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Admixtures for concrete

preface:

In the 1940s and 1950s, efforts to support the introduction of admixtures in concrete on a large scale met with many resistance because there was little understanding of their mode of action, leading to many unsatisfactory experiences.
Today, the situation is different. Admixtures have become such an important part of concrete that in the near future the definition of concrete should be revised to include admixture as a primary component of concrete mixtures.

The recognition that properties of concrete, in both the fresh and hardened states, can be modified by adding certain materials to concrete mixtures has been responsible for the large growth of the concrete admixtures industry during the last 50 years. Hundreds of products are being advertised today. In some countries it is common that 70 to 80 percent of all concrete production contains one or more admixtures. Therefore, it is important for civil engineers to have some information about the properties of admixtures for better selection and application in concrete works.
Generally, admixtures are used in concrete to improve workability, accelerate or retard setting time, control strength development, and improve the durability to frost action, thermal cracking, alkali-aggregate expansion, sulfate attack, and corrosion of the reinforcement. Important classes of concrete admixtures, their physical-chemical characteristics, mechanism of action, applications, and side effects are described in this chapter.

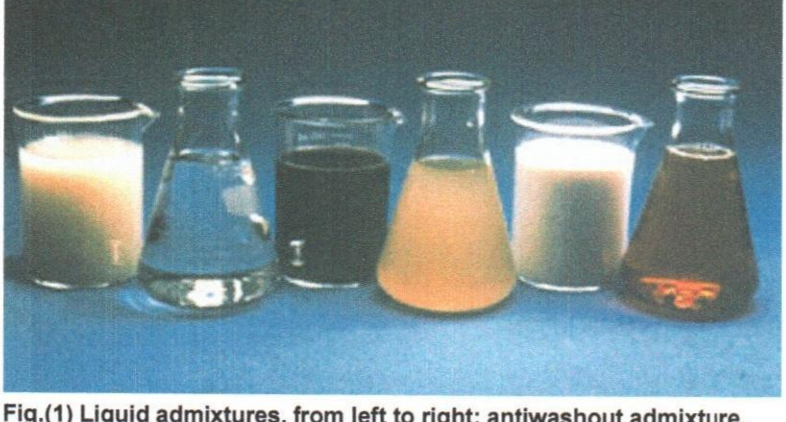


Fig.(1) Liquid admixtures, from left to right: antiwashout admixture, shrinkage reducer, water reducer, foaming agent, corrosion inhibitor, and air-entraining admixture.

Importance of admixtures:

ASTM C 125 defines an admixture as a material other than water, aggregates, hydraulic cements, and fiber reinforcement that is used as an ingredient of concrete or mortar and added to the batch immediately before or during mixing.
Admixtures are chemicals which are added to concrete at the mixing stage to modify some of the properties of the mix. Admixtures should never be regarded as a substitute for good mix design, good workmanship, or use of good materials.

The important properties of concrete, in both the freshly made and hardened states, can be modified by application of admixtures in which that gave such an indication to the admixture industry that within 20 years after the beginning of development of the industry in the 1940s, nearly 275 different products were advertised in England and 340 in Germany.

Today, most of the concrete production contains one or more admixtures; it is estimated that in the developed countries some 80 to 90 percent of concrete produced contains chemical admixtures.

The reason for developing of production of concrete admixtures offered a great physical and economic benefits with respect to concrete. These benefits maked it possible to use wide range of matrial in the production of concrete admixtures with improved many physical properties such as workability,durability,permability,etc.

Admixtures, although not always cheap, do not necessarily represent additional cost because their use can result in economical savings for example,it reduce in the cost of labour required to concrete compaction , or improve durability without taking additional measures .it should be ensured that properly used admixtures will be beneficial to concrete. In most developed countries, admixtures have become essential component of concrete same as cement, aggregate and water.

Functions:

The most common benefits for using admixtures in fresh or hardened concrete are:

- Increase workability without increasing water content or decrease water content at the same workability.
- Retard or accelerate time of initial setting.
- To adjust the setting time.
- Reduce or prevent settlement.
- Improve penetration and Pumpability of the concrete.
- Reduce Segregation in grouts.
- High Early Strength.

- Produce non-skid Wearing Surface.
- Improve finishability.
- To reduce the total cost of the materials used in the concrete.
- Increase Durability of Concrete by increasing its resistance to freezing and atmospheric factors.
- To accelerate the rate of strength development at early ages.
- To Inhibit the Corrosion of Reinforcement.
- Reduce Heat of Hydration.
- To compensate for poor aggregate properties.
- Strengthen the bond between old and new concrete.
- Increase the weight of the concrete per cubic meter.
- Production of light weight concrete.
- Give Color to concrete to be used for architectural purposes.
- Decrease capillary flow of water and make it impermeable.
- To obtain high strength concrete.
- Control expansion caused by aggregate –alkali reaction.
- Control slump loss of concrete.
- Reduce cost of concrete.
- Reduce bleeding.
- Reduce drying shrinkage.
- To increase bong strength between concrete and steel reinforcement.
- Increase the resistance of concrete to impact and abrasion.
- Increase resistance to chemical attack.

General requirements for using of concrete admixtures:

- It shall not have adversely effect on concrete and steel reinforcement.
- Calcium chloride or chloride-based admixtures should not be added at all to reinforced concrete,prestressed concrete or concrete with buried matrial.
- The benefits resulting from the use of admixtures should be appropriate with the increase of costs.
- The suitability and effectiveness of any of admixtures must be checked in lab or experimental mixtures especially when large projects are undertaken .
- If two or more types of admixtures are used at the same concrete mix they must be present adequate information to show the extent of their effectiveness with each other and to verify their compatibility.
- Note that the behavior of admixtures mixed with highly sulfate-resistant cements varies than in the case of portland cement.therefore,sufficient information should be

available on the extent of performance of proper admixtures with different types of cement.

- Admixtures must be supplied packed in drums or airtight containers with the name printed on it ;commercial production date,shell life as well as certificate of properties of the admixtures supplied and compliance with the relevant standard specifications.admixtures should be stored in a way that protects them from moisture, sunlight and heat.

Types of admixtures:

1. **Chemical admixtures** - Accelerators, Retarders, Water-reducing admixture, Super Plasticizers, Air entraining agents etc.

