ELKEM MICROSILICA®…..THE VERSATILEINGREDIENT

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ABSTRACT

Microsilica has been a major ingredient in construction for many years, improving the properties of a wide range of materials, including concrete, roofing products, tiles, siding boards and wall boards.

It has become particularly important in non-asbestos fibre cement recipes where it ensures the properties of the new products match or exceed the performance of the original asbestos versions.

However, although microsilica has been in construction use for over 30 years, it is still a mystery to some in the industry.

This paper will explain what microsilica is and how it is produced and used in construction products, with particular reference to fibre cement.

It will cover the effect of microsilica on construction product properties.

By the use of modern, practical examples, it will also illustrate how microsilica can be cost effectively used in many varied applications.

INTRODUCTION

Microsilica (also known as 'Condensed silica fume' and 'Silica fume') is a co-product of the silicon and ferrosilicon alloy industry, first sampled and analysed in 1947. The fume, collected from the chimney of a smelting plant, showed a high content of amorphous silicon dioxide (over 90%). Realising the potential of this material, a project was initiated to test the material as widely as possible and to establish methods to collect commercially viable quantities.

Full trials began in 1950, on concrete made with the inclusion of microsilica. In 1952 specimens were buried in the sulphate rich, acidic, alum shale under Oslo in Norway. These crude field tests were the first to illustrate the incredible durability imparted to cementitious materials containing microsilica.

By the 1970's, a filtering system had been designed that would successfully collect the material on an industrial scale and in 1975, the first Standards were issued.

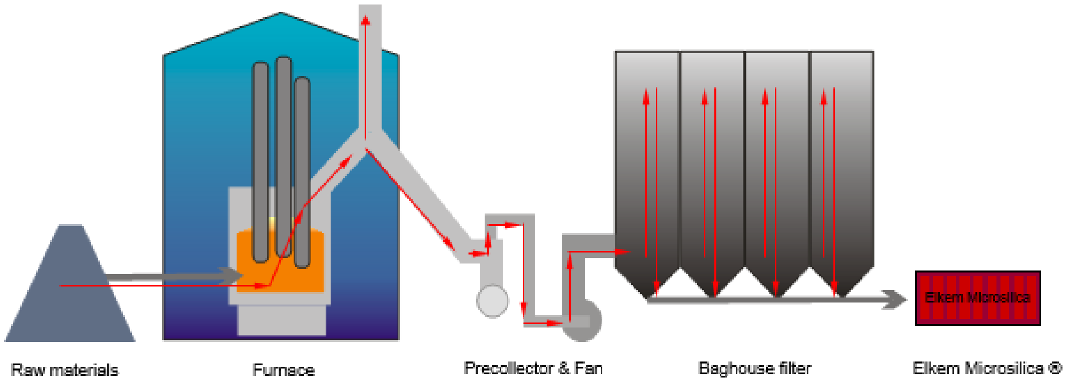
Initially, due to its high pozzolanic activity, microsilica was used as a cement replacement. As more data became available from testing and fieldwork, the material became used as an additional cementitious component, giving increased performance in the fresh and hardened states of materials.

There are now many Standards and Codes of Practice around the world that allow the use of microsilica in cement based materials.

Microsilica Production

Microsilica is produced during the high temperature reduction of quartz to give silicon or ferrosilicon. As the quartz is heated to 2000°C in an electric arc furnace, it gives off silicon monoxide gas at it forms the metal. This gas rises and combines with additional oxygen in the upper parts of the chimney stack and condenses as it cools. This condensation forms the pure, spherical particles of microsilica. The average particle size is 0.15 micron.

The material is drawn through cooling pipes and a pre-collector and into the filter house. In this building are hundreds of filter bags that trap the microsilica and let the hot air escape. The microsilica is then automatically emptied from the bags and blown into a holding silo.



