Module-1: Concrete Ingredients

Cement – Cement manufacturing process, steps to reduce carbon footprint, chemical composition and their importance, hydration of cement, types of cement testing of cement.
Fine aggregate: Functions, requirement, Alternatives to River sand, M-sand introduction and manufacturing.
Coarse aggregate: Importance of size, shape and texture. Grading and blending of aggregate.
Testing on aggregate, requirement. Recycled aggregates Water – qualities of water. Chemical admixtures – plasticizers, accelerators, retarders and air entraining agents. Mineral admixtures – Pozzolanic and cementitious materials, Fly ash, GGBS, silica fumes, Metakaolin and rice husk ash.

CEMENT

- Cement, any material that hardens and becomes strongly adhesive after application.
- Manufactured substance consisting of gypsum plaster, or Portland cement
- Portland cement hardens and adheres after being mixed with water.

HISTORY OF CEMENT:

- The term "Portland cement" was first used in 1824 by Joseph Aspdin, a British cement-maker, because of the resemblance between concrete made from his cement and Portland stone, which was commonly used in building in Britain.

- The first modern Portland cement, made from lime and clay materials heated until they formed clinkers was produced by Isaac Charles Johnson in Britain in 1845.

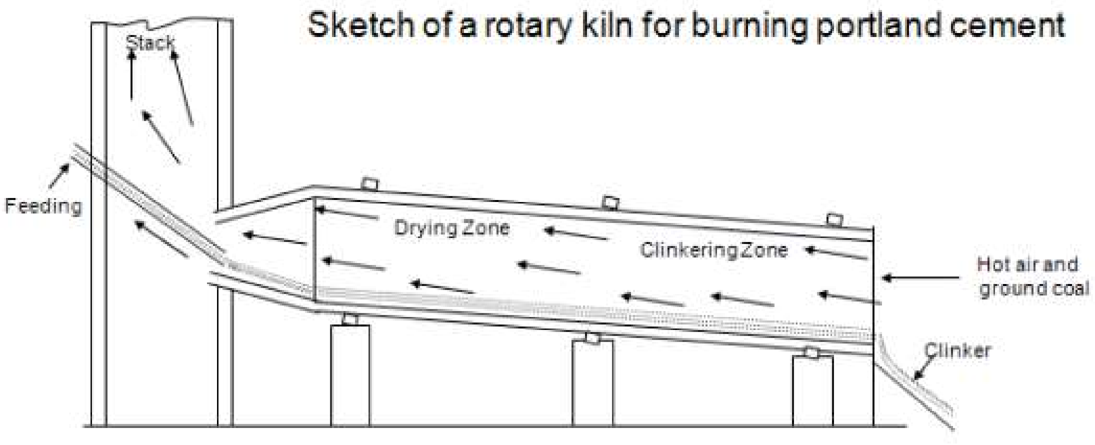
- At that time cements were usually made in upright kilns where the raw materials were spread between layers of coke, which was then burnt.
- The first rotary kilns were introduced about 1880. Portland cement is now almost universally used for structural concrete.

HOW IS IT MADE?

- Limestone for calcium and Clay or shale for Silica/Alumina is used as raw materials.
- The manufacturing process of Portland cement clinker consist essentially of grinding the raw materials, mixing them in appropriate proportion, burning the raw material in a kiln at a temperature of 1400-1500 $^{o}{}_{C}$ until material partially fuses into balls known as clinker and grinding to cooled clinker together with a small amount of gypsum rock. The mixture of raw material is burned in a rotary kiln

The Kiln:

- The heart of the cement plant of largest moving part of any machine o inclined, rotatesup to 50m long and 5m diam. Heated by fire jet.The rotary kiln is along steel cylinder lined with refractory brick (length/diameter ~30).Modern kilns may reach 6m in diameter and over 180m in height with a production capacity exceeding 1000 tons a day.



Sketch of a rotary kiln for burning portland cement

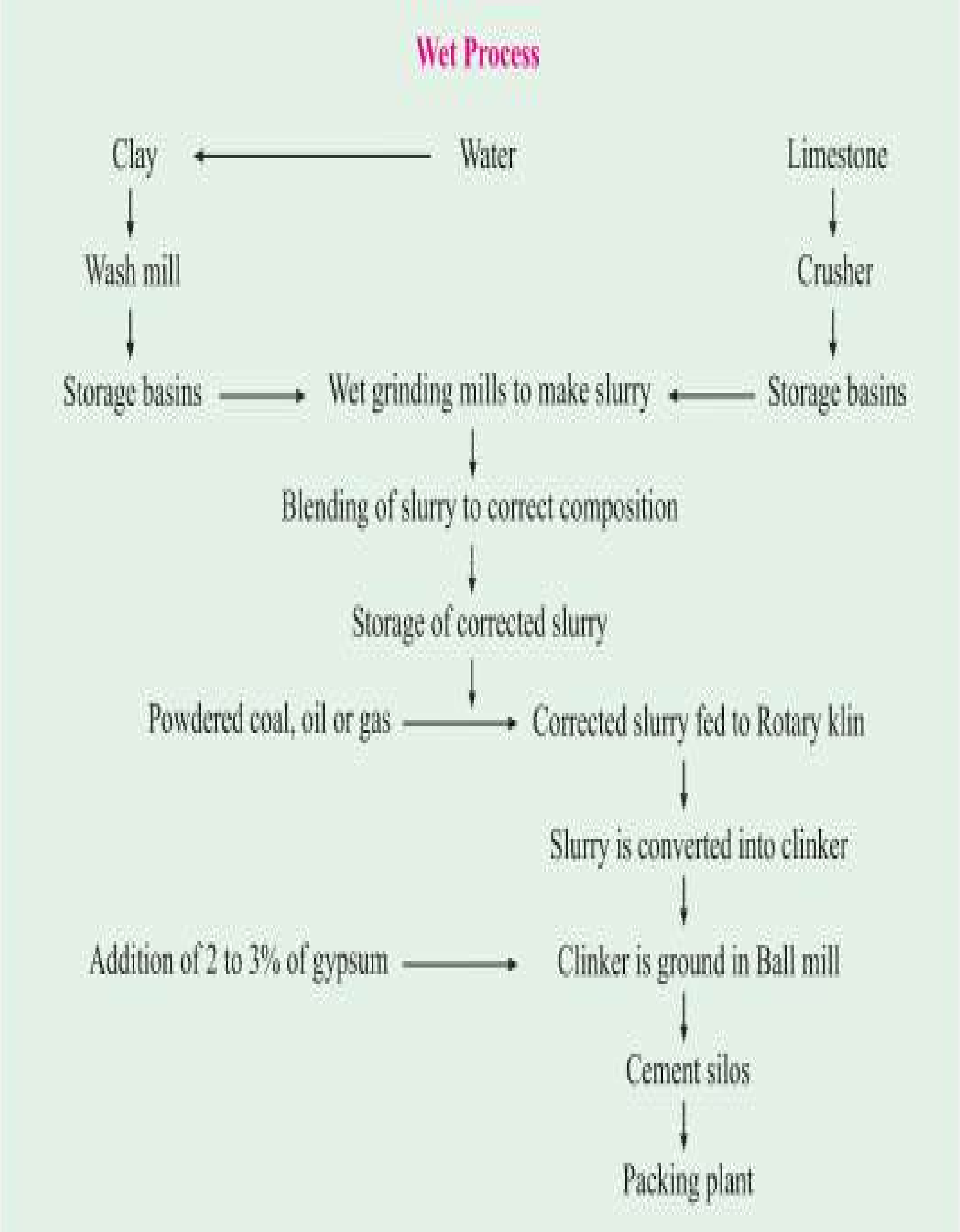
- The kiln is inclined a few degrees from the horizontal (about 4 cm\m) and is rotated about its axis at a speed of about 60 to 150 revolution \ hour).
- Pulverized coal or gas is used as the source of heat. The heat is supplied from the lower end of the kiln. The max. Temperature near the lower end of the kiln is generally about 1400-1500 OC.
- The upper end of the kiln the temperature is around 150 OC.
- The mixture of the raw material is fed from the upper end of the kiln. This material move toward the lower end by effect of inclination and rotation of the kiln. Thus the material is subjected to high temperature at lower end of the kiln.
- The materials that are introduced into the rotary kiln are subjected to several distinct process as they move downward.
- When the raw materials are fed into the kiln, drying of the material takes place, and any free water in the raw material is evaporated.
- Clay losses its water about 150 to 350 OC.
- Clay decomposes at a range of 350 to 650 OC.
- Magnetite in raw material loss about 600 OC.
- The limestone losses its CO2 at about 900 OC.
- At 1250 to 1280 OC some liquid formation begins and compound formation Start to takes place.
- Clinkering begins at about 1280 OC. The liquid that forms during the burning process causes the charge to agglomerate into nodules of various sizes, usually 1-25 mm in diameter known as Portland cement clinker.