Chemical admixtures are commonly classified by their function in concrete but Often they have some additional action. These admixtures are the most important and The most common types of agent used in the field of concrete and they are specialized in Reducing water mixing and controlling the hardening of concrete by delaying or Accelerating. The classification of ASTM C 494-
(*Standard specification for chemical admixtures for concrete*) divides the **water reducing and set controlling** admixtures into seven types is as follows:

- Type A—Water-reducing admixtures or plastisizer
- Type B—Retarding admixtures,
- Type C—Accelerating admixtures,
- Type D—Water-reducing and retarding admixtures,
- Type E—Water-reducing and accelerating admixtures,
- Type F—High range Water-reducing admixtures or superplastisizer
- Type G—Water-reducing, high range, and retarding admixtures

1.1 **Water-reducing admixtures (plasticizer) :**

Water reducers can be modified to give varying degrees of retardation while others do not significantly affect the setting time.
According to ASTM C 494-10, admixtures which are only water-reducing are called Type **A**(TYPE A water reducer can have little affect on setting time), but if the water-reducing properties are associated with retardation, the admixture is classified as Type **D**. There exist also water-reducing and accelerating admixtures (Type **E**)

but these are of little interest.
The two main groups of admixtures of Type **A** are:
(a) Lignosulfonic acids and their salts, and
(b) hydroxylated carboxylic acids and their salts.
The modifications and derivatives of these do not act as retarders, and may even behave as accelerators they are therefore of Type **A** or **E**.

The effectiveness of water-reducing admixtures with respect to strength varies considerably with the composition of cement, being greatest when used with cements of low alkali or low C3A content.

Generally, The typical dosage of a plasticizer varies from 200 mℓ to 450 mℓ per 100 kg of cementitious material. the dosage per 100 kg of cement is lower in mixes with a high cement content.
Some water-reducing admixtures are more effective when used in mixes containing pozzolana than in Portland-cement-only mixes. Whereas an increased dosage of water-reducing admixture increases the workability.

Effect on durability
The straight addition of admixtures of this type does not come any increase in permeability and indeed where the admixture is used to reduce the w/c, then permeability is considerably reduced.

Effect on bleeding
Water reducers decrease, increase, or have no effect on bleeding, depending on the chemical composition of the admixture. A reduction of bleeding can result in finishing difficulties on flat surfaces when rapid drying conditions are present.

Effect on shrinkage
Admixture of this type when used as workability aids on water reducers do not adversely affect the shrinkage but invariably increase shrinkage.

Effect on creep
Materials of this type of admixture have no deleterious effect on the creep of concrete but invariably increase creep.

Detrimental effect
- While using water reducing agent. Care must be taken in controlling the air content in the mix. Most water-reducing agent entrain air due to their surfactant properties.
- At high dosages of lignosulphonate material, retardation of the mix occurs.

Applications of Water Reducing Concrete Admixtures:

The application of the type of admixtures are as follows:

- When concrete pours are restricted due to either congested reinforcement or this sections.
- b) When harsh mixes are experienced such as those produced with aggregates (crushed). Then considerable improvement in the plastic properties of concrete can be obtained.
- c) When required strengths are difficult to obtain within specified maximum cement content and where early lifting strengths are required.
- d) By addition of this admixture in concrete cement economics of about 10% can be obtained.

These admixtures are used for following purposes:

1. To achieve a higher strength by reduce the quantity of mixing water,decreasing the water cement ratio at the same workability,reduce cement content or increase slump.
2. To achieve the same workability by decreasing the cement content so as to reduce the heat of hydration in mass concrete.
3. To increase the workability so as to ease placing in accessible locations.
4. For concretes of equal cement content, air content, and slump, the 28-day strength of a water-reduced concrete containing a water reducer can be 10% to 25% greater than concrete without the admixture.
5. Typical water reducers reduce the water content by approximately 5% to 10%.
6. Plasticizers are usually based on lignosulphonate, which is a natural polymer, derived from wood processing in the paper Industry.

1.2 Super plasticizers:

Superplasticizers, also called high range water-reducing admixtures because of their ability to reduce three to four times the mixing water in a given concrete mixture compared to normal water-reducing admixtures,it is the most effective type of water-reducing admixture and called Type F by ASTM.and there exist also a high range water-reducing and set-retarding admixture classified as Type G. Superplasticizers developed in the 1970s and have found wide acceptance in the concrete construction industry.

They can greatly reduce water demand and cement contents and make low water-cement ratio, high-strength concrete with normal or enhanced workability. A water reduction of 12% to 30% can be obtained through the use of these admixtures. The reduced water content and water-cement ratio can produce concretes with (1) ultimate compressive strengths in excess of 70 MPa , (2) increased early strength gain, (3) reduced chloride-ion penetration, and (4) other beneficial properties associated with low water-cement ratio concrete.

The quantity of the superplasticizer is generally specified by the supplier. In the absence of such data. A dose of 1 to 6 liters per cubic meter of concrete may be used. If they are used in excess of the specified quantity, the rate of evolution of heat is increased, but the total heat of hydration is not much affected. Superplasticisers are added immediately before use. Some of the examples of superplasticisers are: 1- sulphonated melamine formaldehyde Condensates, 2- naphthalene sulphonate formaldehyde condensates, 3- modified lignosulphonate, 4- sulfonic-acid esters and carbohydrate esters.

Superplasticizer are used to produce *flowing* concrete in situations where placing inaccessible locations,areas of congested reinforcement,in floor or pavement slabs or where very rapid placing is required. A second use of superplasticizer is in the production of very high-strength concrete, using normal workability but a very low water/cement ratio.Fig.2 illustrates these two applications of superplasticizers.