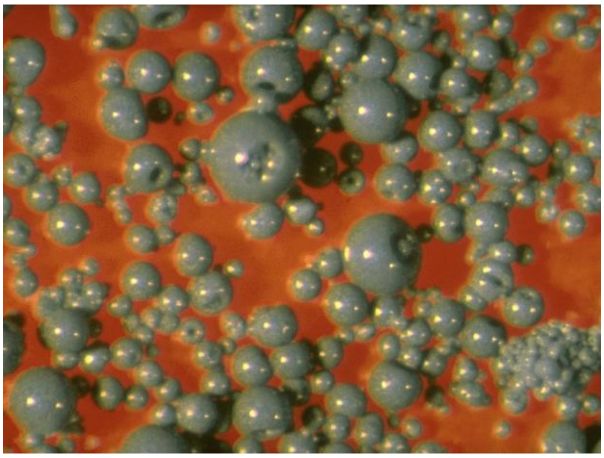
At this stage the microsilica has a bulk density of around 200kg/m^3. It can be bagged immediately as undensified powder, but even that amount of handling does create some natural agglomeration, giving a final density of 200-350kg/m^3. Undensified microsilica does suit some application areas but it is quite hard to handle and dusty in use. It can be further densified by continuing to loosely agglomerate the particles to give a final density of 500-700kg/m^3 and a material that is less dusty and more user friendly.

Thisdensified form of powder is frequently used by ready mixed concrete producers.

Finally, stable slurry can be produced with the raw microsilica while it is charged and hot from the furnace. An aqueous suspension of microsilica in water, usually 50% weight for weight is produced. The liquid has a specific gravity of around 1.4 and is much easier to handle than powders. This slurrification process can take up to 2 weeks to optimise quality and stability, and is a completely different material to 'instant slurries' sometimes produced on construction sites. These materials are really only pre-wetted powders that must be used immediately because they rapidly settle out if they are not frequently agitated.

A correctly manufactured liquid suspension of microsilica represents the optimum in user friendliness, with no dust issues, very easy handling and perfect dispersion of the microsilica particles.

This slurry form of microsilica is frequently used by fibre cement producers.



Microsilica Application

Microsilica is usually included as an additional cementitious material at a (dry) percentage of the original cement content. The percentage addition depends on the quality and performance required in the final product.

Microsilica will enhance the properties of any material containing cement, and the largest global application area is concrete in all its forms, with fibre cement a close second where microsilica allows manufacturers to successfully replace asbestos fibres in recipes.

The amount of microsilica used in various applications varies but typical dosages are listed below:

Pumping aid in concrete	2-3%
High qualityfibre cement products	4-7%
High strength cementitious products	7-15%
Underwater concrete applications	12-15%
Concrete spraying	8-12%

In all practical cases, the only true way to optimise the microsilica dosage is to carry out trials with the materials to be used. One interesting characteristic of microsilica is that its effectiveness in cementitious systems depends to a great extent on how well it is dispersed in a recipe.

This can frequently decide the form of microsilica that is used.

For example, in ready mixed concrete, the high shear mixing forces during production means that microsilica disperses fairly readily, so powders are most frequently used.

As a contrast, in the fibre cement industry, where less mixing energy is involved in the production process, microsilica slurry is the preferred option because of its easy dispersion characteristics.It is also one major reason that high quality microsilica slurry is often selected as the best technical option.

Mixing procedures vary from production unit to production unit, but the general rule is to get the microsilica into recipes as soon as possible and mix thoroughly. This ensures maximum dispersion time.

How does Microsilica work?

Physically - The ultrafine microsilica spheres force themselves in between the cement grains, separating them and at the same time reducing the voids in the fresh cementitious mix.

The particles act like fine ball bearings and whilst making mixes more cohesive, they add mobility allowing mixes to flow readily.

