UNIT 4 ADMIXTURES

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4.1 INTRODUCTION

Admixtures are the chemicals which are used in excess of the basic ingredients of concrete i.e. cement, water, fine aggregate and coarse aggregate which you already studied in previous units. These admixtures are added to the concrete mix either immediately before or during the mixing of ingredients with the aim to modify or alter one or more of the specific properties of fresh and hardened concrete. The use of admixtures should bring about the changes, which otherwise would not have been possible economically by changing or adjusting the proportions of cement, fine aggregates and coarse aggregates. It may be remembered that admixtures are no substitute for good concreting practice. Admixtures should not affect some of the concrete properties adversely to improve some other properties of concrete. An admixture should be employed only after an appropriate evaluation of its effects on the particular concrete under the conditions in which the concrete is intended to be used

It becomes difficult to predict in general the effect and results of using a particular brand of admixture, as, many a times the change in brand of cement, aggregate grading, mix proportions and richness of mix alter the properties of concrete; Sometimes many admixtures affect more than one property of concrete, sometimes they affect the desirable property adversely. It is thus often necessary to conduct test on the representative samples of materials for a particular job under simulated job conditions in order to obtain reliable information on the properties of concrete containing admixtures.

The admixtures are chemicals obtained from basically waste materials. They may be silicon or polymer based. The properties commonly modified by admixtures is given in section 4.2. Various types of admixtures available are mentioned in section 4.3. The admixtures are generally added in small quantities hence a relatively better control must be exercised to ensure proper quantity of admixture, as an excess quantity may be detrimental to the properties of concrete. In using any admixture careful attention should be given to the instruction provided by the manufacturer of the product.

Objectives

After studying this unit, you should be able to :

* describe the role of admixtures in making good concrete with high strength and high parformance,
* classify the different types of admixtures, and
* know the different types of admixtures, factors affecting their performance, dosage, how much and to what extent they affect the properties of fresh and hardened concrete.

4.2 CLASSIFICATION OF ADMIXTURES

According to the typical characteristic effect produced by admixtures, they can be broadly grouped into following categories :

i) Accelerating admixtures
ii) Retarding and water reducing admixtures
iii) Grouting admixtures
iv) Air-entraining admixtures
v) Air-detraining admixtures
vi) Gas forming admixtures
vii) Expansion-producing admixtures
viii) Waterproofing and permeability reducing admixtures
ix) Corrosion inhibiting admixtures
x) Fungicidal, germicidal and insecticidal admixtures
xi) Bonding admixtures
xii) Pozzolanic admixtures
xiii) Colouring admixtures or pigments
xiv) Concrete hardening admixtures
xv) Superplasticizer

4.3 FUNCTIONS OF ADMIXTURES

Some of the important properties of fresh and hardened concrete which can be altered by use of admixtures are :

i) To improve workability
ii) To reduce heat of evolution
iii) To increase strength
iv) To accelerate the initial set of concrete i.e. to speed up the rate of development of strength at early ages
v) To retard initial set
vi) To increase durability of concrete which includes improvement of resistance to special conditions of exposure
vii) To control alkali-aggregate reaction
viii) To increase impermeability of concrete
ix) To reduce grouting
x) To increase bond between old and new concrete surface
xi) To inhibit corrosion in concrete
xii) To entrain air in concrete and thus decreasing unit weight of concrete

xiii) To produce hard; nonskid surface

xiv) To produce concrete of fungicidal, germicidal and insecticidal properties.

4.4 ACCELERATORS

Accelerating admixtures are added to concrete to increase the rate of early strength development in concrete i.e. to increase the rate of hydration of cement or to shorten the setting time. An increase in rate of early strength development may help in

i) earlier removal of formwork hence allowing more repeated use of formwork resulting in increase in output in prefabrication industry

ii) reduction in required period of curing

iii) advance the time a structure can be placed in service

iv) partially compensate for the retarding effect of low temperature during cold weather concreting

v) emergency repair work.

Due to reduction in setting time of concrete by using accelerating admixtures following benefits can be achieved :

i) Early finishing of the surface.

ii) Reduction of pressures on forms or of period of time during which the forms are subjected to hydraulic pressure.

iii) More effective plugging of leaks against hydraulic pressure.

Normally, the most common material used as an admixture to accelerate the early strength development of concrete is calcium chloride. But some of the soluble carbonates, flurosilicates and organic compounds such as trietholamine are also used sometimes, which are capable of reducing the period during which concrete remains plastic to less than 10 minutes. Some set accelerators are produced under the trade name "Quickest" which when added to the cement, produces setting in few seconds. These are quite frequently used for making cement plugs to stop pressure leaks. There are many brands of accelerators now available in Indian market which are mentioned in section 4.16. However calcium chloride being cheapest and are still very commonly used and hence, this material is discussed in details here.

