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Micro Silica in Concrete–The Special Concrete

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ABSTRACT

Concrete is the most important engineering material and the addition of some other materials can change the properties of concrete. With the increase in trend towards the wider use of concrete for high rise buildings there is a growing demand of concrete with higher compressive strength. so to achieve that micro silica can be added to concrete Micro silica also known as silica fume is an amorphous (non-crystalline) polymorph of silicon dioxide, silica. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production. The paper summarizes important physical and chemical properties of micro silica for an evaluation of micro silica from an Environment Health and Safety (EHS) point of view. Silica fume is an ultrafine material with spherical particles less than 1 µm in diameter, the average being about 0.15 µm. This makes it approximately 100 times smaller than the average cement particle. The bulk density of silica fume depends on the degree of densification in the silo and varies from 130 to 600 kg/m^3. The specific gravity of silica fume is generally in the range of 2.2 to 2.3 Around 500.000 MT of micro silica are sold to the construction industry world-wide and are used in fiber cement, concrete, oil-well drilling and even in polymers. Micro silica contains trace amounts of heavy metal oxides and organic deposits, which originate from natural raw materials. But Evidences indicate that micro silica is not a hazardous product when used in construction. The advantages of using micro silica can be considerable as it reduces thermal cracking caused by the heat of cement hydration and can improve durability to attack by sulphate and acidic waters.

Keywords: micro silica; polymorph; ultrafine; cement; advance material; non hazardous

1.0 INTRODUCTION

1.1 General

Micro silica is a mineral admixture which composes of very fine glassy spheres of silicon dioxide (SiO2). Most of the micro silica particles are less than 1 micron in diameter and generally 50 to 100 times finer than average cement or fly ash particles.

Silica fume is a byproduct in the carbothermic reduction reaction of high-purity quartz with carbonaceous materials like coal, coke, wood-chips, in electric arc furnaces in the production of silicon and ferrosilicon alloys. Micro silica, also known as Silica fume is fine amorphous silica. Added to concrete, it reacts with the cement hydration products which dramatically improve the concrete strengths, durability and impermeability, allowing concrete to be used in a very efficient way like never used before. Silica fume can be used in a variety of cementitious products such as concrete, grouts, and mortars as well as in elastomeric, polymer, refractory, ceramic and rubber applications. Silica Fume is used in concrete to improve its properties. It has been found that Silica Fume improves compressive strength, bond strength, and abrasion resistance; reduces permeability; and therefore helps in protecting reinforcing steel from corrosion. High strength and high performance concrete are being widely used throughout the world and to produce them, it is necessary to reduce the water binder ratio and increase the binder content. High strength concrete means good abrasion, impact and cavitations resistance. Using high strength concrete in structures today would result in many economical advantages. The globalization of the Indian economy paved the way for easy availability of micro-silica and latest superplasticisers in the country. M60 and higher grades of concrete are now becoming popular in the country with its proven utility in the construction of important structures.

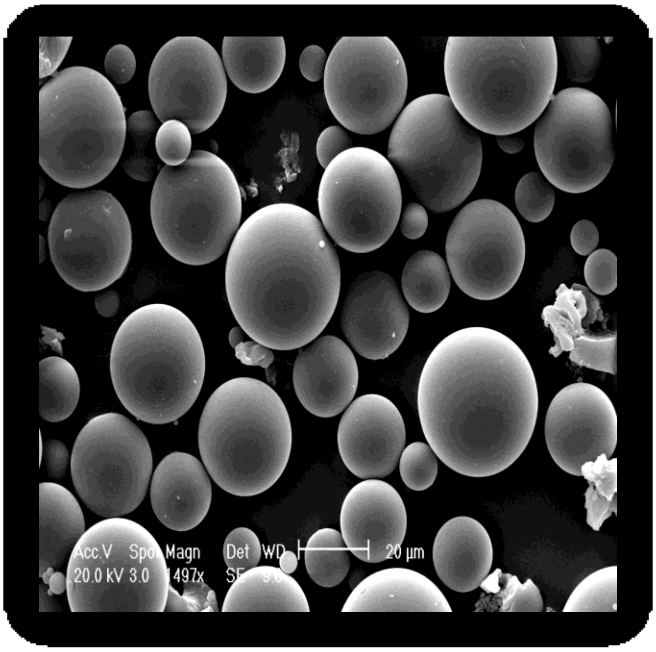

Figure 1: Micro silica is 100 times finer and than cement the particles are spherical

1.2 Increase the Strength of Concretes

The tensile (flexural) strength of concrete increases with compressive strength and the tensile strength typically only about 10% of the compressive strength. Compared with normal concrete the ratio of tensile strength tends to be slightly lower for silica fume concrete.

