Admixtures

A material other than water, aggregates, or cement that is used as an ingredient of concrete or mortar to control setting and early hardening, workability, or to provide additional cementing properties.

Why is admixture used?

Over decades, attempts have been made to obtain concrete with certain desired characteristics such as high compressive strength, high workability, and high performance and durability parameters to meet the requirement of complexity of modern structures.

The properties commonly modified are the heat of hydration, accelerate or retard setting time, workability, water reduction, dispersion and air-entrainment, impermeability and durability factors.

Types of Admixtures

Chemical admixtures - Accelerators, Retarders, Water-reducing agents, Super plasticizers, Air entraining agents etc.

Mineral admixtures - Fly-ash Blast-furnace slag, Silica fume and Rice husk Ash etc

1. Water-reducing admixture / Plasticizers:

These admixtures are used for following purposes:

1. To achieve a higher strength by decreasing the water cement ratio at the same workability as an admixture free mix.
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. Water reduction more than 5% but less than 12%
5. The commonly used admixtures are Ligno-sulphonates and hydrocarbolic acid salts.
6. Plasticizers are usually based on lignosulphonate, which is a natural polymer, derived from wood processing in the paper industry.

Actions involved:

1. **Dispersion:**

Surface active agents alter the physic chemical forces at the interface. They are adsorbed on the cement particles, giving them a negative charge which leads to repulsion between the particles.

Electrostatic forces are developed causing disintegration and the free water become available for workability.

2. **Lubrication:**

As these agents are organic by nature, thus they lubricate the mix reducing the friction and increasing the workability.

3. **Retardation:**

A thin layer is formed over the cement particles protecting them from hydration and increasing the setting time. Most normal plasticizers give some retardation, 30–90 minutes

3. Accelerators:

An admixture which, when added to concrete, mortar, or grout, increases the rate of hydration of hydraulic cement, shortens the time of set in concrete, or increases the rate of hardening or strength development.

Accelerating admixtures can be divided into groups based on their performance and application:

1. **Set Accelerating Admixtures**,

Reduce the time for the mix to change from the plastic to the hardened state.

Set accelerators have relatively limited use, mainly to produce an early set.

2. **Hardening Accelerators**,

Which increase the strength at 24 hours by at least 120% at 20ºC and at 5ºC by at least 130% at 48 hours. Hardening accelerators find use where early stripping of shuttering or very early access to pavements is required. They are often used in combination with a high range water reducer, especially in cold conditions.

Calcium chloride is the most effective accelerator and gives both set and hardening characteristics. However, is limited due to acceleration of **corrosion of steel reinforcement** and decrease resistance of cement paste in a **sulfate environment**. For this reason, it should not be used in concrete where any steel will be embedded but may be used in plain unreinforced concrete.

Chloride-free accelerators are typically based on salts of **nitrate, nitrite, formate and thiocyanate**. Hardening accelerators are often based on high range water reducers, sometimes blended with one of these salts.

Accelerating admixtures have a relatively limited effect and are usually only cost effective in specific cases where very early strength is needed for, say, access reasons. They find most use at low temperatures where concrete strength gain may be very slow so that the relative benefit of the admixture becomes more apparent.

In summary, a hardening accelerator may be appropriate for strength gain up to 24 hours at low temperature and up to 12 hours at ambient temperatures. Beyond these times, a high range water reducer alone will usually be more cost-effective.

4. Set Retarders:

The function of retarder is to delay or extend the setting time of cement paste in concrete. These are helpful for concrete that has to be transported to long distance, and helpful in placing the concrete at high temperatures.

When water is first added to cement there is a rapid initial hydration reaction, after which there is little formation of further hydrates for typically 2–3 hours. The exact time depends mainly on the cement type and the temperature. This is called the **dormant period** when the concrete is plastic and can be placed. At the end of the dormant period, the hydration rate increases and a lot of calcium silicate hydrate and calcium hydroxide is formed relatively quickly. This corresponds to the setting time of the concrete.

Retarding admixtures delay the end of the dormant period and the start of setting and hardening. This is useful when used with plasticizers to give workability retention. Used on their own, retarders allow later vibration of the concrete to prevent the formation of cold joints between layers of concrete placed with a significant delay between them.

The mechanism of set retards is based on absorption. The large admixture anions and molecules are absorbed on the surface of cement particles, which hinders further reactions between cement and water i.e. retards setting. The commonly known retards are **Calcium Ligno-sulphonates** and **Carbohydrates derivatives** used in fraction of percent by weight of cement.

5. Air Entrained Admixtures:

An addition for hydraulic cement or an admixture for concrete or mortar which causes air, usually in small quantity, to be incorporated in the form of minute bubbles in the concrete or mortar during mixing, usually to increase its **workability** and **frost resistance.**

Air-entraining admixtures are **surfactants** that change the surface tension of the water. Traditionally, they were based on fatty acid salts or vinsol resin but these have largely been replaced by synthetic surfactants or blends of surfactants to give improved stability and void characteristics to the entrained air.

