2.6 MINERAL ADMIXTURES

It is a siliceous materials used to strengthen the durability properties that is classified as pozzolanic or cementitious materials. It acts as by-product agent. E.g.: fly ash.

Mineral admixtures are finely divided siliceous materials which are added to concrete in relatively large amounts, generally in the range 20 to 70 percent by mass of the total cementitious material.

Natural mineral admixture

a. Clay and Shales
b. Opalinc Cherts
c. Diatomaceous Earth
d. Volcanic Tuffs and Pumicites.

Artificial mineral admixture

1. **Fly ash**
2. **Silica fume**
3. **Ground Granulated Blast Furnace Slag (GGBFS)**
4. **Metakaoline**
5. Rice Husk ash
6. Surkhi

Fly ash

- ✓ Fly ash is a by-product obtained during the combustion of coal in thermal power plants.
- ✓ Fly ash is the most widely used pozzolanic material all over the world.

The fly ash or pulverized fuel ash is the residue from the combustion of pulverized coal collected by the mechanical dust collectors or electrostatic precipitous or separators from fuel gases of thermal power plants.

The most important benefit is reduced permeability to water and aggressive chemicals. Properly cured concrete made with fly ash creates a denser product because the size of the pores are reduced. This increases strength and reduces permeability. The use of fly ash can result in better workability, pumpability, cohesiveness, finish, ultimate strength, and durability. The fine particles in fly ash help to reduce bleeding and segregation and improve pumpability and finishing, especially in lean mixes.

Classification of fly ash.

Fly is classified into two classes.

Class F:

Fly ash normally produced by burning anthracite or bituminous coal, usually has less than 5% CaO. Class F fly ash has pozzolanic properties only.

Class C:

Fly ash normally produced by burning lignite or sub-bituminous coal. Some class C fly ash may have CaO content in excess of 10%. In addition to pozzolanic properties, class C fly ash also possesses cementitious properties.

Effects of Fly Ash on Fresh Concrete:

- Reduction of water demand for desired slump.
- With the reduction of unit water content, bleeding and drying shrinkage will also be reduced.

Effects of Fly Ash on Hardened Concrete:

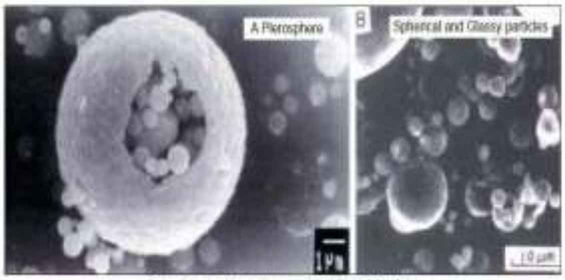
- Contributes to the strength of concrete due to its pozzolanic reactivity.
- Continued pozzolanic reactivity concrete develops greater strength at later age not at initial stage.
- Resulting in decrease of water permeability and gas permeability.

Application:

- Many high-rise buildings
- Industrial structures
- Water front structures
- Concrete roads, Roller compacted concrete dams.

Effect on Heat of Hydration:

Replacement of cement by fly ash results in a reduction in the temperature rise in fresh Concrete. This is particular importance in mass concrete where cooling, following a large temperature rise, can lead to cracking.



Scanning electron micrograph of Class F Fly Ash.

Pozzolanic action

The pozzolanic reaction is the chemical reaction that occurs in Portland cement upon the addition of pozzolans. The pozzolanic reaction converts a silica-rich precursor with no cementing properties, to a calcium silicate, with good cementing properties.

UNIT II

CHEMICAL AND MINERAL ADMIXTURES

SYLLABUS

Accelerators – Retarders - Plasticizers - Super plasticizers - Water proofers - Mineral Admixtures like Fly Ash, Silica Fume, Ground Granulated Blast Furnace Slag and Metakaoline - Effects on concrete properties.

2.1 ADMIXTURES

Admixtures are ingredients other than cement, fine aggregate and coarse aggregate to improve the quality of concrete. The addition of an admixture may improve the concrete with respect to its strength, hardness, workability, water resisting power etc.