As the compressive strength of silica fume concrete increase, the tensile strength also increases, but at a gradually decreasing ratio. Researchers reports the splitting-tensile strengths as a percentage of compressive strength of 10% silica fume concrete (w/c = 0.35) ranged from 8.5% to 8.9% at ages of 28 to 182 days, whereas similar concrete without silica fume ranged from 9.4% to 10.7%.

2.0 METHODOLOGY

The methodology adopted comprised of both preliminary and experimental investigations which are carried out using the study material which are presented below with important chemical reactions:-

Pozzolonic Effect:-

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

OPC + H2O → CSH (Calcium silicate hydrate) + Ca(OH)2.

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

Ca(OH)2 + SiO2 → H2O + CSH.

2.1 Preliminary Investigations

For the preliminary investigations in lab, two materials for comparison that is micro silica and cement were subjected to physical and chemical analyses to determine whether they are in compliance with the standard used or not. The experiment was designed to investigate the silica fume as partial replacement for cement in concrete. The replacement levels of cement by silica fume are selected as 5%, 10%, 15%, 20% and 25% for standard size of cubes for the M30 grade of concrete. The specimens of standard cast iron cubes of size 150 x 150 x 150 mm were casted with silica fume. Compressive testing machine was used to test all the specimens. The specimens were casted with M30 grade of concrete with different replacement levels of cement from 0 to 40% with silica fume. Thirty two samples was casted and the cubes were put in curing tank for 7, 14, and 28 days and density of the cube, and compressive strength were determined and recorded down accordingly. The other materials used are listed as follow:

2.1.1 Cement

Ordinary Portland cement (OPC) of 33 MPA grade was used in this study. The cement conformed to the requirements of IS: 456-2000

Table 1: The basic components of cement

SiO2	17-25 %
Al2O3	4-8 %
Fe2O3	0.5-0.6 %
CaO	61-63 %
MgO	0.1-4.0 %
SO3	1.3-3.0 %
Na2	0.4-1.3 %

2.1.2 Aggregates

There are very vital component of concrete mixture which constitutes 70 -75% by volume and 60-80% by weight of the whole structure. The sand used was collected from New Delhi. It was clean and free from organic material and clay. The coarse aggregate used was retained on a 4.7mm test sieve and contained only so much fine materials that were permitted for various sizes in the specification.

2.1.3 Water

The water used for the study was free from acids, suspended solids, organic matter, alkalis and impurities which when present may have adverse impact on the strength of concrete. The PH of water was 6.

2.2 MIXING AND PLACING CONSIDERATIONS

2.2.1 Handling the Micro Silica

Micro silica presents some handling problems because of its extreme fineness. A cement tanker that can easily hold 30 metric tons of cement accommodates only 7 to 8 tons of dry micro silica and requires 20 to 40 percent more time for discharging. Some compounds mix micro silica with water to form slurry that is easily transportable in trailers designed to handle liquids only.

Figure 2: Sample of micro silica.

2.2.2 Water Requirements

Silica fume can be expected to produce an increased water demand, which is normally countered by the use of admixtures. The water demand of concrete containing silica fume increases with increasing amounts of silica fume this increase is caused primarily by the high surface area of the silica fume. To achieve a maximum improvement in strength and durability, silica-fume concrete should contain a high range water reducing admixture.