All exhaust gases produced during the burning process of the materials leave the kiln through the stack.

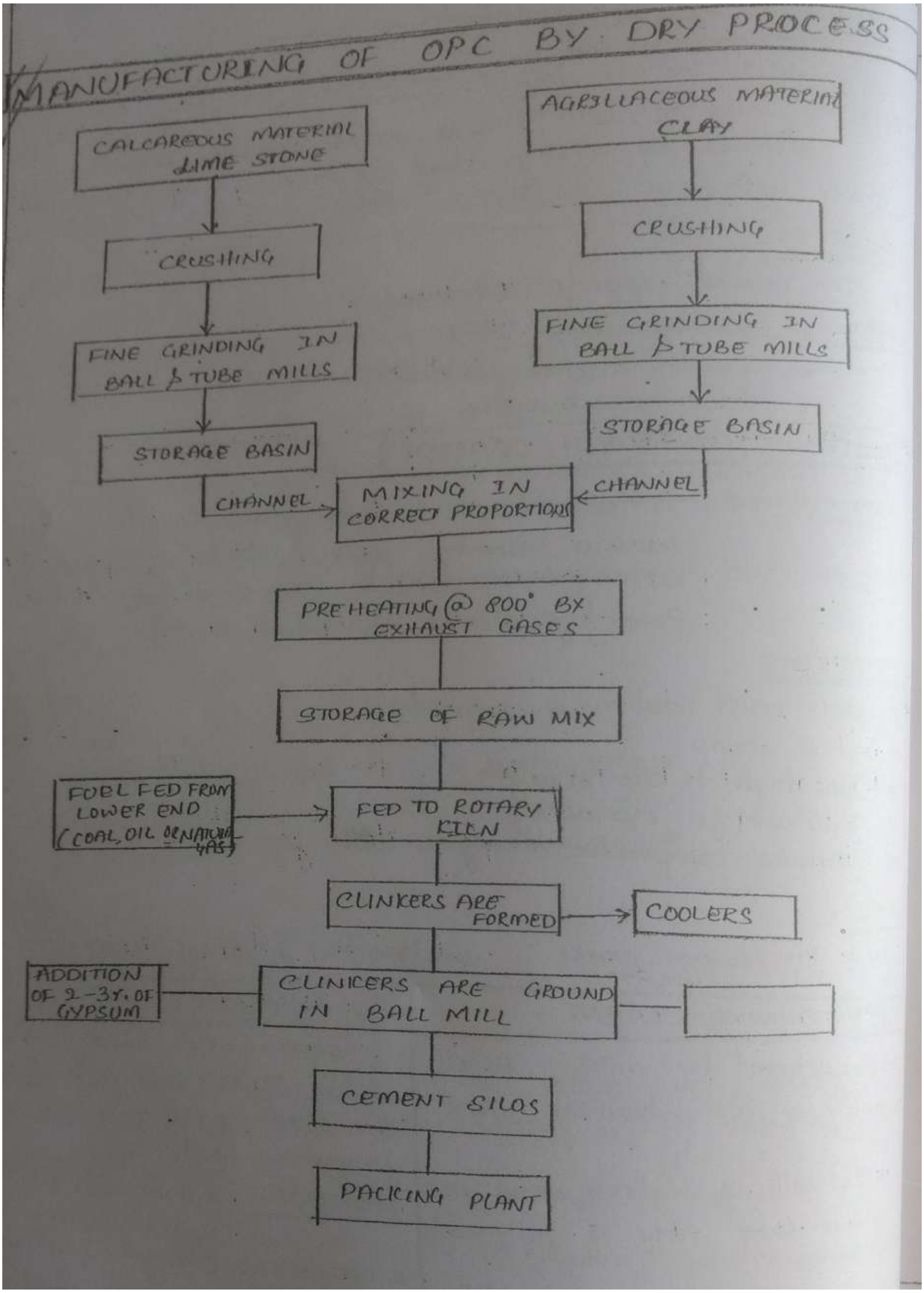
COOLING & GRINDING

- Rapid cool – glassyGrinding starts golf ball size. Ends about 2-80 microns, 300 m^2/kg. Grinding depends on application. Typical plant capacity is about: 1 MT/y
- Portland cement is manufactured by inter grinding the Portland cement clinker with some (3 to 6 %) gypsum rock.

