

# Force 10,000<sup>®</sup>

## Force 10,000 Microsilica and its uses in Concrete

One of the newest construction materials available to designers and engineers is Force 10,000<sup>®</sup>, a microsilica-based concrete admixture which expands the versatility and capability of portland cement concrete. This new technology can dramatically improve concrete strengths, durability and impermeability, allowing concrete to be used in ways never before possible. Applications of Force 10,000 are broad, and include high-strength structural columns, less permeable parking garage decks, and abrasion resistant hydraulic structures.

This introductory bulletin will describe what microsilica is and how it works in concrete, as well as some of the practical considerations specifiers should be aware of when considering microsilica concrete. Additional Engineering Bulletins will discuss specific applications of Force 10,000 concrete.

### Background

Condensed silica fume is a by-product from silicon and ferrosilicon industries, where these metals are produced in

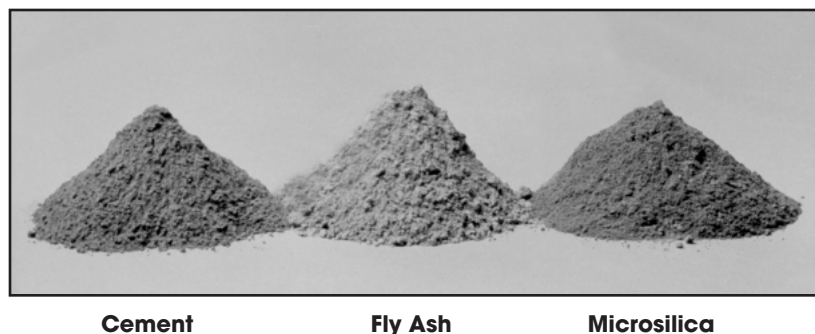
submerged electric arc furnaces. As the molten metal is produced, a silica-based gas is emitted. This gaseous fume, as it rises, cools rapidly and forms extremely minute, glassy, spherical particles. The condensed silica fume, referred to as microsilica, is collected in a bag house, a system for filtering the hot air and gases vented from the furnace.

Until the last few decades, the microsilica particles were considered a waste product and discarded. However, during the 1950's European researchers began to examine potential uses and investigate potential applications for microsilica, including its use in combination with portland cement.

### Physical and Chemical Composition

The physical characteristics of microsilica are quite different than standard concrete components, but the chemical make-up is rather similar. Microsilica is an extremely fine particulate, with average diameters 100 times finer than cement particles. Specific gravities of microsilica are low, about 2.2, versus 3.15 for most portland cements. Because microsilica is an extremely fine material, its raw bulk densities are very low, varying from 144 to 400 kg/m<sup>3</sup> (9 to 25 lbs/ft<sup>3</sup>), versus a dry bulk density of 1506 kg/m<sup>3</sup> (94 lbs/ft<sup>3</sup>) for cement. Figure 1 provides a visual comparison of cement, fly ash, and microsilica.

Figure 1



Cement

Fly Ash

Microsilica

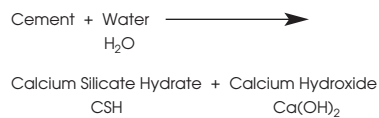
Table 1			
Chemical Analysis			
	Cement	Fly Ash	Microsilica
SiO <sub>2</sub> Silica	21.3%	49.0%	92 - 98%
Al <sub>2</sub> O <sub>3</sub>	4.5	24.6	0.5
Fe <sub>2</sub> O <sub>3</sub>	4.0	7.3	2.1
MgO	2.4	1.6	0.3
CaO	63.1	9.1	0.8
Na <sub>2</sub> O	0.1	0.2	0.1
K <sub>2</sub> O	1.2	0.6	1.0
SO <sub>3</sub>	2.2	0.4	0.2

The chemical make-up of microsilica is almost pure silicon dioxide (SiO<sub>2</sub>). Table 1 compares a typical chemical analysis of the three common concrete constituents pictured in Figure 1.

### How Microsilica Works in Concrete

Microsilica improves concrete through two primary mechanisms — the basic pozzolanic reaction, and a microfiller effect.

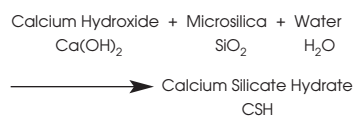
When water is added to portland cement hydration occurs forming two products, as shown below:



The calcium silicate hydrate formed is the glue, or binder, which holds the system together. The weaker calcium hydroxide does not contribute as a binder, and can occupy as much as one quarter of the volume of the hydration products. Further, the calcium hydroxide can combine with carbon dioxide to form a solu-

ble salt which will leach through the concrete, and can cause efflorescence, a familiar architectural problem. When high amounts of calcium hydroxide are present, concrete may be more vulnerable to sulphate attack, chemical attack, and adverse alkali-aggregate reactions.