2.2.3 Placing, finishing and curing

The gel compound that forms during the first few minutes of mixing micro silica concrete consumes water and stiffens the mixture, making the adjustments for placing. Scientists have proven that micro silica concretes often require 1 to 3 inches more slump than conventional concrete for equal workability. After concrete has been placed there is a tendency for the solids (aggregates) to Settle and displace the water, which is pushed upwards. If the process is excessive, the water appears as a layer on the surface. The tendency of a concrete to bleed is affected by the constituents and their proportions, particularly the grading of the fine aggregate, the water content and any admixtures. Excessive bleeding can produce a layer of weak laitance on the top of the concrete and may result in plastic settlement cracks but bleeding can also be beneficial in avoiding plastic shrinkage cracks, which can form on concrete placed on hot or windy days, where the rate of evaporation of moisture from the surface exceeds the rate of bleeding.

Concrete containing silica fume shows significantly reduced bleeding. As silica fume dosage is increased, bleeding will be reduced. This effect is caused primarily by the high surface area of the silica fume to be wetted; there is very little free water left in the mixture for bleeding, out that because of the reduced bleeding, care should be taken to prevent early moisture loss from freshly placed silica-fume concrete, particularly under conditions that promote rapid surface drying.

A reduction in the early age temperature rise can reduce the risk of early-age thermal cracking and detailed guidance is provided in CIRIA Report C660, Early-age thermal crack control in concrete. However a slower release of heat can reduce the initial rate of strength gain. This may necessitate longer periods before striking formwork and/or removal of props especially when casting thin, exposed sections in winter conditions in cooler climates.

CIRIA Report C660 suggests that silica fume should be considered equivalent to CEM I in regard to heat generation. It also points out that silica fume, when used with a high range water reducing admixture, can achieve equivalent strength with reduced binder content (subject to any minimum limit on binder content) and thereby lower heat output.

2.2.4. Color effects

Freshly mixed concrete containing micro silica can be almost black, dark gray, or any other color depending upon the amount of micro silica and its carbon content. The more is the carbon and iron in the admixture, the darker will be the resulting concrete. Hardened concretes are not much darker than normal concretes when dry. Sometimes there is a faint bluish tinge shade observed.

Figure 3: Micro Silica colors

2.3 PREPARATION OF SPECIMENS

For preparation, a total number of 9 cubes for the control and cement replacement levels of 5%, 10%, 15%, 20% and 25% were produced respectively. For the compressive strength, 150mm x 150mm x 150mm cubes mould were used to cast the cubes and 3 specimens were tested for each age in a particular mix (i.e. the cubes were crushed at 7 ,14 and 28 days respectively). All freshly cast specimens with moulds are left for 24 hours before being demoulded and then submerged in water for curing until the time of testing.

2.4 MIX PROPORTIONING

The proportion of micro silica included in a concrete mix is usually expressed in terms of the percentage by weight of cement. It is normally regarded as an addition to the cement content of the mix, not as a cement replacement. The amount included in the concrete for a particular use should be determined to suit that situation and the suitability of the concrete checked by means of trial mixes. Mix Proportioning by weight was used and the cement/aggregates ratio was of 1: 2: 4

The following amounts of micro silica are normally used:-

Normal concrete 5-10% of cement by weight
High strength concretes 5-15% of cement by weight
As a pumping aid 2-5% of cement by weight

Table 2: Mix proportion for 30Mpa Concrete

Materials	**Mix Proportion (Kg)**					
	Control	**MS 5%**	**MS 10%**	**MS 15%**	**MS 20%**	**MS 25%**
Cement(Kg)	360.0	350.5	333.0	313.5	294.0	278.5
Micro silica (Kg)	0	16.5	35.0	52.5	71.0	88.5
Total Water (Liter)	140	140	140	140	140	140
Fine Aggregate(Kg)	750	750	750	750	750	750
Coarse Aggregate (Kg)	1150	1150	1150	1150	1150	1150
MS432 (Liter)	3	3	3	3	3	3
W/C	0.4	0.4	0.4	0.4	0.4	0.4

2.5 SPECIMENS TESTING

After the 28 day curing period, the specimens were taken outside the curing tank and were tested under a compressive testing machine of 2000KN capacity for compressive strength. The crushing loads were noted and the average compressive strength of three specimens is determined. The compressive strength value of specimens subjected to different replacement level with Fly ash and Micro Silica has been presented :-