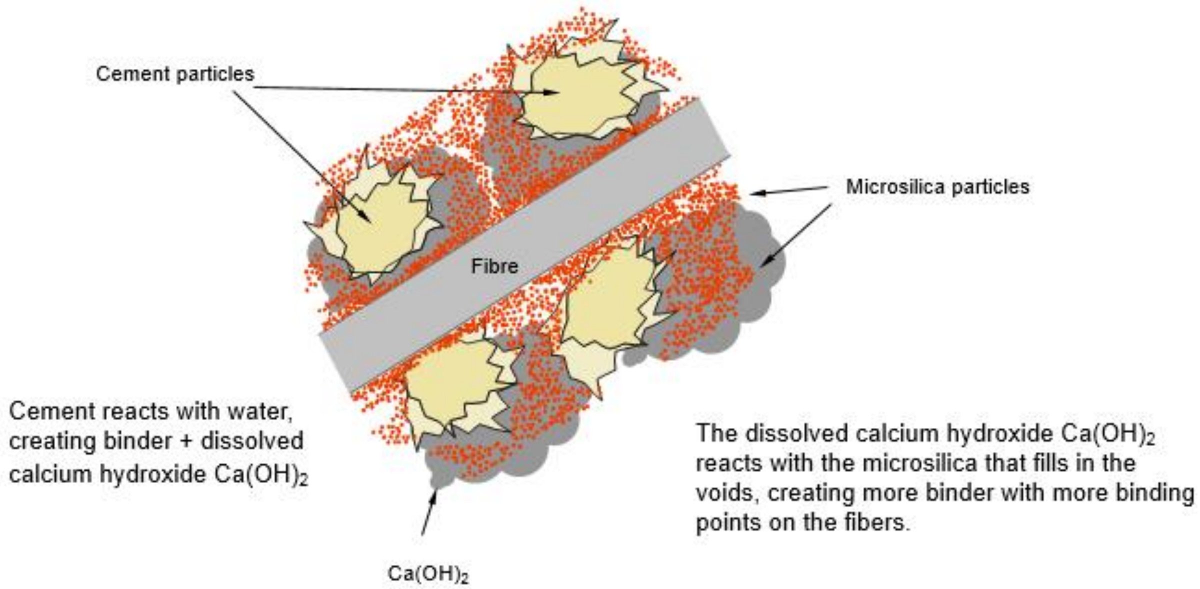
This gives fresh microsilica mixes great ‘mouldability’ without cracking and enables surface finishes to be applied early in a production process.

Chemically - Microsilica is a highly reactive pozzolan.

This means that it will react with the calcium hydroxide produced during the cement hydration reaction to form additional calcium silicate hydrates.

Because the microsilica particles are ultrafine, with a specific surface area of around 20,000m^2/kg and a SiO_2 content around 90%, the reactivity is high.

Due to the very fine size of the microsilica particles, the crystalline structure formed is also very fine, filling the voids in the matrix which densifies the whole cementitious structure.



Microsilica is also unique in the way it interacts with fibres in cementitious mixes, particularly in fibre cement, where microsilica particles force individual fibres apart, distributing then evenly in a mix. In addition the microsilica coats each fibre to provide a highly localised shield of hydration product that protects the fibres. The high strength of the microsilica hydration crystals also anchors the fibres more effectively, reducing ‘pull out’.

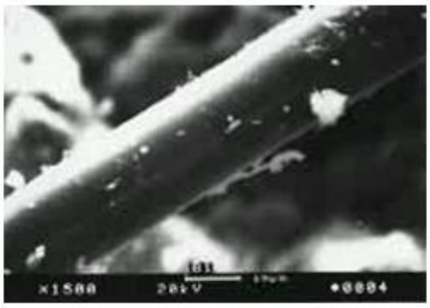


Photo 1 PVA Fibre surface Without microsilica

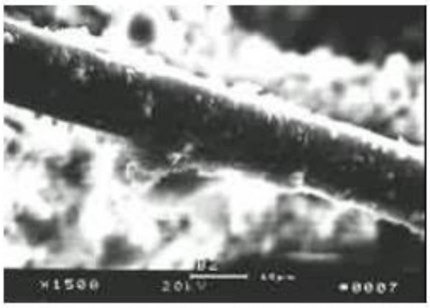


Photo 2 PVA Fibre surface with 4% microsilica


Photo 3 PVA Fibre surface with 8% microsilica

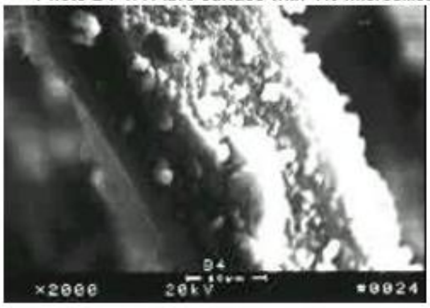


Photo 4 PVA Fibre surface with 12% microsilica

Properties of Concrete with microsilica

Fresh Properties	**Hardened Properties**
Cohesive	Strength
Non-segregating	Impermeability
Low bleed	Abrasion Resistance
Thixotropic	Chemical Resistance
Sprayable	Durability

Major Structures

The use of microsilica in major structures around the world is well documented with many famous case histories. Exceptional durability and a very low total life cost are the trademark of the bridges, tunnels and buildings constructed using microsilica concrete.

