
**Scientific Report about:**

# (Introduction of chemical admixtures and effects of using in concrete constructions)

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**Feb 2024**

## 1- General:

Concrete is the mostly used man-made material used in construction industry and is the second after water as the most utilized thing on the Earth. Simply said, it is a four-ingredient combination is described as having coarse aggregates (size from 6.5 to 38 mm or larger), which make up the majority of the mix, fine aggregates (with a size range of 0.025 to 6.5 mm), like sand, which fill in the gaps, binding materials, like lime or Portland cement, which hold the components together, and water, which reacts with the binding materials. We get a paste known as matrix when we combine these four ingredients. This step of the process is known as fresh concrete or green concrete, and as the water reacts with the binding substance, it hardens into stone. This response is referred to as concrete hydration. Concrete can be cast into any desired shape while it is still in its fresh state by using forms. This characteristic of concrete enables the most effective use of the material. In typical structural concrete, the ratio of water to cement greatly influences the concrete's characteristics. All other factors being equal, stronger concrete results from reduced water content. An admixture is a component that is added to the concrete mix in quantities no greater than 5% by mass of cement. It can lead to savings in other areas, such as the cost of labor needed to effect compaction, the amount of cement that would otherwise be required, or the improvement of durability. To reduce the water/cement ratio while maintaining the desired workability, a water-reducing admixture is used in concrete mixes. However, properly used admixtures are not a fix for low-quality mix components, improper mix proportions, or poor workmanship in transporting placement, and compaction techniques.

**Figure 1- Concrete structure**

## 2- Introduction:

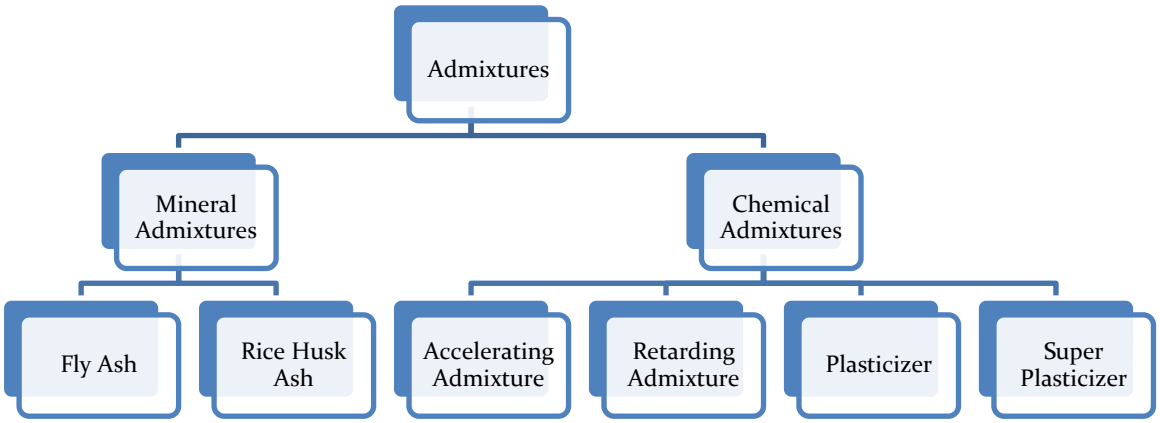
In general concrete is a material that forms the basis of our modern life. It is the most widely construction material used because it is easy to place and mold, low cost, its ingredients is widely available and it has good compressive strength. Concrete is a composite material consist of aggregates embedded in a hard matrix of cement filling the space between the aggregate particles.


**Figure 2- Concrete material ingredients**

On the other hand, there are some disadvantages of using concrete since it is brittle material and has low tensile stress. For several years researchers were trying to find ways to decrease the disadvantages and make using concrete more effective or improving its characteristics by using admixtures. ASTM C15 [1] defined admixtures "as materials other than water, aggregates, and hydraulic cement that is used as an ingredients of concrete or mortar and is added to the batch immediately before or during mixing". In general, using admixtures in concrete improve its workability, accelerating or retarding setting time, controlling development of concrete strength and enhancing durability to deterioration process. Mindess [2] categorized the admixtures in four groups; air entraining agents, chemical admixtures, mineral admixtures and miscellaneous admixtures.

**3- Admixtures:**

It is the fifth ingredient of concrete other than cement, sand, aggregate and water and found invariably in modern day concrete. Admixtures are used to enhance the properties of concrete.




