_3H_{32}$) or calcium aluminate monosulphate (C_4ASH_{18}). The calcium aluminate trisulphate hydrate is known as ettringite.

$$C_3A+32H+3CaSO_4 \rightarrow C_6AS_2H_{32} \text{(trisulphate hydrate) (ettringite)}$$

$$C_3A+18H+CaSO_4 \rightarrow C4ASH_{18} \text{ (Calcium Aluminatemonosulphate).}$$

When sulphate in solution gets" depleted, the aluminate concentration goes up due to renewed hydration of C_3A and C_4AF. At this stage ettringie becomes unstable and is gradually converted in to mono — sulphate, which the final product of hydration of Portland cements, is containing more than 5 percent C_3A.

$$C_3A+6H \rightarrow C_3AH_6$$

TYPES OF CEMENT

1. Ordinary Portland cement
2. Rapid hardening cement

3. Extra Rapid Hardening cement
4. Sulphate Resisting Cement
5. Portland Slag cement
6. Quick setting cement
7. Super sulphated cement
8. Low heat cement
9. Portland pozzolana cement
10. Air Entraining cement
11. Colored cement : white cement
12. Hydrophobic Cement
13. Masonry Cement
14. Expansive cement
15. High Alumina Cement
16. Oil Well Cement

1.<u>ORDINAY PORTLAND CEMENT</u>:

This cement is the basic Portland cement and is used in general for most of concrete construction work in general

Applications

Super Cement can be used in several applications such as:

- Civil engineering and building applications.
- Enhance properties for ready-mixed concrete.
- High early strength for concrete producers and precast manufacturers.

Concrete, mortars and grouts containing Portland cements must be specified and used correctly for best performance. The cement content must be correct and the water: cement ratio as low as possible consistent with satisfactory placing, through compaction and effective curing.

Properties

- Grey color.
- Consistent strength meeting all the conformity criteria in SASO 143/1979.

- Compatible with admixtures such as air-entraining agents and workability aids, with additions such as fly-ash and ground granulated blast furnace slag and with pigments. Trial mixes are recommended to determine the optimum mix proportions.

Availability

Super Cement is available in 50kg Bags and in Bulk.

This product should be stored in unopened bags, clear of the ground, in cool dry conditions and should be stacked in a safe and stable manner.

Information on the maximum storage period can be found on SASO 143/1979.

Conditions of Use

- Super Cement may be used in the range of traditional nominal mixes as for traditional Portland cement.
- Super Cement should not be mixed with additions or other cement types.
- To achieve optimum performance from Super Cement in concrete or other products, it is essential that is correctly specified and used.

- As with other cements in building work, there is no substitute for good practice and workmanship.
- It is essential to use the correct materials, proportions and mix the materials properly, add the correct amount of water, compact, cure and protect as appropriate.
- When using PCC cement, it is particularly important to ensure the effective curing is applied.
- Normal hot and cold weather practice should also be followed.

2. RAPID HARDENING CEMENT

Rapid hardening cement is similar to Ordinary Portland cement but with higher tri-calcium silicate (C3S) content and finer grinding. It gains strength more quickly than OPC, though the final strength is only slightly higher. This type of cement is also called as High-Early Strength Portland Cement. The one-day strength of this cement is equal to the three-day strength of OPC with the same water-cement ratio.

Following are the advantages and uses of the rapid hardening cement:

1. It is used where formwork has to be removed as early as possible in order to reuse it.

2. It is used where high early strength is required.

3. It is generally used for constructing road pavements, where it is important to open the road to traffic quickly.

4. It is used in industries which manufacture concrete products like slabs, posts, electric poles, block fence, etc. because moulds can be released quickly.

5. It is used for cold weather concreting because rapid evolution of heat during hydration protects the concrete against freezing.

3. EXTRA RAPID HARDENING CEMENT

A Portland cement containing calcium aluminate to give rapid hardening and setting properties:

- For repair and maintenance where rapid hardening is required, eg, fence posts, setting manholes, repairs to paths and steps.
- Suitable for concrete, mortar, rendering and floor screeds.
- Takes foot traffic in 4-6 hours and vehicular traffic in 8-12 hours.

Extra Rapid is a rapid setting and hardening Portland based cement. At present there is no appropriate British Standard for this product.

Extra Rapid is quality assured cement covered by the British Standards Institution Registered Firms Scheme (BS EN ISO 9001: 2000).

Applications

Extra Rapid is for repair and maintenance in building work where rapid setting and rapid hardening properties are beneficial, eg, concrete; mortar, rendering and floor screed repairs typical uses are as follows:

- Concrete drives and paths.
- Concrete steps.
- Fixing fence posts, railings and copings.
- Setting manholes.
- Repairing rendering and floor screeds.

Extra Rapid may be used in the range of traditional nominal mixes as for traditional Portland cement. Recommended mixes are given in the Lafarge Cement Builders' Guide, available from the contacts overleaf.

Properties

- Portland cement based.

- Contains calcium alurninate to give rapid setting and rapid hardening properties.
- Sets soon after placing and gains strength rapidly to allow normal services to be brought back into operation in a working day.
- Similar final strength to Master Crete Original.

4. SUPHATE RESISTING CEMENT (SRC)

Sulphate Resisting Portland Cement is a type of Portland cement in which the amount of Tricalcium aluminate (C3A) is restricted to lower than 5 % and (2 C3A + C4AF) is lower than 25%. SRC can be used for structural concrete wherever OPC or PPC or Slag Cement is usable under normal conditions. The use of SRC is particularly beneficial in such conditions where the concrete is exposed to the risk of deterioration due to sulphate attack. The use of SRC is recommended for following applications:

- Foundations, piles.
- Basements and underground structures.
- Sewage and. Water treatment plants.
- Chemical, Fertilizers and Sugar factories.
- Food processing industries and Petrochemical projects.
- Coastal works.
- Also for normal construction works where OPC is used.

- Construction of building along the coastal area within 50 km from sea.

5. PORTLAND SLAG CEMENT

Lafarge Cement is a very high performance blended Portland Slag Cement available in the major markets in East India. Lafarge Cement is well accepted and appreciated by the consumers for its superior product quality and the consistency in product delivery.

Lafarge Cement uses highly reactive slag obtained from the best sources in the country which contributes in improving the density of the resultant concrete mix thus increasing the durability of the structure constructed.

Advantage

High Compressive Strength: Lafarge PSC is produced by blending high quality pulverized clinker with consistent slag of over 95% glass content. This provides very high compressive strength exceeding 60MPa at 28 days.

Ideal for the Indian Climate: Lafarge PSC has a very low heat of hydration and is hence suitable for mass concreting and concrete cast under hot weather conditions. Workability retention is also enhanced.

High Soundness: Lafarge cement bps very high soundness as reflected through the extremely low values of expansion through the Le-Chatelier test and Autoclave tests. Its C3A content is low, thus making it more resistant to sulphate attacks when compared to other cements.

Low Co-efficient of Permeability: Its chemical properties contribute to a very low co-efficient of permeability in the concrete prepared, thus making it an ideal choice for construction of dams, foundations, tunnels, or other sub-soil constructions and structures that are in contact with water.

6.QUICK SETTING CEMENT

Rapid Set Cement is very fast setting hydraulic cement used in concrete applications requiring the highest durability and fastest strength gain. Mix Rapid Set Cement with water and aggregates to produce high-performance, one-hour strength concrete, mortar and grout mixtures. The High-Strength, low shrinkage, and superior durability of Rapidest Cement result in unparalleled concrete performance. Rapid Set® Cement has a proven record of successful projects dating back to 1960.

USES:

Excellent for diverse projects including highway pavements, bridges, runways,, tunnels, harbors, precast, sidewalks, floors, and many other projects. For larger jobs, Rapid Set® Cement mixtures may be batched using conventional ready-mix or volumetric mixer equipment.

Many state and local municipalities throughout the U.S. specify Rapid Set® Cement in their concrete mix designs when speed and durability are important.

Set Time:

Initial Set 15 minutes Final Set 35 minutes.

7. SUPER SULPHATED CEMENT

This cement is made by grinding a mixture of well granulated blast furnace slag (80 to 85 percent) calcium sulphate (10 to 15 percent) and ordinary cement (1 to 2 percent). This cement is ground finer than the Portland cement. One of the significant properties of this cement is its low total heat of hydration. It is therefore very useful for mass concrete works. This cement is highly restraint to chemical attack. Concrete made from this type of cement expands if curing is done under water and shrinks if curing is done in air. •

8. LOW HEAT CEMENT

We know that hydration of cement is an exothermic action which produces large quantity of heat during hydration. In case of mass concrete work like dams, bridges, abutments, this heat causes shrinkage of concrete during its curing period and hence tensile stress are developed in the concrete which results serious cracking.

To avoid this cement having a low rate of heat evolution was first produced in U.S.A low heat cement evolution is achieved by reaching the contents of C3S and C3A which are the compounds evolving the maximum of hydration and increasing C_2S. The feature of low heat cement is a slow rate of gain of strength. But the ultimate strength of low heat cement is same as that of ordinary Portland cement

9. PORTLAND POZZOLANA CEMENT

Portland Pozzolana Cement is a kind of Blended Cement which is produced by either intergrading of OPC clinker along with gypsum and pozzolonic materials in certain proportions or grinding the OPC clinker, gypsum and Pozzolonic materials separately and thoroughly blending them in certain proportions.

Pozzolanaisa natural or artificial material containing silica in a reactive form. It may be further discussed as siliceous or siliceous and aluminous material which in itself possesses little, or no cementitious properties but will in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperature to form compounds possessing cement properties. It is essential that Pozzolana be in a finely divided state as it is only then that silica can combine with calcium hydroxide (liberated by the hydrating Portland Cement) in the presence of water to form stable calcium silicates which have cement properties. The pozzolanic materials commonly used are:

Volcanic ash.

Calcined clay.

Fly ash.

Silica fumes.

Portland Pozzolana Cement is ideally suited for the following construction:

- Hydraulic structures.
- Mass concreting works.
- Marine structures.
- Masonry mortars and plastering.
- Under aggressive conditions.
- All other applications where OPC is used.
- The compressive strength of PPC as per BIS code at present is equivalent to that of 33 grade OPC.

10. AIR ENTRAINING CEMENT

Air-Entraining Cement is made by mixing a small amount of an air-entraining agent with ordinary Portland cement clinker at the time of grinding. The following types of air-entraining agents could be used: Alkali salts of wood resins. Synthetic detergents of the alkyl-aryl sulphonatetype. Calcium lignosulphate derived from the sulphite process in paper making. Calcium salts of glues and other proteins obtained in the treatment of animal hides, these agents in powder, or in liquid forms are added to the extent of 0.025 0.1 per cent by weight of cement clinker. There are other additives including animal and vegetable fats, oil and their acids could be used. Wetting agents, aluminium powder, and hydrogen peroxide could also be used. Air-entraining cement will produce at the time of mixing; tough, tiny, discrete non-coalesceing air bubbles in the body of the concrete which will modify the properties of plastic concrete with respect to workability, segregation and bleeding. It will modify the properties of hardened concrete with respect to its resistance to frost action. Air entraining agent can also be added at the time of mixing ordinary Portland cement with rest of the ingredients.

11. COLOURED CEMENT:

For manufacturing various colored cements, either white cement or grey Portland cement is used as a base. The use of white cement as a base is costly. With the use of grey cement, only red or brown cement can be produced. Coloured cement consists of Portland cement with 5-10% of pigment. The pigment cannot be satisfactorily distributed throughout the cement by mixing, and hence, it is usual to grind the cement & pigment together. Chromium oxide green color Cobalt blue color Iron oxide brown colour The raw materials used for white cement are: High purity limestone (96% $CaCO_3$ & less than 0.07% iron oxide) China clay (0.72-0.8% of iron oxide, silica sand, fluorspar as flux and selenite as retarder) Grey colour of OPC is due to the iron oxide present.

12. MASONRY CEMENT

Ordinary cement mortar, though good when compared to lime mortar with respect to strength and setting properties, is inferior to lime mortar with respect to workability, water retentivity, shrinkage property and extensibility. Masonry cement is a. type of cement which is particularly made with such combination of materials, which when used for making mortar, incorporates all the good properties of lime mortar and discards all the not so ideal properties of cement mortar. This kind of cement is mostly used, as the name indicates, for masonry construction. It contains certain amount of air-entraining agent and mineral admixtures to improve the plasticity and water retentively.

13. EXPANSIVE CEMENT

Concrete made with ordinary Portland cement shrinks while setting due to loss of free water. Concrete also shrinks continuously for long time. This is known as drying shrinkage. Cement used for grouting anchor bolts or grouting machine foundations or the cement used in grouting the prestress concrete ducts, if shrinks, the purpose for which the grout is used will be to some extent defeated. There has been a search for such type of cement which will not shrink while hardening and thereafter. As a matter of fact, a slight expansion with time will prove to be advantageous for grouting purpose. This type of cement which suffers no overall change in volume on drying isknown as expansive cement. Cement of this type has been developed by using an expanding agent and a stabilizer very carefully.

Proper material and controlled proportioning are necessary in. order to obtain the desired expansion. Generally, about 8-20 parts of the sulphoaluminate clinker are mixed with 100 parts of the Portland cement and 15 parts of the stabilizer. Since expansion takes place only so long as concrete is moist curing must be carefully controlled. The use of expanding cement requires skill and experience. One type of expansive cement is known as shrinkage compensating cement. This cement when used in concrete, with restrained expansion, induces compressive stresses which approximately offset the tensile stress induced by shrinkage. Another similar type of cement is known as Self Stressing cement.

14. OIL WELL CEMENT

Oil-wells are drilled through stratified sedimentary rocks through a great depth in search of oil. It is likely that if oil is struck, oil or gas may escape through the space between the steel casing and rock formation. Cement slurry is used to seal off the annular space between steel casing and rock strata and also to seal off any other fissures or cavities in the sedimentary rock layer. The cement slurry has to be pumped into position, at considerable depth where the prevailing temperature may be up to 175°C. The pressure required may go up to 1300 kg/ cm².The slurry should remain sufficiently mobile to be able to flow under these conditions for periods up to several hours and then hardened fairly rapidly. It may also have to resist corrosive conditions from sulphur gases or waters containing dissolved salts. The type of cement suitable for the above conditions is known as Oil-well cement. The desired properties of Oil well cement can be obtained in two ways: by adjusting the compound composition of cement or by adding retarders to ordinary Portland cement. Many admixtures have been patented *as* retarders. The commonest agents are starches or cellulose products or acids. These retarding agents prevent quick setting and retain the slurry in mobile condition to facilitate penetration to all fissures and cavities.

