



# Indonesian Journal of Multidisciplinary Research



Journal homepage: <http://ejournal.upi.edu/index.php/IJOMR/>

## Review on Admixture for Civil Engineer

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### ABSTRACTS

The purpose of this study was to report a review on admixture. This review is important for giving ideas and knowledge about admixture, from the definition to the practical application, to practitioners in the civil engineering field. In short, water-reducing and set-controlling admixtures have proven themselves to be useful tools in the precast industry. They can significantly reduce the water-cement ratio (w/c), decreasing the use of cement, altering the set time to help in production, improving workability, and decreasing permeability. Their use does not, however, preclude the use of good concrete practices such as curing. The type of admixture and dosage recommended varies depending on manufacturers, and it must be considered with other materials. We also discussed the specific operations with the admixture supplier to ensure that the process can be done in the most economical condition.

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### ARTICLE INFO

#### **Article History:**

*Submitted/Received 09 Apr 2021*

*First revised 21 Aug 2021*

*Accepted 22 Aug 2021*

*First available online 23 Aug 2021*

*Publication date 01 Sep 2021*

#### **Keyword:**

*Admixture,  
Chemical admixtures,  
Civil engineer,  
Education.*

## 1. INTRODUCTION

Admixture is one of the ingredients of concrete mix (Al-Kheetan et al., 2018; Maiti et al., 2006). The reason for the large growth in the use of admixtures is that they are capable of importing considerable physical and economic benefits with respect to concrete (Sogancioglu et al., 2013; Ramanathan et al., 2013). Admixtures have been designed to improve concrete construction (Plank et al., 2015). They are not a simple solution as poor mix design or sloppy concrete practice. It should be stressed that, while properly used admixtures are beneficial to concrete, they are no remedy for poor quality mix ingredients, use of incorrect mix proportions, or poor workmanship in transporting, placing, and compaction.

Here, the purpose of this study was to report a review on admixture. This review is important for giving ideas and knowledge about admixture, from the definition to the practical application.

## 2. DEFINITION OF ADMIXTURES

An addition is “a material that is interground or blended in limited amounts into a hydraulic cement during manufacture” and found in ASTM C 219. An admixture (additive) is “a material other than water, aggregates, hydraulic cement and fiber reinforcement that is used as an ingredient of cement or mortar and is added to the batch immediately before or during its mixing” as reported in ASTM C 125.

Precautions concerning the choice and usage of admixtures are

- (i) Require admixtures to conform to ASTM specifications (performance based).
- (ii) Follow manufacturer’s instructions regarding dosage but check results.
- (iii) Ensure reliable procedures are established for accurate batching of the admixture.
- (iv) Take into account effects on other concrete properties.

## 3. SET CONTROLLING ADMIXTURE

Chemical admixtures are used in concrete mixtures to produce particular engineering properties such as rapid hardening, water-proofing, or resistance to cold (Alsadey, 2018; Manoharan et al., 2009). Chemical Admixtures for Concrete surveys recent developments in admixture technology, explaining the mechanisms by which admixtures produce their effects, the various types of admixtures available.

According to the American Concrete Institute (ACI), an admixture is defined as “a material other than water, aggregates, cementitious materials, and fiber reinforcement, used as an ingredient of a cementitious mixture to modify its freshly mixed, setting or hardened properties, and that is added to the batch before or during its mixing.”. Figure 1 shows the photograph of mixtures.

There are two broad categories:

- (i) Chemical admixtures – water-soluble additions
- (ii) Mineral admixtures – finely ground solid materials



**Figure 1.** Photograph of mixture.

#### **4. CHEMICAL ADMIXTURES**

Chemical admixtures are the ingredients in concrete other than Portland cement, water, and aggregate that are added to the mix immediately before or during mixing (Ondova *et al.*, 2012). Producers use admixtures primarily to reduce the cost of concrete construction; to modify the properties of hardened concrete; to ensure the quality of concrete during mixing, transporting, placing, and curing; and to overcome certain emergencies during concrete operations.

Successful use of admixtures depends on the use of appropriate methods of batching and concreting. Most admixtures are supplied in ready-to-use liquid form and are added to the concrete at the plant or the Jobsite. Certain admixtures, such as pigments, expansive agents, and pumping aids are used only in extremely small amounts and are usually batched by hand from premeasured containers.

The effectiveness of an admixture depends on several factors including type and amount of cement, water content, mixing time, slump, and temperatures of the concrete and air. Sometimes, effects similar to those achieved through the addition of admixtures can be achieved by altering the concrete mixture-reducing the water-cement ratio, adding additional cement, using a different type of cement, or changing the aggregate and aggregate gradation.

#### **5. FIVE FUNCTIONS CHEMICAL ADMIXTURES**

Admixtures are classed according to function. There are five distinct classes of chemical admixtures: air-entraining, water-reducing, retarding, accelerating, and plasticizers (superplasticizers) (Gupta & Singh, 2018). All other varieties of admixtures fall into the specialty category whose functions include corrosion inhibition, shrinkage reduction, alkali-silica reactivity reduction, workability enhancement, bonding, damp proofing, and coloring.