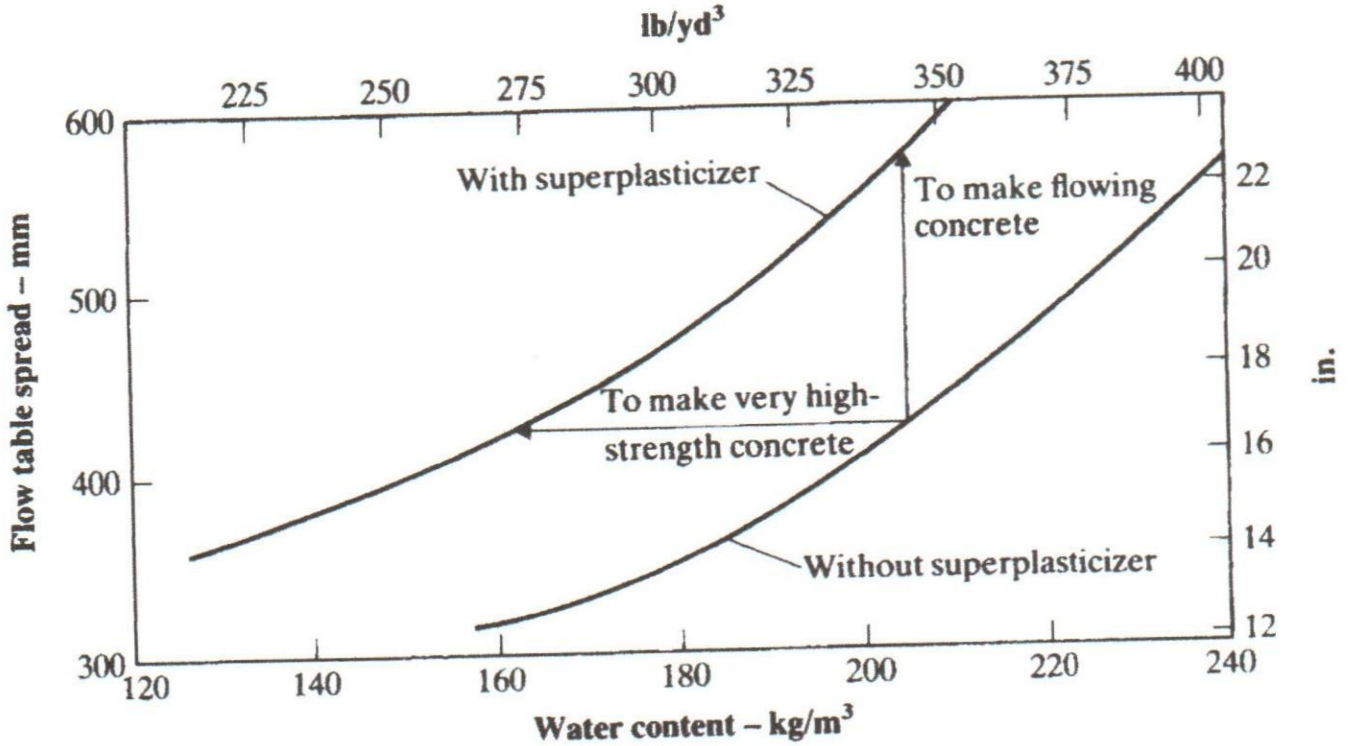
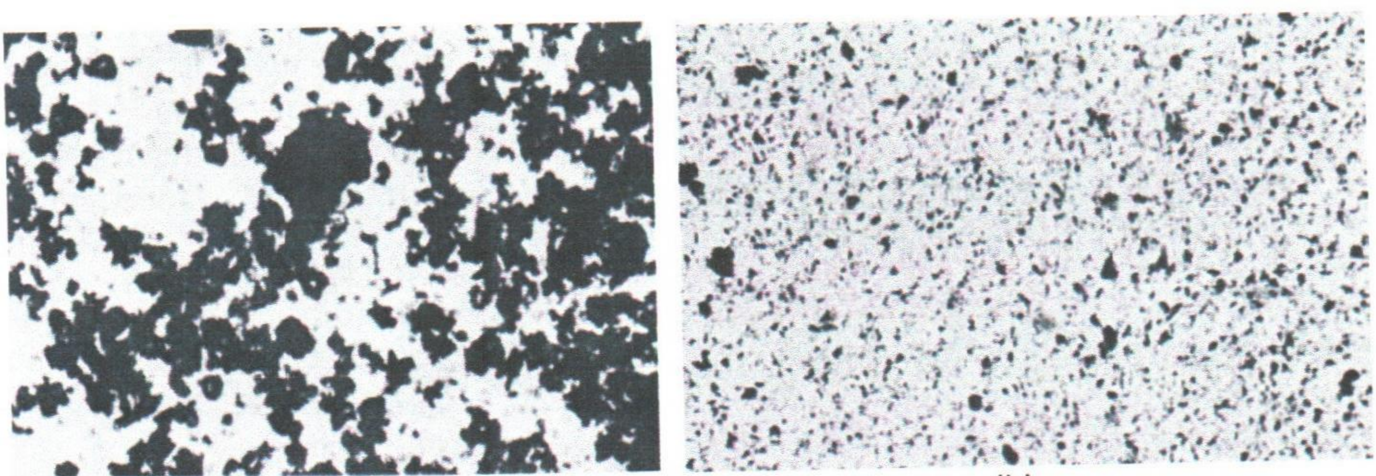


Fig.2: typical relation between flow table spread and water content of concrete made with and without admixtures.

Superplasticizer cause cement to spread through the action of the sulfonic acid being absorbed on the surface of cement particles. Causing them to become negatively charged.This increase the workability at a given water/cement ratio,and raising the slump to 75mm to 200mm.The resulting flowing concrete is cohesive and not causing bleeding or segregation,especially if reduce coarse aggregate and increase fine aggregate by 4 to 5 percent.it should be remember in designing of formwork the flowing concrete can exert full hydrostatic pressure Fig3(explain the mechanism of action of superplasticizer).



(a) (b)

Fig.3: a) cement particles with no superplasticizer present. (b) Cement particles with superplasticizer present

When the purpose is to achieve a high strength at a given workability the use of superplsticizer can reduce water 25 to 30 percent compared to water-reduce admixture,then the use of low water/cement ratio is possible so that very high strength concrete is obtained see fig.4 .Strength as high as 100 mpa at 28 days, when the water/cement ratio is 0.28 are achieved, with curing even higher strength is possible.For increasing strength at later ages than 28 days superplsticizer can be used with partial placement of cement by fly ash.

The workability gained by this admixture is of short duration and that cause high slump loss, after 30 to 90 minutes the workability return to normal.For this reason the superplasticizer should be added to the mix quickly before placing .

Superplasticizer do not affect the setting of concrete except in the case of cements with a very low C_3A content when there may be excessive retardation. The use of this admixture with air entrain admixture can reduce the amount of entrianed air and modify the air-void system.

Disadvantage of superplasticizers:

The only disadvantage of superplasticizer is their high cost which is due to the expense of Manufacturing a product with a high molecular mass.

Advantages:

a) The concrete using this admixture can be placed with little or no compaction and is not subject to excessive bleeding or segregation.

b) They can be used as high dosages became they do not markedly change the surface tension of water.

c) It does not significantly affect the setting of concrete except that when used the cements having a very low C3A content.

d) They do not influence shrinkage, creep modulus of elasticity or resistance to freeing to thawing.