Air entrainment is used to produce a number of effects in both the plastic and the hardened concrete. These include:

- Resistance to freeze–thaw action in the hardened concrete.
- Increased cohesion, reducing the tendency to bleed and segregation in the plastic concrete.
- Compaction of low workability mixes including semi-dry concrete.
- Stability of extruded concrete.
- Cohesion and handling properties in bedding mortars.

Mineral Admixtures

Types of Mineral Admixtures

1. Cementitious

These have cementing properties themselves. For example:

- Ground granulated blast furnace slag (GGBFS)

2. 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

- Fly ash
- Silica Fume
- Rice Husk Ash
- Metakaolin

Pozzolanic Action:

The additive act in three ways

1. Filler
2. Nucleating
3. Pozzolanic

1. Filler:

These additives/admixtures are finer than cement, so when added to concrete they occupy the small pores previously left vacant.

2. Nucleating:

These fine particles accelerate the rate of hydration and precipitation starts.

3. Pozzolanic:

When cementing material reacts with water the following reaction take place:

$$C2S + H\ CSH + CH$$

$$C3S + H\ CSH + CH$$

CSH is responsible for strength while CH is a soluble material reacts and dissolves in water leaving behind pores.

So when admixture is added

$$SiO3 \text{ or } Al2O3+CH\ CSH$$

Thus it reduces the amount of CH & increase CSH

Conditions to Declare a Material Pozzolan:

- Having silica + Alumina oxide+ ferrous oxide more than 70%.
- Surface area on normal admixture is more than 300m²/kg.
- Surface area should be more than cement used.

3. Ground Granulated Blast Furnace Slag (GGBFS)

Ground granulated blast-furnace slag is the **granular material** formed when molten iron blast furnace slag (a by-product of iron and steel making) is rapidly chilled (quenched) 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).

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.

Benefits:

1. **Durability**
2. GGBFS cement is routinely specified in concrete to provide protection against both sulphate attack and chloride attack
3. GGBFS is also routinely used to limit the temperature rise in large concrete pours. The more gradual hydration of GGBFS cement generates both lower peak and less total overall heat than Portland cement.
4. **Appearance**
5. In contrast to the stony grey of concrete made with Portland cement, the near-white color of GGBFS cement permits architects to achieve a lighter colour for exposed fair-faced concrete finishes, at no extra cost.
6. **Strength**
7. **Co**ncrete containing GGBFS cement has a higher ultimate strength than concrete made with Portland cement. It has a higher proportion of the strength-enhancing calcium silicate hydrates

(CSH) than concrete made with Portland cement only, and a reduced content of free lime, which does not contribute to concrete strength. Concrete made with GGBFS continues to gain strength over time, and has been shown to double its 28 day strength over periods of 10 to 12 years.

4. Fly Ash:

The finely divided residue resulting from the combustion of ground or powdered coal. Fly ash is generally captured from the chimneys of coal-fired power plants; it has POZZOLANIC properties, and is sometimes blended with cement for this reason.

Fly ash includes substantial amounts of silicon dioxide (SiO_2) (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.

Class F Fly Ash:

The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash. This fly ash is pozzolanic in nature, and contains less than 10% lime (CaO). The glassy silica and alumina of Class F fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime, with the presence of water in order to react and produce cementitious compounds.

Class C Fly Ash:

Fly ash produced from the burning of younger lignite or subbituminous coal, in addition to having pozzolanic properties, also has some self-cementing properties. In the presence of water, Class C fly ash will harden and gain strength over time. Class C fly ash generally contains more than 20% lime (CaO). Unlike Class F, self-cementing Class C fly ash does not require an activator. Alkali and sulfate (SO_4) contents are generally higher in Class C fly ashes.

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.

5. Silica Fume

- By-product of semiconductor industry

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.

Silica fume was first ‘obtained’ in Norway, in 1947, when environmental restraints made the filtering of the exhaust gases from the furnaces compulsory.

Silica Fume consists of very fine particles with a surface area ranging from 60,000 to 150,000 ft^2/lb or 13,000 to 30,000 m^2/kg, with particles approximately 100 times smaller than the average cement particle. Because of its extreme fineness and high silica content, Silica Fume is a highly effective pozzolanic material. Silica Fume is used in concrete to improve its properties. 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.

6. Rice Husk Ash:

This is a bio waste from the husk left from the grains of rice. It is used as a pozzolanic material in cement to increase durability and strength.

The silica is absorbed from the ground and gathered in the husk where it makes a structure and is filled with cellulose. When cellulose is burned, only silica is left which is grinded to fine powder which is used as pozzolana.

Source:

http://www.aboutcivil.org/concrete-technology-admixtures.html