15. HIGH ALUMINA CEMENT:-

High alumina refractory cement is used for the construction of industrial furnaces, reaction vessel etc where high temperature strength, volume stability, and chemical action particularly the vulnerable areas of Iron & Steel, Cement Ceramics, Chemical and other industries.

The Central Glass &Ceramic Research Institute, Calcutta has developed a new technique of sintering for the production of High Alumina Cements : 45- 50%, 65-66% and 72-78% alumina types that can be used for making castable for recommended maximum service temperature ranging from 1300^0cto 1800ºC. The new process has certain advantages such as low temperature of sintering, minimizing the use of high-cost infra- structural facilities, low cost of production. The technology is also suitable for and adaptable by the medium scale, the small scale and the mini scale sector of the industries.

OTHER CEMENTITIOUS MATERIAL:

GGBS: **Ground granulated blast-furnace slag** (**GGBS** or **GGBFS**) is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. Ground granulated blast furnace slag is a latent hydraulic binder forming calcium silicate hydrates (C-S-H) after contact with water. It is a strength-enhancing compound improving the durability of concrete. It is a component of metallurgic cement (CEM III in the European norm EN 197). Its main advantage is its slow release of hydration heat, allowing limitation of the temperature increase in massive concrete components and structures during cement setting and concrete curing, or to cast concrete during hot summer.

Applications

GGBS is used to make durable concrete structures in combination with ordinary Portland cement and/or other pozzolanic materials. GGBS has been widely used in Europe, and increasingly in the United States and in Asia (particularly in Japan and Singapore) for its superiority in concrete durability, extending the lifespan of buildings from fifty years to a hundred years.

Two major uses of GGBS are in the production of quality-improved slag cement, namely Portland Blast furnace cement (PBFC) and high-slag blast-furnace cement (HSBFC), with GGBS content ranging typically from 30 to 70%; and in the production of ready-mixed or site-batched durable concrete.

Concrete made with GGBS cement sets more slowly than concrete made with ordinary Portland cement, depending on the amount of GGBS in the cementitious material, but also continues to gain strength over a longer period in production conditions. This results in lower heat of hydration and lower temperature rises, and makes avoiding cold joints easier, but may also affect construction schedules where quick setting is required.

Chemical Composition

Chemicals	Present in GGBS
CaO	30-50%
SiO_2	28-38%
Al_2O_3	8-24%
MgO	1-18%
MnO	0.68%
TiO_2	0.58%
K_2O	0.37%
N_2O	0.27%

Fly ash: Fly ash is a byproduct from burning pulverized coal in electric power generating plants. During combustion, mineral impurities in the coal (clay, feldspar, quartz, and shale) fuse in suspension and float out of the combustion chamber with the exhaust gases. As the fused material rises, it cools and solidifies into spherical glassy particles called fly ash. Fly ash is collected from the exhaust gases by electrostatic precipitators or bag filters. The fine powder does resemble portland cement but it is chemically different. Fly ash chemically reacts with the byproduct calcium hydroxide released by the chemical reaction between cement and water to form additional cementitious products that improve many desirable properties of concrete. All fly ashes exhibit cementitious properties to varying degrees depending on the chemical and physical properties of both the fly ash and cement. Compared to cement and water, the chemical reaction between fly ash and calcium hydroxide typically is slower resulting in delayed hardening of the concrete. Delayed concrete hardening coupled with the variability of fly ash properties can create significant challenges for the concrete producer and finisher when placing steel-troweled floors.

The chemical composition of fly ash depends upon the type of coal used and the methods used for combustion of coal.

Component	Bituminous Coal	Sub bituminous Coal	Lignite Coal
SiO2 (%)	20-60	40-60	15-45
Al2O3 (%)	5-35	20-30	20-25
Fe2O3 (%)	10-40	4-10	4-15
CaO (%)	1-12	5-30	15-40
LOI (%)	0-15	0-3	0-5

RICE HUSK ASH: Rice husk ash are the hard protecting covering of grains of rice. It is used as fuel in the boilers for processing of paddy producing energy through direct combustion or by gasification. For every 1000kgs of paddy milled, about 22okgs of husk is produced. Concrete made with RHA as a partial cement substitute to levels of 10% to 20% by weight of cement has superior performance characteristics compared to normal concrete.

Chemical composition:

1	Silicon Dioxide	86.94%
2	Aluminium Oxide	0.2%
3	Iron Oxide	0.1%
4	Calcium Oxide	0.3 – 2.25%
5	Magnesium Oxide	0.2 – 0.6%
6	Sodium Oxide	0.1 -0.8%
7	Potassium Oxide	2.15 – 2.30%

Silica Fume: Silica fume is a by-product from the production of elemental silicon or alloys containing silicon in electric arc furnaces. At a temperature of approximately 2000°C the reduction of high-purity quartz to silicon produces silicon dioxide vapor, which oxidizes and condenses at low temperatures to produce silica fume. One of the most beneficial uses for silica fume is in concrete. Because of its chemical and physical properties, it is a very reactive pozzolan. Concrete containing silica fume can have very high strength and can be very durable. Silica fume is available from suppliers of concrete admixtures and, when specified, is simply added during concrete production.

Placing, finishing, and curing silica-fume concrete require special attention on the part of the concrete contractor.

Silica fume particles are extremely small, the mean primary particle size ranges from 0.1 to 0.2 µm, 95% of the particles are finer than 1 µm. It contains 85%–95% silica (SiO_2). The particles are spherical in shape.

Factors influencing and affecting Hydration of cement:

- **Chemical** composition of the cement: The mineral composition of cement and their ratios are the main factors affecting the setting and hardening of cement. As mentioned above, various mineral components will reveal different characteristics when reacting with water. For example, the **increase of C3A** can **speed up the setting and hardening rate of cement**, and the **heat of hydration is high** at the same time. Generally speaking, if mixed materials are added into the cement clinker, the anti-erosion will increase, and the heat of hydration and the early strength will decrease.
- **Cement type**
- Sulphate content

- Fineness: The size of cement particles directly affects the hydration, setting and hardening, strength and heat of hydration. ***The finer the cement particles are, the larger the total surface area is and the bigger the area contacting with water is. Thus, the hydration will be quick, the setting and hardening will be accelerated correspondingly, and the early strength will be high.*** However, if the cement particles are too small, it is easy for them to react with the water and the calcium dioxide in the air to destroy the storage of cement. If the cement is too fine, its shrinkage is large in the hardening process. Thus, the finer the cement is ground, the more energy will lose and the higher the cost will be. Usually, the grain size of the cement particles is within 7-200pm (0.007-0.2mm).

- Water/cement Ratio: If the cement consumption is unchanged, **the increase of the mixing water content will enhance the amount of capillary porosities, lower the strength of cement paste, and extend the setting time**. Therefore, in practical projects, the amount of water and cement will be changed without modifying the water-cement ratio (the minimum amount of cement is regulated to ensure the durability of concrete) when the liquidity of cement concrete is adjusted.
- Curing temperature: The curing environment has sufficient temperature and moisture which is conducive to the hydration and setting and hardening process of cement and benefits the development of the early strength. If the moisture of the environment is very dry, the water in the cement will evaporate, leading to insufficient hydration and ceasing of the hardening. Serious cracks will happen sometimes. Usually, the temperature rises at the time of curing, and the hydration of

cement and the development of early strength become fast. If the hardening process occurs at a low temperature, the final strength won't be affected though the development of the strength is slow. But if the temperature is under 0^0C, the hydration of cement will stop and the strength will not only stop growing but also destroy the structure of cement paste due to the condensation of water. In actual projects, the setting and hardening process of cement products is accelerated by steam curing and autoclave curing.

- Effects of admixture: Hydration, setting, and hardening of Portland cement are constrained by C3S, C3A. And all the admixtures that affect the hydration of C3S, C3A can change the performance of the hydration, the setting and hardening of Portland cement. For example, the accelerator agents (such as CaC12, Na2S04) can accelerate the hydration and the hardening of cement and improve its strength. On the contrary, the retarding agents (such as calcium lignosulphonate) can delay hydration and hardening of cement and affect the development of the early strength.

Physical Properties of Cement:

Different blends of cement used in construction are characterized by their physical properties. Some key parameters control the quality of cement. The physical properties of good cement are based on:

- Fineness of cement

- Soundness
- Consistency
- Strength
- Setting time
- Heat of hydration
- Loss of ignition
- Bulk density
- Specific gravity (Relative density)

AGGREGATES

Aggregates:

Earlier, aggregates were considered as chemically inert materials but now it has been recognized that some of the aggregates are chemically active and also that certain aggregates exhibit chemical bond at the interface of aggregate and paste. The mere fact that the aggregates occupy 70-80 per cent of the volume of concrete, their impact on various characteristics and properties of concrete is undoubtedly considerable. To know more about the concrete it is very essential that one should know more about the aggregates which constitute major volume in concrete. Without the study of the aggregate in depth and range, the study of the concrete is incomplete. Cement is the only factory made standard component in concrete. Other ingredients, namely, water and aggregates are natural materials and can vary to any extent in many of their properties. The depth and range of studies that are required to be made in respect of aggregates to understand their widely varying effects and influence on the properties of concrete cannot be underrated.

Classification:

Aggregate are classified as below:

Based on

1. **SIZE:** Fine aggregate and Coarse Aggregate.
2. **SPECIFIC GRAVITY**: Light weight, Normal Consistency, and heavy weight aggregates
3. **AVAILABILITY**: Natural Gravel & Crushed Aggregates
4. **SHAPE**: Round, Cubical, Angular, Elongated and Flaky aggregates
5. **TEXTURE:** smooth, Granular, Crystalline, honey combed, and porous.

SIZE OF AGGREGATE:

The largest maximum size of aggregate practicable to handle under a given set of conditions should be used: Using the largest possible maximum size will result in

(i) Reduction of the cement content

(ii) Reduction in water requirement

(iii) Reduction of drying shrinkage. However, the maximum size of aggregate that can be used in any given condition may be limited by the following conditions:

(i) Thickness of section; (ii) Spacing of reinforcement;

(iii) Clear cover; (iv) Mixing, handling and placing techniques.

The maximum size of aggregate should be as large as possible within the limits specified, but in any case not, greater than one-fourth of the minimum thickness of the member

Aggregates are **divided into two categories** from the consideration of size **(i) Coarse aggregate and (ii) Fine aggregate. The size of aggregate bigger than 4.75 mm is** considered as **coarse aggregate and aggregate whose size is 4.75mm and less is considered as fine aggregate.**

SHAPE OF AGGREGATE:

- The shape of aggregates is an important characteristic since it affects the workability of concrete.
- It is difficult to really measure the shape of irregular body like concrete aggregate which are derived from various rocks.
- The shape of the aggregate is very much influenced by the type of crusher and the reduction ratio i.e., the ratio of size of material fed into crusher to the size of the finished product. Many rocks contain planes of parting or jointing which is characteristic of its formation.
- From the standpoint of economy in cement requirement for a given water/cement ratio, rounded aggregates are preferable to angular aggregates.

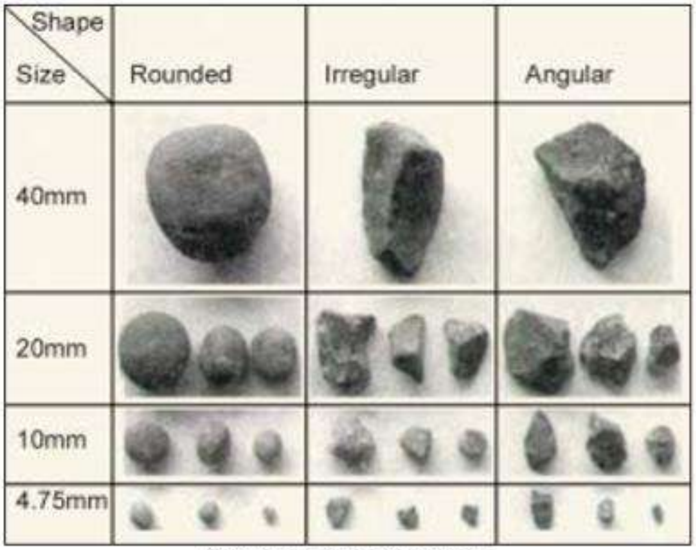
- Flat particles in concrete aggregates will have particularly objectionable influence on the workability, cement requirement, strength and durability. In general, excessively flaky aggregate makes very poor concrete.

Shape of Particle:

Classification	Description	Examples
Rounded	Fully water wornor completely shaped by attrition	River or seashore gravels; desert, seashore and windblown sands
Irregular or Partly rounded	Naturally irregular or partly shaped by attrition having rounded edges.	Pit sands and gravels; land, or dug flints; cuboid rock'.
Angular	Possessing well-defined edges formed at the intersection of roughly planar faces	Crushed rocks of all types; t a l u s ; screes (loose sand)

Flaky	Material, usually angular, of which the thickness is small relative to the width and/or length	Laminated rocks

Round (spherical) concrete aggregate. Flaky concrete aggregate. Crushed concrete aggregate.



Shape and size of aggregates

Angular aggregates are superior to rounded aggregates from the following two points of view:

a) Angular aggregates exhibit a better interlocking effect in concrete, which property makes it superior in concrete used for roads and pavements.

b) The total surface area of rough textured angular aggregate is more than smooth rounded aggregate for the given volume. By having greater surface area, the angular aggregate may show higher bond strength than rounded aggregates.

- ✓ For water/cement ratio below 0.4 the use of crushed aggregate has resulted in strength up to 38 per cent, higher than the rounded aggregate.
- ✓ With an increase in water/cement ratio the influence of roughness of surface of the aggregate gets reduced.
- ✓ The shape of the aggregates becomes more important in case of high strength and high performance concrete where very low water/cement ratio is required to be used.
- ✓ To produce mostly cubical shaped aggregate and reduce flaky aggregate, improved versions of crushers are employed, such as Hydrocone crushers, Barmac rock on rock VSI crusher etc.
- ✓ Sometimes ordinarily crushed aggregates are further processed to convert them to well graded cubical aggregates.

TEXTURE OF AGGREGATE:

Surface texture is the property, the measure of which depends upon the relative degree to which particle surfaces are polished or dull, smooth or rough. Surface texture depends on hardness, grain size, pore structure, structure of the rock, and the degree to which forces acting on the particle surface have smoothed or roughened it. Hard, dense, fine-gained materials will generally have smooth fracture surfaces. Experience and laboratory experiments have shown that the adhesion between cement paste and aggregate is influenced by several complex factors in addition to the physical and mechanical properties.

- ✓ As surface smoothness increases, contact area decreases, hence a highly polished particle will have less bonding area with the matrix than a rough particle of the same volume.
- ✓ A smooth particle, however, will require a thinner layer of paste to lubricate its movements with respect to other aggregate particles. it will, therefore, permit denser packing for .equal workability and hence, will require lower paste content than rough particles.