Air-entraining admixtures, which are used to purposely place microscopic air bubbles into the concrete, are discussed more fully in Air-Entrained Concrete.

- (i) **Water-reducing admixtures** usually reduce the required water content for a concrete mixture by about 5 to 10 percent. Consequently, concrete containing a water-reducing admixture needs less water to reach a required slump than untreated concrete. The treated concrete can have a lower water-cement ratio. This usually indicates that a higher-strength concrete can be produced without increasing the amount of cement. Recent advancements in admixture technology have led to the development of mid-range water reducers. These admixtures reduce water content by at least 8 percent and tend to be more stable over a wider range of temperatures. Mid-range water reducers provide more consistent setting times than standard water reducers.
- (ii) **Retarding admixtures**, which slow the setting rate of concrete, are used to counteract the accelerating effect of hot weather on the concrete setting. High temperatures often cause an increased rate of hardening which makes placing and finishing difficult. Retarders keep concrete workable during placement and delay the initial set of concrete. Most retarders also function as water reducers and may entrain some air in concrete.
- (iii) **Accelerating admixtures** increase the rate of early strength development, reduce the time required for proper curing and protection, and speed up the start of finishing operations. Accelerating admixtures are especially useful for modifying the properties of concrete in cold weather.
- (iv) **Superplasticizers**, also known as plasticizers or high-range water reducers (HRWR), reduce water content by 12 to 30 percent and can be added to concrete with a low-to-normal slump and water-cement ratio to make high-slump flowing concrete. Flowing concrete is highly fluid but workable concrete that can be placed with little or no vibration or compaction. The effect of superplasticizers lasts only 30 to 60 minutes, depending on the brand and dosage rate, and is followed by a rapid loss in workability. As a result of the slump loss, superplasticizers are usually added to the concrete at the Jobsite.
- (v) **Corrosion-inhibiting** admixtures fall into the specialty admixture category and are used to slow corrosion of reinforcing steel in concrete. Corrosion inhibitors can be used as a defensive strategy for concrete structures, such as marine facilities, highway bridges, and parking garages, that will be exposed to high concentrations of chloride. Other specialty admixtures include shrinkage-reducing admixtures and alkali-silica reactivity inhibitors. The shrinkage reducers are used to control drying shrinkage and minimize cracking, while ASR inhibitors control durability problems associated with alkali-silica reactivity.

## 6. TYPES OF WATER-REDUCING AND SET-CONTROLLING ADMIXTURES

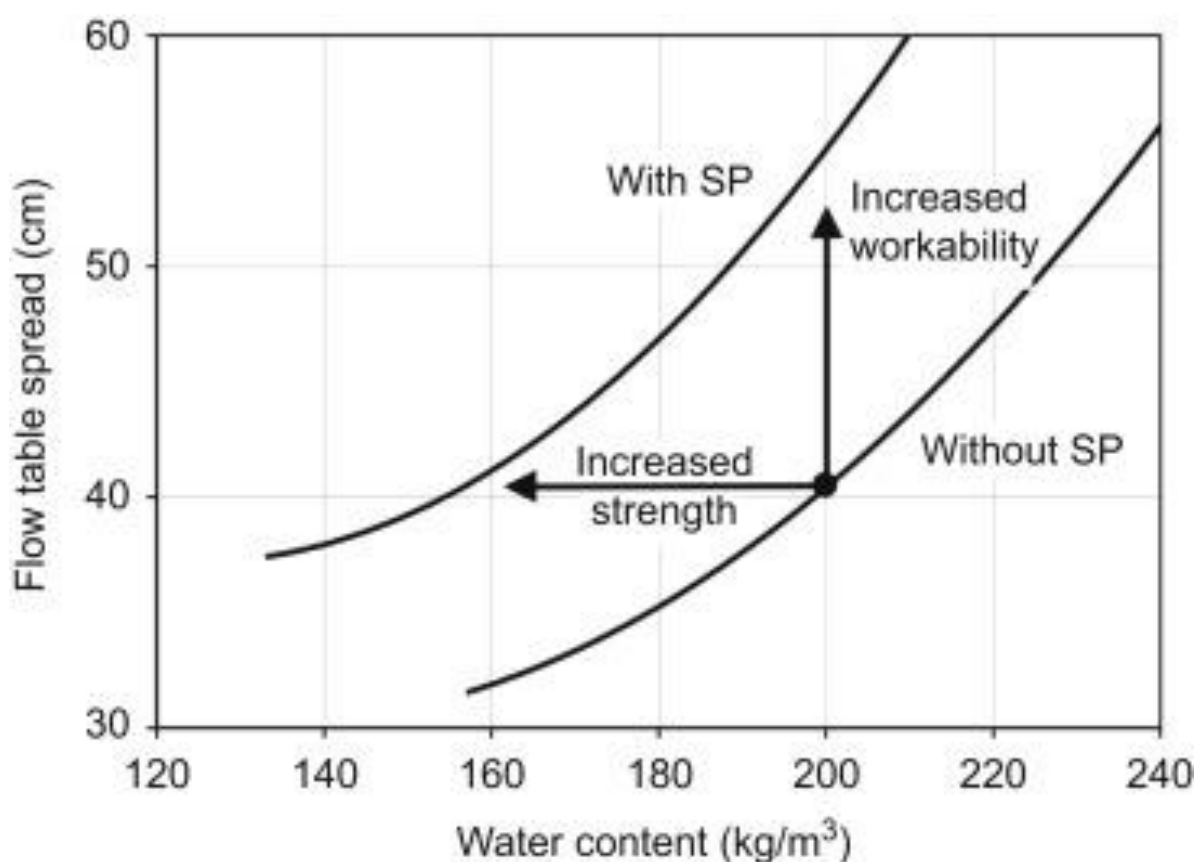
The American Society of Testing and Materials (ASTM) specification C494 covers eight types of chemical admixtures (**Table 1**). This table shows the type of admixture. Each of these admixture types is defined by the range at which it decreases to water (see **Figure 2**). Types A, D, and E must reduce the water content by at least 5%. Types F and G are high-range water-reducing (HRWR) admixtures and are required to reduce the water content of a concrete mix by at least 12%. This may, in some circumstances, decrease the water content of a mix by 30% or more. Types B and C have no water-reducing requirements.