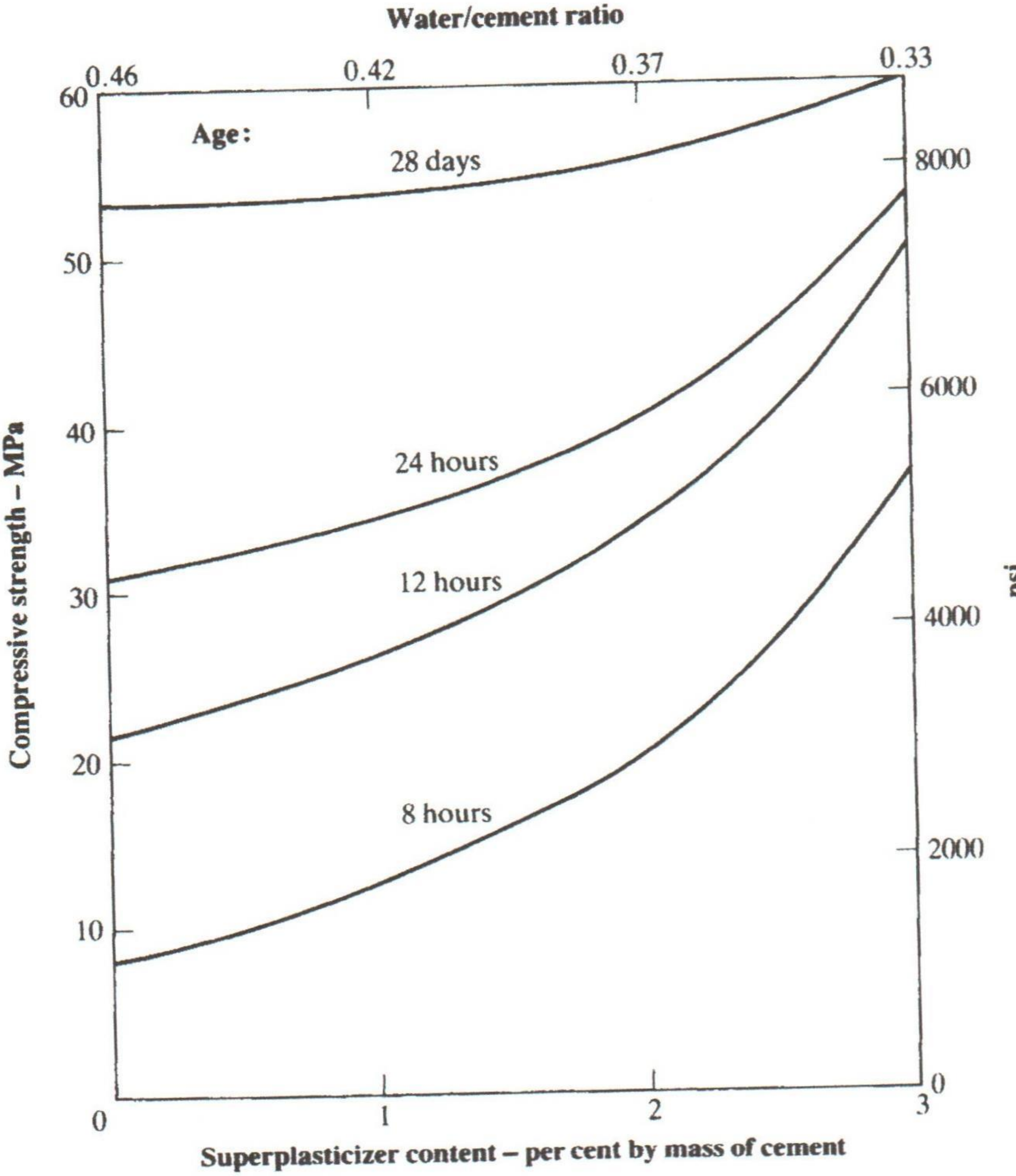


Fig.4: The influence of the additional of superplasticizer on the early strength of Concrete made with a cement content of 370kg/m3 and cast at room Temp.All the concretes of the same workability and made with rapid Hardening portland cement.

1.3 Accelerating admixtures:

According to the report by ACI Committee 212:
Accelerating admixtures are useful for modifying the properties of portland cement concrete

Accelerating admixtures are used to reduce the initial setting time of concrete. They speed up the process of initial stage of hardening of concrete hence they are also called as accelerators. These accelerators also improves the strength of concrete in it early stage by increasing the rate of hydration.

Main uses of Accelerating Concrete Admixtures:

Earlier hardening of concrete is useful in several situations such as

- These admixtures are suitable for concreting in winter conditions
- During any emergency repair work
- In case of early removal of formwork
- Less period of curing
- During any Emergency repair works.

Disadvantages of Accelerating Concrete Admixtures

- It has increased drying shrinkage
- It offers reduced resistance to sulphate attack
- CaCl2 high risk of corrosion of steel – not permitted in reinforced concrete
- It is more expensive and less effective

Some of the accelerating admixtures are triethenolamine, calcium formate, silica fume, calcium chloride, finely divided silica gel etc. Calcium chloride is the cheap and commonly used accelerating admixture.

Chloride Calcium for accelerating admixture:

Is the best known and most widely used accelerator.
Calcium chloride admixture to concrete has many beneficial effects on some properties of concrete Fresh and hardened, which shows the effect of calcium chloride on concrete as follows:

- **Final and initial setting time:**
  It notices a decrease in the initial setting time, as well as its effect on the cohesion resistance between the steel and concrete at normal and low temperatures when calcium chloride is added to the mixture Concrete is 2% by weight of cement.

- **Early strength:**
  Calcium chloride gives concrete an early strength without reducing the final strength And this is an important advantage for many reasons including:
  1. Reduce period of formwork removal to half.
  2. The speed of removal of formwork lead to early use of the building.

- **Protection from effect of cold and damp weather**: the percentage of increase in Concrete strength is affected by temperature, where the required maximum strength is at a temperature of 37.7°C, there is a clear change in the resistance if the temperature is decreased.
  Here, the benefit of calcium chloride appears, as it makes concrete look like in Moderate weather the benefit is due to the increase in the heat generated from the Reaction and its stability, although the use of calcium chloride at normal temperatures,
  It leads to obtaining the required resistance at half the time, except that it was Observed that the percentage increase in the resistance is greater for low Temperatures, for example in Temperature of 21.1°C Concrete treated with calcium Chloride obtains resistance in one day is equivalent to what untreated concrete earns In three days.

- **It should** be noted that calcium chloride is not considered an anti-freeze and therefore preventive measures must be followed 3 days in very cold weather for a while.

- **Additional benefits of calcium chloride:**
  1. Increases the final strength of concrete in addition to increasing the early strength, and experiments has shown an increase of 9% over a three-year period.
  2. Increasing the workability of fresh concrete while maintaining the water-cement ratio (w/c) obtaining high density concrete.
  3. Increasing the resistance of the concrete surface to abrasion and by using calcium chloride the resulting resistance will be similar to that obtained from processing with wet burlap for three days.
  4. Reduces m**oi**sture loss during mixing and helps facilitate mixing with water.

- **Special notes on the use of calcium chloride:**
  1. Calcium chloride is added to water not water added to calcium chloride as pouring water over calcium chloride will produce it forms a dry surface layer that is difficult to dissolve.

2. Calcium chloride should not be added more often of the required proportions.
3. Calcium chloride is used in the form of a solution or powdered powder.
4. There must be no contact between calcium chloride and dry cement.
5. When used in hot areas, the concrete must be covered.
6. Increases the rate of resistance of the resulting concrete and added calcium chloride in the first three days, but the rate of this increase decreases in the following days.

- **Many other pro properties of concrete** are affected to various degrees by **calcium chloride**. ageneral guide is provided in table1.

