How Does Silica Fume Work in Concrete?

Silica fume is produced as a by-product in the manufacture of silicon metal and ferrosilicon alloys, which are commonly used in numerous industrial applications including steel and aluminum production, production of silicone, computer chip fabrication, and more.

And while these materials present a great value, their by-product silica fume plays a greater role in the concrete industry. Read on to find out what exactly silica fume is and what makes it an invaluable addition to concrete.

What is Silica Fume?

Silica fume, also known as volatilized silica, micro silica, or condensed silica fume, is a pozzolanic material, which presents a gray-colored d powder, somewhat similar in appearance to fly ashes or Portland cement. It consists primarily of non-crystalline (or amorphous) Silicon Dioxide (SiO2), with each particle being approximately 0.01 times the size of an average cement particle.

Whenever concrete producers need to modify the natural properties of concrete, SCM's or supplemental cementing materials can be used to achieve desired properties. These materials are typically added to concrete during batching and are used as a replacement for a portion of the Portland cement.

Silica fume is one example of such SCM's. Due to its chemical and physical properties, concrete containing silicon fume can become very durable and gain incredible strength.

However, there are certain problems associated with the use of silica fume in concrete. As such, its indiscriminate use is not recommended. Instead, applications of silica fume should be limited to highly specialized products.

What Does "Pozzolanic" Mean?

Pozzolanic material describes a material that can react with Calcium Hydroxide (CH). It is a siliceous or siliceous and aluminous material that possesses no cementitious value, but, in presence of moisture and a highly divided form, chemically reacts with CH at regular temperatures to form a material with cementitious properties.

The term Pozzolanic comes from a little Italian city, Pozzuoli. In this city, the early Romans combined volcanic ash with a lime rock to create mortars to bind massive stones together. Even today, two thousand decades later, the resulting structures maintain their sturdiness.

Silica fume is one example of artificial pozzolanic materials and is, therefore, widely used within the concrete industry.

How Does Silica Fume Work in Concrete?

After Portland cement is mixed with water, they begin “hydrating” or responding to each other. During this process, a chemical reaction forms two chemical molecules:

1. **Calcium Silicate Hydrate (CSH), which is the main compound responsible for crystallization.**
2. **Calcium Hydroxide (CH), which is a by-product of the reaction, also known as “free lime”. This compound is responsible for nothing more than leaching from concrete or lining accessible pores inside the concrete.**

A pozzolanic reaction occurs between silica fume and the CH, creating additional CSH molecules within the voids of hydrated cement particles. These additional CSH molecules provide enhanced flexural, compressive, and bond-power for concrete. They also create a generally healthier matrix, as extra CS supplies fill in regions that would have stayed as little voids otherwise, subject to deleterious substances and potential ingress.

Silica fume for use in concrete is available in both dry and wet forms. It is usually added during concrete production at 5% to 10% by weight at a concrete plant and has been successfully produced in both dry-batch and central-mix plants.

Pros and Cons of Silica Fume in Concrete

Today, silica fume is widely used in the construction industry, so it is important to understand what properties silica fume brings to concrete, as well as its associated advantages and disadvantages.

Advantages of Microsilica in Concrete

Being an effective pozzolanic material, silica fume is commonly added to concrete to improve its properties, in particular bond strength, compressive strength, and corrosion resistance.

The main advantages of using silica fume in concrete include:

- Silica fume presents a neutral inorganic filler with incredibly stable chemical and physical properties. It does not participate in the curing reaction, does not contain crystalline water, and does not affect the reaction metabolism.
- Adding silica fume to concrete can increase thermal conductivity and flame retardant, as well as change adhesive viscosity.
- It has great adsorption performance, produces no agglomeration phenomenon, is easy to mix, and offers good infiltration for various types of resin.
- The addition of silica fume allows reducing epoxy resin’s exothermic peak temperature of curing reaction, the shrinkage rate of solidified products, and their linear expansion coefficient. This allows preventing cracking by eliminating internal stress.
- Silica fume possesses properties like strong densification, reasonable size distribution, as well as large wear resistance and hardness. This can significantly increase the compressive strength, tensile strength, affect the strength and wear resistance of the cured products, and increase the abrasion resistance by 0.5 to 2.5 times.