	Surface Texture	Examples
1	Glassy	Black flint
2	Smooth	Chert, slate, marble, some rhyolite
3	Granular	Sandstone, Oolites

4	Crystalline	Fine: Basalt, trachyte, medium: Dolerite; granophyre, granulite, micro granite, some limestones; many dolomites. Coarse: Gabbro, gnesis, granite, granodiorite, syenite
5	Honeycombed and Porous	Scoria, Pumice trass

Surface Characteristics of Aggregate

Measurement of Surface Texture

Direct methods

1. Making a cast of the surface and magnifying a section of this.
2. Tracing the irregularities, by drawing a fine point over the surface and drawing a trace magnified by mechanical, optical, or electrical means.
3. Getting a section through the aggregates and examining a magnified image.

Indirect methods

1. Measurement of the degree of dispersion of light falling on the surface.
2. Determining the weight of a fine powder required to fill up the interstices of the surface to a truly smooth surface.

3. The rock surface is held against rubber surface at a standard pressure and the resistance to the flow of air between the two surfaces is measured.

TESTING OF AGGREGATES:

1. BULK DENSITY OF AGGREGATE:

1. The bulk density or unit weight of an aggregate gives valuable information regarding the shape and grading of the aggregate.
2. For a given specific gravity the angular aggregates show a lower bulk density.
3. The bulk density of aggregate is measured by filling a container of known volume in a Standard manner and weighing it.

3. Bulk density shows how densely the aggregate is packed when filled in a standard manner.

4. The bulk density depends on the particle size distribution and shape of the particles. One of the early methods of mix design makes use of this parameter bulk density in proportioning of concrete mix.
5. The higher the bulk density, the lower is the void content to be filled by sand and cement. The sample which gives the minimum voids or the one which gives maximum bulk density is taken as the right sample of aggregate for making economical mix.
6. The method of determining bulk density also gives the method for finding out void content in the sample of aggregate.

7. For determination of bulk density the aggregates are filled in the container and then they are compacted in a standard manner.

8. The weight of the aggregate gives the bulk density calculated in kg/litre or kg/m3. Knowing the specific gravity of the aggregate in saturated and surface-dry condition, the void ratio can also be calculated.

$$\text{Percentage voids} = \frac{G_s - \gamma}{G_S} \times 100$$

G_S = sp gravity of aggregate, γ = bulk density in kg /lt

2 BULKING OF AGGREGATES

The free moisture content in fine aggregate results in bulking of volume. Bulking phenomenon can be explained as follows:

1. Free moisture forms a film around each particle. This film of moisture exerts what is known as surface tension which keeps the neighbouring particles away from it.
2. The force exerted by surface tension keeps every particle away from each other. Therefore, no point contact is possible between the particles. .

3. This causes bulking of the volume. The extent of surface tension and consequently how far the adjacent particles are kept away will depend upon the percentage of moisture content and the particle size of the fine aggregate

4. It is interesting to note that the bulking increases with the increase in moisture content upto a certain limit and beyond that the further increase in the moisture content results in the decrease in the volume and at a moisture content representing saturation point, the fine aggregate shows no bulking

5. It can be seen-from graph that fine sand bulks more and coarse sand bulks less. From this it follows that the coarse aggregate also bulks but the bulking is so little that it is always neglected. Extremely fine sand and particularly the manufactured fine aggregate bulks as much as about 40 per cent.

Procedure:-

The extent of bulking can be estimated by a simple field test. A sample of moist fine aggregate is filled into a measuring cylinder in the normal manner. Note down the level, say h_l . Pour water into the measuring cylinder and completely inundate the sand and shake it. Since the volume of the saturated sand is the same as that of the dry sand, the inundated sand completely offsets the bulking effect. Note down the level of the sand say, h_2. Then (h_1 — h_2) shows the bulking of the sample of sand under test.

$$\text{Percentage of bulking} = \frac{h_1 - h_2}{h_2} \times 100$$

The field test to find out the percentage of bulking is so simple that this could be conducted in a very short time interval and the percentage of bulking so found out could be employed for correcting the volume of fine aggregate to be used. This can be considered as one of the important methods of field control to' produce quality concrete. Since volume batching is not adopted for controlled concrete, the determination of the percentage of moisture content is not normally required.

2. Bulkingof Fine Aggregate:

1. The increase in the volume of a given mass of fine aggregate caused by the presence of water is known as bulking
2. The bulking of fine aggregate is caused by the films of water which push the particles apart. The extent of bulking depends upon the percentage of moisture present in the sand and its fineness.
3. It is seen that the bulking increases gradually with moisture content up to a certain point and then it begins to decrease with further addition of water due to merging of films, until when the sand is inundated
4. At this stage the bulking is practically nil, with ordinary sands the bulking usually varies between 15 per cent and 30 per cent. A typical graph shown in Fig. gives the variation of per cent bulking with moisture content.

5. Finer sand bulks considerably more and the maximum bulking is obtained at higher water content than the coarse sand. In extremely fine sand the bulking may be of the order of 40 per cent at a moisture content of 10 per cent but such sand is unsuitable for concrete.

6. In the case of *coarse* aggregate the increase in volume is negligible due to the presence of free water as the thickness of moisture film is very small, compared with particle size.

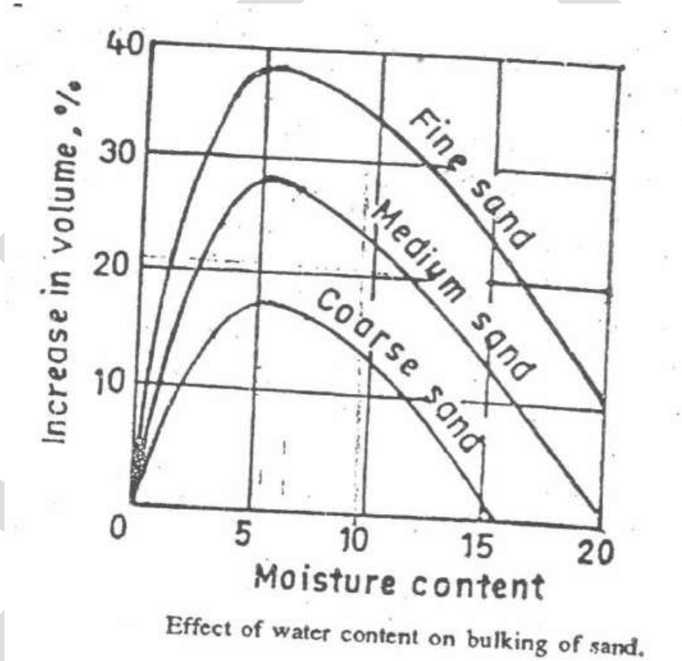


Fig: Effect of water content on bulking of sand.

The percentage bulking is obtained in accordance with IS : 2386 (Pan III)-1963.

7. If the sand is measured by volume and no allowance is made for bulking, the mix will be richer than that specified because for given mass, moist sand occupies a considerably larger volume than the same mass of the dry sand.

8. This result in a mix deficient in sand increasing the chances of **segregation and honeycombing** of the concrete. The yield of the concrete will also be reduced.

9. It is necessary in such a case to increase the measured volume of the sand by the-percentage bulking, in order that the amount of sand put into concrete may be the amount intended for the nominal mix used (based on dry sand).

10. If no allowance is made for the bulking of sand a nominal concrete mix 12:4 for example will correspond to 1: 1.74: 4 for a bulking of 15 per cent. An increase in bulking from 15 per cent to30 per cent will result into an increase in the concrete strength by as much as 12 per cent. If no allowance is made for bulking the concrete strength may vary by as much as 25 per cent.

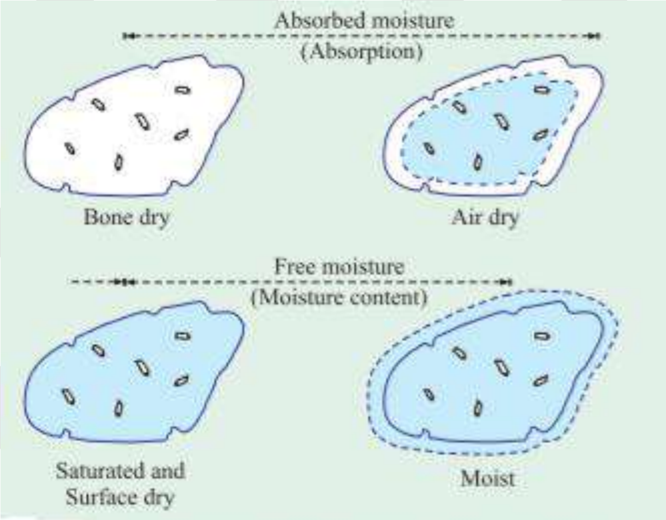
3. ABSORPTION AND MOISTURE CONTENT

1. Some of the aggregates are porous and absorptive. Porosity and absorption of aggregate will affect the water/cement ratio and hence the workability of concrete.

2. The porosity of aggregate will also affect the durability of concrete when the concrete is subjected to freezing and thawing and also when the concrete is subjected to chemically aggressive liquids.

3. The water absorption of aggregate is determined by measuring the increase in weight of an oven dry sample when immersed in water for 24 hours. The ratio of the increase in weight to the weight of the dry sample expressed as percentage is known as absorption of aggregate.

4. But when we deal with aggregates in concrete the 24 hours absorption may not be of much significance, on the other hand, the percentage of water absorption during the time interval equal of final set of cement may be of more significance.



Diagrammatic representation of Moisture in Aggregate.

5. The aggregate absorbs water in concrete and thus affects the workability and final volume of concrete. The rate and amount of absorption within a time interval equal to the final set of the cement will only be a significant factor rather than the 24 hours absorption of the aggregate.

3.1 Measurement of Moisture Content of Aggregates

1. Determination of moisture content in aggregate is of vital importance in the control of the quality of concrete particularly with respect to workability and strength. The measurement of the moisture content of aggregates is basically a very simple operation. But it is complicated by several factors.
2. The water content can be expressed in terms of the weight of the aggregate when absolutely dry, surface dry or when wet. Water content means the free water, or that held on the surface of the aggregate or the total water content which includes the absorbed water plus` the free water, or the water held in the interior portion of aggregate particles.

The measurement of the moisture content of aggregate in the field must be quick, reasonably accurate and must require only simple apparatus which can be easily handled and used in the field. Some of the methods that are being used for determination of moisture content of aggregate are given below:

1. Drying Method
2. Displacement Method
3. Calcium Carbide Method

4. Measurement by electrical meter.
5. Automatic measurement

1.Drying Method

The application of drying method is fairly simple. Drying is carried out in an oven and the loss in weight before and after drying will give the moisture content of the aggregate. If the drying is done completely at a high temperature for a long time, the loss in weight will include not only the surface water but also some absorbed water. Appropriate corrections may be made for the saturated and surface dry condition. The oven drying method is too slow for field use. A fairly quick result cans be obtained by heating the aggregate quickly in an open pan. The process can also be speeded up by pouring inflammable liquid such as methylated spirit or acetone over the aggregate and igniting it.

2. Displacement Method

The laboratory the moisture content of aggregate can be determined by means of pycnometer or by using Siphon-Can Method. The principle is that the specific gravity of normal aggregate is higher, than that of water and that a given weight of wet aggregate will occupy a greater volume than the same weight of the aggregate when dry. By knowing the specific gravity of the dry aggregate, the specific gravity of the wet aggregate can be calculated. From the difference between the specific gravities of the dry and wet aggregates, the moisture content of the aggregate can be calculated.

3. **Calcium Carbide Method**

A quick and reasonably accurate method of determining the moisture content of fine aggregate is to mix it with an excess of calcium carbide in a strong air-tight vessel fitted with 'Pressure gauge. Calcium carbide reacts with surface moisture in the aggregate to produce acetylene gas. The pressure of acetylene gas generated depends upon the moisture content of the aggregates. The pressure gauge iscalibrated by taking a measured quantity of aggregate of known moisture content and then such a calibrated pressure gauge could be used to read the moisture content of aggregate directly. This method is often used to find out the moisture content of fine aggregate at the site of work. The equipment consists of a small balance, a standard scoop and a container fixed with dial gauge. The procedure is as flows:

Weigh 6 grams of representative sample of wet sand and pour it into the container. Take one scoop full of calcium carbide powder and put it into the container. Close the lid of the container and shake it rigorously. Calcium carbide reacts with surface moisture and produces acetylene gas, the pressure of whichdrives the indicator needle on the pressure gauge. The pressure gauge is so calibrated, that it gives directly percentage of moisture. The whole job takes only less than 5 minutes and as such, this test can be done at very close intervals of time at the site of work.

3. **Electrical Meter Method**

Recently electrical meters have been developed to measure instantaneous or continuous reading of the moisture content of the aggregate. The principle that the resistance gets changed with the change in moisture content of the aggregate has been made use of. In some sophisticated batching plant, electrical meters are used to find out the moisture content and also to regulate the quantity of water tobe added to the continuous mixer.

4. Automatic Measurement

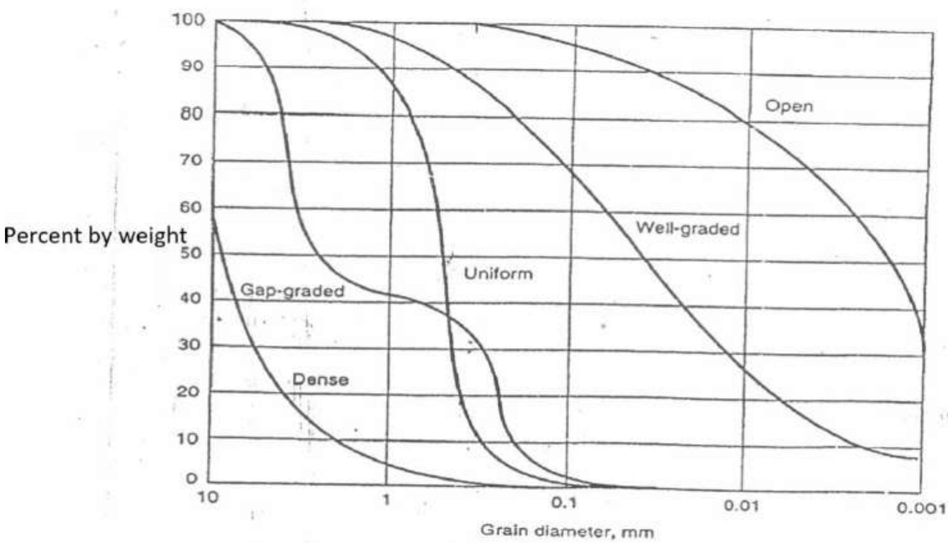
In modem batching plants surface moisture in aggregates is automatically recorded by means of some kind of sensor arrangement. The arrangement is made in such a way that the quantity of free water going with aggregate is automatically recorded and simultaneously that much quantity of water is reduced. This sophisticated method results in an accuracy of ± 0.2 to 0.6%.