Practical considerations

- All chloride-based accelerators promote corrosion of reinforcing steel and should not Be used in:
  1. reinforced concrete
  2. water-retaining structures
  3. prestressed concrete
  4. steam-cured concrete

- Overdosing with these materials can cause instant setting of the concrete resulting in equipment damage.
- Accelerators work more effectively at lower ambient temperatures.

TABLE I.
How calcium chloride affects various other properties of concrete

Property	Approximate change
Heat of hydration at 1 day	30 percent increase[a]
Tensile strength at 28 days	Slight decrease
Flexural strength at 7 days	10 percent increase[b]
Flexural strength at 28 days	0 to 15 percent decrease[b]
Volume change	0 to 15 percent increase
Watertightness	Improved at early age; no improvement later
Cavitation	Surface loss reduced by half
Efflorescence	Appearance hastened
Sulfate resistance	Aggravated[c]
Alkali-silica reaction	Increased up to 100 percent[d]
Discoloration	Trowel burns in flatwork, or mottled effect[e]

a After about 1½ days it decreases

b Depending on curing conditions, amount of calcium chloride, and the brand, type and amount of cement used

c But not with Type V cement and adequate air content

d But little effect if proper precautions taken to use pozzolan and low-alkali cement

e Depending on material selection, proportioning, mixing, placing, finishing, curing. Mottled effect develops in concrete that is not moist cured, producing light spots on dark background with cement of low alkali content or dark spots on light background with cement of high alkali content.

1.4 Retarding admixtures:

Retarding admixtures are used to delay the rate of setting of concrete. High Temperatures of fresh concrete (30°C) are often the cause of an increased rate of Hardening that makes placing and finishing difficult. One of the most practical methods Of counteracting this effect is to reduce the temperature of the concrete by cooling the Mixing water and/or the aggregates. Retarders do not decrease the initial temperature Of concrete. The bleeding rate and bleeding capacity of concrete is increased with Retarders. Retarding admixtures are useful in extending the setting time of concrete, but they are often also used in attempts to decrease slump loss and extend workability, Especially prior to placement at elevated temperatures. The detail of this approach is Shown in Fig.5

There are three types of retarding admixtures recognized by ASTM: Type B, which Simply retards the hydration of the Portland cement; Type D, which not only retards The hydration but also acts to disperse the cement and thereby provide water Reduction; and finally Type G, which is a high range water reducing and set retarding Admixture.

The amount of water reduction for an ASTM C 494 (AASHTO M 194) Type B retarding admixture is normally less than that obtained with a Type A water reducer. Type D admixtures are designated to provide both water reduction and retardation. In general, some reduction in strength at early ages (one to three days) accompanies the use of retarders. The effects of these materials on the other properties of concrete, such as shrinkage, may not be predictable. Therefore, acceptance tests of retarders should be made with actual job materials under anticipated job conditions. The classifications and components of retarders are listed in Table 2.

Uses:

- When placing concrete in hot weather, particularly when the concrete is pumped.
- To prevent cold joints due to duration of placing.
- In concrete which has to be transported for a long time.
- In case of large concrete pours.
- Concrete construction involving sliding formwork.

Chemical type for Retarding Concrete Admixture:

- Unrefined lignosulphonates containing sugar, which of course the component responsible for retardation.
- Hydroxyl carboxylic acid and their salts
- Carbohydrates including sugar
- Soluble zinc

- Soluble borates etc.

Mode of action :
It is thought that retarding admixtures are absorbed on to the C3A phase in cement forming a film around the cement grains and presenting or reducing the reaction with water. After a while thus film breaks down and normal hydration proceeds. This a simple mixture and there is a reason to believe that retards also interact with C3S since retardation can be extended to a period of many days.

Advantage of Retarding Concrete Admixture :

- The hydroxyl carboxylic acid type admixture normally produces concrete having a slightly lower aim content them that of a control mix.
- Materials of this class (lignosulphonate containing sugar and derivatives of hydroxyl carboxylic acid) in some cases have a much higher dispersing effect and hence water reducing capacity.
- Durability increases.

Detrimental effect:

- When lignosulphonate based material used, then the air content might be 0.2 to 0.3% higher unless materials of the tributyle phosphate type are added.
- As the water content increases, so there is a tendency for drying shrinkage.

Type of admixture	Desired effect	matrial
Retarders (ASTM C 494 and AASHTO M 194, Type B)	Retard setting time	Lignin Borax Sugars Tartaric acid and salts
Water reducer and retarder(ASTM C 494 and AASHTO M 194, Type D)	Reduce water content (minimum 5%) and retard set	See water reducer typeA
Water reduce –high range and retarder (ASTM C 494 and AASHTO M 194, Type G)	Reduce water content (minimum 12%) and retard set	See superplasticizer and water reducer

Table 2: concrete admixture by classification

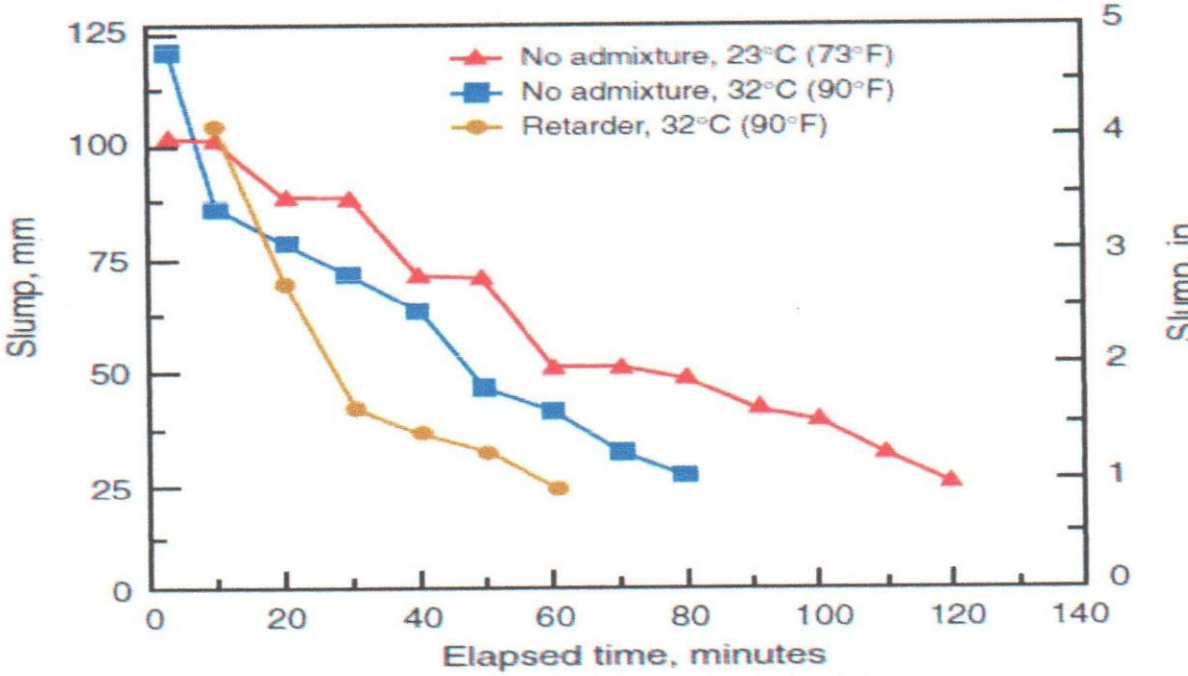


Fig.5: Slump loss at various temperatures for conventional concretes prepared with and without set-retarding admixture

