

# Silica Fume

## INTRODUCTION

Silica fume, also known as Microsilica is fine amorphous silica. Added to concrete at around 30kg/m<sup>3</sup> it changes the **rheology** and reacts with the cement hydration products to dramatically improve concrete strengths, durability and impermeability, allowing concrete to be used in ways never before possible.

## WHAT IS SILICA FUME?

Silica fume is a filter powder generated from the reduction of high purity quartz – ferrosilicon metals or silicon metals. Silica fume consists primarily of very fine smooth spherical silicon oxide particles with an extremely high surface area.

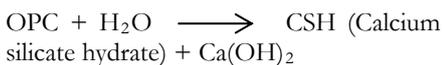
Silica fume's chemical and physical typical composition is shown in Fig.1 in comparison with OPC cement and fly ash.

## HOW SILICA FUME WORKS IN CONCRETE?

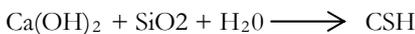
Silica fume improves concrete through two mechanism:-

### 1. Pozzolanic effect:

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



In the presence of silica fume, the silicon dioxide from the silica fume will react with the calcium hydroxide to produce more aggregate binding CSH as follows:-



The reaction reduces the amount of calcium hydroxide in the concrete as shown in Fig. 2. The weaker calcium hydroxide does not contribute to strength. When combine with carbon dioxide, it forms a soluble salt which will leach through the concrete causing efflorescence, a familiar architectural problem. Concrete is also more vulnerable to sulphate attack, chemical attack and adverse alkali-aggregate reactions when high amounts of calcium hydroxide is present in concrete.

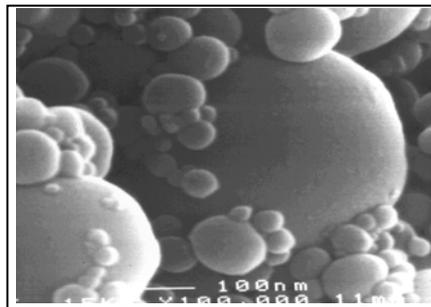
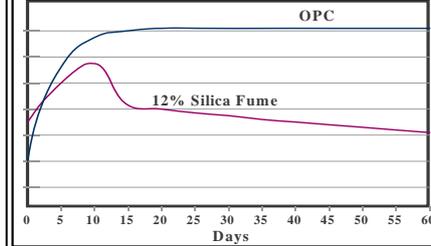
### 2. Microfiller effect :

Silica Fume is an extremely fine material, with an average diameters 100x finer than cement (Fig 3). At a typical dosage of 8%

**Fig. 1 Chemical and Physical Composition**

	Unit	OPC	Flyash	Silica Fume
SiO <sub>2</sub>	%	17 - 25	40 - 55	<b>90 - 98</b>
CaO	%	60 - 67	1 - 5	<b>0.2 - 0.7</b>
Al <sub>2</sub> O <sub>3</sub>	%	2 - 8	20 - 30	<b>0.4 - 0.9</b>
Fe <sub>2</sub> O <sub>3</sub>	%	0 - 6	5 - 10	<b>1 - 2</b>
Other	%	1 - 8	4 -15	<b>2 - 3</b>
S. G	Kg/m <sup>3</sup>	3150	2100	<b>2200</b>
Bulk density	Kg/m <sup>3</sup>	1400	900 - 1000	<b>550 - 650</b>
Surface Area	m <sup>2</sup> /kg	200 - 500	200 - 600	<b>20,000</b>

**Figure 2 – Silica Fume Reacts With The Weak Leachable Ca(OH)<sub>2</sub> to Form Strong Dense CSH Free Lime**



**Figure 3 – Silica Fume is 100x finer than cement and the particles are spherical.**

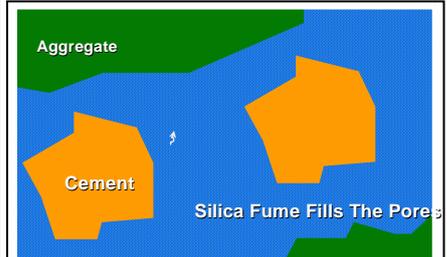
by weight of cement, approximately 100,000 particles for each grain of cement will fill the water spaces in fresh concrete (Fig 4). This eliminates bleed and the weak transition zone between aggregate and paste found in normal concrete. This microfiller effect will greatly reduced permeability and improves the paste-to-aggregate bond of silica fume concrete compared to conventional concrete.

The silica reacts rapidly (fig 5) providing high early age strengths and durability. The efficiency of silica fume is 3-5 times that of OPC and consequently vastly improved concrete performance can be obtained.

## FRESH CONCRETE PROPERTIES

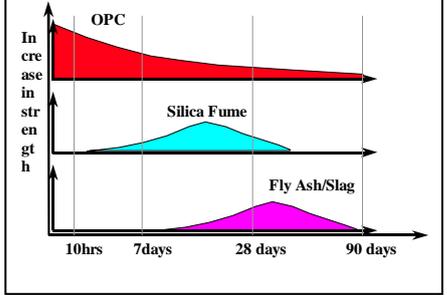
Due to its very fine nature and thus greater surface area, silica fume will increase the water demand. The use of a

superplasticizer to compensate for the higher water demand is universally recommended. Superplasticizers have a greater effect in silica fume concrete than in normal concretes because of the larger total surface area. It is possible now to dose high dosage of superplasticizers for very low water cement ratios concrete without bleeding and segregation problems encountered with normal OPC concrete. It enables



**Figure 4 – Approximately 100,000 Silica Fume particles fill the space between cement grains.**

**Figure 5 – Silica Fume Contributes Predominantly to Strength Between 3-28days.**



us to produce very flowable concrete without segregation and very high strength concrete. (70 to 120 MPa). Silica fume also lubricates the concrete and increases pumpability.