Needs of Admixtures

- To modify properties of fresh and hardened concrete.
- To ensure the quality of concrete during the mixing, transporting, placing, and curing.
- To overcome certain unexpected emergencies during concrete operations by using admixtures and etc…
- To reduce the cost of concrete construction.
- To achieve certain properties in concrete more effectively than by other means.
- To maintain the quality of concrete during the stages of mixing, transporting, placing, and curing in ad-verse weather conditions.
- To overcome certain emergencies during concreting operations.

Types of Admixture

Concrete admixtures are generally divided into 2 types

1. Chemical admixture
2. Mineral admixture

Chemical Admixtures

Chemicals mixed with concrete ingredients and spread throughout the body of concrete to favourably modify the molding and setting properties of concrete mix known as chemical admixtures.

Chemicals added to the concrete immediately or during mixing to modify its properties in the fresh hardened state.

Types:

- ✓ Accelerators – speed up the initial set of concrete.
- ✓ Retarders – delay the setting time of concrete mix.
- ✓ Plasticizers and Super-plasticizers - water reducers.
- ✓ Air entraining admixtures
- ✓ Waterproofers Pigments
- ✓ Corrosion - inhibiters
- ✓ Chemicals Anti-fungal admixtures

2.1.1 Accelerators

Accelerating admixtures are added to concrete to increase the rate of early strength development in concrete to

- ✓ Permit earlier removal of formwork;
- ✓ Reduce the required period of curing;
- ✓ Advance the time that a structure can be placed in service;
- ✓ Partially compensate for the retarding effect of low temperature during cold weather concreting;
- ✓ In the emergency repair work.

Commonly used materials as an accelerator:

- Calcium chloride (Not used now)
- Some of the soluble carbonates
- Silicates fluosilicates (Expensive)
- Some of the organic compounds such as triethenolamine (Expensive)

In the past one of the commonly used materials as an accelerator was calcium chloride. But, now a days it is not used. Instead, some of the soluble carbonates, silicates fluosilicates and some of the organic compounds such as triethenolamine are used.

Accelerators such as fluosilicates and triethenolamine are comparatively expensive. The recent studies have shown that calcium chloride is harmful for reinforced concrete and prestressed concrete. It may be used for plain cement concrete in comparatively high dose.

Some of the accelerators produced these days are so powerful that it is possible to make the cement set into stone hard in a matter of five minutes are less. With the availability of such powerful accelerator, the underwater concreting has become easy. Similarly, the repair work that would be carried out to the waterfront structures in the region of tidal variations has become easy. The use of such powerful accelerators have facilitated, the basement waterproofing operations. In the field of prefabrication also it has become an invaluable material. As these materials could be used up to 10°C, they find an unquestionable use in cold weather concreting.

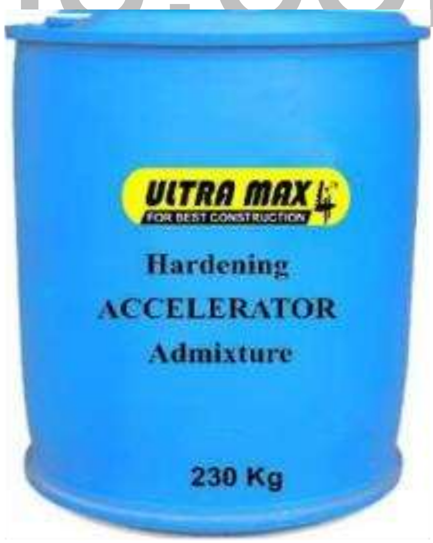
Some of the modern commercial accelerating materials are Mc-Schnell OC, Mc-Schnell SDS, Mc-Torkrethilfe BE, manufactured by Mc-Bauchemic (Ind) Pvt. Ltd. MC-Torkrethilfe BE is a material specially formulated to meet the demand for efficient and multifold properties desired for sprayed concrete and shotcreting operations. A field trial is essential to determine the dose for a given job and temperature conditions when the above materials are used.