4.SOUNDNESS OF AGGREGATE:

Soundness refers to the ability of aggregate to resist excessive changes in volume as a result of changes in physical conditions. These physical conditions that affect the soundness of aggregate are the freezing the thawing, variation in temperature, alternate wetting and drying under normal conditions and wetting and drying in salt water. Aggregates which are porous, weak and containingany undesirable extraneous matters undergo excessive volume change when subjected to the above conditions. Aggregates which undergo more than the specified amount of volume change is said to be unsound aggregates. If concrete is liable to be exposed to the action of frost, the coarse and fine aggregate which are going to be used should be subjected to soundness test.

5. GRADING OF AGGREGATE:

Sieve designation	Nominal size of sieve opening
3"	75 mm
1.5"	37.5 mm
3/4"	19 mm
3/8"	9.5 mm
No. 4	4.75 mm
No. 8	2.36 mm
No. 16	1.18 mm
No.30	600 μm.
No.50	300 μm.
No.100	150 μm.
No.200	75 μm.



Five Types of Gradation

1. Aggregate comprises about 55 per cent of the volume of mortar and about 85 per cent volume of mass concrete. Mortar contains aggregate of size of 4.75 mm and concrete contains aggregate up to a maximum size of 150 mm.
2. Thus it is not surprising that the way particles of aggregate fit together in the mix, as influenced by the gradation, shape, and surface texture, has an important effect on the workability and finishing characteristic of fresh concrete, consequently on the properties of hardened concrete.
3. Volumes have been written on the effects of the aggregate grading on the properties of concrete and many so called "ideal" grading curves have been proposed.
4. It is well known that the strength of concrete is dependent upon water/cement ratio provided the concrete is workable.

5. Good grading implies that a sample of aggregates contains all standard fractions of aggregate in required proportion such that the sample contains minimum voids.

6. A sample of the well graded aggregate containing minimum voids will require minimum paste to fill up the voids in the aggregates. Minimum paste mean less quantity of cement andless quantity of water, which will further mean increased economy, higher strength, lower-shrinkage and greater durability.

7. The advantages due to good grading of aggregates can also be viewed from another angle. If concrete is viewed as a two phase material, paste phase and aggregate phase, it is the paste phase which is vulnerable to all ills of concrete.

8. Paste is weaker than average aggregate in normal concrete with rare exceptions when very soft aggregates are used.

9. The paste is more permeable than many of the mineral aggregates. It is the paste that is-susceptible to deterioration by the attack of aggressive chemicals. In short, it is the paste which is a weak link in a mass of concrete. The lesser the quantity of such weak material, the better will be the concrete.

10. This objective can be achieved by having well graded aggregates. Hence the Importance of good grading.

11. One of the practical methods of arriving at the practical grading by trial and error method is to mix aggregates of different size fractions in different percentages and to choose the one sample which gives maximum weight or minimum voids per unit volume, out of all the alternative samples. Fractions which are actually available in the field, or which could be made available in the field including that of the fine aggregate will be used in making samples.

5.1Gap-graded Aggregate:

The gap grading is defined as grading in which one or more intermediate size fractions are absent.

The term continuously graded is used to distinguish the conventional grading from gap-grading on a grading curve gap grading is represented by a horizontal line over the range of sizes omitted.

Some of the important features of gap-graded aggregate are:

1. For it given aggregate-cement ratio and water-cement ratio, the highest workability is obtained with lower sand content in case of gap-graded aggregate than when continuously graded aggregate is used.

2. In the More workable range of mixes, gap-graded aggregate show a greater tendency to segregation. Hence gap-grading is recommended mainly for mixes of relatively low workability that are to be compacted by vibration.

3. Gap graded aggregate does not affect Compressive ortensile strengths.

The following advantages are claimed for gap graded concrete:

1. Sand required will be of the order of about 26 per cent as against about 40 per cent in the case of continuous grading.

2. Specific surface area of the gap graded aggregate will be low, because of high percentage of C.A. and low percentage of F.A.

3. Requires less cement and lower water/cement ratio.

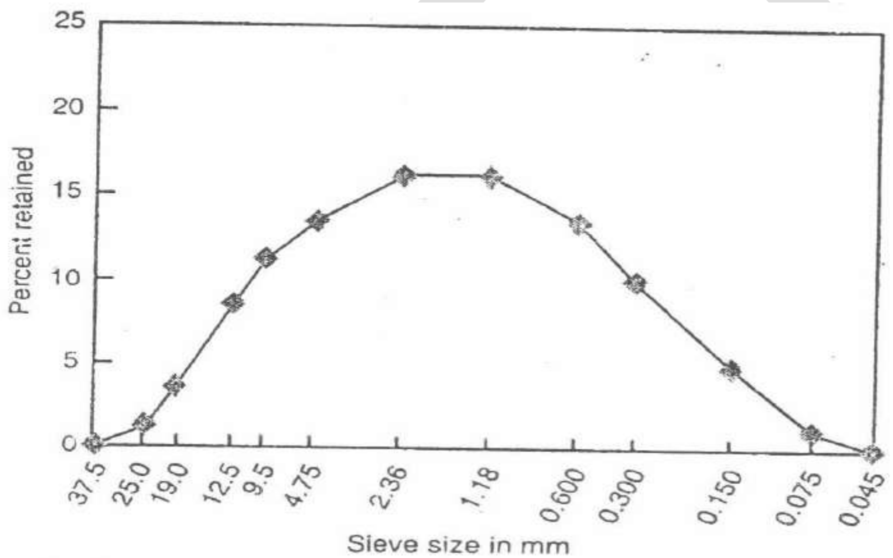
4. Because of point contact between C.A. to C.A. and also on account of lower cement and matrix content, the drying shrinkage is reduced.

5.2 Combined Aggregate Grading

1. Aggregate is sometimes analyzed using the combined grading of fine and coarse aggregate together, as they exist in a concrete mixture.
2. This provides a more thorough analysis of how the aggregates will perform in concrete. Sometimes mid-sized aggregate, around the 9.5 mm (3/8 in.) size, is lacking in an aggregate supply, resulting in a concrete with high shrinkage properties, high water demand, poor workability, poor pump ability, and poor place ability. Strength and durability may also be affected.
3. Fig. illustrates an ideal gradation; however, a perfect gradation does not exist in the field—but we can try to approach it. If problems develop due to a poor gradation, alternative aggregates, blending, or special screening of existing aggregates, should be considered.

4. The combined gradation can be used to better control workability, pumpability, shrinkage, and other properties of concrete.

5. With constant cement content and constant consistency, there is an optimum for every combination of aggregates that will produce the most effective water to cement ratio and highest strength.



Optimum combined aggregate grading for concrete.

6. DELETARIOUS SUBSTANCE IN AGGREGATE:

The deleterious substances found in the aggregate can be divided in to three broad categories:

1. **Impurities** which interfere with the process of hydration of cements.
2. **Coatings** which prevent the development of good bond between aggregate and the cement paste.
3. **Unsound particles** are weak or develop chemical reaction between the aggregate and cement paste.

1. **Impurities**

- The impurities in the form of organic matter interfere with the chemical reactions of hydration.
- These impurities generally consisting of decayed. vegetable matter and appear in the form of humus or organic loam.
- These are more likely to be present in sand than in coarse aggregate which is easily washed.
- The effect impurities is tested as per IS :2386- 1963

2. Coatings

- The clay and other fine material like silt and crusher dust may be present in the form of surface coatings which interfere the bond between aggregate and the cement paste.

- Since the good bond is essential to ensure a satisfactory strength and durability of concrete, the problem of coating of impurities is an important one.
- The soft or loosely adherent coatings can be removed by washing.
- The well bonded chemically stable coatings have harmful effect that the shrinkage may be increased.
- However, aggregate with chemically reactive coatings can lead to serious trouble.
- The silt and the fine dust if present in excessive amounts increases the amount of water required to wet all particles in the mix.

3. Unsound particles

- The sand obtained from seashore or from a river estuary (usually) contains salt, and sometimes the percentage may be as high as 6 percent of mass of sand.
- The salt can be removed from the sand by washing it with fresh water before use.
- If salt is not removed, it absorbs moisture from air and may cause efflorescence and slight corrosion of reinforcement may also occur.

- The total amount of deleterious materials shall not exceed 5 percent as per IS 383-1976. The limits of deleterious materials given material.

Limits of deleterious materials

Deleterious substances	Fine aggregate		Coarse aggregate	
	uncrushed	crushed	uncrushed	crashed
Coal and lignite	1.0	1.0	1.0	1.0
Clay lumps	1.0	1.0	1.0	1.0
Soft fragments	-	-	3.0	-
Material passing 75-tun IS sieve	3.0	3.0	3.0	3.0
Shale	1.0	-	-	-

7. SIEVE ANALYSIS (Fineness modulus):

1. This is the name given to the operation of dividing a sample of aggregate into various fractions each consisting of particles of the same size.
2. The sieve analysis is conducted to determine the particle size distribution in a sample of aggregate, which we call gradation.

3. A convenient system of expressing the gradation of aggregate is one which the consecutive sieve openings are constantly doubled, such as 10 mm, 20 mm, 40 nun etc.
4. Under such a system, employing a logarithmic scale, lines can be spaced at equal intervals to represent the successive sizes.

Apparatus:

Indian standard test sieves: line wire cloth Nos. 2.36 mm, 1.18 mm, 600 pm, 300 pm, 150 pm, and square hole perforated plates 80 mm. 40 mm, 20 mm, I0 mm and 4.75 mm (refer to IS z 460-1978 and Table 24.2 for equivalent sieves), weighing balance (sensitive to 1/1000th of the test sample): sieve shaker, trays, rice plates, drying oven (to operate between 100 to 110°C).

Procedure:

a. Coarse aggregate

1. Take 10 kg of coarse aggregate of nominal size 20 mm from a sample of 50 kg by quartering.
2. Carry out sieving by hand.. Shake each sieve in order i.e., 80 mm, 40 mm, 20 mm, 10 mm, 4.75 mm over a clean dry tray for •a period of not less than 2minutes. 'Die shaking is done with a varied motion z backwards and forwards, left to right, circular- clockwise and anticlockwise and with frequent jarring, no that the material is kept moving over the sieve surface in frequently changing directions.
3. Find the mass of aggregate retained on each sieve taken in order.

b. Fine-Aggregate

1. Take 1 kg of sand from a laboratory sample of 10 kg by quartering and break clay lumps, if any, in a clean dry rice plate.
2. Arrange the sieves in order of IS sieve nos. 4.75 mm, 2.36 mm. 1.18 mm, 600 pm, 300 ttm and 150 pm keeping sieve nos. 4.75 mm at the top and 1501.1m at the bottom. Fix them in the sieve shaking machine with the pan at the bottom and cover at the top.]
3. Keep the sand in the top sieve. Carry out the sieving in the set of sieves as arranged before for not less than 10 minutes.
4. Find mass retained on each sieve.

All in Aggregate

1. Take 10 kg of all in-aggregate from a sample or prepare it from aggregates taken in proportion of 2: 5 by mass (16 kg 1 40 kg) by quartering.
2. Carry out preliminary separation of coarse and fine aggregates by sieving the all-in-aggregate on 10 mm sieve by hand and find out the masses.
3. Carry out the sieving of coarse and fine aggregates as described in a. and b, respectively. The line portion may be reduced in bulk by quartering (IS: 383-1970).

4. Plot the grading curves for a, b and c showing percentage mass passing through the test sieves and calculates the fineness modulus. The following limits may be taken as guidelines.The following limits may be taken as guidelines.

1) Fine sand : 2.2 – 2.6
2) Medium sand : 2.6 – 2.9
3) Coarse sand : 2.9 – 3.2

} Fineness Modulus

8. SPECIFIC GRAVITY OF COARSE AGGREGATE:

Scope

For design of concrete mix, information should be available about the specific gravity of the aggregates. Specific gravity of an aggregate gives valuable information on its quality and properties. If the specific gravity is above or below that normally assigned to a particular type of aggregate, it may indicate Eat shape ltd grading of aggregate has altered.

It is also important in determination of moisture content and in many concrete mix design calculations. It also required for the calculations of volume yield of concrete.

Average S.G of a rock or aggregate sample may vary from 2.6 to 2.8.

Apparatus

Balance of capacity of 5 kg or more (sensitive 0.5 gm), weight box, and wire basket 200 mm in diameter200 mm height of 4.75 mm IS sieve net, water tub immersing the wire basket in water, suitable cement for suspending the wire basket from cement rule pan of balance and absorbent cloth for surface drying of the sample.

Procedure

1. Take about 5 kg of aggregate by method of quartering , rejecting all material passing a 10 mm I S Sieve
2. Wash thoroughly to remove dust etc. from surface of particles. Dry to constant mass at a temperature of 105.±5°C.

Note: Where the aggregate is used in moist condition it is not necessary to dry it to constant mass.

3. Immerse the sample in water at 22 to 32°C period of (24.5) hours (30 minutes for laboratory practice).
4. Remove the aggregate from water and roll e in a large piece of an absorbent cloth until all visible films of water are removed, although the surface of particles will still appear to be damp.
5. Now, weigh 3 kg of this sample in the saturated surface dry condition and note down the mass as W, gm.

6. Place the weighed aggregate immediately in the wire basket and dip it in water. Weight this basket with aggregate, while keeping it in water, with the help of the balance. Note (its mass as W3 gm.)
7. Dry the sample to the constant weight at the temperature of 100 to 110°C for 24 hours.
8. Cool to room temperature and weigh.
9. Calculate the specific gravity and absorption of the aggregate.
10. Repeat the procedure for fresh aggregate.

$$Bulk\ \ Specific\,Gravity = \frac{Mass\ of\ \ Sample\ in\ air}{Loss\ in\ mass\ of\ \ sample\ in\ water} = \frac{W_1}{W_1 - (W_3 - W_2)}$$

W_1= Mass of saturated surface dry

W_2 = Mass of basket in water.

W_3 = Mass of basket sample in water.

9. FLAKINESS AND ELONGATION INDEX:

Theory

An aggregate having least dimension less than 3/5th its mean dimension is termed as flaky. Mean dimension is the average of the sieve sizes on which the particles pass and the sieve size on these are retained. On the other hand the particles g the largest dimensions (length) greater than 9/5 the mean size is termed as elongated.