CEMENT MANUFACTURING PROCESS



Dry Process


MANUFACTURING OF OPC BY DRY PROCESS
CALCAREOUS MATERIAL
LIME STONE
AGRILLACEOUS MATERIAL
CLAY
CRUSHING
CRUSHING
FINE GRINDING IN BALL & TUBE MILLS
FINE GRINDING IN BALL & TUBE MILLS
STORAGE BASIN
STORAGE BASIN
CHANNEL
CHANNEL
MIXING IN CORRECT PROPORTIONS
PREHEATING @ 800° BY EXHAUST GASES
STORAGE OF RAW MIX
FUEL FED FROM LOWER END (COAL, OIL OR NATURAL GAS)
FED TO ROTARY KILN
CLINKERS ARE FORMED
COOLERS
ADDITION OF 2-3% OF GYPSUM
CLINKERS ARE GROUND IN BALL MILL
CEMENT SILOS
PACKING PLANT

Steps to reduce carbon footprint

- **Increasing energy efficiency by optimizing processes and modernizing factories.**

  Introducing new cement plants using the best available technology or upgrading old plants.

- **Substituting fossil fuels with other energy sources.**

  Alternative fuels such as biomass, tires and industrial waste can be used to replace fossil fuels in cement kilns. This allows not only a reduction in the consumption of fossil fuels but also the safe disposal of waste that would otherwise be incinerated or land filled.

- **Using additives in cement to develop a large range of products according to their application.**

  Natural products such as pozzolan or industrial by-products such as fly ash (a by-product of coal-fired power stations) or slag (a by-product of the steel industry) can be used in the cement production process as cement additives. These decarbonated additives have hydraulic binding qualities and can be used to produce less carbon-intensive cements.

Chemical Composition

Oxide Composition of Portlant Cement

• Portland cement is composed of four major oxides: lime (CaO), silica (SiO_2), alumina (Al_2O_3), and iron (Fe_2O_3).
• Also Portland cement contains small amount of magnesia (MgO), alkalies (Na_2O and K_2O), and sulfiric anhydrite (SO_3).

Approximate Composition Limits of Oxides in Portland cement

Oxide	Common Name	Content, %
CaO	Lime	60-67
SiO_2	Silica	17-25
Al_2O_3	Alumina	3-8
Fe_2O_3	Iron	0,5-6
MgO	Magnesia	0,1-4
Na_2O and	Alkalies	0,2-1,3
K_2O	Sulfuric	1-3

Major Compounds of Portland Cement (Bogue's Compound Composition)

Name	Chemical formula	Abbreviation
• Tricalcium silicate	3CaO.SiO2	C3S
• Dicalcium silicate	2CaO.SiO2	C2S
• Tricalcium aluminate	3CaO.Al2O3	C3A
• Tetracalciumalumino	4CaO.Al2O3.	C4AF

Bogue's Compound Composition

- C3S=4.07(CaO)-7.6(SiO2)- 6.72(Al2O3)-1.43(Fe2O3) – 2.85(SO3)
- C2S= 2.87 (SiO2) - 0.75(3Cao. SiO2)
- C3A= 2.65(Al2O3) – 1.69 (Fe2O3)
- C4AF = 3.04 (Fe2O3)

Heat of Hydration

The heat of hydration is the heat generated when water and Portland cement react. Heat of hydration is most influenced by the proportion of C3S and C3A in the cement, but is also influenced by water-cement ratio, fineness and curing temperature. As each one of these factors is increased, heat of hydration increases.

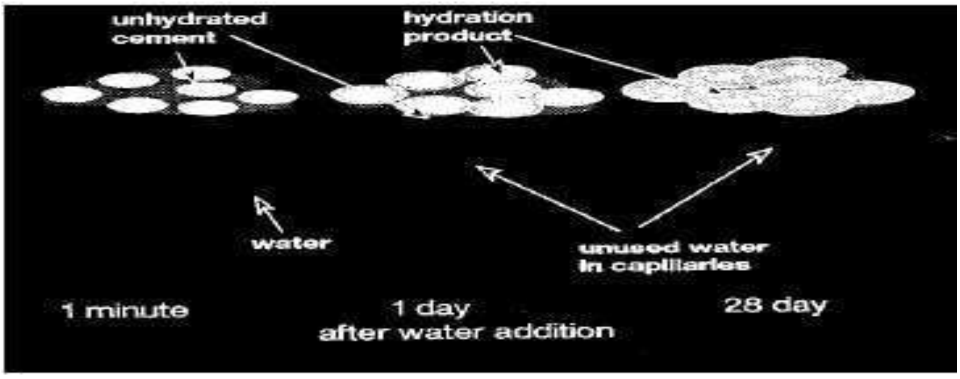
•For usual range of Portland cements, about one-half of the total heat is liberated between 1 and 3 days, about three-quarters in 7 days, and nearly 90 percent in 6 months.

- The heat of hydration depends on the chemical composition of cement.

Hydration

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

OPC hydration



- Hydration starts as soon as the cement and water are mixed.

- The rate of hydration and the heat liberated by the reaction of each compound is different.
- Each compound produces different products when it hydrates.
- Tricalcium silicate (C3S). Hydrates and hardens rapidly and is largely responsible for initial set and early strength. Portland cements with higher percentages of C3S will exhibit higher early strength.
- Tricalcium aluminate (C3A). 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 cement to set almost immediately after adding water.
- Dicalcium silicate (C2S). Hydrates and hardens slowly and is largely responsible for strength increases beyond one week.
- Tetracalcium aluminoferrite (C4AF). Hydrates rapidly but contributes very little to strength. Its use allows lower kiln temperatures in Portland cement manufacturing. Most Portland cement color effects are due to C4AF

Characteristics of Hydration of the Cement Compounds

Compounds	Reaction Rate	Amount Liberated	Strength	Heat Liberation
C3S	Moderate	Moderate	High	High
C2S	Slow	Low	high later	Low
C3A	Fast	Very high	Low	Very high
C4AF	Moderate	Moderate	Low	Moderate

Reactions of Hydration

- 2C3S + 6H = C3S2H3 + 3Ca(OH)2

(100 + 24 = 75 + 49)

- 2 C2S + 4H = C3S2H3 + Ca(OH)2

(100 + 21 = 99 + 22)

- C3A + 6H = C3AH6

[C3A + CaSO4. 2H2O = 3Cao. Al2O3. 3CaSO4. 31H2O] Calcium sulfoaluminate

Types of cement

(a) Ordinary Portland Cement
    (i) Ordinary Portland Cement 33 Grade– IS 269: 1989
    (ii) Ordinary Portland Cement 43 Grade– IS 8112: 1989
    (iii) Ordinary Portland Cement 53 Grade– IS 12269: 1987
(b) Rapid Hardening Cement
(c) Extra Rapid Hardening Cement
(d) Sulphate Resisting Cement
(e) Portland Slag Cement
(f) Quick Setting Cement
(g) Super Sulphated Cement
(h) Low Heat Cement
(j) Portland Pozzolana Cement
(k) Air Entraining Cement
(l) Coloured Cement: White Cement
(m) Hydrophobic Cement
(n) Masonry Cement
(o) Expansive Cement
(p) Oil Well Cement
(q) Rediset Cement
(r) Concrete Sleeper grade Cement
(s) High Alumina Cement
(t) Very High Strength Cement

Testing of cement

Testing of cement can be brought under two categories:

- Field testing
- Laboratory testing.