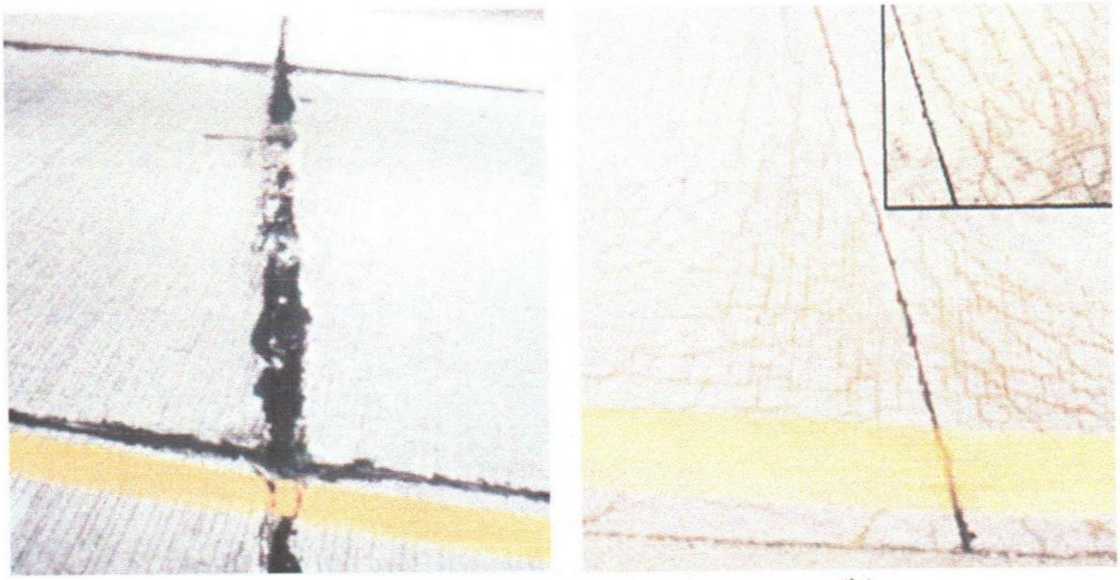
1.5 Air Entraining Agent Concrete Admixtures:

Air-entraining admixtures are used to introduce and stabilize microscopic air bubbles in concrete. Air entrainment will improve the durability of concrete exposed to cycles of freezing and thawing (Fig.6). Entrained air greatly improves concrete's resistance to surface scaling caused by chemical de icers (Fig.7).

The presence of quantities of entrained air in the concrete mixture is substitute of the presence of additional quantities of fine sand in the mixture ,for this reason it is preferable to use air entrain admixture in the mix that suffer from lack of presence of fine sand.. Furthermore, the workability of fresh concrete is improved significantly, and segregation and bleeding are reduced or eliminated.

Air-entrained concrete contains minute air bubbles that are distributed uniformly throughout the cement paste. Entrained air can be produced in concrete by use of an air-entraining cement, by introduction of an air entraining admixture, or by a combination of both methods. An air-entraining cement is a portland cement with an air-entraining addition interground with the clinker during manufacture. An air-entraining admixture, on the other hand, is added directly to the concrete materials either before or during mixing.

The primary ingredients used in air-entraining admixtures are listed in Table 3.



(a) (b)

Fig.6: a) Frost damage (crumbling) at joints of a pavement. b) frost indued crack near joint.

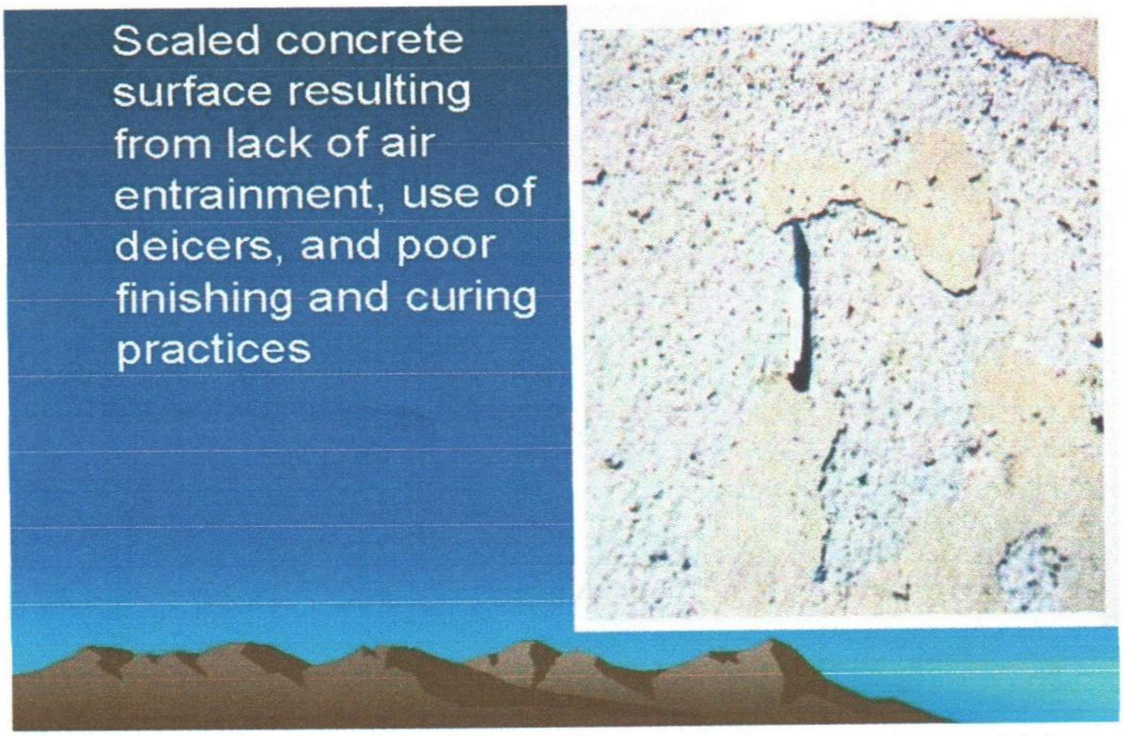


Fig.7: Scaled concrete surface resulting from lack of air entrainment, use of deicers, and poor finishing and curing practices.