There is also a class of water reducers called mid-range water-reducing (MRWR) admixtures that reduce the water content from about 6% to more than 12% while maintaining slump and avoiding excessive retardation. Generally, this class of water-reducing admixtures falls into either the Type A or F category. Mid-range water reducers were developed to fill in the gap between Type A admixtures capable of producing a 5-in. slump and Type F admixtures

capable of producing a 12-in. slump. They have proven very effective with the use of fly ash and other cement substitutes.

**Table 1.** Types of water reducing and set controlling admixture.

No	Type	Definition
1.	Type A	Water-reducing admixtures
2.	Type B	Retarding admixtures
3.	Type C	Accelerating admixtures
4.	Type D	Water-reducing and retarding admixtures
5.	Type E	Water-reducing and accelerating admixtures
6.	Type F	Water-reducing, high-range admixtures
7.	Type G	Water-reducing, high-range, and retarding admixtures
8.	Type S	Specific performance admixtures



**Figure 2.** Effect of water content on flow table spread.

### 6.1. Type A – Water-Reducing Admixtures

Type A water reducers typically decrease the water content of a concrete mix by 5 to 10%. With all admixtures, the results and dosage rates will vary with the cement and other materials used. A typical dosage rate for Type A is between 2 and 6 fl oz per 100 lbs of cementitious materials (130 to 390 mm per 100 kg). Most Type A water reducers are composed of organic materials that act as set retardants. Other ingredients are added during manufacture to provide a “normal” setting time. Excessive dosage rates will retard the setting time of concrete. Dosage rates should conform to the manufacturer’s recommendations and be tested in trial batches.

## 6.2. Type B – Retarding, and Type D – Water-Reducing and Retarding Admixtures

Retarding admixtures cause a decrease in the hydration rate of hydraulic cement and an increase in the setting time of concrete. Retarders are used to offset the effect of high temperatures and improve the workability of concrete in warmer temperatures. Benefits of retarders include reduced cold joints and better finish in hot weather. While retarding admixtures can be beneficial, they are not a substitute for good hot-weather concreting procedures.

Some retarders can stop or significantly slow the hydration of portland cement. These are known as hydration stabilizers. Hydration stabilizers are used primarily in the ready-mixed industry to control the set time of concrete wash water, unused or returned concrete, and for long hauls. Hydration stabilizers may be beneficial in concrete that is steam cured. Forecasters who use ready-mixed concrete should check with their suppliers to see what admixtures are available.

## 6.3. Type C – Accelerating, and Type E – Water-Reducing and Accelerating Admixtures

Accelerators are used to shorten the setting time and to increase early strength development. Precasters can benefit by using accelerators, as they reduce bleeding and allow earlier finishing. Accelerators also increase early strength, which can protect the concrete from freezing, and they allow for faster removal of forms. Accelerators are available in chloride and non-chloride compounds. The use of chloride-based accelerators in reinforced concrete subjected to weathering should be avoided. Accelerators do not act as antifreeze for concrete. Good cold-weather concrete practices must be followed.

## 6.4. Type F – High-Range Water-Reducing, and Type G – High-Range Water-Reducing and Retarding Admixtures

Type F and G admixtures are known as high-range water-reducing (HRWR) admixtures or superplasticizers. They are capable of producing large water reductions or great flowability without causing undue set retardation or entrainment of air in cementitious mixtures. HRWRs must reduce the water content of a concrete mix by at least 12% and may reduce it by more than 30% from a control mix.