Calcium chloride in concrete increases early strength. The effectiveness of calcium chloride in promoting early strength is dependent on many factors such as the amount of calcium chloride, type of cement, richness of mix, temperature of concrete and curing conditions. With 2% calcium chloride the increase in compressive strength has been observed to be 7 N/mm^2 at 1 day when used with rapid hardening cement while with Ordinary Portland Cement this increase would be achieved only after 5 to 7 days. By the age of 28 days there is no difference between the strengths of Rapid Hardening Cements with and without $CaCl_2$, but in case of Ordinary Portland Cement the addition of $CaCl_2$ would still show an improved strength. Calcium chloride is generally more effective in increasing the early strength of rich mixes with low water/cement ratio than of lean ones.

The quantity of $CaCl_2$ added to the mix must be carefully controlled. Addition of 1 percent $CaCl_2$ affects the rate of hardening as much as a rise in temperature of 6°C. A $CaCl_2$ content of 1 or 2 percent is generally sufficient, the latter figure should not be exceeded unless a test with the cement to be actually used in construction is made. However at low temperature higher doses of $CaCl_2$ can be used.

Calcium chloride generally accelerates setting and an excess of $CaCl_2$ can cause flash $CaCl_2$ in amounts 0.1, 0.3, 0.5 and 1% has accelerated the set by 15 minutes, 25 minutes, 45 minutes and 85 minutes respectively. Addition of 3 percent of the salt reduced the time of set from about 10 hours to one hour at 3°C and from $3\frac{1}{2}$ hours to 45 minutes at 20°C. Calcium chloride within permissible limit does not cause any corrosion to embedded reinforcement. However the same should not be used in prestressed concrete because of possible stress corrosion of prestressed steel. It also should not be used where stray electric currents are expected.

$CaCl_2$ can be used with both OPC as well as RHC but it is more effective with RHC as more rapid the natural rate of hardening of the cement the earlier becomes apparent the action of the accelerator. Calcium chloride however, must not be used with aluminous cement.

$CaCl_2$ generally increases volume changes in concrete and hence more shrinkage. It also increases the alkali-aggregate reaction, and reduces the resistance of concrete to sulphate attack.

It is important that calcium chloride be uniformly distributed throughout the mix, and this is best achieved by dissolving the additive in the mixing water thoroughly before it enters the mixers. $CaCl_2$ should be added to water and not water to $CaCl_2$ since a coating may form which is difficult to dissolve.

4.5 RETARDERS

A delay in the setting of the cement paste can be achieved by mixing a retarding admixture to concrete mix. They slow down the chemical process of hydration, leaving more water for workability and allowing concrete to be finished and protected before drying out. Retarders are useful in concreting in hot weather when the normal setting time is shortened by the higher temperature. The retarders are used when large number of layers or pours are to be cast without formation of cold joints. The delay in hardening caused by the retarders can be used to obtain an architectural finish of exposed aggregate. In case of sealing oil wells the cement grouts have to remain very workable for more than 3 to 4 hours even at high temperature of about 200°C and above. Sometimes concrete may have to be placed in difficult conditions and delay may occur in transporting and placing. In "Ready Mixed Concrete", the concrete is manufactured in a centralised batching plant and then conveyed to work site by dumper. If worksite/delivery site is at a large distance considerable time will be taken to transport the concrete. In all above cases the setting of concrete is to be delayed such that at the delivery end, concrete is fresh, plastic and sufficiently workable. This is achieved by addition of retarders.

The materials generally used as set controlling admixtures belong to the following groups :

i) Lignosulphonic acids and their salts.

ii) Modifications and derivatives of lignosulphonic acids and their salts.

iii) Hydroxylated carboxylic acids and their salts.

iv) Modifications and derivatives of hydroxylated carboxylic acids and their salts.

Some of these act as water reducing admixture also. Presently admixtures are manufactured to combine set retarding and water reducing properties. They are usually mixtures of conventional water reducing agents plus sugars or hydroxylated carboxylic acids or their salts.

The most commonly known retarder is calcium sulphate. It is interground to retard the setting of cement. The appropriate amount of gypsum (calcium sulphate) 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.

Common sugar is one of the most effective retarding agent. Addition of excessive amounts will cause indefinite delay in setting. At normal temperatures addition of sugar 0.05 to 0.10 percent 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.

Use of retarder must be done carefully. Unless one is thoroughly experienced with the use of retarder as an admixture to the concrete, he should not attempt to use such admixtures without proper technical advice. Any mistake made in this respect may have disastrous effect at later stages.

4.6 GROUTING ADMIXTURES

Grout-mixture for its varied applications necessitates in developing certain properties. Most important of them is that the grout mix should be at least shrinkage compensating and in some cases even more expansive than shrinkage compensating. In some cases grout mixture may have to set quickly and in some cases it should remain plastic for longer duration so that it can flow into cracks and cavities where it is supposed to fill up. Grouting admixture should have combination of some of the following properties :

i) Accelerating

ii) Retarding

iii) Gas forming

iv) Workability

v) Expanding

Accelerating property can be developed by using one of the accelerating agent like calcium chloride. Retarding and dispersing agents may be used to make the grout more flowable and pumpable. Expansive property can be attributed by adding expansive agents like gypsum etc. There should also be a suitable thixotropic substance which prevent segregation and provides a high bond to the contact surface without voids in the grouted mass.