Type of admixture	Desired effect	matrial
Air entrain admixtures(ASTM C 260 and AASHTO M 154)	Improve durability in freeze-thaw,deicer,sulfate,and alkali-reactive environments Improve workability	Salts of wood resins(vensol resins),some syntheticdetergents,slats of sulfonated lignin,salts of petroluim acids,salts of protenaceous matrial,fatty and resinous acids and their salts,alkybbenzene sulfonates,salts of sulfonated hydrocarbons.

Table 3: concrete admixture by classification

Practical considerations of air entrain admixture:

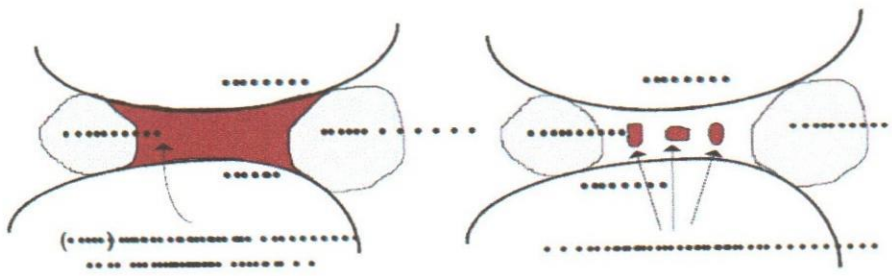
- Air entrainment may reduce the strength of concrete and overdosing can cause major loss of strength. As a rule-of-thumb, 1% air may cause a strength loss of 5%. It is therefore important that mixes be specially designed for air entrainment and that the percentage of air entrained during construction is monitored.
- Because the doses are so small, special dispensers and accurate monitoring are required.
- Different types and sources of cement/cement extenders may result in the entrainment of different amounts of air for the same dose and mix proportions.
- A change in cementitious content, in the grading or proportions of the fine fractions of sand will normally alter the volume of air entrained.
- The amount of air entrained may depend on the source and grading of sand in concrete.
- Forced-action mixers entrain larger volumes of air than other types.
- Increasing ambient temperature tend to reduce the volume of air entrained.
- The use of ground granulated blastfurnace slag (GGBS) and fly ash (FA) tends to reduce the amount of air entrained.
- Duration of mixing can also affect air

1.6 Permeability reducing admixtures:

The purpose of using this admixture is:
It helps to resist penetration of water into the concrete, but it does not completely prevent penetration of water. and to get to a high degree of permeability resistence,the

design of the concrete mixture should be taken care of, then the two processes of compaction and treatment should be taken care of.
Concrete permeability can be improved through the following three axes:

- **Water Proofing Agents:**
  It prevents concrete from absorbing rainwater and contact surface water a percentage ranging from 0.1% to 0.4% of Wax is added, such as petroleum oils and waxes. Polymeric matrials are also used for this purpose,in the form of concrete surface paints to fill air gaps and capillary cracks on the surface.
- **Superplasticizers:**
  It is useful here indirectly, as it works to reduce the mixing water and thus obtain At the lowest possible ratio of voids in the mixture, the permeability of the concrete is improved.
- **Pozzolanic Materials (Filling Effect):**
  Pozzolanic substances are substances that react with free calcium hydroxide resulting from the reaction Cement with water, forming insoluble compounds such as silicon and calcium aluminates which are silica fume works to fill the internal gaps and capillary pores, an example is silica fume.
  It is a substance consisting of very fine grains with a surface area of about four to five times By product. The surface area of cement (20000 cm2/g) which is a by product manufacture of silicon and ferrosilicon alloy.
  Silica dust reacts with hydroxide calcium forms hydrated calcium silicate, which does not dissolve and leads to the reduction of internal cavities and the capillary pores as shown in the fig.8.



Hydration process for concrete containing silica fume

Hydration process for concrete containing Portland cement

Fig.8: The role of silica dust in improving the permeability of concrete

1.7 Antiwash admixtures:

Antiwashout admixtures increase the cohesiveness of concrete to a level that allows limited exposure to water with little loss of cement. This allows placement of concrete in water and under water without the use of tremies. The admixtures increase the viscosity of water in the mixture resulting in a mix with increased thixotropy and resistance to segregation. They usually consist of water soluble cellulose ether or acrylic polymers.

The effect of this type of admixture can be summarized as follows:

- Concrete is able to withstand the segregation of the concrete.
- Improve the strength of concrete to bleeding.
- Concrete containing this admixture is detrimental to workability and self-leveling.
- Sililozic sort of this admixture helps to retard initial and final setting time,in which the initial setting time can reach up to 18 hours and increasing final setting time to nearly 48 hours.
- This admixture has reduced the pressure resistance of the poured concrete underwater by 20% compared to strength of the same concrete cast-in place.

1.8 Coloring admixtures (pigments):

Coloring admixtures are the pigments which produce color in the finished concrete. The admixtures used to produce color should not affect the concrete strength. Generally coloring admixtures are added to cement in a ball mill, then colored cement can be obtained which can be used for making colored concrete. Some of the coloring admixtures and their resultant colors are tabulated below.

Admixture	Color obtained
Iron or Red oxide	Red
Hydroxides of iron	Yellow
Barium manganite and Ultramarine	Blue
Chromium oxide and chromium hydroxide	Green
Ferrous oxide	Purple
Carbon black	Black
Manganese black , Raw umber	Brown

Table4: colouring admixtures and their resultant colours.

1.9 Corrosion Preventing Admixtures: Corrosion of steel in reinforced concrete structure is general and it is severe when the structure is exposed to saline water, industrial fumes, chlorides etc. To prevent or to slow down the process of corrosion preventing admixtures are used. Some of the corrosion preventing admixtures used in reinforced concrete are sodium benzoate, sodium nitrate, sodium nitrite etc.

2. Mineral Admixtures:

Puzzolana may be defined as a siliceous material which
whilst itself possessing no cementitious properties, either processed or unprocessed and in finely divided form, reacts in the presence of water with lime at normal temperatures to form compounds of low solubility having cementitious properties. Puzzolanas may be natural or artificial, fly ash being the best known in the latter category. Before the advent of cement these were used with lime to make concrete. Currently its principal use is to replace a proportion in cement when making concrete. The advantages gained are economy, improvement in workability of concrete mix with reduction of bleeding and segregation. Other advantages are greater imperviousness, to freezing and thawing and to attack by sulphates and natural waters.In addition the disruptive effects of alkali-aggregate reaction and heat of hydration are reduced. It is generally held that the addition of natural puzzolanas reduce the leaching of soluble compounds from concrete and contributes to the impermeability of the concrete at the later ages.The main

justification for using puzzolanas is the possibility of reducing costs. If they are to reduce costs, they must be obtained locally and it is for this reason that they have not so far been much in use.