The composition of HRWRs has seen a great change during the last several years. In the past, the most common HRWRs consisted of products commonly referred to as melamine (MSFC) or naphthalene (NSFC) based chemicals. A problem with MSFC- and NSFC-based products is they have limited slump-life capabilities. In the past several years, melamine- and naphthalene-based high-range water reducers have been replaced by a new class of chemicals called “polycarboxylates” or PCs. PCs consist of comb-shaped molecules that provide water reduction without affecting setting time. They are highly engineered and provide a wide range of slump-life capabilities. They are also very efficient in producing self-consolidating concrete (SCC).

## 7. MINERAL ADMIXTURE

Mineral admixtures include fly ash (*FA*), silica fume (*SF*), ground granulated blast furnace slag (*GGBS*), metakaolin (*MK*), and rice husk ash (*RHA*) which possess certain characteristics through which they influence the properties of concrete differently (Nedunuri et al., 2020). The reported benefits of mineral admixtures are often associated with the harden properties of concrete; however, mineral admixtures may also influence the properties of wet concrete between the time of mixing and hardening in one or more of the following ways as they may

affect water demand, the heat of hydration, setting time, bleeding, and reactivity (Gökçe et al., 2019). In the authors' view, no literature summarizes the effect of these mineral admixtures on the properties of fresh concrete. Moreover, the effect of mineral admixtures on the durability and the mechanical properties of concrete remained a focus of interest. Nevertheless, the effect of mineral admixtures on the properties of fresh concrete is very important as these properties may affect the durability and mechanical properties of concrete. Comparative studies have been done such as the effect of blast furnace slag and fly ash on the hydration of fresh cement paste, the effect of silica fume (*SF*), metakaolin (*MK*), fly ash (*FA*), and ground granulated blast furnace slag (*GGBS*) on the setting times of high-strength concrete. This paper has been written to summarize the available literature and provide the reader with a distinctive comparative analysis on the effect of mineral admixtures on water demand, the heat of hydration, setting time, bleeding, and reactivity of concrete. Also, the effect of physical and chemical characteristics of fly ash (*FA*), silica fume (*SF*), ground granulated blast furnace slag (*GGBS*), metakaolin (*MK*), and rice husk ash (*RHA*) on the fresh concrete has been reviewed.

## 8. CHEMICAL REACTION OF MINERAL ADMIXTURES WITH ORDINARY PORTLAND CEMENT

*FA* reaction with ordinary Portland cement (OPC) is a two-stage process (Najjar et al., 2017). In the first stage, during the early curing, the primary reaction is with  $\text{Ca(OH)}_2$ ; however, the reaction rate depends on the curing temperature. At room temperature, the slower  $\text{Ca(OH)}_2$  activation minimizes the reaction rate. The effectiveness of the use of fly ash in concrete depends on many factors including the following: (i) the chemical and phase composition of *FA* and OPC; (ii)  $\text{Ca(OH)}_2$  concentration of the reaction system; (iii) the morphology of *FA* particles; (iv) the fineness of *FA* and OPC; (v) the development of heat during the early age of hydration process; (vi) the reduction in mixing water requirements with *FA*.

Variations in chemical composition and reactivity of *FA* affect early-stage properties and the rheology of concrete. It is advised to determine the acceptability of *FA* through trial mixes by considering workability, strength development, and durability. In the second stage, with a continuing supply of moisture, the lime reacts pozzolanically with the *FA* and produces additional hydration products of a fine pore structure.

The pozzolanic reaction may be represented as:

Calcium hydroxide + silica = Tricalcium silicate + water

Calcium hydroxide (lime) depletes with time and its reaction affects the long-term gain of strength in *FA* concrete as compared to ordinary Portland cement concrete; however, despite this reduction, there is sufficient lime to maintain a high pH. It is important to mention that the resulting products due to the addition of *FA* are different from the resultant products formed in OPC concrete. *FA* produces a very much finer pore structure with time presuming there is reached to water to maintain the hydration process. A pH of more than 13 at 20°C (68°F) is required with the lime to start the reaction by decomposing the Si–O–Si link in *FA*.

Unlike *FA* in which Si–O–Si link has to break to make it reactive with lime, *GGBS* requires to be activated to react with lime. *GGBS* due to its glassy structure reacts very slowly with water in the presence of activators. Commonly, sulfates and/or alkalis act as activators, reacting chemically with the *GGBS*. These activators disturb the glassy structure and react to increase the pH of the system up to critical. In contrast to *FA*, *GGBS* only needs a pH level less than 12 and activators. In concrete, due to the hydration of cement,  $\text{Ca(OH)}_2$  is produced and acts as an activator.