Figure 4: Cube moulds

Table 3: Replacement of fly ash with micro silica

Sr. No.	Replacement levels in percentage	IS code method Compressive strength M30 grade concrete (28 days) N/mm2	
		Fly ash replacement	Micro silica replacement
1	5%	67.27	67.05
2	10%	71.12	69.46
3	15%	63.195	70.02
4	20%	63.115	63.34
5	25%	60.55	59.72

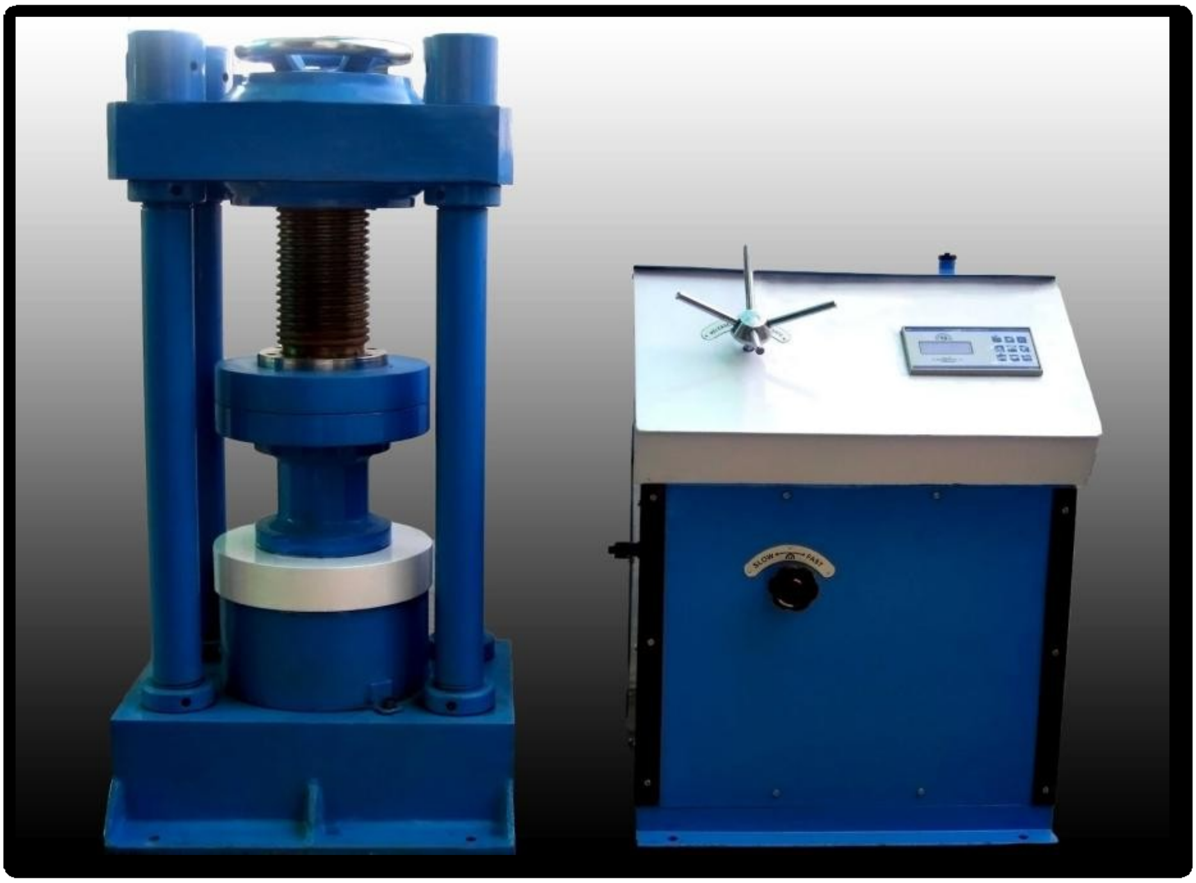

Figure 5: Compression testing machine

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2.5.1 Compressive Strength of Concrete

The test was carried out to obtain compressive strength of M30 grade of concrete. The compressive strength of concrete with OPC and silica fume at the age of 7, 14 and 28 days are presented in table 4 here and shows a significant improvement in the strength of concrete because of the high pozzolanic nature of the micro silica and its void filling ability. The compressive strength of the mix M30 at 7, 14 and 28 days age, with replacement of cement by micro silica was increased gradually up to an optimum replacement level of 12% and then decreased. There is a decrease in workability as the replacement level increases, and hence water consumption will be more for higher replacements.