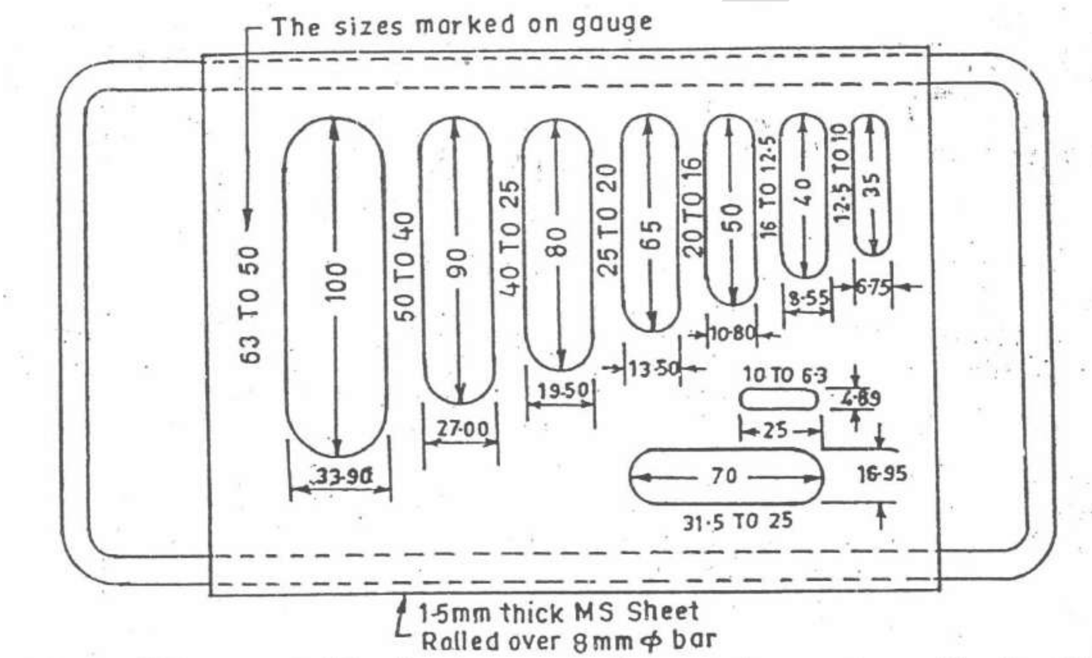
The presence of excess of flaky and elongated particles in concrete aggregate decreases the workability appreciably for a given water-cement ratio, requiring larger amounts of sand, cement and water. The flaky and elongated particles tend to orient in plane and cause laminations which adversely the durability of the concrete. The percentage of flaky and elongated particles should be limited to 10% to15%

Apparatus

Balance a set of 10 sieves ranging from 63mm IS sieve to 6.3mm Is sieve; thickness gauge and length shown in Figs.

Procedure

1. Flakiness Index of the coarse Aggregate



1. Take a sufficient quantity W_1, of coarse aggregate by quartering so as to provide at least 200 pieces of any fraction.

2. Carry out sieving by hand. Shake each sieve Order:63mm, 50mm, 40mm, 31.5mm, 25mm,20mm, l6mm, 12.5mm, 10mm and 6.3mm, over a clean dry tray for a period not less than 2 minutes. The shaking is done with a varied motion: backward and forward, left to right, circular, clockwise and clockwise and with frequent jarring, so that the trial is kept moving over the sieve surface in frequently changing directions.

3.Pass the separated aggregate fractions as retained on the sieves in step 2 through the corresponding slots in the thickness gauge shown in Fig e.g., the material passing through 50-mm sieve and retained on 40mm sieve is passed through.Determine the mass of aggregate passing though each of the slots.

4 Find the total mass W3 of the materials passing through the slots of the thickness gauge.

5. Calculate the flakiness index as defined.

The flakiness index is an empirical factor expressing the total material passing through the slots of the thickness gauge as the percentage of the mass of sample taken for testing.

(d) Flakiness, index of coarse aggregate

Mass of aggregate, W_1 = …..gm.

[**flakiness index of CA = (W_2/W_1) x 100)**

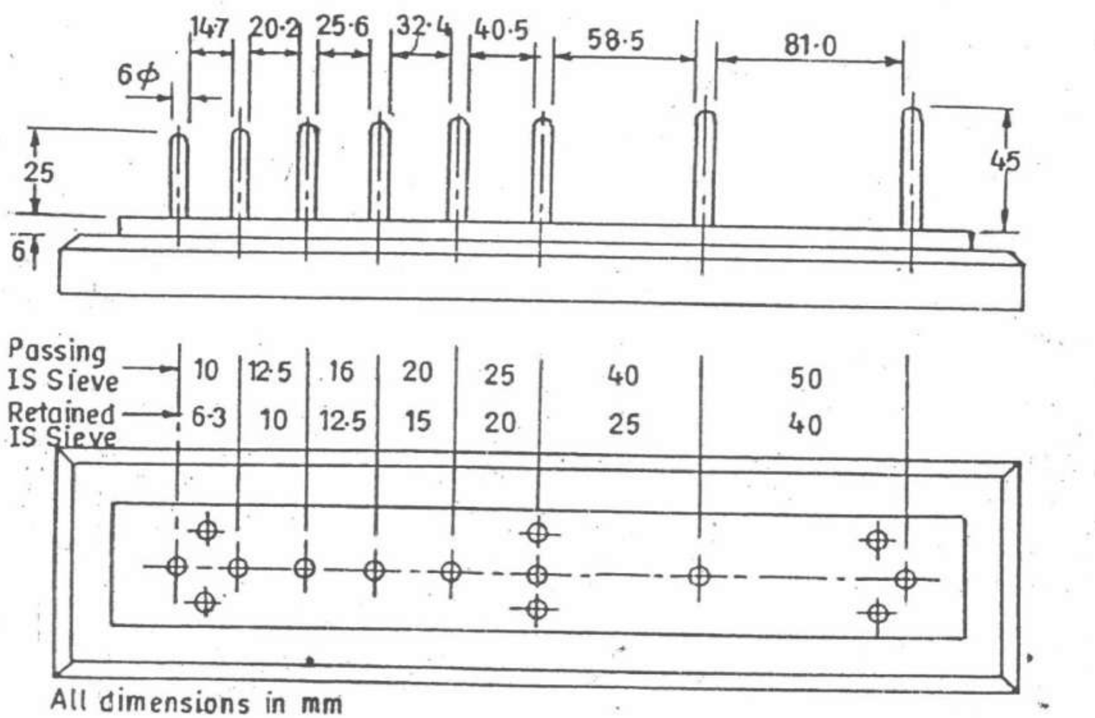
Sl. No.	Size of Aggregate			Mass of aggregate passing through the slot, gm
	Passing through IS : sieve, mm	Retained on IS : sieve, mm	Thickness gauge size, mm	
1.	63	50	33.90	
2.	50	40	27.00	
3.	40	31.5	19.50	
4.	32.5	25	16.95	
5.	25	20	13.50	
6.	20	16	10.80	
7.	16	12.5	8.55	
8.	12.5	10	6.75	
9.	10	6.3	4.89	
			$\Sigma W = W_2$	

Elongation index of coarse aggregate:

1. Take a sufficient quantity W3 of coarse aggregate by quartering so as to provide at least 200 pieces of any fraction.
2. Carry out sieving by hand. Shake each sieve in order: 63mm, 50mm, 40mm, 31.5mm, 25mm, 20mm, 16mm, and 12.5mm. l0mm, and 6.3mm. (IS: 2386, Part 1-1963) as explained in the part (a) so that the material is kept moving over the sieve surface in frequently changing directions;

3. Pass the separated aggregate fractions as retained on the sieves in step 2 through the' corresponding length gauge size shown Fig. e.g., the material passing through 50mm sieve and retained on 40mm sieve is passed through

- **Elongation index of coarse aggregate:**



The length gauge.

4. A particle of length which cannot pass through the corresponding gauge size is taken as retained by the length gauge. Determine the mass of aggregate retained on each of the length gauge sizes.

5. Find the total mass W4 of the material retained on the length gauges.

6. Determine the elongation index as percentage material retained by the length gauges of the total material taken for testing.

(b) Elongation index of aggregate

Mass of aggregate, W_3 = ...gm.

Sl. No.	Size of Aggregate			Mass of aggregate retained on the length gauge, gm
	Passing through IS : sieve, mm	Retained on IS : sieve, mm	Length gauge size, mm	
1.	63	50	—	
2.	50	40	81.0	
3.	40	31.5	58.5	
4.	31.5	25	—	
5.	25	20	40.5	
6.	20	16	32.4	
7.	16	12.5	25.6	
8.	12.5	10	20.2	
9.	10	6.3	14.7	
			$\Sigma W = W_4$	

Elongation index = $\frac{W_4}{W_3} \times 100$ = ... per cent.

10. IMPACT TEST VALUE OF AN AGGREGATE:

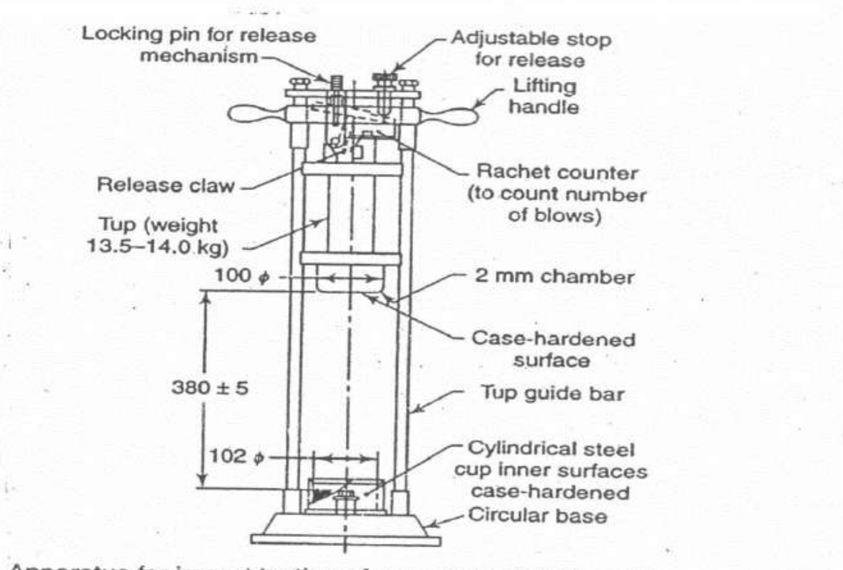
Scope

This test may be considered as an alternative to the aggregate crushing test. The special apparatus needed for aggregate impact test is simple and relatively cheap and is portable while the crushing test requires a 40-50 tones testing machine, which is expensive.

The impact test on an aggregate is a useful guide to its behavior when subjected to wear but other characteristics such as toughness and brittleness must also be taken in to account. The test does not necessitate (require) the cutting and shaping of special test pieces.

Equipment

Impact testing machine; rifle box (sample splitter) ; electric oven ; standard rammer ; 12.5mm; l0mm and 2.36mm are sieves; shovel; pans and a measure of standard dimensions.



Apparatus for impact testing of aggregates (all dimensions are in mm)

Description of Apparatus

a) Impact Testing Machine

It consists of a heavy metal base supporting two heavy vertical metal columns (called guides).Within these two guides a hammer weighing 14 kg with a cylindrical lower end of 100 nun diameter is arranged to slide and fall under its own weight. The hammer falls on to tire aggregate placed in a cylindrical steel cup of 105 mm internal diameter and 50 mm deep which is fixed concentrically with the hammer. The fall of the hammer is 375 ± 5 mm and it should be fitted with an automatic mechanism for raising and releasing it. It should also have a catch to hold it in its upper position while fixing and tilling the cup. A device for automatically counting the number of blows should be provided.

b) Riffle Box

It is a stationary sample divider. It divides the sample in two parts. As shown in Fig. It consists of a number of sloping narrow chutes discharging alliteratively on opposite sides where the split aggregate is collected in boxes placed under the chutes. The sample to be spitted is poured evenly over the top hopper and the sample is received by the two boxes (or pans) at the bottom. The chutes of riffle should have a steepest possible slope so that the material may get rapid flow. The distance between two chutes should be three times the size of the particles.

Procedure

1. Obtain the aggregate sample from the bin or stock pile in, such a way as to represent the whole aggregate. This can be done by riffle box or-by quartering. The sample must be poured evenly over the top of the box, and the aggregate is collected in the boxes at the bottom. Now reject one half of the sample and the other half are again poured, trial process is repeated until the desired quantity of the sample is obtained.

1. Dry the aggregate sample for 4 hours in an oven at a temperature of 100-110°C.
2. Obtain about 350 gm of aggregate of size passing through 12.5mm IS Sieve and retained on 10mm IS Sieve and measure by levelling and striking off level a measure 75mm in diameter and 50 mm in height in three equal layers and giving each layer 25 strokes with standard rammer.
3. Weigh (A) and pour the aggregate in the cylinder of the impact testing machine, level the surface and give twenty-five strokes with standard rammer,
4. Release the falling hammer and repeat the procedure until 15 blows are given to the aggregate at 2 seconds interval.
5. Remove the sample from the cylinder and subject it to sieving on 2.36mm IS sieve.
6. Weigh the sample passing through 2.36mm IS sieve and expresses this as the percentage of the total mass of tile aggregate.
7. Perform three tests and average of the three is taken (B).
8. Hence aggregate impact value = (B/A) x 100.

11. ABRASION TEST USING LOS-ANGELES MACHINE:

Scope

Abrasion testing of aggregate is of more direct application to the testing of stone aggregate for wearing. It has been found that the aggregate which shows a low loss in this test will generally be hard, tough; resistant to abrasion and strong which are the desirable and necessary qualities for durability of concrete.