*SF* as a pozzolan reacts with  $\text{Ca(OH)}_2$  and about 25% of *SF* can consume most of the  $\text{Ca(OH)}_2$  at 28 days. This is very important as the  $\text{Ca(OH)}_2$  crystals are relatively weak, brittle, and not

cementitious and cracks can easily propagate through regions concentrated with  $\text{Ca}(\text{OH})_2$  crystals, that is, the aggregate cement paste matrix interface.

The calcination process (dehydroxylation) of kaolin is actually a transformation from crystalline to amorphous phase. The amount and type of amorphous phase influence the activity of the additives (Teklay et al., 2014). Two properties comprise the activity of additives: chemical activity (usually pozzolanic) and microfilter effect. The former is sturdily linked to the crystallinity of the source kaolin; that is, well-structured kaolinite is changed into less reactive *MK* (Teklay et al., 2014). Dehydroxylation of kaolinite at atmospheric conditions costs mass loss of 13.76% and in result changes  $\text{SiO}_2 \cdot 2\text{Al}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$  into  $\text{SiO}_2 \cdot 2\text{Al}_2\text{O}_3$ . It is also reported that, after dehydroxylation at  $570^\circ\text{C}$  ( $1058^\circ\text{F}$ ), kaolin completely changes to the amorphous phase and the chemical activity is a linear function of amorphous phase content in its range of 50–100% (Teklay et al., 2014). *MK* of amorphous phase content less than 20% can be considered as inert materials in the pozzolanic activity viewpoint. Amorphous phase contents in *MK* have also influenced the activity strength index (the ratio of the compressive strength of standard mortar cubes, prepared with 80% reference cement plus 20% additive by mass, to the compressive strength of the standard mortar cube prepared with reference cement only, tested at the same age); however, there is no increase in activity strength index by the increase of amorphous phase index above 55%.

The reaction between *RHA* and  $\text{Ca}(\text{OH})_2$  solution yields C–S–H gel. The morphology of C–S–H gel is like congregate, having a large specific area due to the higher porous structure. This C–S–H gel and its large specific area are the main reason for improving the concrete properties with the addition of *RHA*.

## 9. MINERAL ADMIXTURES USED IN CONCRETE AND THEIR IMPORTANCE

The basic components of cement mortar are cement, water, and aggregates. But, often, other substances are added to these three in preparing the cement mortar. The purpose of these additional substances is to improve the quality of the mortar. These substances are collectively called admixtures. Admixtures can be broadly classified into two types – chemical admixtures and mineral admixtures.

Mineral admixtures are basically derived from other substances and not chemically manufactured. Fly ash, blast furnace slag, silica fume are popular examples of mineral admixtures.

## 10. IMPORTANT MINERAL ADMIXTURES AND THEIR AFFECT ON CONCRETE

Fly ash, ground granulated blast furnace slag, and silica fume are the most commonly used mineral admixtures. They have different roles to play in the concrete mix and enhance various properties of the concrete. A comparison of various mineral admixtures based on various properties is shown in **Table 2**.



**Table 2.** Comparison of Various Mineral Admixtures based on Various Properties.

	<b>Fly ash</b>	<b>GGBFS</b>	<b>Silica fume</b>	<b>Rice husk ash</b>	<b>Metakaolin</b>
<b>Physical properties</b>	Greyish, lightweight, and fine particles	White powdery substance heavier than fly ash	Amorphous, very fine particles, heavier than fly ash	Amorphous, very lightweight, fine particles. (Threat to the environment.)	Whitish in color and fine particles.
<b>Chemical composition</b>	20 – 60 % silica 5 – 35 % Al <sub>2</sub> O <sub>3</sub> 1 – 12 % CaO Traces of MgO	28 – 38 % silica 8 – 24 % Al <sub>2</sub> O <sub>3</sub> 30 – 50 % CaO 1 – 18 % MgO	85 % silica 1 % Al <sub>2</sub> O <sub>3</sub> 6 % Fe <sub>2</sub> O <sub>3</sub> 12 % carbon	90 % silica 5 % carbon 3 % K <sub>2</sub> O	Dehydroxilated form of kaolinite clay
<b>Source</b>	A by-product in thermal power plants	A by-product in iron-producing blast furnaces	A by-product in silicon producing electric arc furnaces 3 – 4 parts of cement replacement per 1 part of silica fume	Rice husk	From kaolinite clay
<b>% addition in concrete</b>	Upto 30 % cement replacement	25 – 70 % cement replacement	Better compressive strength and resistance to abrasion	Around 20 % cement replacement	8 – 10 % cement replacement
<b>Advantages of addition</b>	Improves strength and durability of concrete Increased resistance towards chemical attacks Better workability	Improved durability Increased setting time Strength gain continues for a long period of time Reduced risk of damages by alkali-silica reaction Resistant to chloride and sulfate attacks	The reduced permeability of chloride ions Improved workability Reduces bleeding	The heat of hydration of concrete is reduced Permeability of concrete is reduced Improved resistance to chloride and sulfate attacks	Increased compressive & flexural strengths Reduced permeability More resistant to chemical attacks Durability is increased
<b>Availability</b>	Produced in abundance but availability is poor	A sufficient amount of GGBFS is available	A sufficient quantity of silica fume is available	Abundant	Abundant

### 10.1. Admixture-1: Fly Ash

Pulverized coal is combusted in thermal power plants for electricity generation. A by-product of this combustion reaction is fly ash. The electrostatic precipitators (ESPs) used inside chimneys of the power plants remove fly ash before ejecting out the combustion gases into the atmosphere. Fly ash is a very fine particle-like residue, which has pozzolanic properties (See **Figure 3**). Hence it is often blended with cement.