Field Testing

It is sufficient to subject the cement to field tests when it is used for minor works. The following are the field tests:

(a) Open the bag and take a good look at the cement. There should not be any visible lumps. The colour of the cement should normally be greenish grey.

(b) Thrust your hand into the cement bag. It must give you a cool feeling. There should not be any lump inside.

(c) Take a pinch of cement and feel-between the fingers. It should give a smooth and not a gritty feeling.

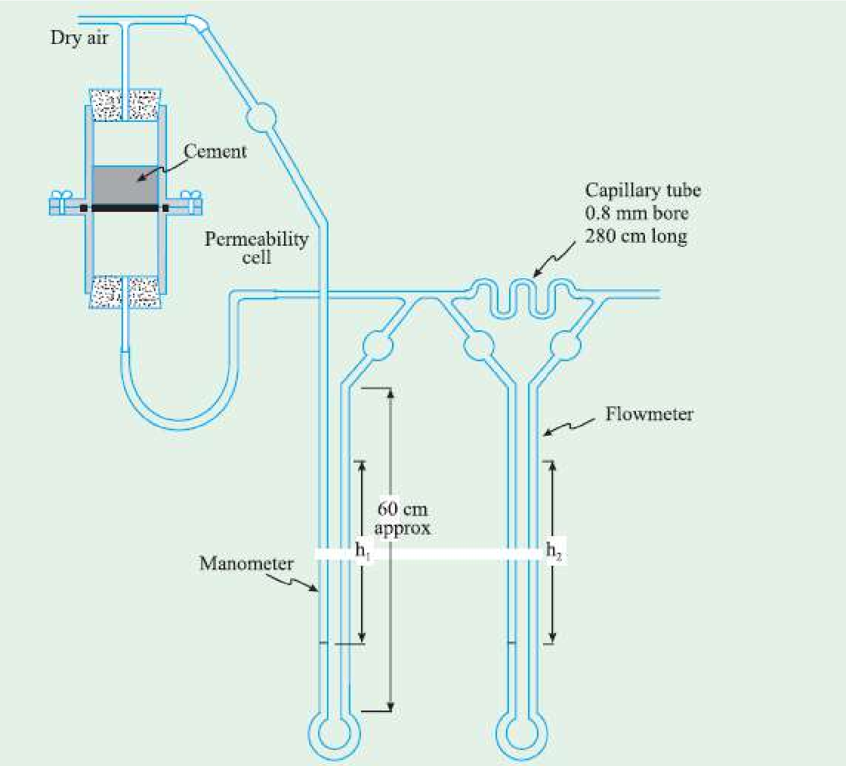
(d) Take a handful of cement and throw it on a bucket full of water, the particles should float for some time before they sink.

(e) Take about 100 grams of cement and a small quantity of water and make a stiff paste From the stiff paste, pat a cake with sharp edges. Put it on a glass plate and slowly take it under water in a bucket. See that the shape of the cake is not disturbed while taking it down to the bottom of the bucket. After 24 hours the cake should retain its original shape and at the same time it should also set and attain some strength. If a sample of cement satisfies the above field tests it may be concluded that the cement is not bad. The above tests do not really indicate that the cement is really good for important works. For using cement in important and major works it is incumbent on the part of the user to test the cement in the laboratory to confirm the requirements of the Indian Standard specifications with respect to its physical and chemical properties. No doubt, such confirmations will have been done at the factory laboratory before the production comes out from the factory. But the cement may go bad during transportation and storage prior to its use in works.

The following tests are usually conducted in the laboratory.
(a) Fineness test. (b) Setting time test.
(c) Strength test. (d) Soundness test.
(e) Heat of hydration test. (f) Chemical composition test.

Fineness of cement is tested in two ways :
(a) By sieving.
(b) By determination of specific surface (total surface area of all the particles in one gram of cement) by air-permeability apparatus. Expressed as cm2/gm or m2/kg. Generally Blaine Air permeability apparatus is used.

Sieve Test
Weigh correctly 100 grams of cement and take it on a standard IS Sieve No. 9 (90 microns). Break down the air-set lumps in the sample with fingers. Continuously sieve the sample giving circular and vertical motion for a period of 15 minutes. Mechanical sieving devices may also be used. Weigh the residue left on the sieve. This weight shall not exceed 10% for ordinary cement. Sieve test is rarely used.
Air Permeability Method
This method of test covers the procedure for determining the fineness of cement as represented by specific surface expressed as total surface area in sq. cm/gm. of cement. It is also expressed in m2/kg. Lea and Nurse Air Permeability Apparatus is shown in Fig.



This apparatus can be used for measuring the specific surface of cement. The principle is based on the relation between the flow of air through the cement bed and the surface area of the particles comprising the cement bed. From this the surface area per unit weight of the body material can be related to the permeability of a bed of a given porosity. The cement bed in the permeability cell is 1 cm. high and 2.5 cm. in diameter. Knowing the density of cement the weight required to make a cement bed of porosity of 0.475 can be calculated. This quantity of cement is placed in the permeability cell in a standard manner. Slowly pass on air through the cement bed at a constant velocity. Adjust the rate of air flow until the flow meter shows a difference in level of 30-50 cm. Read the difference in level (h1) of the manometer and the difference in level (h2) of the flow meter. Repeat these observations to ensure that steady conditions have been obtained as shown by a constant value of h1/h2. Specific surface Sw is calculated from the following formula:

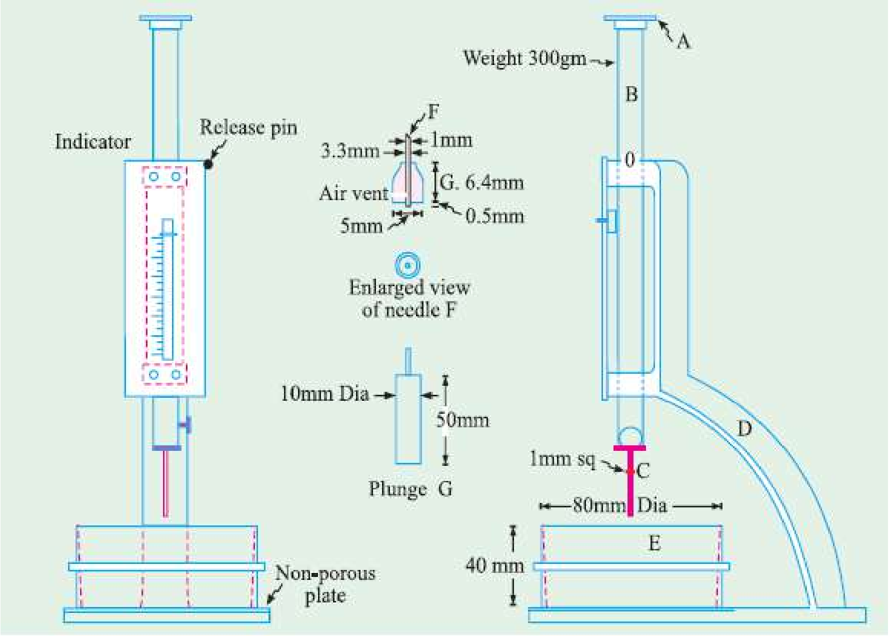
$$S_w = K\sqrt{h_1 / h_2} \quad \text{and} \quad K = \frac{14}{d\,(1-\xi)}\sqrt{\frac{\xi^3 A}{CL}}$$

Where:-
□ = Porosity, i.e., 0.475
A = Area of the cement bed
L = Length (cm) of the cement bed
d = Density of cement, and
C = Flow meter constant.

The specific surface for various cements is shown in Table 2.5. Fineness can also be measured by Blain Air Permeability apparatus. This method is more commonly employed in India. Fig. shows the sketch of Blaine type Air Permeability apparatus.

Standard Consistency Test/ Normal consistency Test

For finding out initial setting time, final setting time and soundness of cement, and strength a parameter known as standard consistency has to be used. It is pertinent at this stage to describe the procedure of conducting standard consistency test.



The standard consistency of a cement paste is defined as that consistency which will permit a Vicat plunger having 10 mm diameter and 50 mm length to penetrate to a depth of 33-35 mm from the top of the mould shown in Fig. The appartus is called Vicat Appartus. This appartus is used to find out the percentage of water required to produce a cement paste of standard consistency. The standard consistency of the cement paste is some time called normal consistency (CPNC). The following procedures is adopted to find out standard consistency. Take about 500 gms of cement and prepare a paste with a weighed quantity of water (say 24 per cent by weight of cement) for the first trial. The paste must be prepared in a standard manner and filled into the Vicat mould within 3-5 minutes. After completely filling the mould, shake the mould to expel air. A standard plunger, 10 mm diameter, 50 mm long is attached and brought down to touch the surface of the paste in the test block and quickly released allowing it to sink into the paste by its own weight. Take the reading by noting the depth of penetration of the plunger. Conduct a 2nd trial (say with 25 per cent of water) and find out the depth of penetration of plunger. Similarly, conduct trials with higher and higher water/cement ratios till such time the plunger penetrates for a depth of 33-35 mm from the top. That particular percentage of water which allows the plunger to penetrate only to a depth of 33-35 mm from the top is known as the percentage of water required to produce a cement paste of standard consistency. This percentage is usually denoted as ‘P’. The test is required to be conducted in a constant temperature (27° + 2°C) and constant humidity (90%).

Setting Time Test

Initial Setting Time

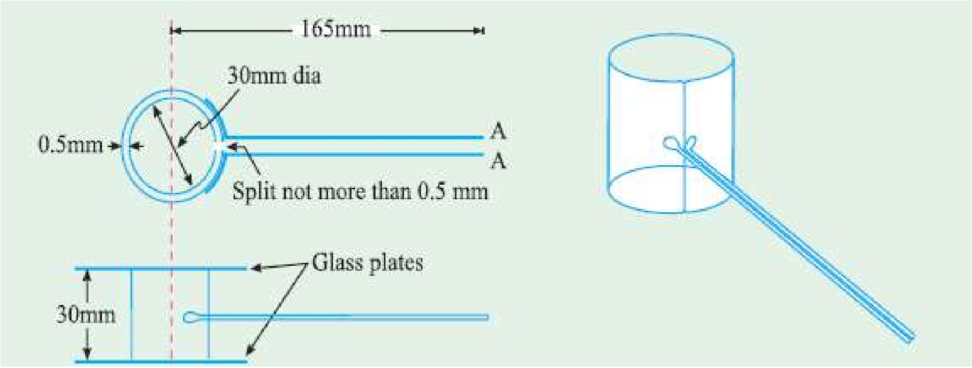
Lower the needle (C) gently and bring it in contact with the surface of the test block and quickly release. Allow it to penetrate into the test block. In the beginning, the needle will completely pierce through the test block. But after some time when the paste starts losing its plasticity, the needly may penetrate only to a depth of 33-35 mm from the top. The period elapsing between the time when water is added to the cement and the time at which the needle penetrates the test block to a depth equal to 33-35 mm from the top is taken as initial setting time.

Final Setting Time

Replace the needle (C) of the Vicat appartus by a circular attachment (F) shown in the fig. The cement shall be considered as finally set when, upon, lowering the attachment gently cover the surface of the test block, the centre needle makes an impression, while the circular cutting edge of the attachment fails to do so. In other words the paste has attained such hardness that the centre needle does not pierce through the paste more than 0.5 mm.

Soundness Test

It is very important that the cement after setting shall not undergo any appreciable change of volume. Certain cements have been found to undergo a large expansion after setting causing disruption of the set and hardened mass. This will cause serious difficulties for the durability of structures when such cement is used.



The testing of soundness of cement, to ensure that the cement does not show any appreciable subsequent expansion is of prime importance. The unsoundness in cement is due to the presence of excess of lime than that could be combined with acidic oxide at the kiln. This is also due to inadequate burning or insufficiency in fineness of grinding or thorough mixing of raw materials. It is also likely that too high a proportion of magnesium content or calcium sulphate content may cause unsoundness in cement. For this reason the magnesia content allowed in cement is limited to 6 per cent. It can be recalled that, to prevent flash set, calcium sulphate is added to the clinker while grinding. The quantity of gypsum added will vary from 3 to 5 per cent depending upon C3A content. If the addition of gypsum is more than that could be combined with C3A, excess of gypsum will remain in the cement in Free State. This excess of gypsum leads to an expansion and consequent disruption of the set cement paste. Unsoundness in cement is due to excess of lime, excess of magnesia or excessive proportion of sulphates. Unsoundness in cement does not come to surface for a considerable period of time. Therefore, accelerated tests are required to detect it. There are number of such tests in common use. The appartus is shown in Fig. It consists of a small split cylinder of spring brass or other suitable metal. It is 30 mm in diameter and 30 mm high. On either side of the split are attached two indicator arms 165 mm long with pointed ends. Cement is gauged with 0.78 times the water required for standard consistency (0.78 P), in a standard manner and filled into the mould kept on a glass plate. The mould is covered on the topwith another glass plate. The whole assembly is immersed in water at a temperature of 27°C – 32°C and kept there for 24 hours.