The pozzolanic microsilica reacts with the calcium hydroxide and water to produce more aggregate-binding calcium silicate gel, while simultaneously reducing the calcium hydroxide content, as shown in the chemical reaction below:



This additional glue improves bonding within the concrete matrix and helps reduce permeability, while the reduction in calcium hydroxide improves concrete durability.

The beneficial effect of microsilica can be seen more dramatically from the two scanning electron photomicrographs shown in Figures 2 and 3:

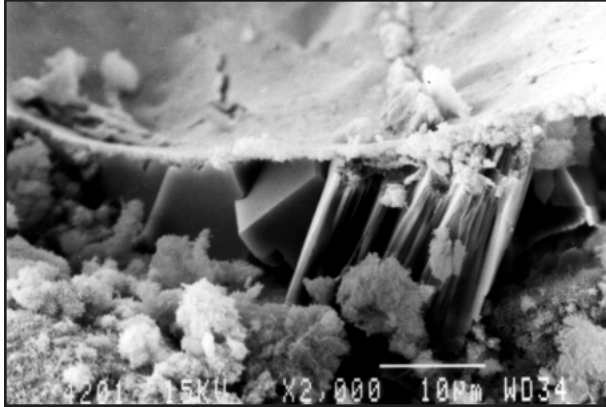
Figure 2 is magnified over two thousand times and highlights the aggregate-to-paste interface of a concrete matrix without microsilica. The top portion of the photo is a socket formerly occupied by the aggregate. Calcium hydroxide crystals are present underneath the interface, thereby preventing a good paste-(lower left corner)-to-aggregate bond.

Conversely, Figure 3 shows a similar view with microsilica concrete. The top portion shows an aggregate socket with no calcium-hydroxide crystals beneath the interface. The paste forms an excellent bond to the aggregate, producing stronger concrete, and reducing permeability.

The second mechanism by which microsilica improves concrete quality is through the so-called “microfiller effect”. Most condensed silica fume has an average particle size of about 0.15 micrometers, while a typical portland cement has an average particle size of 15 micrometers. Because of this size relationship, there are over 50,000 particles of microsilica for each grain of cement in a mix containing 10% microsilica by weight of cement (as depicted in Figure 4).

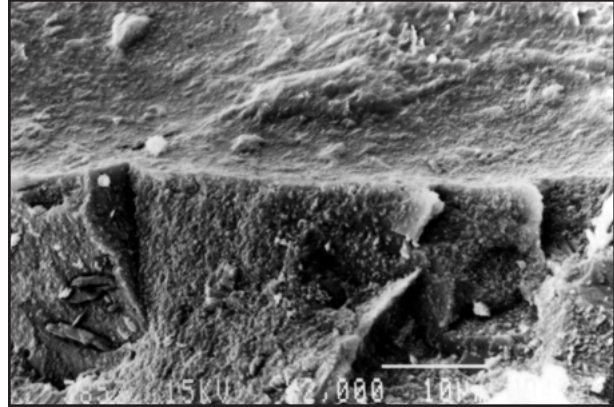
The extreme fineness of microsilica allows it to fill the microscopic voids between cement particles. The microfiller effect is credited with greatly reducing permeability and improving the paste-to-aggregate bond of microsilica concrete compared to conventional concrete.

**Figure 2**



**Concrete without Microsilica**

**Figure 3**



**Concrete with Microsilica**

### Placing, Finishing and Curing Considerations

Microsilica concrete is not difficult to work with, but because it is used for special applications, care should be taken to ensure that good quality concreting practices are followed.

The water demand of concrete can increase when microsilica is added to the mix. Just as with aggregates, the smaller sized microsilica particles have an increased surface area, and thereby, increased water demand. One method of compensating for this effect is to increase the water content; however, this leads to a lower quality concrete. The use of a superplasticizer, or high-range water reducer, in conjunction with the microsilica is almost universally recommended.

Depending on the dosage of microsilica, the fresh concrete may be more cohesive and sticky than conventional concrete. Due to this cohesiveness, slumps 25 to 50 mm (1 to 2 in.) higher than normal should be used for similar types of place-

ment. For ease of placement, the highest practical slump (attained through the use of superplasticizers) should be specified. Despite the increased cohesiveness, microsilica concrete produces a very creamy paste and is very pumpable.