Gas forming admixtures will be used while grouting is completely confined areas, such as under machine foundation. Aluminium powder is the most commonly used agent, which chemically reacts and forms small bubbles of hydrogen and produces expansion of the grout. This expansion eliminates settlement and shrinkage.

Workability agents such as fly-ash, bentonite clay, pozzolanic materials may be used to improve workability without increasing water and thus not thinning the grout.

4.7 AIR ENTRAINING ADMIXTURES

These admixtures introduce small amount of air in the fresh concrete. This air is known as entrained air. Entrained air is minute spherical bubbles of size ranging from 5 microns to 80 microns distributed evenly in the entire mass of the concrete. Air-entraining admixtures are surface active agent which has the property of reducing surface tension of water and thus enabling the water to hold air when agitated, resulting in a foam. Air entraining agent should be able to produce firm minute bubbles which should not break easily. This entrained air bubbles constitute a definite part of fine aggregate and lubricate the concrete. The bubbles act like ball bearing and help in rolling one aggregate particle over other instead of sliding as occur in normal cases and hence improves the workability in general of the mix.

The entrain air bubbles reduce the capillary forces in concrete as the capillaries are interrupted by relatively large air-voids in air-entrained concrete. Moreover the air voids are not interconnected hence capillary forces of water diminishes as soon as it encounters with such air void.

4.7.1 Types of Air Entraining Agents

The following are general types of compounds which are used to make air entraining agent :

i) Natural wood resins.

ii) Animal and vegetable fats and oils, such as tallow, olive oil and their fatty acids such as stearic and oleic acid.

iii) Various wetting agents such as alkali salts or sulphated and sulphonated organic compounds.

iv) Water soluble soaps of resin acids and animal and vegetable fatty acids.

v) Miscellaneous materials such as the sodium salts of petroleum sulphonic acids, hydrogen peroxide and aluminium powder.

There are quite a several brands of air-entraining agents available in Indian market, a comprehensive mention of them is made in Section 4.16

4.7.2 Factors Affecting Amount of Air Entrainment

a) **Type and quantity of air entraining agent:** Different types of air entraining agent will produce different quantity of air entrainment depending on their capability to reduce surface tension of water. Again the more the air entraining agent more will be the entrained air.

b) **Water/cement ratio of the mix:** Very less quantity of water will not produce adequate foaming while very large quantity of water will diffuse the air bubbles. Generally water/cement ratio between 0.4 to 0.55 is found to be optimum.

c) **Type and grading of aggregate:** Air entrainment found to increase with increase in Fineness Modulus of fine aggregate upto 2.5 and thereafter with further increase in Fineness Modulus it is decreased abruptly. Fine aggregate fraction between 300 to 150 micron size found to have large influence in air entrainment. More this size of fraction, more is air entrainment.

d) **Mixing time:** Less mixing will result in less air entrainment while more mixing will lead to loss of air entrainment. Mixing time of $1\frac{1}{2}$ to 2 minutes in normal mixers found to be optimum.

e) **Type of cement:** Air entraining agent should not react with cement. However the alkali content in cement has great influence in air entrainment. More the alkali content, higher is the air entrainment.

4.7.3 Effect of Air Entrainment on Properties of Concrete

i) **Increased resistance to freezing and thawing:** As mentioned earlier, the pore structure of air entrained concrete is largely different from ordinary concrete without air entrainment. Due to minute bubbles distributed evenly over the volume of concrete the increase in volume of water during formation of ice is absorbed by void spaces created by air entrainment. Moreover even though total air void in air entrained concrete is larger, the voids are in the form of minute discrete bubbles hence reduces the tendency to form large crystals of ice in the concrete. It has been found that air entrainment in concrete increases the resistance by about three to seven times in such situations. Figures 4.1 and 4.2 below depict the increase in resistance to freezing and thawing by use of air entrainment.