The use of micro silica is often associated with high strength concrete although its beneficial effects on the durability of the concrete are equally. Realization of this additional strength depends upon uniform mixing of the material in the concrete and adequate workability for compaction followed by thorough compaction and proper curing of the concrete. For concrete work with a large exposed surface, such as a floor slab, it is particularly important to ensure that curing is properly carried out. Strengths of 100 to 130N/mm have been achieved in practice on several projects for the construction of tall buildings in North America, Europe, Asia and Singapore. Tensile strength is similarly increased by the use of micro silica and this can benefit the floors and paved areas.

Table 4: Compressive strength Test Results (N/mm2) for varying Micro Silica Replacement Levels in concrete

Mix description	**Plain**	**5% M.S (micro silica)**	**10% M.S (micro silica)**	**15% M.S (micro silica)**	**20% M.S (micro silica)**
% added of silica fume	0 %	5 %	10 %	15 %	20 %
7 Days	22.2	26.4	30.1	31.2	30.1
14 Days	27.7	28.5	32.4	35.4	34.1
28 Days	33.5	41.5	43.7	46.3	43.5

3.0 DISCUSSIONS

3.1 WORKING OF MICRO SILICA

How Does Silica Fume Work in Concrete?

- Physical effect
- Chemical effect

Silica Fume: Physical Effect

The presence of any type of very small particles will improve concrete properties. This effect is termed either “particle packing” or “micro filling”.

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The carbon black and plain cement mixes showed comparable strengths at both 7 and 28 days, even though the carbon black mixes contained 10 percent less cement (by mass) physical mechanisms do play a significant role, particularly at early ages.

Micro silica is an extremely fine material, with average diameters 100 times finer than cement. By 8% by weight of cement, approximately 100,000 particles for each grain of cement will fill the water spaces in fresh concrete. This eliminates bleed and the weak transition zone between aggregate and paste found in normal concrete. This micro filler effect will greatly reduced permeability and improves the paste-to-aggregate bond of silica fume concrete as compared to conventional concrete. The silica fume reacts rapidly providing high early age strengths and durability. The efficiency of micro silica is 3-5 times that of OPC. Dosages of micro silica used in concrete have typically been in the range of 5 to 20 percent by weight of cement, but percentages as high as 40 have been used in certain places.

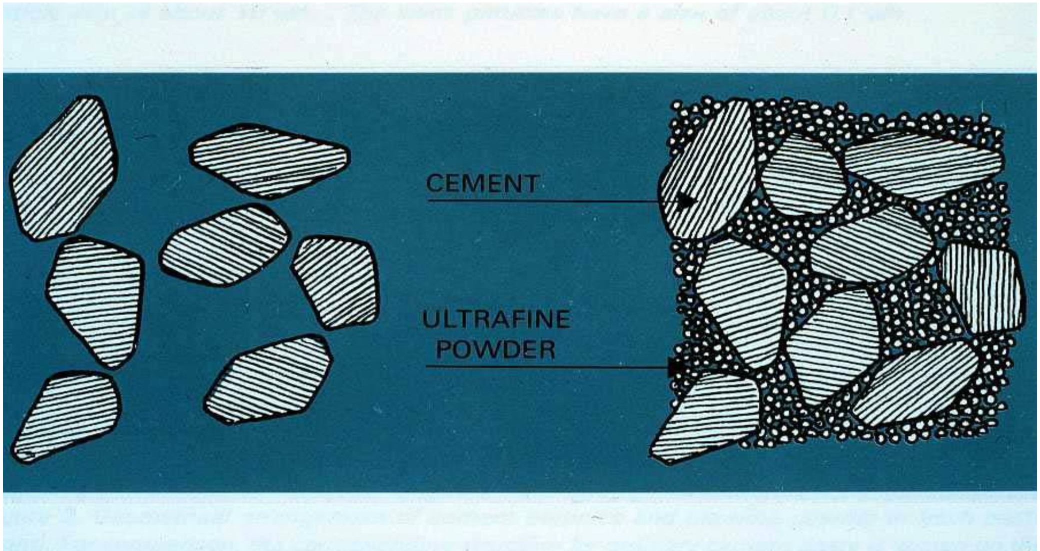

Figure 6: Bonding of micro silica with cement

Silica Fume: Chemical Effect

Silica fume is simply a very effective pozzolanic material.