Measure the distance between the indicator points. Submerge the mould again in water. Heat the water and bring to boiling point in about 25-30 minutes and keep it boiling for 3 hours. Remove the mould from the water, allow it to cool and measure the distance between the indicator points. The difference between these two measurements represents the expansion of cement. This must not exceed 10 mm for ordinary, rapid hardening and low heat Portland cements. If in case the expansion is more than 10 mm as tested above, the cement is said to be unsound. The Le Chatelier test detects unsoundness due to free lime only. This method of testing does not indicate the presence and after effect of the excess of magnesia. Indian Standard Specification stipulates that a cement having a magnesia content of more than 3 per cent shall be tested or soundness by Autoclave test which is sensitive to both free magnesia and free lime. In this test a neat cement specimen 25 × 25 mm is placed in a standard autoclave and the steam pressure inside the autoclave is raised in such a rate as to bring the gauge pressure of the steam to 21 kg/ sq cm in 1 – 11/4 hour from the time the heat is turned on. This pressure is maintained for 3 hours. The autoclave is cooled and the length measured again. The expansion permitted for all types of cements is given in Table 2.5. The high steam pressure accelerates the hydration of both magnesia and lime.

Heat of Hydration

The reaction of cement with water is exothermic. The reaction liberates a considerable quantity of heat. This can be easily observed if a cement is gauged with water and placed in a thermos flask. Much attention has been paid to the heat evolved during the hydration of cement in the interior of mass concrete dams. It is estimated that about 120 calories of heat is generated in the hydration of 1 gm. of cement. From this it can be assessed the total quantum of heat produced in a conservative system such as the interior of a mass concrete dam. A temperature rise of about 50°C has been observed. This unduly high temperature developed at the interior of a concrete dam causes serious expansion of the body of the dam and with the subsequent cooling considerable shrinkage takes place resulting in serious cracking of concrete. The use of lean mix, use of pozzolanic cement, artificial cooling of constituent materials and incorporation of pipe system in the body of the dam as the concrete work progresses for circulating cold brine solution through the pipe system to absorb the heat, are some of the methods adopted to offset the heat generation in the body of dams due to heat of hydration of cement. Test for heat of hydration is essentially required to be carried out for low heat cement only. This test is carried out over a few days by vaccum flask methods, or over a longer period in an adiabatic calorimeter. When tested in a standard manner the heat of hydration of low heat Portland cement shall not be more than 65 cal/gm. at 7 days and 75 cal/g, at 28 days.

Chemical Composition Test

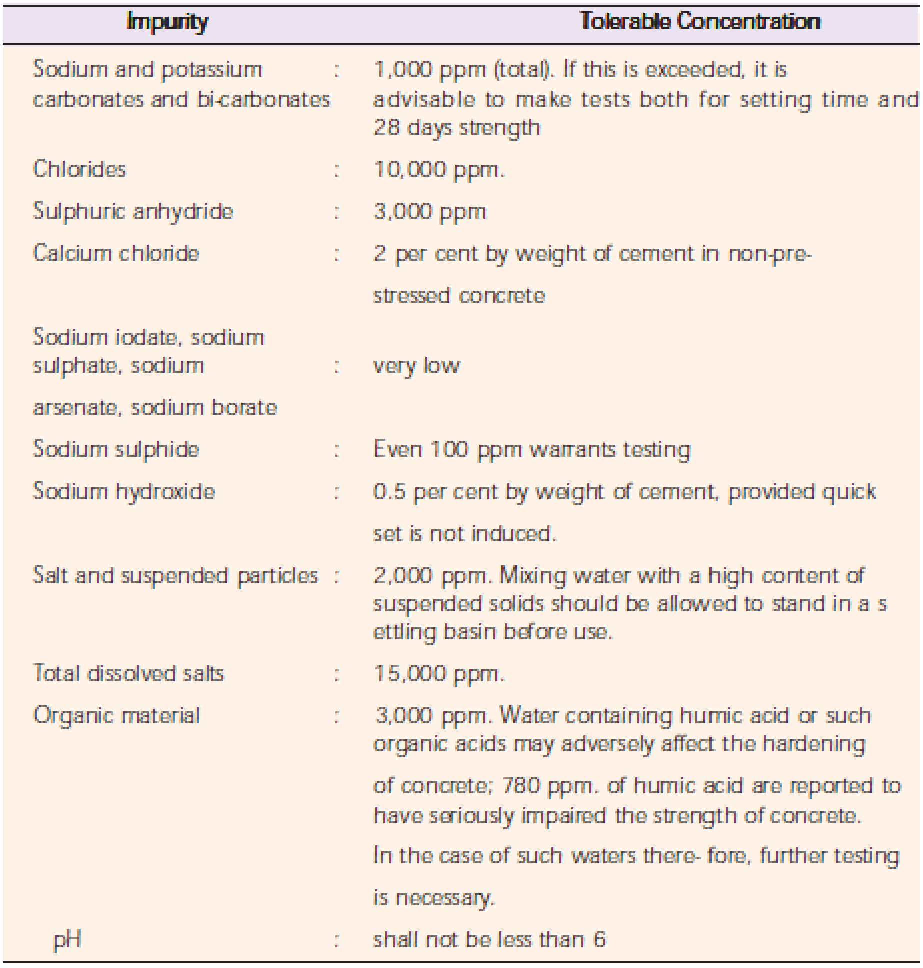
A fairly detailed discussion has been given earlier regarding the chemical composition of cement. Both oxide composition and compound composition of cement have been discussed. At this stage it is sufficient to give the limits of chemical requirements. The Table 2.6 shows the various chemical compositions of all types of cements. Ratio of percentage of lime to percentage of silica, alumina and iron oxide, when calculated by the formulae,

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

Not greater than 1.02 and not less than 0.66
The above is called lime saturation factor per cent.