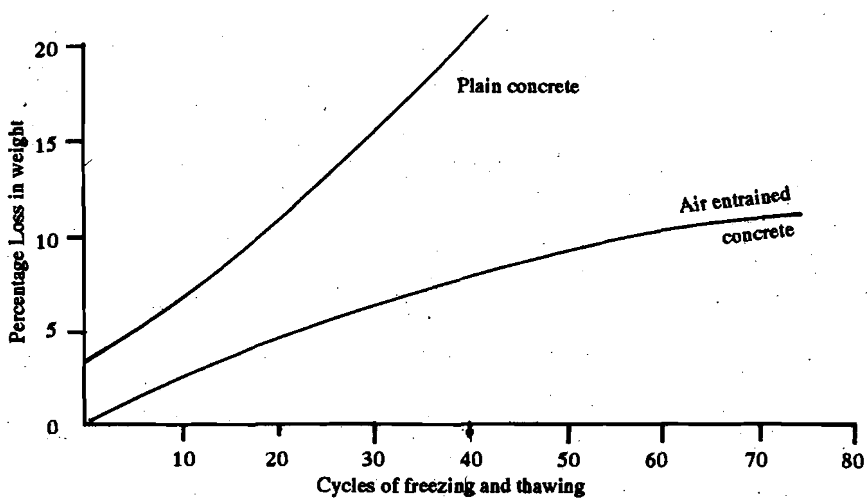

Figure 4.1 : Resistance to Freezing and Thawing

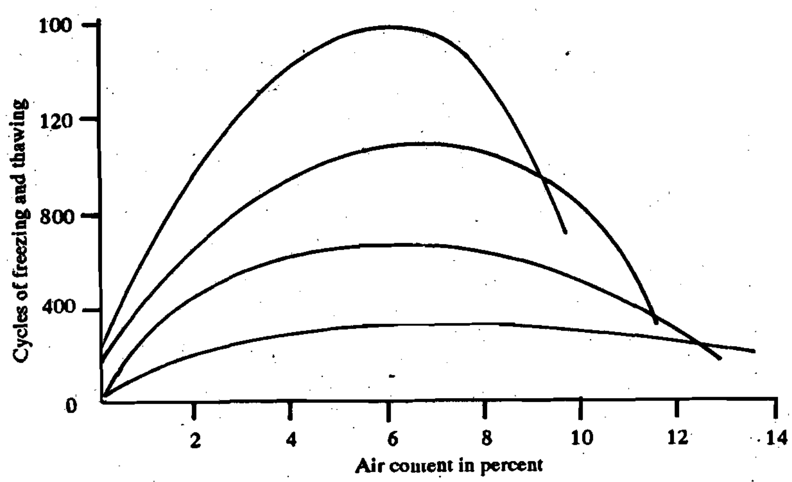

Figure 4.2 : Optimum Air Content for Durability

In Figure 4.1 percentage loss in weight is shown against number of cycles of freezing and thawing given in 10% $CaCl_2$ solution for both plain concrete and concrete with 5% air entrainment. Figure 4.2 shows number of cycles of freezing and thawing required to produce failure in the specimen with different air content and different cement content.

ii) **Effect of air entrainment on workability :** Introduction of air entrainment improves the workability of concrete. What is more important is that placeability of air entrained concrete is much superior than concrete without air entrainment. For example 7 cm slump air entrained concrete is much superior than 12 cm slump non air entrained concrete so far as placeability is concerned specially in difficult situations like thin long sections, congested with reinforcement sections etc. This also leads to producing segregation, bleeding and honeycomb free homogeneous concrete. The concrete containing entrained air is more plastic and fatty.

The workability of the mix increases with increase in air entrainment. However once the concrete is placed and compacted, the extra air may be made to escape by prolonging the vibration to achieve the desired density in the hardened concrete.

It is observed that 5 percent air may increase the compacting factor by 0.07. A corresponding increase of the slump would be from 12 mm to 50 mm. The increase in the workability is rather greater for water water mixes than for drier ones, and for leaner mixes than for richer mixes. Further it has been shown that the increase of workability is greater for angular aggregates than for rounded ones.

iii) **Effect of air entrainment on strength :** Air entrainment introduces air voids and hence logically will reduce strength. Generally a decrease in strength of 5.5 percent has been found for each percent of air entrainment. However against constant workability, the water/cement ratio in case of air entrained concrete can be reduced which will lead to increase in strength. In most cases wherever there is a scope to reduce the water/cement ratio, this increase in strength reported to be higher than the 5.5 percent loss of strength due to incorporation of each percent of air entrainment.

iv) **Effect of air entrainment on permeability :** As mentioned earlier, the air entrainment reduces the capillary forces of percolating water by interrupting the capillary channel by relatively large voids. Also greater density and uniformity of concrete with entrained air due to its increased workability and modified pore structure leads to improvement of permeability characteristic of concrete. Possible reduction in water/cement ratio is also one of the factors for reduced permeability.

v) **Effect of air entrainment on other properties :** Segregation, bleeding and consequent formation of laitance are reduced greatly by air entrainment. This is due to the fact that air bubbles up the aggregate and cement and hence reduce the rate of sedimentation. The bubbles also decrease the effective area through which the draining of water is possible. Finally the bubbles increase mutual adhesion between cement and aggregate.

Air entrainment lowers permeability and absorption and hence air entrained concrete will be more resistant to chemicals like sulphate, chlorides etc. Air entrainment also reduces unit weight of concrete.

4.7.4 Dosage of Air Entrainment

Dosage of air entrainment depends on many factors like purpose for which concrete is used, climatic condition, maximum size of aggregate and richness of the mix. However, in general for mass concreting air entrainment should be low i.e. 2 to 3 percent while in case of thin sections where placeability is difficult, the same can be increased to 5 to 6 percent. For reinforced concrete of relatively high cement content the limit would be between 3 to 4 percent. In any case air entrainment should not be less than 2 percent and more than 6 percent.