Accelerating Plasticizers:

Certain ingredients are added to accelerate the strength development of concrete to plasticizers or superplasticizers. Such accelerating superplasticizers, when added to concrete result in faster development of strength. The accelerating materials added to plasticizers or superplasticizers are *triethenolamine chlorides, calcium nitrite, nitrates and flousilicates etc.* The accelerating plasticizers or accelerating super plasticizers manufactured by well-known companies are chloride free.

Advantages / Effects of accelerator on concrete properties:

- ✓ Reduced bleeding,
- ✓ Earlier finishing
- ✓ Improved protection against early exposure to freezing and thawing,
- ✓ Earlier use of structure
- ✓ Reduction of protection time to achieve a given quality,
- ✓ Early removal of form, and early load application.
- ✓ Increases the rate of gain of strength.
- ✓ Enables earlier release from precast moulds thus speeding production.
- ✓ Reduces segregation and increase density and compressive strength.
- ✓ Cures concrete faster and therefore uniform curing in winter and summer can be achieved.
- ✓ Early use of concrete floors by accelerating the setting of concrete.
- ✓ Reduces water requirements, bleeding, shrinkage and time required for initial set.



2.3 PLASTICIZERS

To decrease the water content with higher workability of concrete, some chemicals may be added to concrete is called water reducer. The water reducing admixtures are two types;

- Plasticizer
- Super plasticizer

Plasticizers for concrete increase the workability of the wet mix or reduce the water required to achieve the desired workability and are usually not intended to affect the properties of the final product after it hardens.

These plasticizers can help the difficult conditions for obtaining higher workability without using excess of water. One must remember that addition of excess water, will only improve the fluidity or the consistency but not the workability of concrete.

The excess water will not improve the inherent good qualities such as homogeneity and cohesiveness of the mix which reduces the tendency for segregation and bleeding. The use of superplasticizers has become almost a universal practice to reduce water/cement ratio for the given workability, which naturally increases the strength. The organic substances or combinations of organic and inorganic substances, which allow a reduction in water content for the given workability, or give a higher workability at the same water content, are termed as plasticizing admixtures. The advantages are considerable in both cases: in the former, concretes are stronger, and in the latter they are more workable.

The basic products constituting plasticizers are as follows:

- ✓ Anionic surfactants such as lignosulphonates and their modifications and derivatives, salts of sulphonates hydrocarbons.
- ✓ Non-ionic surfactants, such as polyglycol esters, acid of hydroxylated carboxylic acids and their modifications and derivatives.
- ✓ Other products, such as carbohydrates etc. Among these, calcium, sodium and ammonium lignosulphonates are the most used.

Plasticizers are used in the amount of 0.1% to 0.4% by weight of cement. At these doses, at constant workability the reduction in mixing water is expected to be of the order of 5% to 15%. This naturally increases the strength. The increase in workability that can be expected, at the same w/c ratio, may be anything from 30 mm to 150 mm slump, depending on the dosage, initial slump of concrete, cement content and type. A good plasticizer fluidizes the mortar or concrete in a different manner than that of the air-entraining agents. Some of the plasticizers, while improving the workability, entrains air also. As the entrainment of air reduces the mechanical strength, a good plasticizer is one which does not cause air-entrainment in concrete more than 1 or 2%. Such a product would allow adsorption into cement particles without any significant interferences with the hydration process or hydrated products. Normal water reducing admixtures may also be formulated from wholly synthetic raw materials.

Amount used

- Plasticizers are used in the amount of 0.1% to 0.4% by weight of cement.

Limitations

- A good plasticizer is one which does not cause air-entrainment in concrete more than 1 or 2%.

Results – effects

- At constant workability –

The reduction in mixing water is expected to be of the order of 5% to 15%. Naturally increases the strength.

- At constant w/c ratio –

Increased workability.

Slump of 30mm to 150 mm.

Used at

Where high degree of workability is required

- Thin walls of water retaining structures with high percentage of steel reinforcement
- Deep beams, column and beam junctions
- Tremie concreting

- Pumping of concrete
- Hot weather concreting
- Concrete to be conveyed for considerable distance and in ready mixed concrete industries.