- Low content of impurities, pure silicon powder, and stable chemical and physical properties add arch resistance and good insulation properties to the curing material.
- Silica fume consists of finely sized grains and distributes reasonably, meaning that it can effectively eliminate or reduce stratification and precipitation.
- Silica (SiO2) within silica fume belongs to inert materials. This means that it doesn't come into reaction with most alkaloids and acids. If the silicon powder is evenly distributed on the surface of objects, it increases cavitation and corrosion resistance by 3 to 16 times.
- The relative elastic modulus of silica fume is between 10% and 20% after 300 to 500 freeze-thaw cycles, while the elastic modulus of concrete without silica fume addition is 30% to 73% after 25 to 50 cycles. Therefore, the addition of silica fume to concrete allows for improving frost resistance.
- Silica fume has a small bulk density of 0.2 - 0.8 or 1 - 2.2. When used as polymer filling material, it can reduce the amount of loading and save the required amount of polymer, thus reducing the overall cost of the product.

Disadvantages of Fumed Silica in Concrete

Silica fume is not a magic compound. Naturally, the use of silica fume in concrete comes with certain difficulties:

- **Difficult construction and poor workability.** The workability of concrete is a significant factor in the development of concrete mix proportion. Unfortunately, silica fume concrete presents poor workability. Concrete containing silica fume is not easy to plaster and is difficult to be made vibrating close-grained. This leads to decreased smoothness and uniformity of the concrete surface.
- **Dry shrinkage.** Silica fume increases the concrete's shrinkage rate, especially early dry shrinkage. This affects the overall strength of concrete by making it more prone to cracking. For example, after the construction is complete, strengthening sprinkler and water maintenance can decrease the problem, but the cracks are still unavoidable in most construction projects.
- **Temperature cracks.** Concrete containing silica fume develops quickly, while the corresponding concrete hydration heat dissipates quickly as well. This leads to rising in concrete hydration heat temperature, increasing the high-temperature stress within the material. The concentration of stress within the dry shrinkage crack can make the crack extend, leading to the formation of transfixion cracks.

Applications of Silica Fume in Concrete

The two main applications of micro silica in concrete involve creating high-performance and high-strength concrete mixtures.

1. High-Performance Concrete (HPC)

High-performance concrete (HPC) produced with silica fume has been identified as one of the most valuable advanced materials required for the construction of infrastructure.

In addition to enhanced durability and increased strength, HPC containing silica fume provides increased resistance to abrasion, chemicals, and corrosion, enhanced toughness, and improved sustainability and life-cycle cost efficiencies.

Parking decks, highway bridges, bridge deck overlays, and marine structures are subject to continuous deterioration due to abrasion, rebar corrosion current, and chemical attack. Silica fume is used to protect concrete against seawater, deicing salts, heavy impact, and traffic, thus minimizing maintenance expenses.

Key advantages of high-performance concrete include:

- Increased impact and abrasion resistance on floors, decks, overlays, and vertical structures
- Extremely high electrical resistivity
- The very low permeability of water intrusion and chloride
- Superior resistance to chemical impact from acids, chlorides, sulfates, and nitrates

2. High-Strength Concrete

High-strength concrete produced with silica fume provides greater design flexibility for engineers and architects. It is traditionally used in high-rise buildings for the benefit of increasing usable space, as it allows for the use of smaller columns. High-strength concrete containing silica fume is often used in prestressed and precast girders, allowing larger spans in structural bridge designs.

Key benefits of high-strength concrete include:

- High elastic modulus exceeding 7 million psi (40,000 Mpa)
- Compressive strength of up to 20,000 psi (140 Mpa)
- High early strength for precast applications and fast-track projects
- High flexural strength of up to 2,000 psi (12 MPa)

The Takeaway

Silica fume is a highly efficient pozzolanic material that has significant potential for use in concrete, as it allows to enhance durability and mechanical properties of the material. The applications of silica fume in concrete include bridges, parking structures, bridge decks, high-rise buildings, and more.

Shop high-quality densified silica fume and undensified silica fume from HSA Material today.