One of the biggest differences in using microsilica concrete occurs during finishing. The addition of microsilica will virtually eliminate bleed water, making it more susceptible than conventional concrete to plastic shrinkage cracking. Practices outlined in the Guide for Concrete Floor and Slab Construction (ACI 302) and Hot Weather Concreting (ACI 305) should be followed to provide a good surface.

Finishing and curing practices which have worked successfully in the field generally involve underfinishing and overcuring the concrete. Curing should begin immediately following the finishing operation, and can include fog misting and placing wet burlap over the surface. Careful attention to

curing is essential; as with any concrete, microsilica concrete will perform much better when properly cured. The Standard Practice of Concrete Curing (ACI 308) should be closely followed.

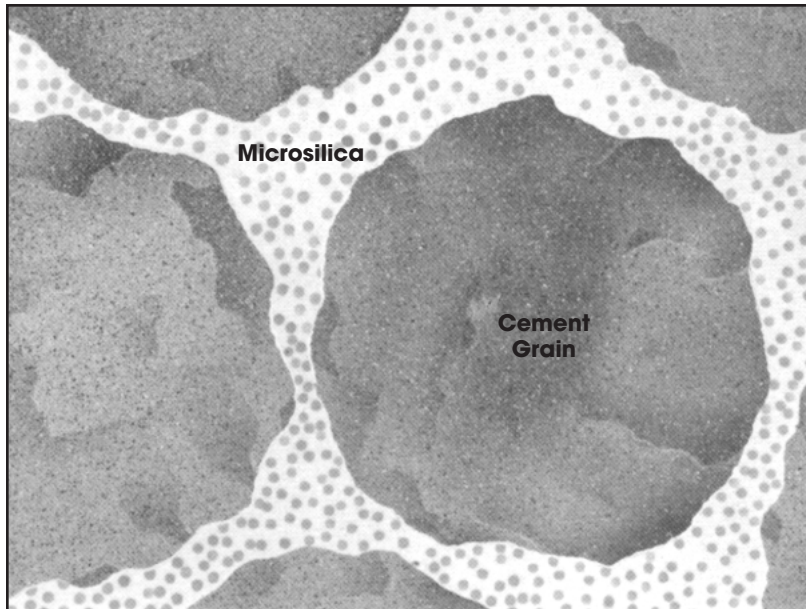
The addition of microsilica can also influence the color of both plastic and hardened concrete. Typically, a microsilica concrete is darker gray than conventional concrete, and it can become almost black, depending on the dosage of microsilica used. This does lighten or bleach out with time.

### Specifying Microsilica in Concrete

Microsilica is typically specified in dosages expressed by weight of cement. Dosages will vary depending on the application and the level of protection required, and typically range between 5% and 15% microsilica by weight of cement.

Grace has developed sample specifications for high strength, corrosion protection and durability applications using Force

**Figure 4**



The Capitol South parking garage, with 111,600 m<sup>2</sup> (1,200,000 ft<sup>2</sup>) of concrete, is the largest microsilica parking garage in the United States. Force 10,000 was specified because it produces lower permeability concrete which protects against corrosion of the reinforcing steel in the structure.

10,000 concrete. Your Grace representative will be able to work with you to modify the sample specifications to meet your specific needs.

### Summary of Benefits

Because of the pozzolanic nature and extreme fineness of the microsilica, Force 10,000's use in concrete can improve

many of its properties, opening up a wide range of applications. Its benefits include:

#### Dramatically Increased Strength

- Ready-mixed concrete compressive strengths of 70 to 140 MPa (10,000 to 20,000 psi)
- Flexural strengths of 10 to 14 MPa (1,500 to 2,000 psi)

#### Significantly Reduced Permeability/Increased Resistivity

- Rapid chloride permeability test results below 1000 coulombs
- Reduced water and gas permeability
- High resistivities providing corrosion protection

#### Improved Durability

- Higher resistance to aggressive chemical attack
- Better resistance against sulfate attack
- Improved hydraulic abrasion-erosion resistance
- Better resistance to adverse alkali-aggregate reactivity

These benefits make microsilica concrete suitable for a number of applications, ranging from structural beams and columns, to parking garage and marine structures, to chemical plant slabs, to dam spillways. These benefits and applications will be topics of future Engineering Bulletins.

**North American Customer Service: 1-877-4AD-MIX1 (1-877-423-6491)**



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