Fly ash consists of silica ( $\text{SiO}_2$ ), alumina ( $\text{Al}_2\text{O}_3$ ), and calcium oxide ( $\text{CaO}$ ) as its major components. Fly ash can be of two types – C type and F type. C type fly ash is rich in calcium and possesses both cementitious and pozzolanic properties whereas F type fly ash is low in calcium content and possesses only pozzolanic properties. The explanations are:

- (i) Fly ash particles are mostly spherical and increase the workability of concrete.
- (ii) The setting time of concrete is also increased by adding fly ash to it. Increased setting time allows better hardening of concrete and finally, a better strength is obtained.
- (iii) Fly ash added to the concrete mix reduces the segregation and bleeding of concrete. Segregation of concrete is a case in which particles of different sizes tend to segregate out. Whereas bleeding of concrete is a situation in which water comes out to the surface of the concrete. Both segregation and bleeding are unwanted.
- (iv) The temperature of fresh concrete rises above normal and when it cools down, cracks may develop. Replacing a certain quantity of cement with fly ash helps to reduce this temperature rise, hence avoiding the chances of cracking of fresh concrete.
- (v) Creep and shrinkage are usually higher in fly ash added concrete because of the increased amount of paste in the concrete (formed due to mass replacement of cement).
- (vi) Sulfate resistance is enhanced.
- (vii) Alkali aggregate reaction is inhibited.



**Figure 3.** Fly ash.

## 10.2. Admixture-2: Ground Granulated Blast Furnace Slag (GGBFS)

Blast furnace slag is a by-product of the iron extraction process from iron ore (See **Figure 4**). Amongst all mineral admixtures, blast furnace slag has the highest specific gravity (2.8 to 3.0). Typically, the slag fineness is slightly more than that of the cement.

There are various types of slag possible like air-cooled slag, expanded or foamed slag, granulated slag, and pelletized slag. Among these, only the granulated slag is commonly used as a mineral admixture. It is a highly reactive form of slag and is usually quenched to form a hardened matter which is then ground into particles of fineness almost the same as that of cement. Hence the name, ground granulated blast furnace slag.

GGBFS possesses both cementitious and pozzolanic properties. An activator is needed to hydrate the slag. The explanations are:

- (i) GGBFS increases the initial setting time of the concrete. But, it does not alter the workability of the concrete much because its fineness is almost the same as that of the cement.
- (ii) The rate of strength gain of concrete is diminished by the replacement of cement in the concrete with GGBFS.
- (iii) The ultimate strength gain is improved by slag replacement and also the durability of the concrete is increased.
- (iv) Concrete uses in marine purposes are highly prone to chemical attack and corrosion. GGBFS is a very good admixture in this regard because it increases resistance to these attacks.
- (v) However, concrete with GGBFS is reported to have higher carbonation rates than normal Portland cement concrete.



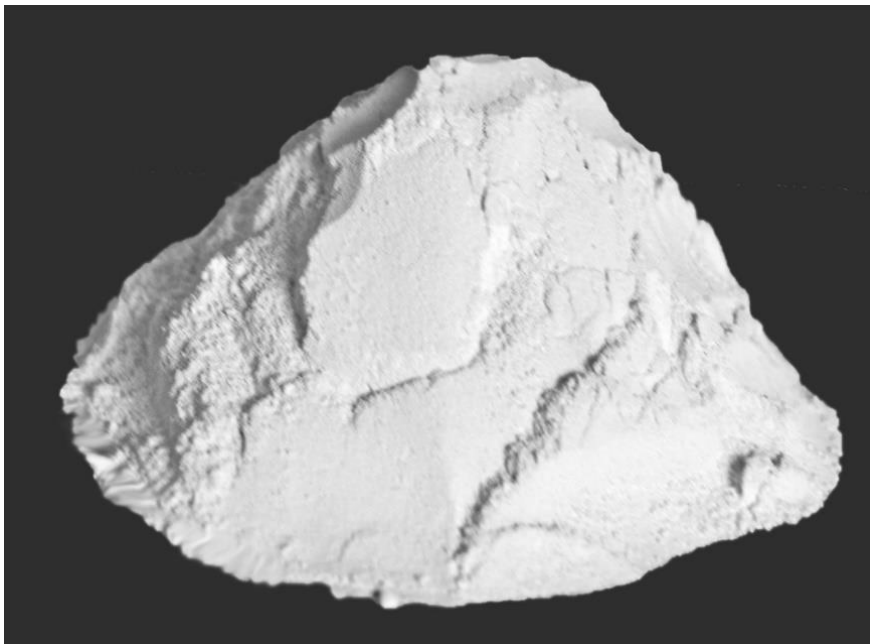
**Figure 4.** Ground granulated blast furnace slag (GGBFS).