Action of Plasticizers

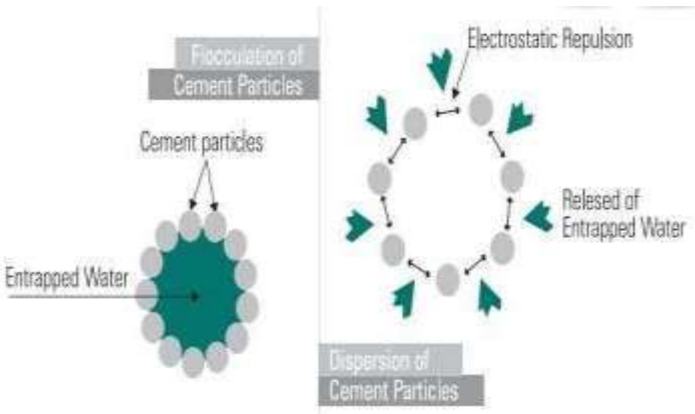
The action of plasticizers is mainly to fluidify the mix and improve the workability of concrete, mortar or grout. The mechanisms that are involved could be explained in the following way:

Dispersion. Portland cement, being in fine state of division, will have a tendency to flocculate in wet concrete. These flocculation entraps certain amount of water used in the mix and thereby all the water is not freely available to fluidify the mix.

When plasticizers are used, they get adsorbed on the cement particles. The adsorption of charged polymer on the particles of cement creates particle-to particle repulsive forces which overcome the attractive forces. This repulsive force is called Zeta Potential, which depends on the base, solid content, quantity of plasticizer used. The overall result is that the cement particles are deflocculated and dispersed.

When cement particles are deflocculated, the water trapped inside the flocks gets released and now available to fluidify the mix.

When cement particles get flocculated there will be inter particles friction between particle to particle and floc to floc. But in the dispersed condition there is water in between the cement particle and hence the inter particle friction is reduced.



2.2 RETARDERS

A retarder is an admixture that slows down the chemical process of hydration so that concrete remains plastic and workable for a longer time than concrete without the retarder. Retarders are used to overcome the accelerating effect of high temperature on setting properties of concrete in hot weather concreting.

Retarders increases the setting time of concrete mix and reduce the water cement ratio. Up to 10% water reduction is achieved

The retarders are used in casting and consolidating large number of pours without the formation of cold joints. They are also used in grouting oil wells. Oil wells are sometimes taken upto a depth of about 6000 meter deep where the temperature may be about 200°C. The annular spacing between the steel tube and the wall of the well will have to be sealed with cement grout.

Retarding admixtures are sometimes used to obtain exposed aggregate look in concrete. The retarder sprayed to the surface of the formwork, prevents the hardening of matrix at the interface of concrete and formwork, whereas the rest of the concrete gets hardened.

The appropriate amount of gypsum to be used must be determined carefully for the given job. Use of gypsum for the purpose of retarding setting time is only recommended when adequate inspection and control is available, otherwise, addition of excess amount may cause undesirable expansion and indefinite delay in the setting of concrete.

In addition to gypsum there are number of other materials found to be suitable for this purpose. They are: starches, cellulose products, sugars, acids or salts of acids. These chemicals may have variable action on different types of cement when used in different quantities. Unless experience has been had with a retarder, its use as an admixture should not be attempted without technical advice. Any mistake made in this respect may have disastrous consequences.

Common sugar is one of the most effective retarding agents used as an admixture for delaying the setting time of concrete without detrimental effect on the ultimate strength. Addition of excessive amounts will cause indefinite delay in setting. At normal temperatures addition of sugar 0.05 to 0.10 per cent have little effect on the rate of hydration, but if the quantity is increased to 0.2 per cent, hydration can be retarded to such an extent that final set may not take place for 72 hours or more.

Skimmed milk powder (casein) has a retarding effect mainly due to sugar content. Other admixtures which have been successfully used as retarding agents are Ligno sulphonic acids and their salts, hydroxylated carboxylic acids and their salts which in addition to the retarding effect also reduce the quantity of water requirement for a given workability. This also increases 28 days compressive strength by 10 to 20 per cent.