Classification:
Puzzolanas are classified as natural and artificial.
2.1 Natural pozzolans*:* All puzzolanas are rich in silica and alumina and contain only a small
quantity of alkalis. Following are some of the naturally occurring puzzolanas:

- Clays and shales.
- Diatomaceous earth and opaline cherts and shales.
- Volcanic tuffs and pumicites.
- Rhenish and Bavarian trass.

2.2 Artificial pozzolans:

2.2.1 Pozzolanic: A pozzolan is a material which, when combined with calcium hydroxide (lime), exhibits cementitious properties. Pozzolans are commonly used as an addition (the technical term is "cement extender") to Portland cement concrete mixtures to increase the long-term strength and other material properties of Portland cement concrete and in some cases reduce the material cost of concrete. Examples are:

1. Fly ash
2. Silica fume
3. Surkhi
4. Rice husk ash

The activity of pozzolan:

When mixed with ordinary Portland cement the silica of the puzzolana combines with the free lime released during the hydration of cement. This action is called puzzolanic action.The puzzolanic activity is due to the presence of finely divided glassy silica and lime which produces calcium silicate hydrate similar to as produced during hydration of Portland cement.The silica in the puzzolana reacts with the lime produced during hydration of Portland cement

and contributes to development of strength. Slowly and gradually additional calcium silicate hydrate is formed which is a binder and fills up the space, gives impermeability, durability and ever increasing strength.

Hydration of Portland cement may be expressed as

$C3S + H2O$ _ C-S-H + $Ca(OH)2$

(Calcium silicate hydrate) (Lime)

Lime produced combines with silica of puzzolana

$Ca(OH)2 + SiO2$ _ C-S-H

(Silica)

2.2.1.1 Fly ash:

Fly ash is the residue from the combustion of pulverized coal collected by mechanical or electrostatic separators from the flue gases or power plants. It constitutes about 75 per cent of the total ash produced. The properties and composition of fly ash vary widely, not only between different plants but from hour to hour in the same plant.

Fly ash includes substantial amounts of silicon dioxide (SiO2) (both amorphous and crystalline) and calcium oxide (CaO). Toxic constituents include arsenic, beryllium, boron, cadmium, chromium, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium, and vanadium.

Specification of fly ash:

Fly ash consists of spherical glassy particles ranging from 1 to 150 _m, most of which passes through a 45 _m sieve. More than 40 per cent of the particles, which are under 10 microns contribute to early age strength (7 and 28 day). Particles of sizes 10 to 45 microns reacts slowly and are responsible for gain in strength from 28 days to one year.

In addition to economic and ecological benefits, the use of fly ash in concrete improves its workability, reduces segregation, bleeding, heat evolution and permeability, inhibits alkali-aggregate reaction, and enhances sulfate resistance. Even though the use of fly ash in concrete has increased in the last 20 years, less than 20% of the fly ash collected was used in the cement and concrete industries.

One of the most important fields of application for fly ash is PCC pavement, where a large quantity of concrete is used and economy is an important factor in concrete pavement construction.

2.2.1.2 Silica fume:

The terms condensed silica fume, microsilica, silica fume and volatilized silica are often used to describe the by-products extracted from the exhaust gases of silicon, ferrosilicon and other metal alloy furnaces. However, the terms microsilica and silica fume are used to describe those condensed silica fumes that are of high quality, for use in the cement and concrete industry.

The effect of silica fume can be explained through two mechanisms—the pozzolanic reaction and the micro filler effect. Like other pozzolanas, silica fume does not have any binding property, but it reacts with Ca(OH2) liberated on hydration of cement. When water is added to cement, hydration occurs forming two primary products. The first product is calcium-silicatehydrate (C-S-H) gel, that is cementitious and binds the aggregate together in concrete and the other product is calcium hydroxide Ca(OH2) Silica fume reacts with calcium hydroxide to produce more aggregate binding C-S-H gel, simultaneously reducing calcium hydroxide. The net result is an increase in strength and durability. The second mechanism is through the micro filler effect. The extreme fineness of silica fume allows it to fill or pack the microscopic voids between cement particles and especially in the voids at the surface of the aggregate particles where the cement particles cannot fully cover the surface of the aggregate and fill all the available space.

Advantages of using silica fume:

There are various advantages in using silica fume such as reduction in bleeding and segregation of fresh concrete, and improvements in the strength and durability characteristics of hardened concrete.It has been found that Silica Fume improves compressive strength, bond strength, and abrasion resistance; reduces permeability of concrete to chloride ions; and therefore helps in protecting reinforcing steel from corrosion, especially in chloride-rich environments such as coastal regions.

2.2.2 Cementitious: These have cementing properties themselves. For example: Ground granulated blast furnace slag (GGBFS)

2.2.2.1 Ground blast furnace slag(GGBFS):

Ground granulated blast-furnace slag is the granular material formed when molten iron(1400-1600°C) blast furnace slag (a by-product of iron and steel making) is rapidly chilled by immersion in water. It is a granular product, highly cementitious in nature and, ground to cement fineness, hydrates like Portland cement.

(Blast-Furnace Slag: A by-product of steel manufacture which is sometimes used as a substitute for Portland cement. In steel industry when iron ore is molted, then in the molted state all the impurities come at its surface which are removed called slag. It consists mainly of the silicates and aluminosilicates of calcium, which are formed in the blast furnace in molten form simultaneously with the metallic iron. Blast furnace slag is

blended with Portland cement clinker to form PORTLAND BLASTFURNACE SLAG CEMENT). The specifications of GGBFS are given in Table 5.

Constituents	Per cent
Manganese oxide,max	5.5
Magnesium oxide,max	17.0
Sulphide sulfer,max	2.0
Glass content ,min	85.0

Table.5: specification of GGBFS (IS:12089).

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

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

Use of GGBFS significantly reduces the risk of damages caused by alkali-silica reaction (ASR), provides higher resistance to chloride ingress, reducing the risk of reinforcement corrosion, and provides higher resistance to attacks by sulfate and other chemicals.

Final remarks of using admixtures:

The various admixtures discussed in this chapter offer many advantages.
But care is necessary in order to realize the full benefits of admixtures.
Some admixtures whose performance in known from experience at normal temp. may behave differently at high or very low temp.
Admixtures can now be used in combinations and those whose performance is known when used separately may not be compatible when used together.a reputable supplier will give technical data for the particular application and advise on possible side effects,but it is essential to carry out tests on trial mixes for any combinations of admixtures using the actual constituents of the mix to be used so as to avoid any loss of effectiveness. Also adequate supervision should be provided at the batching state to ensure that the correct dosage of the admixtures are administered and discharged at the correct part of the mixing cycle.

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