Equipment '

Los-Angeles abrasion testing machine, IS Sieve.

a. **Los-Angeles abrasion testing machine**

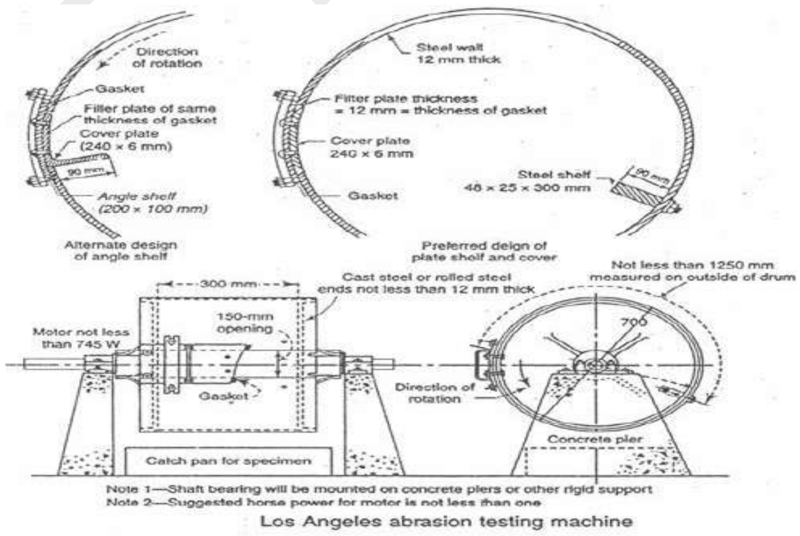
The Los-Angeles Abrasion Testing Machine It shall conform in all its essential characteristics to the design specifications laid down by AASHO designation T: 96-51 and IS : 383-1970. The Los-Angeles, machine consists of cylindrical drum of 710 mm inside diameter mm internal length, mounted longitudinal horizontal shaft. The horizontal axle is so arranged that it does not pass right through the drum. The provided with a firm, rigid 88mm shelf project the circumference of the cylinder, running 1 to end on the inside. The standard speed of revolution is 30 to 33 rpm. For line grading the standard of revolutions is 500, but for coarser grading it the cover to the opening for inserting and the sample should be arranged so that it is flu inside of the drum.

b. <u>Sieves</u>

All the sieves specified for use in this method shall confirm to the standard specifications for sieves for testing purposes (laid down in AASHO Designation M-92 or IS: 383-1970).

c. <u>Abrasive Charge</u>

The abrasive charge shall consist of cast iron spheres approximately 47.5 mm in diameter and each weighing between 390gm and 445gm. (The cast iron sphere shall conform to the composition requirement laid down in AASHO DesignationT-31)



Loss-Angles abrasion Testing Machine

Procedure

1. Determine the charge.
2. Calculate mass from Table 29.1. The test sample shall consist of clean aggregate which has been dried in an oven at 105 to 110°C to a substantially constant mass and shall confirm to one of the in practice the grading or gratings used shall be those most nearly representing the aggregate furnished for the work.
3. Place the test sample and the abrasive charge in the Los-Angeles abrasion testing machine.
4. Rotate the cylinder at a speed of 30 to.33 rpm. For gratings and B, the machine shall be rotated for 500 revolutions and for grading E it shall be rotated for 1000 revolutions.
5. At the completion of the required revolutions, discharge the material carefully from the machine to a tray.
6. Make a preliminary separation of the sample on a sieve coarser than 4.75 mm sieve.
7. Sieve the liner portion on a 1.7 mm IS sieve.
8. The material retained on 1.7 mm IS sieve shall be washed, dried in an oven at 105-1 10°C to a substantially constant mass and accurately weighed to the nearest gram.
9. Determine the loss in mass (represented by the material passing the 1.7 mm IS Sieve) by difference and express it as a percentage of the original mass of sample.

12. BULKING OF FINE AGGREGATE: (Lab test)

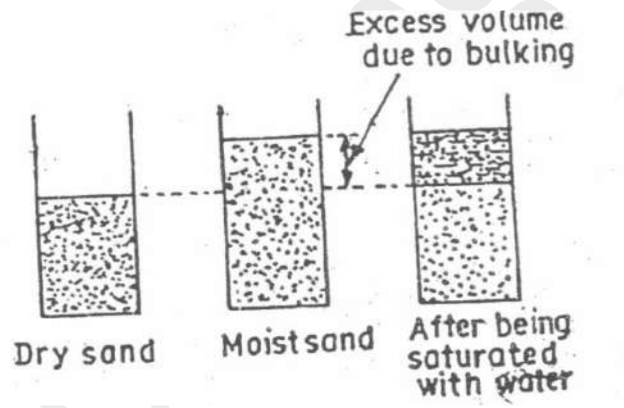
Theory and Scope

In concrete mix design, the quantity of line gate used in each batch should be related to the volume of cement. The difficulty with measurement of line aggregate by volume is the tendency of sand to vary in bulk according to moisture. The cement of this variation is given by this test.

If sand is measured by volume and no allowance for bulking, the mix will be richer than that red because for given mass, moist sand occupies considerably larger volume than the same mass of dry sand, as the particles are less closely packed when the sand is moist. If, as is usual, the sand is measured volume, it is necessary in such a case to the measured volume of the sand, in order that the amount of sand put into concrete may be the amount intended for the nominal mix used (based on the dry sand) the percentage bulking. .The correction to be is only a rough method at the best, but a corrosion of the right order can easily be determined and should be applied in order to keep the concrete.

Apparatus

Balance, cylindrical container, graduated cylinder, beaker, metal tray, steel rule and oven



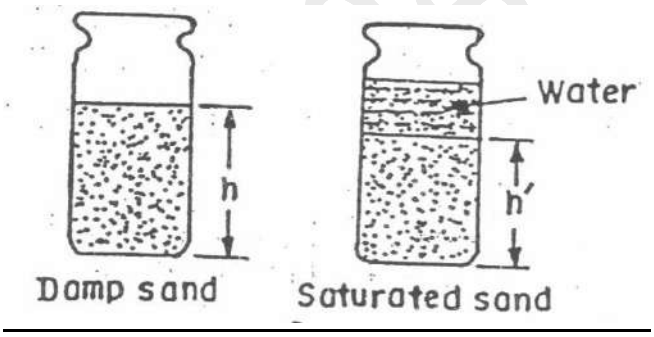
Bulking of Sand

Procedure (lab test)

1. Put sufficient quantity of the oven dry sand be necessary to increase the volume of loosely into the container until it is about two-third full. Level off the top of sand and weigh the container. , Calculate the mass of sand by deducting the mass of container.
2. Push a steel rule vertically down through the sand at the middle to the bottom and measure the height of sand. Let it be 'h' mm.

3. Empty the sand out into a clean metal tray without any loss.
4. Add one per cent of water by mass of sand. Mix the sand and water thoroughly, by hand.
5. Put the wet sand loosely into the container without tamping it.
6. Smooth and level the top surface of the moist sand and measure its depth at the middle with the steel rule. Let it be h' mm,
7. Repeat the steps 4 to 6 of the above procedure with 2 per cent of water by mass. Go on increasing the percentage by one till bulking is maximum and starts falling down and ultimately bulking is zero, i.e., saturated sand occupies the same volume as dry sand.

- **TO DETERMINE BULKING OF FINE AGGREGATE (FIELD TEST)**



Field method for determining bulking of sand

Procedure

1. Fill the container to about two-third full with given sand loosely.
2. Level off the top of sand and measure the height by pushing a steel rule vertically down through the sand at the middle to the bottom, let it be h mm.
3. Take the sand out into a clean metal tray without any loss.
4. Fill the container with water to half full.

5. Pour the sand back into the container and stir it with a steel rod 6 mm in diameter so that volume May reduce to a minimum.
6. Smooth and level the top surface of the inundated sand and measure its depth at the middle with the steel rule. Let it is h' mm.
7. Calculate percentage of bulking of sand due to moisture. Use the following formula.

13. **CRUSHING VALUE TEST:**

Aggregate crushing value gives a relative measure of the resistant of an aggregate sample to crushing under gradually applied compressive load.

This test is made as a single sized aggregate passing 12.5mm and retained on 10mm sieve. The aggregate is placed in a cylindrical mould and the load of 40tonne is applied through the plunger. The material crushed to fines than 2.36mm sieve is separated and expressed as a percentage of the original weight taken in the mould. This % is referred as aggregate is restricted to 30% for concrete used for roods & pavements and 45% may be permitted for others structures.

Crushing Value test on Aggregates:

1. Take about 6.5kg of material consisting of aggregate passing through 12.5mm sieve & retained on 10mm sieve. This indicates that aggregate size to be used are of uniform size.
2. This sample is taken in a cylinder and filled in such a way that, it is filled in 3 layers and each layer is tamped 25 times with the tamping rod.
3. Excess aggregate on the cylinder after filling completely are trimmed off.
4. Then weight of aggregate (A) is found out.
5. This assembly is tested under compressive testing machine and it is located to 40 tonnes in 10 minutes of time.
6. Then this load is released and sample is sieved on 2.36 mm sieve.

7. Let A be the initial weight and B be the weight of erushed aggregate passing 2.36mm sieve.
8. Hence aggregate crushing value = (B/A)x 100.

AGGREGATE ABRASION VALUE

Apart from testing aggregate for crushing and impact, another property which is called abrasion should be tested.

Abrasion means wear & tear of aggregates subjected to loading . Usually aggregates used in the concrete work for road construction, we see more wear & tea, because of vehicle movement. This abrasion can be tested by following test.

1. Deval Attrition Test

2. Dorry Abrasion Test

3. Los Angles Test

Following theory is used in these tests. A sample of aggregate is taken in a rotating cylinder in which these aggregates during the rotation get abrasion (wear and tear) and a powder of aggregate is formed .

This powder of aggregate is weighed and expressed as % w.r.t original weight. This value is called **Abrasion value or Attrition value**.

1. DEVAL ATTRITION TEST:

In the deval attrition test, particles of know weight are subjected to wear in an iron cylinder rotated 10000 times at certain speed.

The proportion of material crushed finer than 1.7mm sieve size is expressed as a % of original material is taken. This % is taken as the **attrition value of the aggregate.**

2. DORRY ABRASION TEST:-

This test involves in subjecting a cylindrical specimen of 25cm height and 25cm diameter to the abrasion against rotating metal disc sprinkled with quartz sand.

The loss in weight of the cylinder after 1000 revolution of the table is determined.

The hardness of the rock sample is expressed in an empherical formula

$$Hardness = 20 - \frac{loss\ in\ grams}{3}$$

Good rock should show an abrasion value of **not less than 17**. A rock sample with a value of less than 14 would be considered poor.

2. LOS ANGLE TEST:-

Los Angle Test is characterized by the quickness with which a sample of aggregate may be tested.

The test involves taking specified quantity of standard size material along with specified number of abrasive charge in a standard cylinder and revolving it for certain specified revolution (20-33rev/min).The particle smaller than 107mm size is separated out.

The loss in weight expressed as % of the original weight taken gives the abrasion value of the aggregate.

The abrasion value should not be more than 30%for wearing surfaces and not more than 45% for concrete other than wearing surface.

- **CLEANLINESS:-**

Concrete aggregates should be free from impurities and deleterious substances which are lightly to interfere with the bond between the aggregates and cement. This leads to reduction in the durability.

Generally the fine aggregates obtained from natural source is slightly to contain organic impurities and silt, clay etc. The manufactured aggregate will not contain these silt impurities but they may contain excess dust. Hence aggregates used for concrete work should be made free from soil, silt and other objectionable particles.

The fine aggregates from shore line will generally contain some % of salts; hence these also can be treated as deleterious material present in the aggregates. The contamination of aggregates by salt will affect the setting property and the strength of concrete.

- **Organic impurities Test:-**

To ascertain whether a sample of fine aggregates contain permissible amount of deleterious material, a simple test called colorimetric test is used.

The sample of sand is mixed with a liquid containing 3% solution of NaOH in water. It is kept for 24 hours and colour developed is compared with standard colour card.

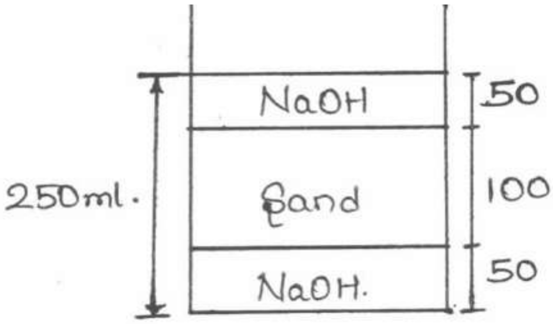
If the colour is darker than that seen in the colour card then the given sample of aggregate is said to contain impurities.

- **PERCENTAGE OF CLAY & SILT: (SEDIMENTATION METHOD):**

Procedure:-

1. Take 250 ml jars; 50mm is filled with NaOH solution. Then 100mm sand is added to the same jar.
2. Again add 50ml of NaOH solution leave it for 3 hours.

3. After 3 hours clay and silt will form a layer above sand layer. If it is greater than 6% then the sand has to be washed.



Bulk Density (lab test)

Following procedure is adopted in the lab to determine the bulk density of aggregates.

1. Take weight of the empty container (W_1).The size of the container for fine aggregates 15cm diameter & 17cm height of nominal capacity 3 litres and for the coarse aggregates 25cm inner diameter and inside height 30cm of nominal capacity 15 litres.
2. Fill the container with the aggregates care should be taken for aggregates should not be compacted in any manner (by tamping or mechanical vibrator).
3. Weight of filled container of the aggregates can be measured (W_2).
4. The cylindrical measure is filled about 1/3rd of each time 25 stokes by a tamping rod.(16mm dia and 60cm long). The measure is carefully struck off level using tamping rod as a straight edge.
5. The net weight of the aggregate in the measure is determined and the bulk density is calculated in kg/litre (W_3).
6. **For loose state :-**

$$\text{Bulk density} = \frac{\text{Net weight of the aggregate } (W_2 - W_1)}{\text{Volume of the container } (\pi r^2 h)}$$

$$\%\text{ of Voids} = \frac{G_S - \gamma_{looser}}{G_S}$$ Gs-Specific gravity of aggregates

For Compacted state:-

$$\text{Bulk density} = \frac{\text{Net weight of the aggregate } (W_2 - W_1)}{\text{Volume of the container } (\pi r^2 h)}$$

$$\%\text{ of Voids} = \frac{G_S - \gamma_{Compacted}}{G_S}$$

Gs-Specific gravity of aggregates

TESTING OF CEMENT

❖ FIELD TESTING

The following are the field tests on cement:

1. The colour of the cement should be uniform. It should be grey color with a light greenish shade.
2. The cement should be free from any hard lumps. Such lumps are formed by the absorption of moisture from the atmosphere. Any bag of cement containing such lumps should be rejected.
3. The cement should feel smooth when touched or rubbed in between fingers. If it is felt rough, it indicates adulteration with sand.
4. If hand is inserted in a bag of cement or heap of cement, it should feel cool and not warm.
5. If a small quantity of cement is thrown in a bucket of water, the particles should float for some time before it sinks.

6. A thick paste of cement with water is made on a piece of glass plate and it is kept under water for 24 hours. It should set and not crack.
7. Take about 100 gram of cement and small quantity water and make a stiff paste pat a cake with sharp edges. Put on a glass plate and slowly take it under water in bucket. See that the shape of cake is not disturbed while taking it down to bottom of the bucket. After 24 hours the cake should be retain its original shape and at the same time it should also set& attain original strength
8. A block of cement 25 mm x25 mm and 200 mm long is prepared and it is immersed for 7 days in water. It is then placed on supports 15cm apart and it is' loaded with a weight of about 34 kg. The block should not show signs of failure.
9. The briquettes of a lean mortar (1:6) are made. The size of briquette may be about 75 mm X25 mm x12 mm. They are immersed in water for a period' of 3 days after drying. If cement is of sound quality such briquettes will not be broken easily.