4.8 AIR DETRAINING ADMIXTURE

Many a times when it is found that an excessive air entrainment has occurred in concrete or unaccounted gas has been released by aggregates or due to use of Hydrophobic cement wherein oleic acid coating on cement particles has been broken during mixing and reacted with alkali of cement forming a foaming substance namely Sodium/Pottasium oleates; an air detraining agent can be used to dissipate excess air or other gases and/or to remove a part of entrained air. Compounds such as tri-n-butyl phosphate, water-soluble alcohols and silicons, dibutylphthalate etc. have been in use as air detraining agents.

4.9 GAS FORMING ADMIXTURES

These are the class of admixtures which when mixed with fresh concrete reacts with hydroxides present in the cement and forms minute bubbles of hydrogen. Sometimes nascent oxygen releasing substances can be used to form gas in plastic concrete. Formation of these gases uniformly in the plastic mass of concrete causes slight expansion in plastic concrete which reduces the cracks and voids created due to normal settlement of concrete during placement. This expansion reduces bleeding and is beneficial in improving the effectiveness of grout for filling joints and improving homogeneity of grouted concrete. The expansion also helps in filling blackouts and openings in concrete structures. It improves the intimacy of contact of the paste with adjacent concrete or aggregate particles as well as embedded steel reinforcing bars.

Aluminium powder is used most commonly as gas forming agent. Hydrogen gas is produced due tó reaction of aluminium with $Ca(OH)_2$. The extent of gas produced depends on the type and amount of aluminium powder, fineness and chemical composition of cement, temperature and mix proportions. The dose of aluminium powder varies between 0.005 to 0.02 percent by weight of cement. Larger dosage may be used for production of light weight concrete (example SIPOREX BLOCKS). The extent and duration of gas production also depend on temperature. For example, the reaction (gas formation) starts at the time of mixing and is completed in 30 minutes at 38°C while it may take several hours to complete the reaction at 4°C. Hence in hot weather the action of aluminium powder may occur too quickly and beneficial action may be lost. In cold weather, the action will be slower and may not progress to desired extent before the concrete has set.

The effect on the strength of the concrete depends to a large extent on the restrained offered to expansion. With complete restrained imposed, the strength is not affected appreciably with very small amounts of aluminium powder. It is, therefore, important that the forms be tight and the grout is completely confined.

Aluminium powder has a tendency to float in water and hence it is to be premixed with fine sand dry and then this mixture is added into the mixer. Zinc and Magnesium powders are also used for this purpose while hydrogen peroxide and bleaching powder can be used in combination to produce oxygen instead of hydrogen bubbles in concrete.

4.10 EXPANSION PRODUCING ADMIXTURES

Expansion producing admixtures may react with constituent parts of concrete and produce a expansive product or may themselves expand when mixed alongwith concrete constituent. The magnitude of this expansion can be adjusted so that the expansion and the subsequent shrinkage of concrete are numerically equal. Such concrete may be called as shrinkless concrete. However magnitude of expansion may be made larger than drying shrinkage and in such cases a residual compressive stress will remain even after drying shrinkage has occurred in the concrete. This concrete is known as self-stressing concrete and compressive stress induced in them may well compensate for tensile stresses that would otherwise manifest themselves as tensile strains and possibly as cracks. The performance of these concretes on a limited scale has been found to be encouraging and there is a good prospect of using such concrete in prestressed concrete.

A number of expansion agents have been reported, such as granulated iron and chemicals and anhydrous sulphoaluminate etc. Granulated iron and chemicals promote oxidation of iron resulting in the formation of iron oxide which occupies an increased solid volume. The expanding agent is also obtained by burning a mixture of gypsum, bauxite and chalk, which form calcium sulphate and calcium aluminate. In the presence of water, these compounds react to form calcium sulphoaluminate hydrate, with an accompanying expansion of the paste. A stabilizer, which is blast-furnace slag; may sometimes be used to take up excess calcium sulphate and bring expansion to an end.

4.11 WATER PROOFING AND PERMEABILITY REDUCING ADMIXTURES

Movement of moisture through concrete structure can be in two ways. If water is retained on one side of the concrete under certain pressure and if there are continuous capillary channels through concrete member, water will percolate through these capillary channels on the other side of concrete member. The water passing in this manner is a measure of permeability. Water can pass through concrete by the action of capillary forces. The materials used to reduce the water flow occurred by the first method are termed permeability reducer, whereas the materials used to reduce second type of flow are known as dempproofers.

A carefully designed mixed concrete incorporating sound materials, low water-cement ratio and efficiently executed will generally be impervious and will not need any waterproofing and damp proofing admixtures. However, since the usual design, placing, curing and in general the various operations involved at the site of work leave much to be desired, it is accepted that the use of a well chosen admixture may prove to be of some advantage in reducing the permeability.

All workability agents including air entraining agent may act as waterproofing and damp proofing agents. Some materials like soda, potash soaps, calcium soap, resins, vegetable oils, fats, waxes and coaltar 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 alongwith lime and calcium chloride. Various types of waterproofing and damp proofing admixtures available in Indian market is mentioned in section 4.16.