Admixtures and Mineral Admixtures play an important role in the production of Performance Concrete; they are used for various purposes depending upon their properties. the main types of chemical admixtures can be summarized as plasticizers, Accelerating/retarding agents, air-entraining agents, waterproofing additives,

shrinkage reduced Admixture and others such as corrosion inhibitors and coloring agents. The mineral admixture is the addition of supplementary cementing materials (SCMs) such as (fly ash, slag, silica fume, husk rice …etc.), into concrete mixtures have been gaining acceptance concerning improving durability and reducing permeability [3] (ACI 212).The workability of concrete can be increased by the addition of super plasticizer and retarder, very high dosages of both admixtures tend to impair the cohesiveness of concrete. Compressive strength is improved by super plasticizer (SP) for all ages, but retarder present lower compressive strength compared with control at an early age, even its ultimate strength is higher than the desired characteristic strength [4] The effect of the over dosage of this admixture (super plasticizer) will lead to reducing the compressive strength [5]

**4-History of Using Admixture in Concrete:**

Records show that ancient structures left by Egyptians, Greek, Roman, and Indian civilizations were mostly based on lime as a binding medium and this material was a versatile material to use in traditional temples and monuments [8]. Besides, the builders were used different kinds on bio admixtures in the preparation of their lime stuccos. The true purpose behind using such admixtures is not well recognized [9], however, the builders were strongly believed that plants and animal derivative used as natural admixture in the lime mortar will able to increase strength and durability of the mortar. Admixtures have been used in concrete and mortar since at least the Roman Empire. The Romans found that certain materials such as milk, blood, and lard, as well as organic materials such as molasses, eggs, and rice paste, allow greater workability in cementitious mixtures. While the first patent for calcium chloride in concrete goes back to 1873 in Germany, modern admixture technology started with basic air-entraining agents, retarders, accelerators, and water reducers in the 1930s in North America. However, it was not until the 1950s that these kinds of products began to be widely used in concrete. ASTM first published its C494 standard in 1962, now titled ―Historical Standard: Standard Specification for Chemical Admixtures for Concrete,

which sets performance criteria for five kinds of admixtures: A, B, C, D, and E. Types F and G, high-range water-reducing admixtures, were not added to the C494 standard until 1980. The ACI 212 Committee publishes a report on "Chemical Admixtures in Concrete" which, until 1981, did not include a High Range Water Reduction (HRWR) in its document. While in the 1970s we saw a sharp increase in the use of admixtures in concrete, in 1979, the first corrosion inhibitor was introduced to help reduce the impact of chloride salt attack (NaCl) on steel reinforcement. Almost 20 years later (1996), shrinkage-reducing admixtures were followed to help solve the cracking problems associated with autogenous drying in high-performance concrete. The 1980s and 1990s saw an increase in the use of admixtures in concrete, which included substantially repetitive projects that used HRWRs as the placement benefits of higher slumps and improved durability of lower water-cementitious material (w/c) ratio concretes were realized.

**Table 1. History of admixture use in concrete (John Newman and B S Choo, (2003) [10].**

| Brief history of admixture use | | |
|---|---|---|
| Romans | Retarder | Urine |
| | Air entrainment | Blood |
| | fibres | Straw |
| Plasticizers | 1932 | Patent for sulphonated naphthalene formaldehyde plasticizers |
| | 193? | Lignosulphonates used as plasticizers |
| | 193? | Hydroxycarboxcilic acid salts used as plasticizers and retarders |
| Water proofers | | Fatty acids, stearates and oleates |
| Air entrains | 1941 | Tallow and fatty acid soaps for frost resistance |
| Super plasticizers | 1963 | Sulphonated naphthalene formaldehyde commercially available |
| | 1963 | Sulphonated melamine formaldehyde patent and available |
| | 1990-1999 | Polycarboxylate ether development and production |

**5-The Admixture used in concrete for the following purpose:**

1. To accelerate the initial setting and hardening of concrete.
2. To retard the initial setting of concrete.
3. To increase the strength of concrete.
4. To improve the workability of fresh concrete.
5. To improve the durability of concrete.
6. To reduce the heat of evaluation.
7. To control the alkali aggregate expansion.
8. To promote pozzolanic properties in concrete.
9. To aid in curing of concrete.
10. To improve wear resistance to concrete.
11. To reduce shrinkage during setting of concrete.
12. To reduce bleeding of concrete.
13. To impart color to concrete.
14. To aerate concrete or mortar to produce light weight concrete.
15. To reduce segregation in grout mixes.
16. To increase the bond between old and new concrete surfaces and also between concrete and reinforcement.
17. To produce fungal, insects etc. resistant concrete.
18. To produce nonskid surface of concrete.
19. To increase the resistance to chemical attack.
20. To decrease the permeability of concrete.
21. To check the corrosion of concrete reinforcement.