Abrasion

There are many case histories where microsilica concrete (often in combination with other technologies such as steel fibres) has been used to resist severe abrasion damage.

Scrap metal reclamation facilities are some of the most aggressive environments for concrete mixes. Wear rates of 10mm/month have been recorded at the most severe sites using conventional 50Mpa concretes. Properly designed microsilica mixes can extend lifespan by up to ten times.

Chemical Resistance

General chemical attack is probably the most prevalent problems in industry. Coatings are generally used in an attempt to protect concrete tanks and floor slabs but if the integrity of the coating is compromised, chemical attack willrapidly take hold.

Companies are now realising that the specification of a high quality microsilica concrete for their floor or containment vessel presents a cost-effective alternative. Microsilica concrete has been successfully used to construct effluent tanks and flumes and channels used to direct aggressive chemicals. Sometimes even these concretes degrade, but at a much-reduced rate compared to normal concretes.

Speed

Many industries now have onerous time constraints on infrastructure repairs and maintenance, requiring concretes to be in use very rapidly after placement.

Microsilica concretes can be designed to give full working strength in hours not weeks, opening up new possibilities and ‘windows’ for vital repair work. Examples are airports, railways, busy factories, major roads and carriageways.

Overall Properties in Concrete

Although specific properties are frequently quoted as the reason for using microsilica in concrete, there are many examples where it has been selected for the whole package of beneficial properties that come with its use.

These can be construction time savings, resistance to a particular aggressor and an overall reduction in 'total life costs'.

It is this 'total package' effect that is perhaps most unique with microsilica.

The use of microsilica in Fibre Cement

Microsilica is used in a very wide range of fibre cement products to enhance the overall properties of the material and enable producers to make high quality asbestos free products.

Properties of Fibre Cement with Microsilica

Products	Properties
Flat Sheets	Strength
Corrugated Sheets	Durability
Roof Tiles	Formability
Siding Boards/Planks	Good laminar bonding
Drainage Pipes	

Microsilica in fibre cement acts both as a filler and as a highly reactive pozzolan.

As explained previously, the fine microsilica particles separate and coat cement grains and fibres, improving their normal efficiency.

In this way, microsilica is a very efficient process aid in the fibre cement industry, particularly when using‘Hatschek’ machines.

The subsequent growth of the dense fine microsilica hydration crystals results in increased strength and a reduction in permeability.

Cellulose and PVA fibres on their own do not perform as well as asbestos fibres.

The addition of microsilica to the cellulose/pva/cement system restores this performance in air cured fibre cement sheets.

In freshly produced ‘green’ sheets, the inclusion of microsilica improves mouldability and prevents longitudinal cracking in corrugated roof sheets. This property also means microsilica recipes produce excellent surface textures when ‘stamped’ with a pattern to mimic wood grain or tiles.

Microsilica improves the inter-laminar bonding between sheet layers.

Microsilica improves bending strength of sheets and also the freeze thaw properties and durability of cured sheets.

In markets where long term product guarantees are normal (30 – 35 years), microsilica reduces the risk of any long term durability problems.

Process Aid

- **Increased Plasticity**
- **Improved Laminar bonding**

Strength

- Increase Modulus of Rupture
- Increase Density

Durability

- Improved Water Resistance
- Increased Freeze / Thaw resistance

Overall Properties in Fibre Cement

Like the use of microsilica in concrete, there are many reasons given for the use of microsilica in fibre cement.

There is no doubt that it acts as a process aid, improving the use of the fibres in recipes and interacting positively with other ingredients in the wet stage.

The plastic properties that microsilica imparts to green fibre cement are also highly beneficial, reducing cracking in corrugated sheets and improving mouldability (particularly useful when moulding ‘handmade’ roofing accessories).

During the curing process, microsilica improves inter laminar bond and once hardened all the sheet properties are improved:

Bending Strength increased

Density increased

Water absorption decreased

Freeze thaw resistance increased

Heat-rain resistance increased

De-lamination reduced

Durability increased

Total life cost reduced

Customer confidence increased

Development

We are now learning that microsilica can also give benefits and commercial savings when used in the production of autoclaved fibre cement sheets.

Microsilica is also used in other application areas where the production process is similar to the production of fibre cement.

These include the production of gasket sheets and millboard.

Microsilica is also used in fire resistant gypsum boards.

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