4.12 SUPERPLASTICIZER

In concrete making, water cement ratio plays a major role. If water cement ratio is less, strength is improved. However with less water cement ratio the workability is reduced, compaction becomes difficult. As a result of inefficient compaction air voids are left in concrete, resulting in reduction of strength. Whenever the concrete is stiff and hence difficult to place and compact, there is a tendency on the part of the workers to increase quantity of water and thereby workability, resulting in higher water cement ratio and hence less strength. This is a dilemma to site engineers. Plasticizers and superplasticizers here come to rescue. Its addition, improves workability even for low water cement ratio. Thus in the mix design of concrete, one more parameter is introduced namely superplasticizers. Its role should be well understood.

Superplasticizers are a new class of water reducing admixtures, chemically different from normal water reducers, capable of reducing water content by as much as 25%. They were first introduced in Japan in 1964 and in Germany in 1972. In recent years, construction agencies over the globe have evinced keen interest in these admixtures.

Superplasticizers have been provisionally grouped in the following four categories :

Category A: Sulphonated Melamine Formaldehyde (MSF) condensate or their sodium salt.

Category B: Sulphonated Napthelene Formaldehyde (NSF) condensate or their sodium salt.

Category C: Modified lignosulphonates (LS).

Category D: Polyhydroxylated Polymer or Mixture of acid-amids and Polysaccharides.

Each category includes products differing from one another because either the base component can have undergone some chemical changes or other chemical substances may be present. Whilst the dosage of conventional plasticizers do not exceed 0.25% by weight in the case of lignosulphate or 0.1% by weight in the case of carboxylic acids, the superplasticizers MSF and NSF are used in considerably higher dosage (0.5 to 1.5%) since they do not entrain air. LS includes admixtures which have an effective fluidizing action but at relatively high dosages, they can produce undesirable effects, such as accelerations or delay in setting times. They may also increase air entrainment in concrete.

When cement is mixed with water and stirred, it forms flocks and settles down imbibing large amount of water, meant for imparting workability to cement concrete. The plasticizing action in plasticizers is physical in nature and is explained by absorption isotherms, i.e. sticking of admixtures particles on cement particles which increases Zeta potential thus causing cement particles to mutually repel each other. The entrapped water within the cement flocks are thus released to increase workability and thus changing the water cement system and therefore its rheology. Mutual repulsion of cement particles also causes their uniform distribution and more number of particles with larger surface area are exposed to water.

By dispersing the cement particles in aqueous solution of superplasticizers, the later are absorbed on the surface of solid particles. If the dosages of superplasticizers is increased beyond limit, the unabsorbed superplasticizers particle will hinder with normal hydration process. However superplasticizers can be safely used at much higher dosage than ordinary plasticizers without the problems of excessive air entrainment, retardation or bleeding which might otherwise be expected in case of ordinary plasticizers.

Cement being very finely and uniformly distributed in aqueous solution of superplasticizers, the morphology of resulting hydrated cement particles are altered considerably forming smaller size crystals with totally different pore structures. The pores and capillaries are of much small dimension than of ordinary concrete. All these make concrete more strong and durable.

The basic advantages of superplasticizers may be classified as :

a) Superplasticizers can be used to increase workability keeping water cement ratio constant. This may result in increase in strength between 5 to 20%.

b) Keeping designed workability constant, water cement ratio can be decreased considerably (water reduction upto 25%) with addition of superplasticizers, thus causing a rise of strength by 70 to 80%. This means keeping cement content low (300 to 325 kg/m^3) high strength concrete can be produced.

c) The most widely used application of water reducing admixtures is to allow reductions in the water cement ratio whilst maintaining the initial workability in comparison to a similar concrete containing no admixtures. This, in turn, allows the attainment of a required strength at lower cement content to effect economies in mix design. Cement saving of the order of 25 to 30% can be achieved by judicious use of superplasticizers.

SAQ 1

a) Explain the role of admixture in making high strength and high performance concrete.

b) Explain the difference between "Water proofing" and "Damp proofing".

c) "All water proofers are basicaly a plasticizer". Explain.

d) Discuss various factors on which amount of air entrainment depends.

4.13 POZZOLANA ADMIXTURES

Pozzolana is a natural or artificial material containing silica in a reactive form. A more formal definition is provided in IS 3812 (Pt II) - 1981. Pozzolana may be stated as a siliceous or siliceous and aluminous material which in itself possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties. It is essential that pozzolana be in a finely divided state as it is only than that silica can combine with lime (liberated by the hydrating portland cement) in the presence of water to form stable calcium silicates which have cementitious properties. Most common naturally occurring pozzolanic materials are volcanic ash, pumicite, opaline shales, diatomaceous earth while artificially occurring pozzolanic materials are Pulverised fuel ash (PFA) or fly ash, burnt clay.