### 10.3. Admixture-3: Silica Fume

Silica fume is basically very fine particles of amorphous silica (See **Figure 5**). It is produced as a by-product in electric arc furnaces in the production of elemental silica or other silicon-based compounds.

Silica fume is highly pozzolanic in nature. The explanations are:

- Being of a very fine nature, silica fume increases the water demand of concrete and hence a superplasticizer is almost always used with it.
- Silica fume makes the concrete mix stickier and more cohesive. Usually, slump loss problems arise due to the addition of silica fume to the concrete.
- There is a drastic reduction in the bleeding of concrete.
- Plastic shrinkage may occur in dry regions where the evaporation rate exceeds the rate at which concrete sets.
- The permeability of concrete is reduced. Silica fume acts both as a pozzolan and a filler and due to consequent reactions, the transition zone between the aggregates and cement paste is strengthened. Chloride permeability is reduced significantly.
- The compressive and flexural strength of concrete is enhanced. The elastic modulus of concrete is also increased by about 15% compared to normal Portland cement concrete. Increased elastic modulus implies that the stiffness of the concrete is increased.
- Creep and shrinkage are also increased at higher replacement levels of 10 – 15 %. However, the resistance to creep and shrinkage deformation is also increased because of the increase in stiffness.
- Silica fume concrete mostly shows good resistance to chemical attacks due to the reduced permeability (exceptions of ammonium sulfate and magnesium sulfate are there).
- Silica fume concrete is ideal for industrial flooring because it provides excellent resistance to abrasion and erosion.
- The fire resistance of silica fume concrete is not impressive. It does not allow the entrapped water to vaporize out because of its low permeability. Hence, due to high pressures developing inside, the concrete tends to crack.
- Carbonation depth is usually lowered.



**Figure 5.** Silica fumes.

#### 10.4. Admixture-4: Rice Husk Ash

During milling of the paddy coming from fields, a lot of rice husk is produced (See **Figure 6**). This rice husk is mostly used as fuel. Rice husk ash is produced by burning the rice husk. It is about a quarter of the mass of the husk. The rice husk ash is a big threat to the environment where it is dumped.

Rice husk ash can be produced by field burning (open) – produces poor quality ash, bed furnace burning (fluidized), and industrial furnace.

Rice husk ash contains a high amount of silica. The explanations are:

- (i) Rice husk ash provides strength to the concrete.
- (ii) It also reduces permeability because it is much smaller in size compared to cement particles.
- (iii) It reduces the heat of hydration of concrete.
- (iv) Rice husk ash also improves the concrete's resistance to chloride and sulfate attacks.



**Figure 6.** Rice husk ash.

#### 10.5. admixture-5: Metakaolin

Ordinary clay and kaolin clay when thermally activated is called metakaolin, in the non-purified form (See **Figure 7**). The particle size of metakaolin is smaller than cement particles. Metakaolin is not an industrial by-product like the other admixtures.

- (i) Metakaolin provides strength to the concrete.
- (ii) It reduces the permeability of the concrete.
- (iii) It helps the concrete resist chemical attacks.
- (iv) It makes the concrete more durable.
- (v) It helps in early strength development in concrete.

(vi) Bleeding of concrete is considerably reduced upon metakaolin addition.

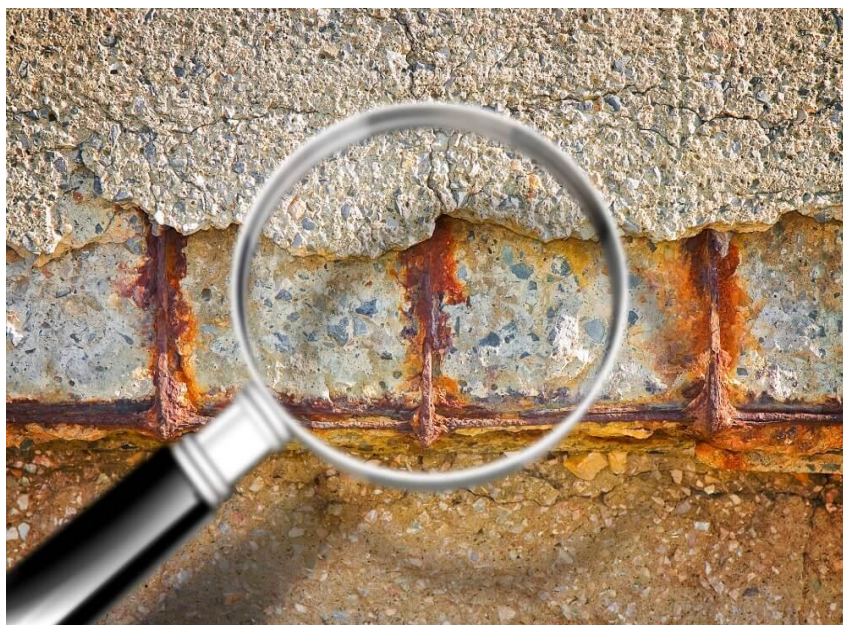
Metakaolin is also used in fiber-cement and Ferro-cement products. It is also used in art sculptures.