Since silica fume concrete exhibits significantly reduced bleeding, the potential for plastic shrinkage is increased. Thus it is necessary to protect the surface of freshly placed silica fume to prevent rapid water evaporation. Practices outlined in the Guide for Hot Weather Concreting (ACI 305) and for Concrete Floor and Slab Construction (ACI 302) should be followed to provide a good surface. Curing should begin immediately following the finishing operation and can include all types of normal curing such as fogging, water spraying, plastic sheets and curing membranes.

## SILICA FUME CONCRETE APPLICATIONS

Because of the pozzolanic and microfiller effect of silica fume, its use in concrete can improve many of its properties opening up a wide range of applications including:-

### Corrosion Resistance

The reduced permeability of silica fume provides protection against intrusion of chloride ions thereby increasing the time taken for the chloride ions to reach the steel bar and initiate corrosion. In addition, silica fume concrete has much higher electrical resistivity compared to OPC concrete thus slowing down the corrosion rate. The combined effect generally increased structures life by 5 – 10 times. Silica fume concrete is therefore suitable for structures exposed to salt water, de-icing salts, ie. harbour structures, ports, bridges, docks, on-shores constructions situated in areas with chlorides in the ground water, soil and in the air.

### Sulphate Resistance

Silica Fume concrete has a low penetrability and high chemical resistance that provides a higher degree of protection against sulphates than low C<sub>3</sub>A sulphate resisting cements or other cementitious binder systems.

### Heat Reduction

By replacing cement with silica fume and observing the efficiency factor of silica fume, a lower maximum temperature rise and temperature differential will take place for concrete with the same strength. It performs better than slag and fly-ash blends in thick sections. It is also the most effective way of achieving low heat without sacrificing early age strength.

### Silica Fume Waterproof Concrete

Because of its low permeability, silica fume can be use as an integral waterproofer for below ground structures where some dampness is acceptable, eg carparks.

### High Strength Concrete

Silica Fume in conjunction with superplasticizers is used to produce very high strength concrete (70 – 120 MPa). High strength concretes provides large economic benefits to developers e.g. reduced column and wall thickness in tall

buildings and improved construction schedule. It is also much more easier to pump silica fume concrete up the high rise buildings during construction.

### Shotcrete

Silica fume is use in shotcrete whether produced by wet or dry process to reduce the rebound, to increase application thickness per pass, improve resistance to wash out in marine construction or wet areas and to improve the properties of hardened shotcrete. With fibres it can eliminate mesh and reduce cracking.

### Abrasion Resistance

Silica fume concrete has very high abrasion resistance. In floor and pavement construction it's use saves money and time and improves operational efficiencies for the facility operator. It also improves the hydraulic abrasion-erosion resistance of concrete thus making it suitable for use in dam spillways.

### Chemical Resistance

Silica fume concrete is widely used in industrial structures exposed to an array of chemicals aggressive. In the alimentary industry the exposure comes from fat acids and other acids, detergents, etc. In the chemical industry there is exposure from mineral acids, phosphates, nitrates, petrochemicals, etc. Silica fume concrete is therefore invaluable in the industrial and agricultural sectors.

## TECHNICAL SUPPORT

Scancem Materials are able to provide technical support related to most aspects of the use of concrete in construction. This support takes the form of:

- Meeting with the owner, architect, engineer and/or contractor to develop a cost effective and technically appropriate silica fume concrete option that invariably offers advantages to all parties; "the win, win, win approach".
- Presentation to interested parties on the mechanisms by which Silica Fume Concrete provides solutions to construction problems.
- Report preparation that details the design methods and assumptions used for any analysis undertaken and include published papers supporting

the use of these design methods.

- Use of computer models to calculate dosages of special additives

## SUGGESTED READING

1. American Concrete Institute "Guide for the Use of Silica Fume in Concrete", ACI Detroit, 1996.
2. Domone, P.L.J., Soutsos, M.N., "An Approach to the Proportioning of High Strength Concrete Mixes", Concrete International, 1994.
3. FIP State of the Art Report, "Condensed Silica Fume in Concrete", Thomas Telford. London, 1988.
4. Holland, T., "Silica Fume Utilisation in Field Concrete", International Workshop on the use of Fly Ash, Slag, Silica Fume and other Siliceous Materials in Concrete, Sydney, Australia, 1988.
5. Holland, T., "Specification for Silica Fume for Use in Concrete", Presented at the Fifth Canmet/ACI International Conference on Fly Ash, Silica Fume Slag and Natural Pozzolans in Concrete, Milwaukee, Wisconsin, 1995.
6. Malhotra, V.M., Ramachandran, V.S., Feldman, R.F., Aitcin, P.C., "Condensed Silica Fume in Concrete", CRC Press Inc, Florida, 1987.
7. Malier, Y., "High Performance Concrete from Material to Structure", E & FN Spon, London, 1992.
8. Zia.P., Leming, M.L., Ahmed, S.H., "High Performance Concrete. A State of the Art Report", Strategic Highways Research Council, Washington DC, 1991.

The information given is based on knowledge and performance of the material Every precaution is taken in the manufacture of the product and the responsibility is limited to the quality of supplies, with no guaranty of results in the field as Scancem Materials has no control over site conditions or execution of works

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