Silica Fume and Other SCMs

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In Technical Bulletins #5 and #8, we discussed Fly Ash and Slag, the most commonly used supplementary cementitious materials in the United States. And while they make up ~95% of the SCM usage in the US, other products do exist that can bring interesting properties to a concrete matrix. Today we'll discuss some of those products, including Silica Fume, Metakaolin, Volcanic Ash, Rice Husk Ash, and others.

Silica Fume

The most widely used of these “other SCMs” is certainly Silica Fume. A byproduct of the production of metallic silicon, the material vaporizes at temperatures over 2000° and then condenses as it cools and is collected. Silica Fume is like fly ash in that it is naturally spherical in shape but is significantly finer… 100 times finer than a cement grain, to be exact. It contains over 85% SiO_2, which makes it a powerful SCM when you consider our goal to maximize the C-S-H growth in concrete. It typically is used to replace 5-10% of cement by weight. It is not normally advisable to use more than this quantity as it can be a difficult material to work with and there is a definite lack of benefit beyond the 10% due to a relatively low amount of CaO in Silica

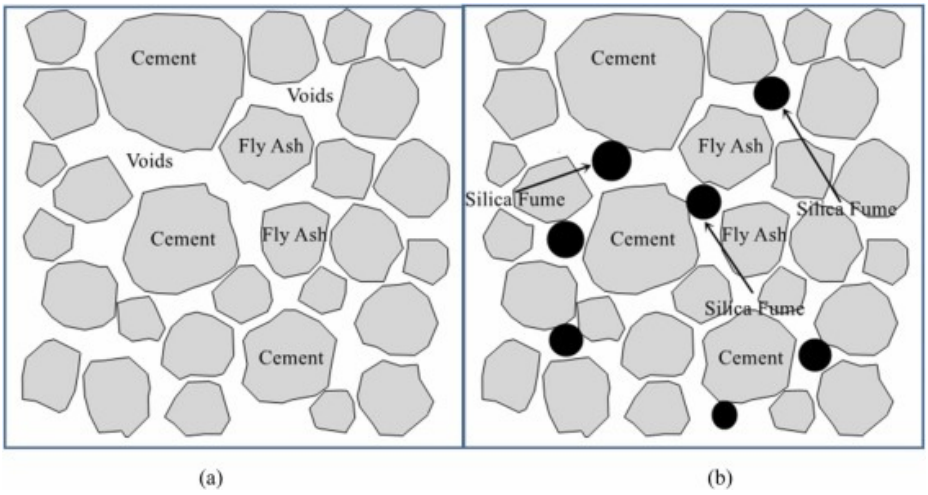
Fume.

Benefits of Silica Fume

The benefits of silica fume stem from two actions, the pozzolanic reaction with cement, that makes cement more efficient due to the high amounts of SiO_2, and the physical size of the particles allows for a *much* tighter matrix with less voids and spaces between materials.

These actions result in a number of benefits:

- - Dramatically increased strengths, particularly at early stages. Using silica fume is almost like a cheat code for achieving strengths over 10,000psi.
- - Decreased permeability. This is due to tighter C-S-H crystals and the fineness of silica fume filling voids. Decreased permeability means chloride penetration resistance, chemical attack resistance, sulfate attack resistance, and abrasion resistance.
- - Silica Fume is often used in bridge decks or other concrete members where near-complete impermeability is required. It's also used in chemical or sewage treatment plants where the environment is highly corrosive to the concrete.



Drawbacks of Silica Fume

Silica Fume can add some pretty incredible properties to concrete but it's not for every project. Here are some of the downsides of using Silica Fume:

- - Cost. Silica Fume is very expensive.
- - Availability. Due to being a byproduct of a niche industry, there is not much silica fume available. Shortages are common.
- - Workability. Silica Fume is extraordinarily sticky, and finishers tend to absolutely hate working with it.
- - Water Demand. The water demand of Silica fume is very high, necessitating the use of a HRWR in conjunction with the silica fume.

- - Bleeding & Evaporation. Silica fume concrete does not bleed. At all. In fact, often a fogger or mister will need to be used to keep the surface of the concrete moist until curing operations can be completed, as the risk for plastic shrinkage cracking is very high.
- - Silica fume is packaged in a number of different ways, but if it is not densified or pelletized it can be extremely hazardous to handle during mixing operations. For this reason, often silica fume is sold in a pelletized form by bag, which means batching is done by hand and adds time to the batching process.

Other SCMs

One of the great areas of research in concrete technology at present is the search for additional SCMs for use in concrete. As Fly ash becomes more scarce and slag more in demand, the need for such SCMs continues to grow. In addition, the push to reduce the carbon footprint of concrete has incentivized the use of SCMs as a way to reduce reliance on portland cement.

Natural Pozzolans

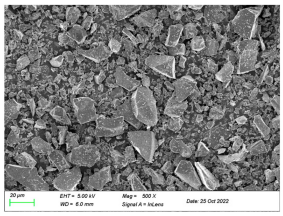
The first thing many of of think about in regards to Natural Pozzolans is often Volcanic Ash. The Romans used Volcanic Ash to wildly successful effect two thousand years ago, and it still can be used to make quality concrete today. See this great article on Roman Concrete Construction Methods.

The Pantheon, Rome. After 2000 years, still the largest unreinforced concrete dome in the world.

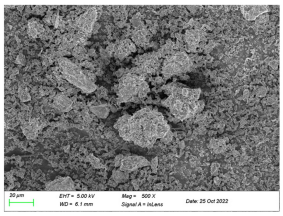
Other natural pozzolans include: calcined shale, calcined clay (Metakaolin), opaline chert, and diatomaceous earth. Aside from Metakaolin, these materials are not often used in the United States, and are extremely variable and dependent on

the qualities of each particular deposit.

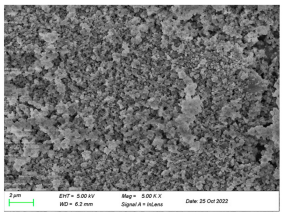
Metakaolin, however, is growing in popularity and use around the world. High purity kaolinite clay is heated to between 1200°-1500° F, and then it is processed to remove impurities and eventually ground to very fine powder. Metakaolin has similar concrete properties to Silica Fume and has therefore helped fill the void when Silica Fume shortages are present.



(a) Slag.



(b) Metakaolin.



(c) Silica fume.

Further options

Other potential SCMs that are getting a new look include ground glass (which would work primarily as a filler), ground bottom ash (which would have similar reactivity to fly ash but higher processing costs and less workability benefits), fluidized bed combustion ash, and rice husk ash. In Asia, rice husk ash is commonly used to make lower quality but highly economical concrete.

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