Use of pozzolanic admixtures improves the following properties of concrete :

a) Lowers the heat of hydration and thermal shrinkage.

b) Increases the water tightness.

c) Reduce alkali-aggregate reaction.

d) Improve resistance to attack by sulphate soils and sea water.

e) Improves later strength.

f) Improves workability.

4.14 CORROSION INHIBITING ADMIXTURES

Concrete and reinforced concrete have proven their worth as modern building materials over the past few decades. Reinforced concrete has in fact opened up a great diversity of design opportunities for the architect. However major problem found in reinforced concrete is the corrosion of reinforcement due to environmental influences. Once corrosion starts it continues. The corroded material i.e. iron oxide has much more volume than original volume causing expansion in hardened concrete. This expansion causes cracks and subsequent spalling of concrete from surface.

It is recognised that steel embedded in heavily alkaline medium with pH-values from 9 upwards will not rust. During the setting of concrete, when cement hydrates, the chemical reaction between cement and water in the concrete causes calcium-hydroxide to be formed as a by product alongwith gel. This ensures the concrete to be alkaline producing a pH value of more than 12.6 which renders the steel surface passive.

Protection of the reinforcement from corrosion is thus provided by the alkalinity of the concrete, which leads to a passivating of the steel. The reserve of calcium hydroxide is very high, so there is no need to expect steel corrosion even when water penetrates to the reinforcement of the concrete. Because of this, even the occurrence of small cracks (upto 0.1 mm width) or blemishes in the concrete need not necessarily lead to damage.

Environmental influences like saline or brackish waters or soils or carbondioxide from atmosphere in particular will reduce the concrete's high pH environment and thus will remove the passivating effect. In conjunction with existing humidity, the result is corrosion of the reinforcement.

Compounds, such as sodium benzoate, sodium nitrate etc. can be used to prevent corrosion of reinforcement. A 2 percent benzonate solution in mixing water may be used to prevent corrosion of reinforcement. Sodium nitrate has been found to be effective in preventing corrosion of steel in concrete containing calcium chloride.

4.15 BONDING ADMIXTURES

Fresh concrete when laid over an old surface, due to shrinkage in the freshly laid concrete there is tendency to pull this newly laid concrete itself away from old surface. For this reason old surface is prepared thoroughly before new concrete is laid by way of hacking the old surface with wire brush and then cleaning with water so that aggregate surfaces are exposed to make sufficient bond with freshly laid concrete. A neat cement paste slurry is often applied to old surfaces before laying fresh concrete to cater for adequate paste for bonding as well to make up the gap created due to plastic shrinkage of fresh concrete. In situations where such measure is not adequate for required bonding between old and new surface, the bonding admixture can be used to join two surfaces.

There are two types of bonding admixtures available. Metallic to which a chemical is added can act as bonding admixture. These particles when comes in contact with fresh concrete oxidizes and expands. The tiny finger like projections that thrust out into both the old and new concrete bind them together.

The second type of bonding admixtures are synthetic latex bonding admixtures which essentially consist of highly polymerized synthetic liquid resins dispersed in water. The commonly used bonding admixtures are made from natural rubber, synthetic rubber or any of a large number of organic polymers or copolymers. The polymers may include polyvinyl chloride, polyvinyl acetate etc. They are water emulsion and when they coalesce to make bond, they release water which is absorbed at the pores of the concrete and later used up for hydration.

SAQ 2

a) In what ways "superplasticizers" are superior to ordinary "plasticizers"

b) Discuss advantages of using expansion producing admixtures.

c) Explain why $CaCl_2$ is more effective with RHC than with OPC.

4.16 COMMONLY AVAILABLE ADMIXTURES IN INDIAN MARKET

a) **Plasticizers and Superplasticizer (IS 9103-79)** : Some of the commonly available admixtures in Indian Market are given in Tables 4.1 to 4.5 for your ready references usefull to understand them.

Table 4.1: Plasticizers and Superplasticizer

Product	Description	Dosage	Manufacturer
Zentrament Super BV liquid	* Superplasticizer * Provides high workability * Makes mix pumpable * Reduces compaction effort * Improves strength	0.5-1 % of cement wt.	M/s M C Bouchemie (Ind) Pvt. Ltd., 296, Perin Nariman St. Bombay-1
Centriplast FF 90 liquid	* Universal Superplasticizer on MSF basis * Makes mix pumpable, flowable * High early and final strength * Excellent compatibility with all cement	0.8-1.6 % for flow concrete 1.5-3 % for high early strength concrete	- do -

(Contd...)