LAB TESTS

1. FINENESS TEST:

The fineness of the cement is measure of the size of particles of cement and is expressed in terms of specific of cement. It can be calculated from the particle size distribution or determined by one of the air permeability methods. The rate of hydration and development of strength depends upon the fineness of cement. To have some same rate of hardening in different brands of cement, the fineness has been standardized. The finer cement has quicker action with water and gains early strength though its ultimate strength remains unaffected. However the shrinkage and cracking of cement will increase with fineness of cement.

Fineness of cement is tested in TWO ways

a) By Sieving (sieve test)

b) By determining the specific surface by AIR —PERMEABILITY Apparatus

a) By Sieving though a 90 – micron Is sieve.

Theory and Scope

The degree of fineness of cement is a measure of the mean size of the grains in cement. The rate of hydration and hydrolysis, and consequent development of strength in cement mortar depends upon the fineness of cement. To have same rate of hardening in different brands of cement, the fineness has been standardized. The finer cement has quicker action with water and gains early strength though its ultimate strength remains unaffected. However, the shrinkage and cracking of cement will increase with the fineness of cement.

As all sieves are not exactly alike and there may be difference in performing tests, the specifications provide that a correction factor shall be obtained by sieving cement standardized by Bureau of Indian Standards in the manner hereafter provided for testing the cement. The difference between the percentage residue on the sieve and that assigned to the standard sample, is the amount of correction and shall be added or subtracted as necessary.

Apparatus

90 micron IS Sieve, rice plate, weighing balance (sensitive to 0. I pm),bristle brush (25 or 40 mm brush with 250 mm handle)

Procedure

1. Weigh accurately 100 gm of cement in it plate and transfer it to a clean dry IS test sieve and break down any air set lumps.

2. While holding the sieve and pan in both hands, sieve with gentle wrist motion until most of the line material has passed through and the residue looks fairly clean. This usually requires three to four minutes.

3. Place the cover on the sieve and remove the pan. With sieve and cover held firmly in one hand, the other side of the sieve is tapped with the handle of the brush which is used for cleaning the sieve. Sweap clean the underside of the sieve.

4. The sieving is continued as described above For 15 minutes. Rotating the sieve continuously throughout the sieving operation, involving no danger of spilling the cement;

5. Empty the pan and wipe it clean with a cloth, Replace the sieve in the pan and remove the cove carefully. Return any coarse material that had been caught in the cover during tapping the sieve.

6. The sieving is continued as described above For 15 minutes. Rotating the sieve continuously throughout the sieving operation, involving no danger of spilling the cement;

7. Weigh the residue (x).

8. % of fineness=(x/100)*100= x% <10%

b) <u>Blaine's AIR PERMEABILITY TEST:</u>

<u>Apparatus</u>

<u>Theory and Scope</u>

The degree of fineness of cement is a measure of the mean size of the grains in the cement. The rare of hydration and hydrolysis and consequent development of strength depends upon the Fineness of cement. To have the same rate of hardening in different brands of cement, the fineness has been standardized. The finer cement has quicker action with water and gains early strength though its ultimate strength remains unaffected. However, the shrinkage and' cranking of cement will increase with fineness of cement.

Apparatus

1. Consisting of a permeability cell. **2.** Perforated disc **3**. Plunger **4.**filter paper, **5.**Manometer **6.**Weight box **7.**Analytical balance **8**. Stop watch **9**. Mercury**10.** Crucible

The Blaine's variable flow air permeability apparatus shown in Fig

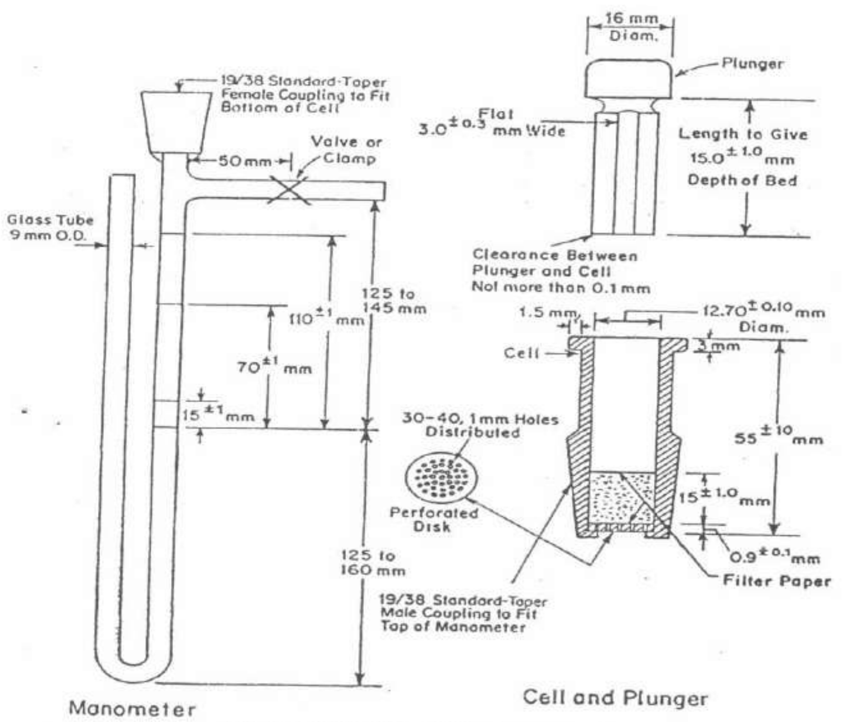
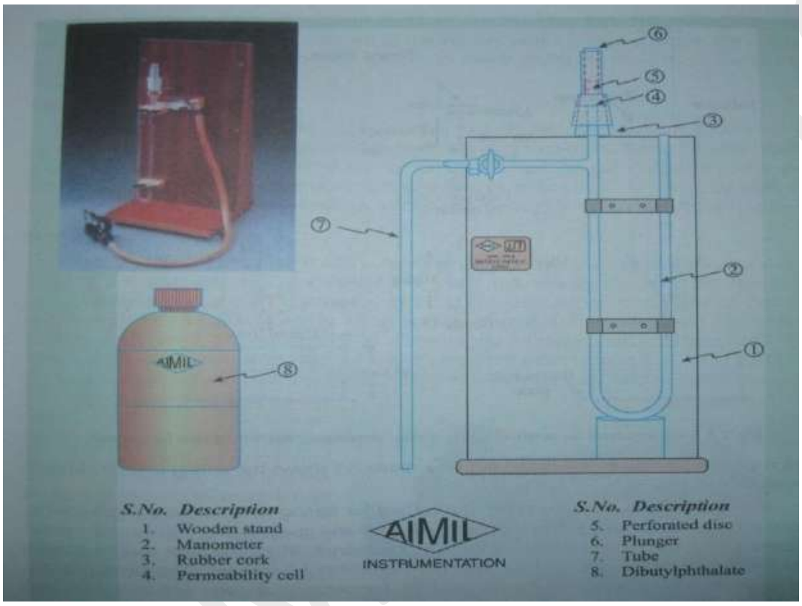


FIG. 1 Blaine Air-Permeability Apparatus

- The Blaine air permeability apparatus is essentially a means of drawing a definite quantity of air through a prepared bed of cement of definite porosity. The number and size of pores in a prepared lied of cement of definite porosity is a imitation of the particles and determines the rate of air flow though the bed.



Procedure

a) Calibration of the Blaine Apparatus

1. Calculate the bulk volume of the compacted bed of cement v by the following formula: $V = (WA - W_B) / \rho$

Where W_A= mass of the mercury required to fill the permeability cell,

W_B = mass of the mercury to fill the portion of the cell not occupied by the bed of cement formed by 2.8 gm of the standard cement sample.

P= density of mercury

2. Determine the mass of sample required to produce a bed having porosity of 0.500 (= e) as follows :ω=3.15v (1-e)

3. Evacuate the air until the fluid moves above the upper line without pulling it over the top of the side outlet. Close the valve and note the time T, taken by manometer liquid to fall from second mark (from top) to the third mark on the manometer when the air is allowed to pernetreate though the compacted bed of standard cement sample. Note the air temperature.

b) Specific- Surface Determination

4. Weigh an amount of cement sample equal to that determined in step 2, in the calibration.

5. Place the perforated disc in the permeability cell, and then add a filter paper, followed by the sample and another filter paper. Compress the specimen with plunger and couple the permeability cell with the manometer.

6. Evacuate the air until the fluid moves above the upper line without pulling it over the top of side tube. Close the valve of manometer and note the time T it takes for the fluid to drop from the second mark to the third mark on the manometer when the air is allowed to permeate through the compacted bed of cement obtained in step 5. Note the air temperature.

7. Calculate the specific surface S in square centimetres per gram of the tested cement by using the following formula, if the temperature at calibration on and at the time of test are within ±3 per cent of each other :

$$S = \frac{S_S \sqrt{T}}{\sqrt{T_S}}$$

Where S, = specific surface of standard cement used in calibration in cm^2/gm,

T_s= measured time in seconds required for the fluid to fall the middle interval for standard sample. And

T = measured time in seconds required for the fluid to drop over the middle interval

8. Compare the test values with the specified values of the cement sample used.

3. STANDARD CONSISTENCY AND SETTING TIME TEST

Theory and Scope

A) StandardConsistency

The object of conducting this test is to find out the amount of water to be added to the cement to get a paste of normal consistency, i.e., the paste of a certain standard solidity, which is used to fix the quantity of water to be mixed in cement before performing tests for setting time, soundness and compressive strength.

b) Setting Time

In order that the concrete may be placed in position conveniently, it is necessary that the initial setting time of cement is not too quick and after it has been laid, hardening should be rapid so that the Structure can be made use of as early as possible. The initial set is a stage in the process of hardening after which any crack that may appear will not re-unite. The concrete is said to be finally set when it has obtained sufficient strength and hardness. Therefore certain limits for initial and final setting times have to be specified.

Apparatus

1.Vicat apparatus with Vicat plunger **2**.Vicat needles **3.**Vicat mould, gauging trowel,**4**. Measuring jar (100 to 200 ml capacity) **3**. Weighing balance (accuracy 0.05 per cent of. **w) 4**. Stop watch, rice plates, -weight box, rubber gloves/ and glass plates.

Note :

Normal consistency of the cement is also defined "as that consistency which will permit Vicat plunger having 10mm dia and 50mm length to penetrate to a depth of 33-35mm from top of the mould in apparatus" that apparatus is **Vicat Apparatus.**

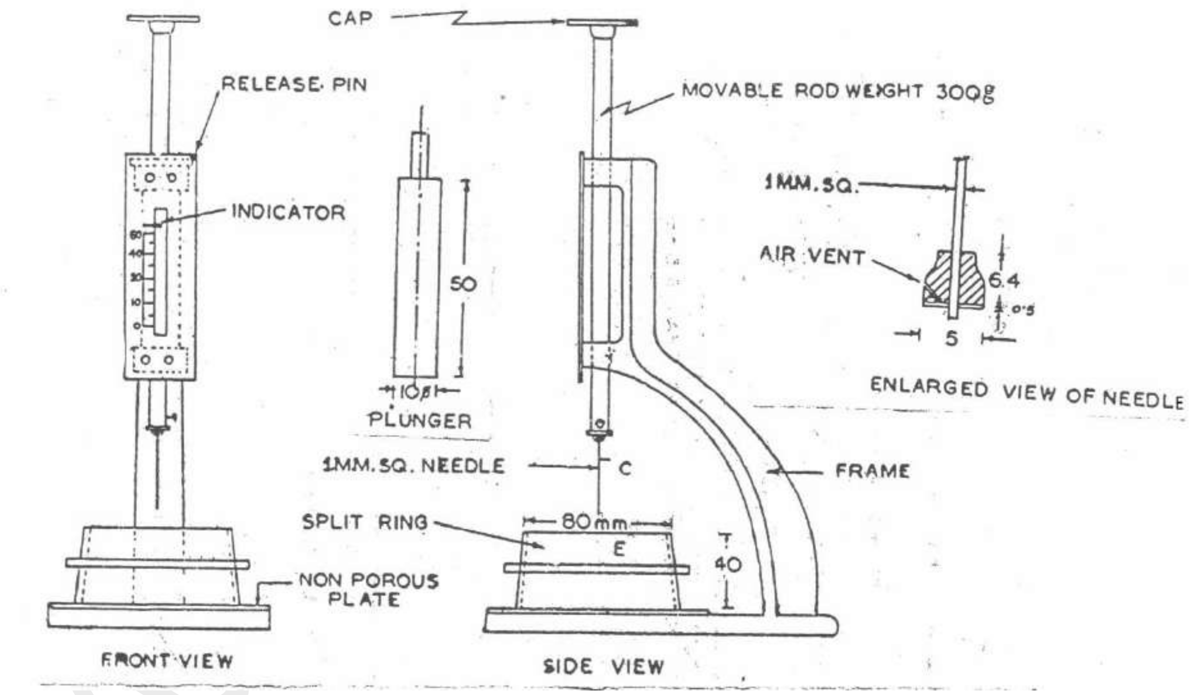


Fig: Vicat Apparatus for Standard Consistency, Initial Setting time, Final setting Time

Procedure

Standard Consistency'/ Normal consistency:

1. For preparing one mould take 400 gm of cement passing 850-micron IS Sieve and prepare a paste of cement with a weighed quantity of water (100 ml) taking care that the time of gauging is between 3 to 5 minutes. The gauging time is counted from the time ofadding water to the dry cement until commencing to till the mould.

2. Fill the Vicat mould resting upon non-porous plate with this paste. After completely filling the mould, smooth off the surface of the paste by single movement of l palm making it level with the top of the mould. The mould maybe slightly shaken to expel air.

3. Place the test block in mould with the non- porous resting place under the rod attached with the plunger A. Lower the plunger gently to touch the Surface of the test block and release it quickly, allowing I to sink into the paste. Take reading of penetration from apparatus.

4. Prepare the trial pastes with varying percentage of water (firstly at an interval of 4%. That of 24%, 28% and 32% and then at an interval of 1% to 0.25% between the percentage range determined the previous test) and test as described above until amount of water necessary for the standard consistency as defined is obtained.

b) Setting Times of Cement

5. Prepare a neat cement paste by gauging the cement with 0.85 P water, where P = standard consistency as found before. The gauging time is again kept between 3 to 5 minutes. Start the stop watch at its instant when the water is added to the cement.

6. Fill the Vicat mould and smooth off the surface of the paste making it level with the top of the mould. The cement block thus prepared is known as block.