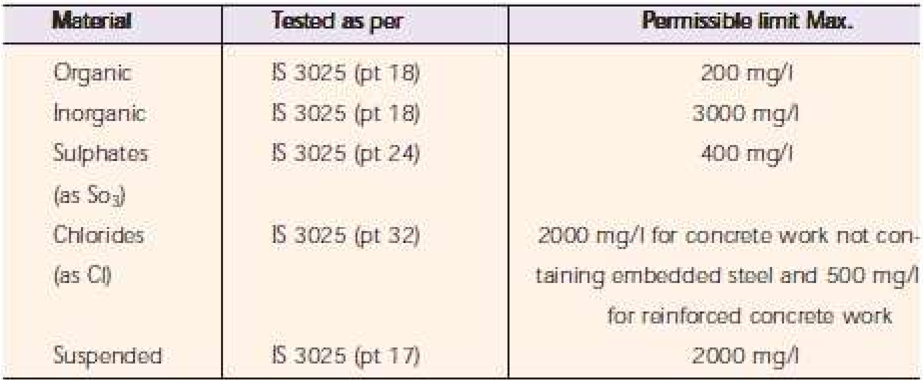
Water Qualities

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 28 days strength
Chlorides	10,000 ppm.
Sulphuric anhydride	3,000 ppm
Calcium chloride	2 per cent by weight of cement in non-pre-stressed concrete
Sodium iodate, sodium sulphate, sodium arsenate, sodium borate	very low
Sodium sulphide	Even 100 ppm 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 salts	15,000 ppm.
Organic material	3,000 ppm. Water containing humic acid or such organic acids may adversely affect the hardening of concrete; 780 ppm. of humic acid 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

Permissible limit for solids as per IS 456 of 2000



Material	Tested as per	Permissible limit Max.
Organic	IS 3025 (pt 18)	200 mg/l
Inorganic	IS 3025 (pt 18)	3000 mg/l
Sulphates (as So_3)	IS 3025 (pt 24)	400 mg/l
Chlorides (as Cl)	IS 3025 (pt 32)	2000 mg/l for concrete work not containing embedded steel and 500 mg/l for reinforced concrete work
Suspended	IS 3025 (pt 17)	2000 mg/l

ADMIXTURES

CHEMICAL ADMIXTURES FOR CONCRETE

Definition: what are chemical admixtures?

The definition of RILEM (International Union of Testing and Research Laboratories for Materials and Structures) is:

- Admixtures for concrete, mortar or paste are inorganic or organic materials
- These are added to the normal components of a mix not normally exceeding 5% by mass of cement or cementitious materials
- Admixtures interact with hydrating cement by physical, chemical or physicochemical actions.
- They modify one or more properties of concrete, mortar or paste either in fresh or hardened state.
- Admixtures are usually very complex compounds chemically excepting a few.
- They are unlikely to be pure compounds but associated with some other minor chemical compounds or they may be mixed formulations.
- It is rather difficult for a civil engineer to understand them through their chemical nature.
- Their effect on cement concrete, mortar or paste can be assessed by (the usual) simple tests on cement, mortar and concrete.
- In most advanced countries, admixtures have become as essential ingredient of concrete as cement, aggregate and water themselves.

Why admixtures? The need.

- If we are pouring a low grade concrete, say M20, If we are not unduly concerned about its water content nor its water-cement ratio,
- If the cost of materials and labour are paid entirely by the owner (or some one else) at whatever rates we have quoted, then, Admixtures will make the concrete more expensive. But then our concrete will be an *indifferent* one,
- Its durability, water tightness and consistent strength will be suspect.
- If we have a problem later on, there is little we can do to rectify it.
- But, in many other situations we cannot get away with such concrete or such an attitude.
- We may have to observe strictly a low w/c ratio as per design requirement
- We may have to transport concrete over large distances or to great heights
- We may need high flowability either due to reinforcement congestion or narrowness of sections or the inability to use vibrators
- We then need chemical admixture.
- All major bridges in India require admixtures for their concrete.
- Cost of admixtures is often compensated by savings in labour costs, placing costs and/ or cement costs.

Usual admixtures:

- For our country, the most common chemical admixtures are plasticizers and Super-plasticizers. These are also known as water reducers and high-range water reducers, respectively.
- Retarders are likely to be needed, especially for hot weather concreting, ready mixed concrete or for special continuous pours

Other types of admixtures are:

- Accelerators
- Air-entraining agents
- Pumping aids
- Shot Crete/ Guniting aids
- Corrosion inhibitors, and some others.

How do they act?

- The chemical, physical or physico-chemical actions of admixtures in cement concrete are quite complex.
- In fact, cement itself is an extremely complex compound with major compounds such as calcium silicates, calcium aluminates, gypsum.
- Besides it contains many alkali and other calcium salts.
- The action of admixtures can, however, be simplified for the sake of Understanding, as:

(i) adsorption
(ii) De-flocculation or dispersion
(iii)Chemical absorption or interaction Often, all the three take place. We should know a little about these so that we can choose admixtures for our job more correctly

Plasticizers/ water reducers

- Of all the admixtures, these are the most commonly used. They are used basically in two ways.
- One, as a plasticizer, to increase flowability of concrete. Flowability or high workability helps in rapid placement, easy compaction, complete filling of deep and narrow formwork, avoidance of honeycombing in congested and/or difficult sections.
- Two, as a water-reducer, to decrease the water content (or water-demand) of a mix without changing its workability.
- If the W/C Ratio is not also changed, reduced water content would mean reduced cement content thus saving on cement costs.
- The saving is likely to be more than the cost of plasticizer addition. If cement content is not changed, then W/C ratio will decrease. Strength will increase. For the same cement content higher grade of concrete can be produced.
- Plasticizer can be used partly for plasticizing and partly for water-reducing in a manner of our choice.

Chemicals of water reducers

- Usually salts of lignosulphonic acid or hydroxylated carboxylic acids (e.g. citric acid)
- Plasticizing action is related to their adsorption and dispersing effects.

Lignosulphonates

- They retard the initial rapid hydration of C_3S and C_3A. Of these two, C_3A adsorbs relatively larger amounts of admixture.