Product	Description	Dosage	Manufacturer
Chemicrete (C-5) Superplasticizer liquid	* Makes concrete pumpable * High early and ultimate strength * Acts as accelerator	0.8-1.5 % by wt. of cement	M/s Chemisol Agencies Pvt. Ltd. 41, Princes Street, Bombay-2
Chemicrete (C-4) Plasticizer liquid	* Water reduction * High early strength * Low permeability	0.5 % by wt of cement	- do -
Sikament-FF liquid	* 25% water reduction * 40% increase in 28 days strength * High strength after 8 hours * Increased frost resistance and water tightness	0.6-3 % by wt. of cement	M/s Sika-Qualcrete Pvt. Ltd., 24-B Park Street, Calcutta-16
Conplast 337 liquid	* Increased workability * Higher strength without increase in cement content * Reduced shrinkage, Permeability * Water reduction	1 litre per 100 kg of cement	M/s Fosroc Chemicals (India) Ltd., IV Floor, Shankar House, Bangalore-80

b) **Air Entraining Agents [IS 9103-79, 7861 (Pt II)-81]**

Table 4.2 : Air Entraining Agents

Product	Description	Dosage	Manufacturer
MC-Mischoel LP liquid	* Improves workability * Avoids bleeding, segregate * Resistance to deicing salt	0.05 to 0.1 % by wt of cement	M/s M C Bauchemie
MC-Mischoel AEA liquid	* Mortar plasticizer * Improves bond strength of mortar * Improves coverage of plasters, screeds	0.25-0.4 % cement wt	- do -
Chemicrete (C-1) AEA liquid)	* Improves workability, cohesion * Reduces honey combing, bleeding * Resistance to freeze & thaw	0.3-0.6 % by wt of cement	M/s Chemisol
Fro-Be liquid	* Improves impermeability * Improves workability * Resistance to freeze & thaw * Reduce honey comb, bleeding etc.	0.03 to 0.15 % by wt of cement	M/s Sika Qualcrete
Frioplast A Flomo AEP	* Air Entraining * Water reducing	0.2 to 0.3 % by wt of cement	- do -

c) **Accelerating Admixtures**

Table 4.3 : Accelerating Admixtures

Product	Description	Dosage	Manufacturer
MC-Schnell SDS liquid	* Accelerating agent, quick setting * Rapid strength development * For quick sealing mortar * Underwater concreting	Depending on acceleration reqd.	M/s M C Bouchemie
Sigunit (Powder)	* Set accelerating * Water proofing	2 to 4% by wt of cement	M/s Sika Qualcrete
MC-Schnell OC Powder liquid	* Accelerating agent chloride free * Makes quick demoulding possible * Accelerates the setting time * For high early strength concrete	Depending on acceleration reqd.	M/s M C Bouchemie

d) **Retarding Admixtures**

Table 4.4 : Retarding Admixtures

Product	Description	Dosage	Manufacturer
MC-Retard 060 liquid	* High performance retarding agent * Avoids cold joints * Suitable for slipforming, Ready mixed concrete	0.2 - 1% of cement wt	M/s M C Bouchemie
Zentrament T5 BV liquid	* High performance retarding superplasticizer * Slump for longer time * Delay in setting * Increased workability	0.2-0.5% by wt of cement	M/s M C Bouchemie
Sikament 500 Sikament 600	* Superplasticizer and set retarder * Slump for longer time * High early and ultimate strength	0.6 to 2% by wt of cement	M/s Sika Qualcrete

e) **Waterproofing Compound (IS 2645-75)**

Table 4.5 : Waterproofing Compounds

Product	Description	Dosage	Manufacturer
MC-Special DM Powder	* Integral waterproofing compound * Increases workability	1 % by wt of cement	M/s M C Bouchemie
Dichtament DM liquid	* High performance waterproofing agent * Makes concrete water tight * Allows higher dispersion and plasticity	0.3 to 0.5% by wt of cement	- Do -
Chemicrete (C-3) Integral Water proofing	* Integral waterproofer	2% by wt of cement	M/s Sika Qualcrete
Plastocrete N	* Integral waterproofer	0.5% by wt of cement	M/s Sika Qualcrete
Noleck CP	- do -	1.5% by wt of cement	- Do -

4.17 SUMMARY

Concrete made with conventional ingredients, namely Cement, FA, CA and water, can normally perform satisfactorily provided strict quality control is adhered to while making concrete. However, in practice, it may not be possible to reach to the expected level of quality control.

Concrete has to perform well against severe environmental conditions. Ordinary concrete in such situations does not perform satisfactorily. Also there may be typical application areas where one or more specific properties of fresh and hardened concrete have to be altered.

In all these cases if an extra ingredient known as "admixture" is added in addition to basic ingredients as mentioned above, concrete is found to perform satisfactorily. Even present day's challenge of making "High Performance Concrete" can be met by using admixtures only.

In this section detailed discussions on few such important admixtures are carried out.

4.18 KEY WORDS

Admixtures : It is an additional material which addes to the green concrete to give some required property.

Accelerators : Agents which are used for increasing the rate of reaction.

Gas forming : Formation of form in a concrete by injecting gas.

Plasticizing : To make a green Concrete in Plastic State.

RHC : Rapid Hardening Cement.

Retarders : Agents used for decreasing the rate of reaction.

4.19 ANSWERS TO SAQs

Cheek your answers of all SAQs with preceding text.

FURTHER READING

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7) F.M. Lea, 1970, *The Chemistry of Cement and Concrete*, 1970.

8) Murdock, L.J., *The Workability of Concrete*, Magazine of Concrete Research No. 1960.

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