Uses of Retarders

- Retarders are used to overcome the accelerating effect of high temperature on setting properties of concrete in hot weather concreting.
- Very useful when concrete has to be place in very difficult conditions and delay may occur in transporting and placing Retarders increase the setting time of the concrete mix and reduced the w/c ratio.
- Usually up to 10% water reduction can be achieved.
- A wide range of water-reducing and set-retarding admixtures are used in ready mixed concrete.

Used at

- Casting and consolidating large number of pours without the formation of cold joints.
- Grouting oil wells, where temperature is about 200 °C, at a depth of 6000 meters.

Limitations of retarders

- Retarders should be used in proper amount. Access amount will cause indefinite setting time.
- At normal temperatures addition of sugar 0.05 to 0.10 per cent have little effect on the rate of hydration, but if the quantity is increased to 0.2 percent,

hydration can be retarded to such an extent that final set may not take place for 72 hours or more

Retarding Agents

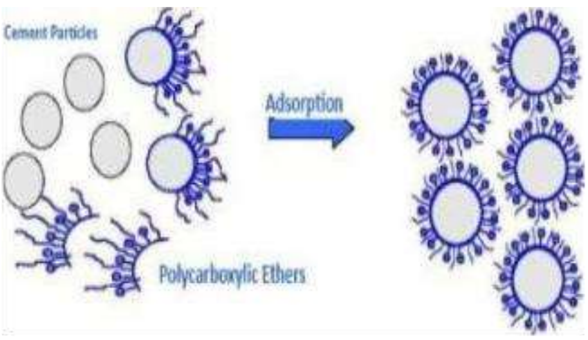
- Gypsum and Calcium Sulphate are well known retarders.
- Other examples are: starches, cellulose products, sugars, acids or salts of acids

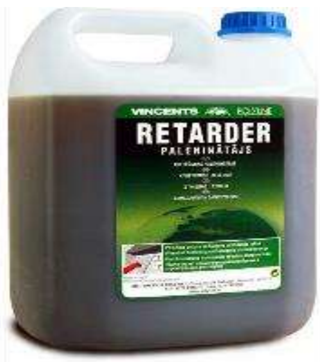
Effect of retarding/water-reducing admixtures on setting time and strength build up

Admixture addition litres/50 kgs.	Setting time hrs.		W : C ratio	Compressive Strength MPa		
	Initial	Final		3 days	7 days	28 days
0	4.5	9	0.68	20	28	37
0.14	8.0	13	0.61	28	36	47
0.21	11.5	16	0.58	30	40	50
0.28	16.0	21	0.58	30	42	54

Retarding Effect

- Reduction in the surface tension of water.
- Induced electrostatic repulsion between particles of cement.
- Lubricating film between cement particles.
- Dispersion of cement grains, releasing water trapped within cement flocs.





2.7 SILICA FUME

Workability: With the addition of silica fume, the slump loss with time is directly proportional to increase in the silica fume content due to the introduction of large surface area in the concrete mix by its addition. Although the slump decreases, the mix remains highly cohesive.

Segregation and bleeding: Silica fume reduces bleeding significantly because the free water is consumed in wetting of the large surface area of the silica fume and hence the free water left in the mix for bleeding also decreases. Silica fume also blocks the pores in the fresh concrete so water within the concrete is not allowed to come to the surface.

Silica fume is a light to dark grey or pink or white cementing material composed of atleast 85% ultra-fine, amorphous non-crystalline spherical silicon dioxide particles give silica fume the super pozzolanic properties.