Hydroxylated Carboxylic Acids

- They adsorb relatively more on the already hydrated products of the cement compounds than on the cement grains themselves.
- This causes the inter-layer water between the silicate hydrates and that between aluminate hydrates to be more mobile. Many water reducers are also retarders to a certain extent. But they are unlikely to delay the setting times beyond the permitted limits
- Some water reducers can accelerate setting. Care is needed with such chemicals in hot weather

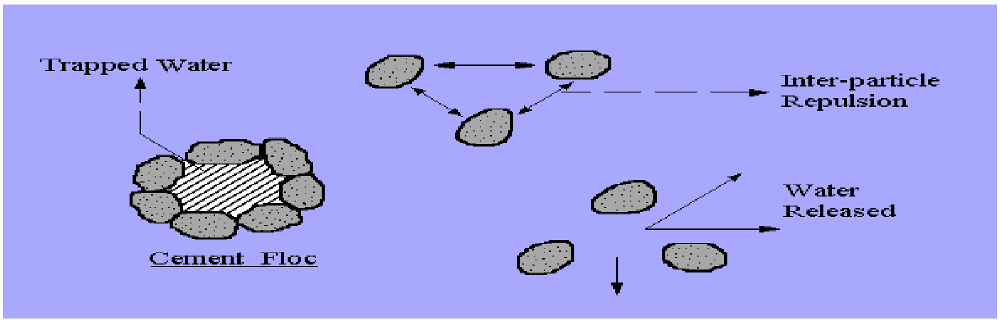
SUPER PLASTICIZERS / HIGH RANGE WATER REDUCERS

- They are also used either as plasticizers or as water reducers.
- They are used in larger doses than plasticizers and are effective in reducing water demand more than 12% and even up to 35 percent. If water reduction is not the criterion super plasticizers help in achieving a flowing concrete i.e. a concrete of very high slump.
- Alternately, a very high strength concrete can be obtained by reducing the W/C ratio drastically, even as low as 0.30.

- In a way they are ‘wonder’ admixtures that have revolutionized concrete technology.
- They have facilitated the use of large volume of fly ash and similar fine pozzolans and yet obtain high performance concrete.

CHEMICALS FOR SUPERPLASTICIZERS

These are, usually:
(i) Sulphonated melamine formaldehyde (SMF)
(ii) Sulphonated naphthalene formaldehyde (SNF)
(iii)Modified lignosulphonates (MLS)
(iv)Poly Carboxylated Ethers (PCE)



Release of Trapped Water from Cement Flocs by the action of super plasticizer

Mineral Admixtures

- Fly ash or Pulverised Fuel Ash (PFA).
- Silica Fume or Micro silica.
- Rice Husk Ash.
- Ground Granulated Blast Furnace Slag (GGBS).
- Metakaolin.

Reason: Why Fly Ash?

- Annually, more than 110 million tonnes of Fly Ash is being generated in India.
- Requires approsimately 65,000 acres of land for disposal

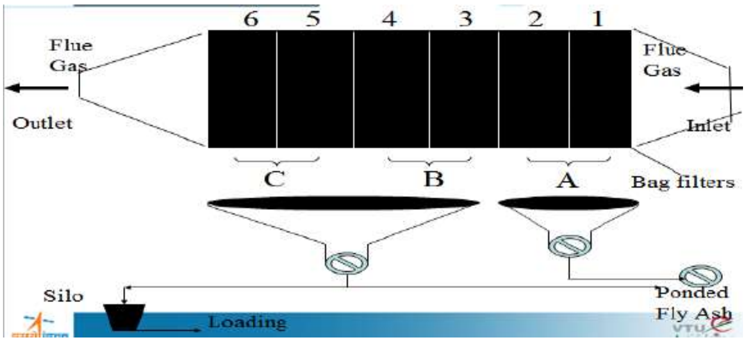
Generation of Fly ash:

- Fly ash is a solid, fine-grained material resulting from the combustion of pulverized coal in thermal plant/furnaces

Collection of Fly ash:

- Bottom ash: Collected from boiler bottom
- Ponded Fly ash: ESP Product Mixed with water
- Dry Fly ash : Separated from field B & C and stored in silo for loading in bunkers

Electrostatic Precipitator



PHYSICAL CHARACTERISTICS OF FLY ASH

Grain size distribution

- Grain size distribution plays an important role in determining the activity of fly ash. The particles in the size range of 5 to 30 µm plays a decisive role in determining the activity of fly ash.
- For fly ashes with low glass content and normal carbon, the reactivity was found to be directly proportional to the amount of particles smaller than 10 µm, and inversely proportional to the amount of particles greater than 45 µm for low calcium fly ashes.
- The particles below 45 µm, which are mostly present in an amorphous form or as glass in the ash, are responsible for the pozzolanic effect.
- But the enhancement in compressive strength appears to be related more to particle sizes below 10 – 20 µm.
-

Fineness

- One of the principal parameters to define the aptitude of the ash to be added to cement as it influences the rate of development of mechanical strength and relative values to be attained.
- However, there is an optimal fineness above which the increase in strength becomes less significant because of the increase in the specific surface.
- Researchers have also stated that finer the fly ash, the higher is the pozzolanic activity.
- Fineness can be expressed in terms of specific surface area determined by Blaine’s Air Permeability method.
- The values are seen to range from 200 – 600 m_2/kg

Specific Gravity

- Specific Gravity varies significantly for particles of different shape, colour and chemical composition
- Irregular shaped, black, coal particles, which contain few mineral grains, have a specific gravity between 1.3 and 1.6 - are non-reactive and dilute the active Pozzolanic material in fly ash
- Variations in the particle densities is due to the presence of bubbles in the glassy particles and voids in the agglomerated particles
- In general, it appears that specific gravity does not have any direct influence on the reactivity of the ash

City Engineering College

Department of Civil Engineering

1. What are Bouge’s compounds? Explain the role in setting and hardening process of cement
2. What are the steps considered for reducing carbon footprint in manufacturing of cement process?
3. Describe briefly fineness modulus of sand and how it is determined in the laboratory
4. What are the various laboratory test conducted on cement? Explain any two
5. What are the types of Cement? Explain any 4 in brief.
6. What are the difference between cement and lime
7. Explain any two tests on cement in detail
8. What are flakiness and elongation index? Explain their effects on properties of concrete
9. Explain procedure for conducting soundness test
10. Explain with Flow chart the manufacture of cement by Wet process
11. Explain with Flow chart the manufacture of cement by Dry process
12. Explain the importance of Shape and texture of aggregate used in concrete
13. Which are the various tests conducted on coarse aggregate for determining its strength
14. Explain the qualities of water used for cement and concrete. Mention the tolerable concentration.
15. What is an Admixture? What is the effect of air entraining on properties of concrete
16. What are chemical admixtures? List the admixtures used in the concrete
17. What are Mineral admixtures? List the admixtures used in the concrete
18. What are the factors affecting Workability of concrete by using admixtures
19. Explain the role of fly ash as an admixture.
20. Write short notes on Accelerators & Retarders
21. With neat sketch explain Effect of plasticizers on cement.
22. In a sieve analysis of 500gram sand sample the weighs in gram retained on different IS sieve were:- 10mm-0, 4.75mm-10, 2.36mm-50, 1.18mm-50, 600micro m- 95, 300micro m- 175, 150micro m – 85, Pan- 35 . Determine the fineness modulus of sand

Staff In-charge HOD