BENEFITS OF SILICA FUME IN HPC

Terence C. Holland, Silica Fume Association

Many designers still look at silica fume as though it were a new material. Silica fume is not new any longer—it has been used in concrete since the 1950s in Norway and since the mid 1970s in the USA. During its introduction in the USA, silica fume was heavily marketed for durability applications. This was, perhaps, the beginning of the era of HPC. Today, the use of silica fume is specified by several state transportation agencies while others have yet to try the material. This article provides a brief summary of how this concrete ingredient is used and its contribution to HPC.

Silica Fume

Silica fume is a highly reactive material that is used in relatively small amounts to enhance the properties of fresh and hardened concrete. Silica fume is a by-product of producing certain metals in electric furnaces. The benefits of adding silica fume are achieved by changes in the microstructure of the concrete. These changes result from two different but equally important processes. The first of these is the physical contribution of silica fume and the second is its chemical contribution.

Physical contribution—Adding silica fume brings millions of very small particles to a concrete mixture. Just like fine aggregate fills in the spaces between coarse aggregate particles, silica fume fills in the spaces between cement grains. This phenomenon is frequently referred to as particle packing or micro filling. Even if silica fume did not react chemically, the micro-filler effect would bring about significant improvements in the nature of the concrete.

Chemical contribution—Because of its very high silicon dioxide content, silica fume is a very reactive material in concrete. As the portland cement in concrete reacts chemically, it releases calcium hydroxide. The silica fume reacts with the calcium hydroxide to form additional binder material, which is very similar to that formed from the portland cement.

The use of silica fume in concrete did not become widely used until the development of high-range water-reducing admixtures or superplasticizers. When used in bridge girders or bridge decks, the amount of silica fume usually ranges from 5 to 10 percent of the total cementitious materials. Silica fume is used to increase mechanical properties, improve durability, and enhance constructibility. Designers and builders of HPC bridges can take advantage of all three of these contributions.

Increase Mechanical Properties

Silica fume gained initial attention in the concrete industry because of its ability to create concrete with very high compressive strengths. Improvements in other mechanical properties, such as modulus of elasticity or flexural strength, are also achieved. The increased compressive strength of silica fume concrete was initially put to use in columns of high-rise structures. More recently, silica fume has been used to produce high strength concrete bridge girders. Using silica fume in HPC will typically allow a reduction in the total amount of cementitious material. This can reduce the maximum temperature reached in a girder during production.

Improve Durability

Although the use of silica fume to produce very high strength concretes has gained a lot of attention, a much larger amount of silica fume is used in applications where durability rather than strength is the primary concern. For most durability applications, the contribution of silica fume is to reduce the permeability of the concrete. Reducing permeability simply extends the time that it takes for any aggressive chemical to penetrate the concrete to a level where it can cause damage.

By far the largest amount of silica fume used for durability has been in structures exposed to chlorides such as bridge decks, marine structures, and parking structures. When using silica fume in HPC bridge decks, it is important to remember that the property of interest is a reduction in permeability. While the strength of this concrete will be increased over that typically used in such an application, it is not practical to try to achieve savings in deck thickness by taking advantage of this increased strength.

Enhance Contructibility

A final contribution of silica fume concrete is its enhancements to constructibility. Here are three examples:

1. Silica fume concrete does not bleed. This property means that there are no capillary channels left after the bleed water evaporates. It also allows for earlier finishing and curing. The downside of the lack of bleeding is the need for protection against plastic shrinkage cracking during placing and finishing.

2. Fresh silica fume concrete is very cohesive. This property is used in shotcrete applications for both repair and new construction. The increased cohesion allows for higher lift thickness and causes significantly less rebound.

3. Silica fume enhances the use of other cementitious materials. Fly ash and ground granulated blast-furnace slag are being used in increasing amounts in all types of concrete. Although the use of these materials can provide excellent long-term concrete performance, their use may not provide the early age properties that a contractor requires to complete a project in a timely fashion. Combining silica fume, portland cement, and fly ash or slag can provide both the early and long-term properties that are required by the designer and the contractor.

Silica fume is not for all concrete. However, in the correct application and when used properly, silica fume can provide concrete with performance levels that are difficult or impossible to achieve with other materials.

Further Information

The information in this article is taken from the Silica Fume User's Manual, currently being prepared by the SFA. For further information about silica fume and availability of the manual, go to www.silicafume.org.

Editor's Note

This article is the first in a series that addresses the benefits of specific materials used in HPC.