- Silica fume, also referred to as micro silica or condensed silica fume, is another material that is used as an artificial pozzolanic admixture.
- Silica fume rises as an oxidised vapour. It cools, condenses and is collected in cloth bags.
- Silica fume is a very fine amorphous (non - crystalline) silica produced in electric arc furnaces as a by-product of the production of elemental silicon or alloys containing silicon.
- At least 85% SiO_2 content
- Mean particle size between 0.1 and 0.2 micron
- Minimum specific surface area is 15,000 m^2/kg
- Spherical particle shape

Properties of Silica Fume

- ☐ Specific gravity : 2.2

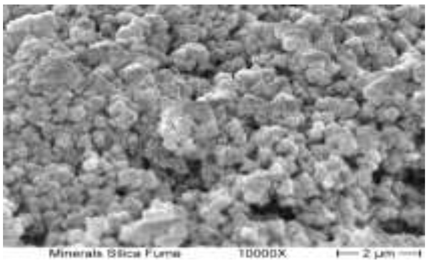
- Typical fineness : 15000 m^2/kg (average particle size ~ 0.1 – 0.5 µm)
- Bulk density : As - produced - 130 to 430 kg/m^3, slurry - 1320 to 1440 kg/m^3, densified - 480 to 720 kg/m^3
- Colour : light grey to dark grey (lighter implies purer)
- Cost : almost 10 times as much as Cement
- Typically used at 5 – 15% replacement level

Working of Silica Fume in Concrete

The second function silica fume performs in cementitious compounds is a physical one. Because silica fume is 100 to 150 times smaller than a cement particle it can fill the voids created by free water in the matrix. This function, called particle packing.

Applications of Silica Fume

- Conserve cement
- Produce ultra-high strength concrete of the order of 70 to 120 Mpa.
- Increase early strength of fly concrete.
- Control alkali - aggregate reaction.
- Reduce sulphate attack & chloride associated corrosion.



Effects of Silica Fume

On fresh concrete:

- The increase in water demand of concrete.
- Lead to lower slump but more cohesive mix.
- Make the fresh concrete sticky in nature and hard to handle.

- Large reduction in bleeding and concrete with micro silica could be handled and transported without segregation.
- Plastic shrinkage cracking and, therefore, sheet or mat curing should be considered.
- Produces more heat of hydration at the initial stage of hydration.
- The total generation of heat will be less than that of reference concrete.

On harden concrete:

- Modulus of elasticity of silica fume concrete is less.
- Improvement in durability of concrete
- Resistance against frost damage.
- Addition of silica fume in small quantities actually increases the expansion.

Forms of Silica Fume

2.4 SUPER PLASTICIZERS (High Range Water Reducers)

They are chemically different from normal plasticizers. Use of super plasticizers permit the reduction of water to the extent upto 30 per cent without reducing workability in contrast to the possible reduction up to 15 per cent in case of plasticizers

The use of super plasticizer is practiced for production of flowing, self-levelling, and self-compacting and for the production of high strength and high performance concrete. The mechanism of action of super plasticizers are more or less same as explained earlier in case of ordinary plasticizer.

Only thing is that the super plasticizers are more powerful as dispersing agents and they are high range water reducers. They are called High Range Water Reducers in American literature. It is the use of super plasticizer which has made it possible to use w/c as low as 0.25 or even lower and yet to make flowing concrete to obtain strength of the order 120 Mpa or more. It is the use of super plasticizer which has made it possible to use fly ash, slag and particularly silica fume to make high performance concrete.

Super plasticizers can produce:

- at the same w/c ratio much more workable concrete than the plain ones,
- for the same workability, it permits the use of lower w/c ratio,
- As a consequence of increased strength with lower w/c ratio, it also permits a reduction of cement content.

The superplasticizers also produce a homogeneous, cohesive concrete generally without any tendency for segregation and bleeding.

Superplasticizers constitute a relatively new category and improved version of plasticizer, the use of which was developed in Japan and Germany during 1960 and 1970 respectively. They are chemically different from normal plasticisers.

Amount used

- Based on various types of super plasticizers different amount is used.

- Lignosulphonates – not more than 0.25%
- Carboxylic acids – 0.1%
- Sulphonated malanie-formaldehyde condensates (SMF) – 0.5 to 3%
- Sulphonated naphthalene-formaldehyde condensates (SNF) – 05 to 3%

Classification of Super plasticizer:

Following are a few polymers which are commonly used as base for super plasticizers.

- Sulphonated malanie - formaldehyde condensates (SMF)
- Sulphonated naphthalene – formaldehyde condensates (SNF)
- Modified lignosulphonates (MLS)

In addition to the above, in other countries the following new generation super plasticizers are also used.