**6-Chemical admixture:**

Chemical admixtures are the elements in concrete other than Portland cement, water, and aggregate that are added to the mix just before or during mixing. Admixtures are largely used by producers to lower the cost of concrete construction, alter the qualities of hardened concrete, guarantee the quality of concrete while it is being mixed, transported, placed, and cured, and resolve specific crises that may arise during concrete operations, they are typically employed to lower casting costs and raise the caliber of concrete. The amount of cement used, the water content, the mixing time, the air temperature, the slump, and the batching processes all have a significant role in the efficiency of chemical admixtures (ACI 212, 2010).[3]

**Figure 2- different types chemical admixtures**

**Table2: types of chemical admixture and description according to ASTM C 494[11]**

| Chemical Admixtures as per ASTM C 494 | |
|---|---|
| type | description |
| A | Plasticizers (Water-reducing Admixtures) |
| B | Super Plasticizers |
| C | Accelerators |
| D | Water Reducing & Retarding Admixture |
| E | Water Reducing & Accelerating Admixture |
| F | High Range Water Reducing Admixture |
| G | High Range Water Reducing & Retarding Admixture |

### 6.1-Plasticizers (Water-reducing Admixtures):

These admixtures are used for following purposes:

i. To achieve a higher strength by decreasing the water cement ratio at the same workability as an admixture free mix.
ii. To achieve the same workability by decreasing the cement content so as to reduce the heat of hydration in mass concrete.
iii. To increase the workability so as to ease placing in accessible locations.
iv. Water reduction more than 5 % but less than 12 %.

The commonly used admixtures are *Lignosulphonates* and *hydro carbolic acid salts*. Plasticizers are usually based on Lignosulphonates, which is a natural polymer, derived from wood processing in the paper industry.

### 6.2-Super Plasticizers:

These are more recent and more effective type of water reducing admixtures also known as *high range water reducer*. The main benefits of super plasticizers can be summarized as follows:

**Increased Fluidity**:

- Flowing
- Self-leveling
- Self-compacting concrete
- Penetration and compaction around dense reinforcement

**Reduced W/C ratio**:

- Very high early strength, > 200% at 24 hours or earlier
- Very high later age strengths, > 100 MPa
- Reduced shrinkage, especially if combined with reduced cement content.
- Improved durability by removing water to reduce permeability and diffusion.

Water reduction: 12 to 30 %

Dosage: Low (0.6 to 2 % on cement)

Examples of commonly used super plasticizers are *Sulphonated Melamine Formaldehyde condensates (SMF)*, *Sulphonated Naphthalene Formaldehyde condensates (SNF)* and *Polycarboxylate Ether super plasticizer (PCE)*.

### 6.3-Accelerators:

It is 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. They can be divided into two groups based on their performance and application.

a. ***Set Accelerating Admixtures****:* They reduce the time for the mix to change from the plastic state to the hardened state. These admixtures have relatively limited use, mainly to produce an early set.
b. ***Hardening Accelerators:*** They increase the strength at 24 hours by at least 120% at 20° C and at 5° C by at least 130% at 48 hours. These admixtures 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.

E.g. calcium chloride, chloride-free accelerators based on salts of nitrate, nitrite, formate and thiocyanate.

### 6.4-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.

E.g. Calcium Lignosulphonates, Carbohydrate derivatives.

## 7-Mineral Admixtures:

These are generally of two types:

1. **Cementitious:**

These have cementing properties themselves. E.g. 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


**Figure 3- different types of mineral admixtures**

**Fly Ash:**

Coal from mines is generally contaminated with clay. When this coal is grinded to fine size and then burnt in thermal power plant, it turns into carbon dioxide. The clay contaminants form ash mainly of silica and alumina. The larger ash settles on the bottom whereas the finer ones called ***fly ash*** fly above.

Thus, fly ash is 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.

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. Fly ash increases cementitious property. These are spherical particles; thus, ball bearing action helps to reduce water demand.

**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.

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.

**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 pozzolan.

## 8- Summary:

Admixture are added to a water-cement mixture to increase the life of the concrete, control setting, and hardening and fix the general concrete behavior. They can be powdered or liquid additives. The additives can be added at the manufacturing point, or at the job site.

Admixtures have increased both compressive strength and durability of concrete through their water/cement (w/c) reduction, hydrophobic effect, increased density etc. This tremendously increased their use in the construction industry today. Also chemical admixture have a disadvantages which is increased drying shrinkages and less resistance to sulphate attacks and high risk of corrosion of steel especially when cacl2 is in the content of admixtures

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