7. For the determination of initial setting time, place the test block confined in the mould and resting it non-porous plates under the rod attached with the needle B, lower the needle gently in contact with the surface of the test block and release quickly. Allowing it to penetrate into the test block.

8. Repeat this procedure until the needle fails to pierce the block for about 5 mm measured from the bottom of the mould. The period elapsed between the time when water is added to the cement and the time at which the needle fails to pierce the test block by about 5 mm is the initial setting time. "According to IS **specification it should not be less than 30 min.**

9. For the determination of final setting time replace the needle B of the Vicat apparatus by the needle with an annular attachment C. The cement is considered finally set when. Upon applying the needle C gently to the surface of the test block, the needle makes an impression thereon. While thee attachment fails to do so. In the event of scum forming on the surface of the test block. Use theunderside of the block for the determination of final setting time. **According to IS specification it should not be more than 10 hours or 600min.**

10. Draw a graph between percentages of water and Penetration of vicat needle (mm)

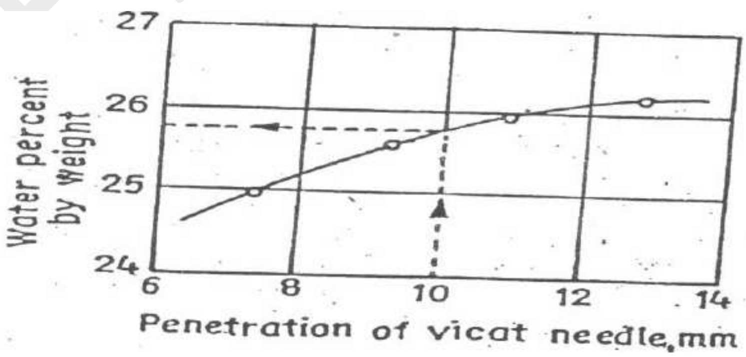


Fig: A typical graph for determining the normal consistency of cement

4. SOUNDNESS TEST

To determine soundness of given cement and lime samples by :

(1) LE-CHATELIER method.

(2) Autoclave Test

Theory:

Excess of free lime and magnesia 'present in cement slake very slowly and cause appreciable change in volume alter setting. In consequence cracks, distortion and disintegration results, thereby giving passage to water and atmospheric gases which may have injurious effect on concrete and reinforcement. This defect is known as unsoundness. The expansion is prevented by limiting the quantities of free lime and magnesia in cement. The test is designed to accelerate this slaking process by application of heat and to measure the extent of expansion and to see if This expansion is less than the specified limit. Indirectly, this test gives the extent of free lime and magnesia present in cement.

- **Le -Chatelier method.**

  Apparatus:

Le - Chatelier' apparatus, two glass plates, temperature controlled water-bath, scale china dish to mix the paste,counter balance, weight box, graduated cylinder, trowel and 850 micron IS sieve.

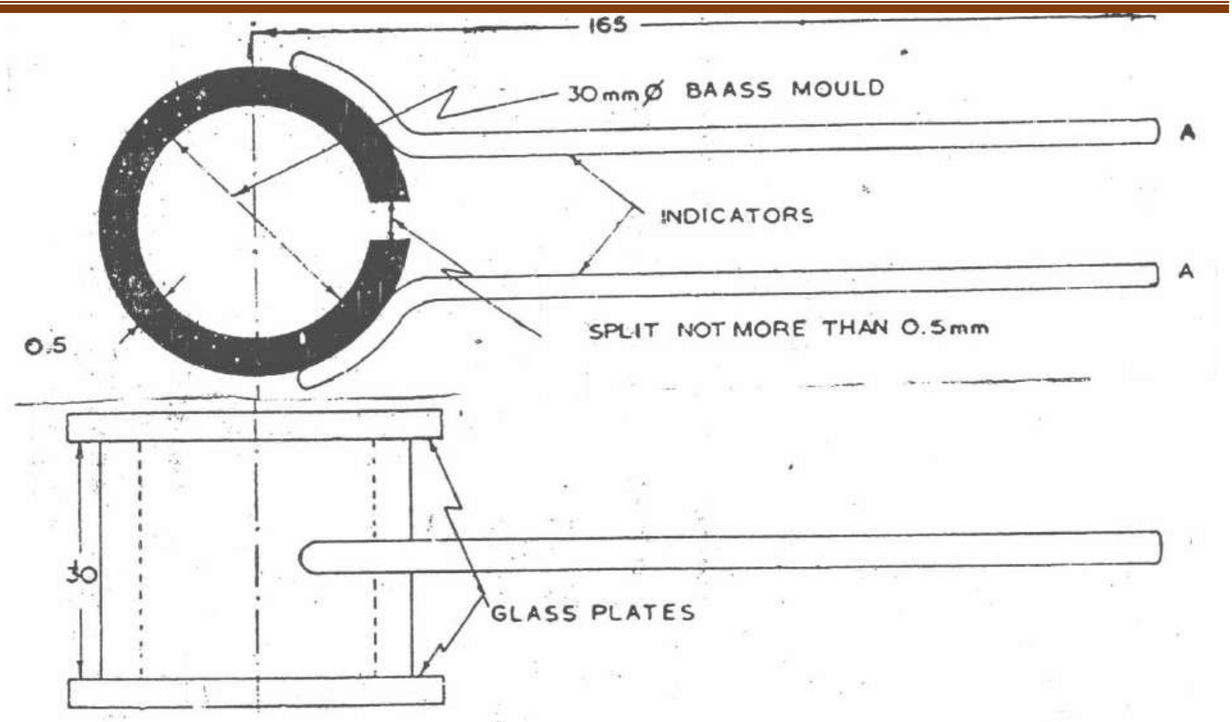


Fig: Le-Chatelier Apparatus

a) To determine the soundness of cement

1. Gauge 100 gmof cement with 0.78 times the water required to make a paste of standard consistency (approximately 30 per cent)
2. Place the Le-Chatelier apparatus on a glass plate and fill it with the paste, and level the top surface.
3. Cover the mould with another piece of glass sheet. Place a small weight on this covering glass-sheet and immediately submerge the whole assembly in water at a temperature of 29 +-2°C and keep there for 24 hours
4. Measure the distance D_I between the indicator points after 2.4 hours and again submerge the mould in water at the temperature prescribed above.
5. Bring the water to boiling point in 25 to 30 minutes and keep it boiling for 3 hours.

6. Remove the mould from the water, allow it to cool and measure the distance D2 between indicator points. F The difference (D2.— D_1) between' .the two measurements gives the expansion- of cement and it should not be more than 10 mm according to IS specifications (IS : 269-1976).
7. Le – Chatelier's test does not reveal soundness caused due to magnesium & calcium sulphate i.eLe-Chatelier's test is suitable for cement which contains excess lime.
8. As per IS recommendation if cement is suspicious of having magnesium i.e% of magnesia present is more than 3% in the cement, then 'Auto – clave method' should be used for testing.

'Auto– Clavemethod'

1. Soundness by auto – clave test which is sensitive to both free magnesia and free lime.
2. In this test a neat cement specimen 25x25mm is placed in a standard auto clave and the steam pressure inside the autoclave is raised in such a way as a bring the gauge pressure of the steam to 21kg / cm2 in 1-11/4 hous from the time the heat is turned on.This pressure is maintained for 3 hours .
3. The auto clave is cooled and the length measured again. The high steam pressure accelerates the hydration of both of magnesia & line.

The autoclave % should not be more than 0.8% No satisfactory test is available for deduction of unsoundness due to an excess of Caso4 but its content can be easily determined by chemical Analysis.

5. COMPRESSION STRENGTH TEST OF CEMENT

Procedure

1. Calculate the material required. The material for each cube shall be mixed separately and the quantities of cement and standard sand shall be as follows:

Cement = 200 gm

Standard sand = 600 gm

Water = (p/4+ 3.0) per cent = 84 gm

Where P is percentage of water for standard consistency

2. Place the mixture of cement and standard sand in the proportions of 1: 3 by mass on a nonporous plate or china dish and mix it dry with a trowel for one minute and then with water until the mixture is of uniform color. The percentage of water to be used shall be (p/4 + 3.0). The time of mixing (gauging) in any event shall not be less than 3 minutes and if the time taken to obtain a uniform color exceeds 4 minutes, the mixture shall be rejected and the operation is repeated with a fresh quantity of cement, sand and water.

3. Place the assembled mould on the table of the vibrating machine and firmly hold it in position by means of suitable clamps. Securely attach the hopper at the top of the mould to facilitatefilling and this hopper shall not be removed until completion of the vibration period.

4. Immediately after mixing the mortar as explained above, fill the entire quantity of mortar in the hopper of the cube mould and compact by vibration. The period of vibration shall be 2 minutes at the specified speed of 12000±400 cycles per minute.

5. Remove the mould from the machine and keep it at a temperature of 27 ±2°C in an atmosphere of at least 90 per cent relative humidity for 24 hours after completion of vibrations.

6. At the end of this period, remove the cu from the mould and immediately submerge it in clean and fresh water and keep there until taken out just prior to breaking. The water in which the cubes a submerged shall be renewed after every 7 days and be maintained at a temperature of 27±2°C. Keep till cubes wet till they are placed in machine for testing.

7. Test the specimens at- the required periods Test three cubes at the periods mentioned below, the periods being reckoned from the completion of vibration. The compressive strength shall be the average of the strengths of the three cubes for each period.

a)Ordinary Portland cement: 3 and 7 days&28 days.

b) Rapid hardening Portland cement: 1and 3days.

QUALITY OF MIXING OF WATER:

Water is the most important and least expensive ingredient of concrete. The functions of the water are as follows

- Water reacts chemically with cement to form the binding material in which the inert aggregates are held in suspension until the matrix *has* hardened.
- Water serves also as a vehicle or lubricant between the fine and coarse aggregates in order that the concrete may be made more readily peaceable in forms.

Generally the cement requires about 3/10 of its mass of water for hydration. Hence the minimum water-cement ratio required is 0.3. But the concrete containing water in this proportion will be very harsh\ and difficult to place. Additional water is required to lubricate the mix, which makes the concrete workable. This additional water must be kept to the minimum, since too much water reduces the strength of the concrete. The water-cement ratio is influenced by the grade of 'concrete, nature and type of aggregates, the workability and durability etc. If too much water is added in the concrete, the excess water along with the cement comes to the surface by capillary action and this cement water mixture forms a scum or thin layer of chalky material known as laitance. This laitanceprevents the bond between the successive layers of concrete and forms a plane of weakness. The excess water may also leak through the joints of the formwork and makes the concrete honeycombed.

***Quality of Mixing Water**

1. The requirement for water is, 'water used in mixing concrete should be clean and free from injurious amounts of oils, acids, alkalies, organic materials or other deleterious substances.
2. The presence of these impurities in the water may affect setting time of cement. Strength of concrete and may cause corrosion of the reinforcement. If the water is fit for drinking it is generally accepted as suitable for making concrete.
3. The suitability of doubtful water for making concrete can be determined by comparing the setting time of cement and the compressive strength of the mortar cubes using the water in question with those obtained by using good water.
4. A tolerance of about 10 per cent is usually allowed when comparing the results. The effluents from sewerage works, gas works and textile paint, textile. Sugar and fertilizer industry are harmful to the concrete.
5. The tests show that water containing excessive amounts of dissolved salts reduces compressive strength by 10 to 30 per cent of that obtained using fresh water. In addition the water containing large quantities of chlorides. E.g. Sea water tends to cause persistent dampness and surface efflorescence, Sea water increases the corrosion of the reinforcing steel.
6. The danger is more in tropical regions, particularly with lean mixes.
7. The water suitable for mixing is also suitable for curing the concrete and washing of aggregates. The final decision as to the source of water supply is governed by the quality of concrete required depending upon the importance of structure and the cost of securing good water.

Table: Tolerable concentrations of some Impurities in Mixing Water

Impurity	Tolerable Concentration.
Sodium and potassium carbonates and bi-carbonates.	1,000 ppm (total). If this is exceeded, it is advisable to make tests both for setting time and 28days strength
Chlorides	10,000ppm.
Sulphuric anhydride	3,000ppm.

Calcium chloride	2 per cent by weight of cement in non-pre-stressed concrete.
Sodium iodate,sodium sulphate,sodium	Very low
Arsenate, sodium borate sodium sulphide	Even 100ppm warrants testing
Sodium hydroxide	0.5 per cent by weight of cement provided quick set is not induced.
Salt and suspended particles	2,000 ppm. Mixing water with a high content of suspended solids should be allowed to stand in a settling basin before use.
Total dissolved slts	15,000ppm.
Organic material	3,000 ppm. Water containing humic acid or such organic acids may adversely affect the hardening of concrete; 780ppm.of humicacid are reported to have seriously impaired the strength of concrete. In the case of such waters there-fore further testing is necessary.
pH	Shall not be less than 6.

Review question:

1. What are the chemical compositions of cement? How the cement is manufactured give flow chart
2. What are the ingredients of cement concrete? Explain their functions?
3. Explain the terms normal consistency, initial setting and final setting time
4. Explain the important size, shape and texture of aggregate
5. What are the bouge's compounds in cement? Explain the role of each compound in strength gaining and hardening process
6. What are the physical requirements of good fine and coarse aggregate?
7. Define "grading of aggregates" what is the importance of grading of aggregates in the manufacture of quality concrete.
8. Discuss briefly the ingredients of Portland cements along with their functions?
9. What are bouge's compounds? Explain their role in setting and hardening process of cement?
10. Describe briefly fineness modulus of sand and how it is determined in the laboratory
11. List various tests conducted on coarse aggregate and explain any two of them
12. List the field tests conducted for cement?
13. List the various lab tests conducted on cement and explain any two of them
14. What are the constituents of cements and explain the role of constituents in controlling?
15. Define the terms (i) Standard Consistency (ii)Fineness (iii) Soundness Explain their significance
16. Distinguish between (i) False set and flash set cement (ii) Dry Process and wet process (iii) Hydraulic cements and nonhydraulic cements.
17. How do you classify aggregates? Describe the characteristics of aggregate influencing the behaviour of concrete?
18. Explain the significance of bulking of Fine aggregate and gap grading?

19. In a sieve analysis of 1000gms of sand, the weights(gms) retained on different IS sieves are 10mm=0, 4.75mm=20, 2.36=100, 1.18mm=100, 600Microns=190, 300Microns=350; 150Microns=170 and passing 150Microns =70. Determine the fineness modulus of sand
20. Explain the manufacturing process of OPC both by wet and dry process (Using flow chart only)
21. Explain any two tests on cement in detail
22. What are flakiness and elongation index? Explain their effects on properties of concrete.
23. Explain impact and abrasion tests on coarse aggregate
24. Write the chemical composition of cement. Write the flow chart of dry process
25. Name any four types of cement. State the properties and applications of any two types of cement