- Acrylic polymer based (AP)
- Copolymer of carboxylic acrylic acid with acrylic ester (CAE)
- Cross linked acrylic polymer (CLAP)
- Polycarboxylate ester (PC)
- Multicarboxylatethers (MCE)
- Combinations of above.

The first four categories of products differ Plasticizers and super plasticizers are water based. The solid contents can vary to any extent in the products manufactured by different companies. Cost should be based on efficiencies and solid content, but not on volume or weight basis. Generally in projects cost

Effects of Super plasticizers on Fresh Concrete:

It is to be noted that dramatic improvement in workability is not showing up when plasticizers or superplasticizers are added to very stiff or what is called zero slump concrete at nominal dosages.

A mix with an initial slump of about 2 to 3 cm can only be fluidised by plasticizers or super plasticizers at nominal dosages. A high dosage is required to fluidify no slump concrete. An improvement in slump value can be obtained to the extent of 25 cm or more depending upon the initial slump of the mix, the dosage and cement content.

Results – benefits

- Permits reduction of water content about 30% without reducing the workability.
- It is possible to use w/c ratio as low as 0.25 or even lower and yet to make flowing concrete to obtain strength of order 120 Mpa or more.

Effect of super plasticizer on concrete properties:

- Significant water reduction
- Reduced cement contents
- Reduce water requirement by 12-30%
- Increased workability
- Reduced effort required for placement
- More effective use of cement
- More rapid rate of early strength development
- Increased long-term strength
- Reduced permeability

Used at

- Production of flowing, self-levelling, self-compacting concrete
- Production of high strength and high performance concrete.

2.5 WATERPROOFERS

Waterproofing admixtures may be obtained in powder, paste or liquid form and may consist of pore filling or water repellent materials.

The chief materials in the pore filling class are silicate of soda, aluminium and zinc sulphates and aluminium and calcium chloride. These are chemically active pore fillers.

In addition they also accelerate the setting time of concrete and thus render the concrete more impervious at early age. The chemically inactive pore filling materials are chalk, fullers' earth and talc and these are usually very finely ground. Their chief action is to improve the workability and to facilitate the reduction of water for given workability and to make dense concrete which is basically impervious.

Some materials like soda, potash soaps, calcium soaps, resin, vegetable oils, fats, waxes and coal tar residues are added as water repelling materials in this group of admixtures.

In some kind of waterproofing admixtures inorganic salts of fatty acids, usually calcium or ammonium stearate or oleate is added along with lime and calcium chloride.

Calcium or ammonium stearate or oleate will mainly act as water repelling material, lime as pore filling material and calcium chloride accelerates the early strength development and helps in efficient curing of concrete all of which contribute towards making impervious concrete.

Some type of waterproofing admixtures may contain butyl stearate, the action of which is similar to soaps, but it does not give frothing action. Butyl stearate is superior to soap as water repellent material in concrete.

Heavy mineral oil free from fatty or vegetable oil has been proved to be effective in rendering the concrete waterproof. The use of Asphalt Cut-back oils have been tried in quantities of 2 1/2, 5 and 10 per cent by weight of cement. Strength and workability of the concrete was not seriously affected.

Production of concrete of low permeability depends to a great extent on successful uniform placing of the material.

An agent which improves the plasticity of a given mixture without causing deleterious effects or which limits bleeding and thereby reduces the number of large voids, might also be classified as a permeability reducing admixture.

Air entraining agents may also be considered under this, since they increase workability and plasticity of concrete and help to reduce water content and bleeding.

An air entrained concrete has lower absorption and capillarity till such time the air content do not exceed about 6 per cent.

Among many other aspects, the w/c ratio used in the concrete, the compaction, curing of concrete, the admixture used to reduce the w/c ratio, the heat of hydration, the micro-cracking of concrete and many other facets influence the structure of hardened cement paste and concrete, which will have direct bearing on permeability, damp-proofing and waterproofing.