**Figure 7.** Metakaolin.

## **11. EFFECT OF ADMIXTURES IN CONCRETE ON THE CORROSION RESISTANCE OF STEEL-REINFORCED CONCRETE**

The effect of admixtures, namely silica fume, latex, methylcellulose, and short carbon fibers (in various combinations), in concrete on the corrosion resistance of steel-reinforced concrete was assessed by measuring the corrosion potential and corrosion current density during immersion in  $\text{Ca}(\text{OH})_2$  and  $\text{NaCl}$  solutions. Silica fume (15% by weight of cement) was most effective for improving the corrosion resistance, due to a decrease of water absorptivity, and not so much due to an increase in electrical resistivity. Latex (20% by weight of cement) improved the corrosion resistance because it decreased the water absorptivity and increased the electrical resistivity. Methylcellulose (0.4% by weight of cement) improved corrosion resistance only slightly. Carbon fibers (0.5% by weight of cement) decreased the corrosion resistance due to a decrease in electrical resistivity. However, the negative effect could be compensated by adding either silica fume or latex, which reduced the water absorptivity (see **Figure 8** and **9**).



**Figure 8.** Corrosion.

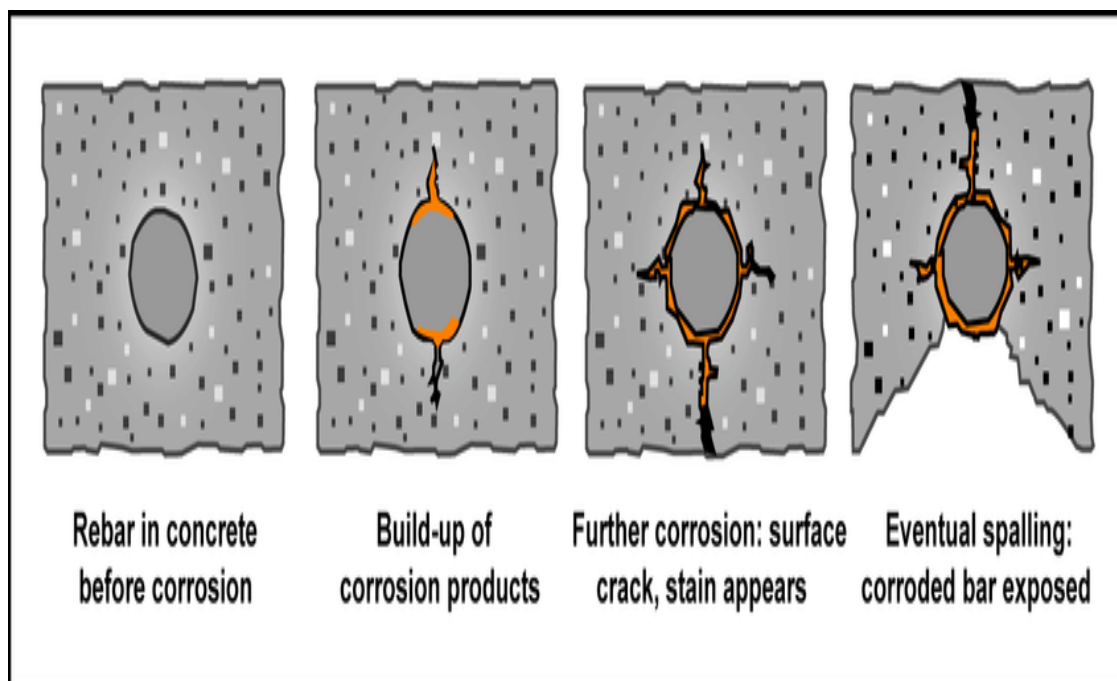


Figure 9. Process Corrosion resistance.

## 12. CONCLUSION

Water-reducing and set-controlling admixtures have proven themselves to be useful tools in the precast industry. They can significantly reduce the water-cement ratio ( $w/c$ ) while decreasing the use of cement, altering the set time to help in production, improving workability, and decreasing permeability. Their use does not, however, preclude the use of good concrete practices such as curing. The type of admixture and dosage recommended varies by manufacturer and must be considered with other materials used. Discuss the specifics of your operations with your admixture supplier and use trial batches to ensure that you are getting the properties you want most economically.

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