Uses

- It is essential to water proof a structure to prevent the seepage of water for its durability.
- Provide water proofing solutions for basements, sunken portions, roofs, terrace gardens and expansion joints etc.

Types of Waterproofers

- Polymer Modified Cementitious Membranes
- Polyurethane Membranes
- Injection Grouting
- Bituminous membranes
- EPD (ethylene-propylene-diene) Membrane
- PVC Membrane

Effect of water proofer on concrete properties:

- To reduce either the surface adsorption into the concrete and the passage of water through the hardened concrete.
- Reducing the size, number and continuity of the capillary pore structure
- Blocking the capillary pore structure
- Lining the capillaries with a hydrophobic material to prevent water being drawn in by absorption / capillary suction.

Functions of Waterproofers

- It reduces the size of capillary pores, their numbers and continuity inside the concrete structure.
- It blocks the capillary pores of concrete, or
- It may line the capillary pores with hydrophobic materials. This prevents the absorption of water in the pores due to capillary absorption.

Materials:

- Hydrophobic or water-repellent chemicals such as oils, petroleum products which can block the entry of water into the pores by forming a layer along the pores in concrete. These materials do not fill the pores.
- Crystalline materials with hydrophilic nature which increases the density of calcium silicate hydrate and / or generate the pore-blocking deposits to resist water penetration.

2.5.1 AIR ENTRAINING ADMIXTURES

One of the important advancements made in concrete technology was the discovery of air entrained concrete.

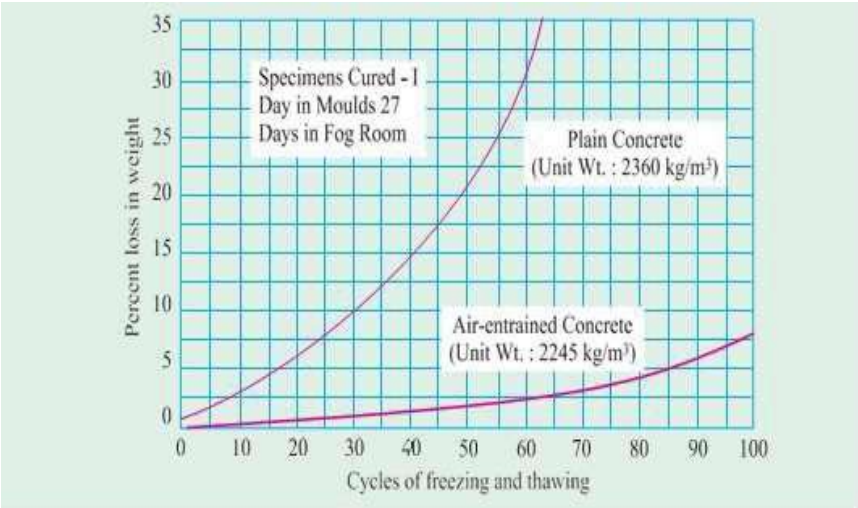
- In the United States and Canada, due to the recognition of the merits of air entrained concrete, about 85% of concrete manufactured in America contains one or the other type of air entraining agent.
- By mixing a small quantity of air entraining agent or by using air entraining cement.
- Minute spherical bubbles of size ranging from 5 microns to 80 microns distributed evenly in the entire mass of concrete.
- These incorporated millions of non-coalescing air bubbles, which will act as flexible ball bearings and will modify the properties of plastic concrete regarding workability, segregation, bleeding and finishing quality of concrete.
- It also modifies the properties of hardened concrete regarding its resistance to frost action and permeability.

Types of Air Entraining Admixtures

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

- Natural wood resins
- Animal and vegetable fats and oils, such as tallow, olive oil and their fatty
- Acids such as stearic and oleic acids.
- Various wetting agents such as alkali salts or sulphated and sulphonated organic compounds.
- Water soluble soaps of resin acids, and animal and vegetable fatty acids.
- Miscellaneous materials such as the sodium salts of petroleum sulphonic
- Acids, hydrogen peroxide and aluminium powder, etc.
- Vinsol resin and Darex are the most important air-entraining agents.

Effect on Freezing and Thawing



Effect on Bleeding