What is pozzolan? A siliceous or siliceous and aluminous material, which in itself possess little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties

Portland cement + water = calcium silicate hydrate + calcium hydroxide
Pozzolan + calcium hydroxide + water = calcium silicate hydrate

The Transition Zone:

The transition zone is a thin layer between the bulk hydrated cement paste and the aggregate particles in concrete. This zone is the weakest component in concrete, and it is also the most permeable area.

Silica fume plays a significant role in the transition zone through both its physical and chemical effects.

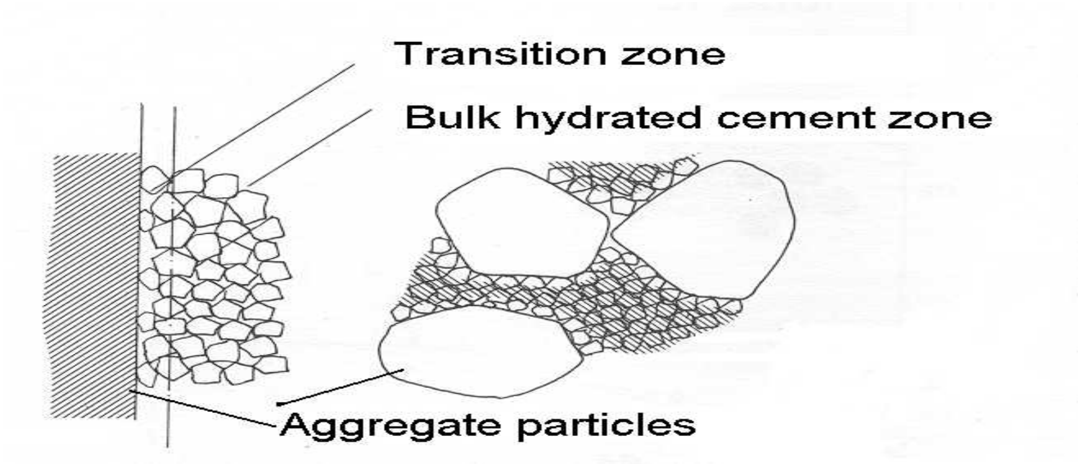

Figure 7: Transition zone in concrete

3.2 HOW MICRO SILICA IMPROVES CONCRETE?

Being finer than fly ash, this pozzolana increases the strength and density and also reduces concrete permeability. Since micro silica particles are only about 1/100th the size of cement grains, the material may possess problems in batching and shipping. These handling problems may be overcome by mixing micro silica with water in slurry. Densification process has also been tried to simplify the mixing and handling.

Addition of micro silica to a concrete mix alters the cement paste structure. The resulting paste contains more of the strong calcium-silicate hydrates and less of the weak and easily soluble calcium hydroxides than do ordinary cement pastes. Because the micro silica particles are so small they disperse among and separate the cement particles. The resulting fine, uniform matrix can give markedly higher compressive, flexural, and bond strength. Micro silica reduces the rate of carbonation, decreases permeability to chloride ions, imparts high electrical resistivity, and has little effect on oxygen transport. Therefore, micro silica concrete can be expected to be strongly protective of reinforcement and embedment.

Figure 8: Micro silica concrete- a better concrete

3.3 APPLICATIONS OF MICRO SILICA CONCRETE

Because of the pozzolanic and micro filler effect of micro silica, it has wide range of applications including:-

1. Corrosion Resistance
2. Sulphate Resistance
3. Heat Reduction
4. Abrasion Resistance
5. Chemical Resistance
6. Use as Silica Fume Waterproof Concrete
7. Use as High Strength Concrete
8. Use as Shotcrete

Figure 9: The Burj Khalifa in Dubai is currently the tallest building in the world where the silica fume concrete contributed to record pumping heights of over 600m in a single operation.

CONCLUSIONS

1) Silica fume increases the strength of concrete more 25%.
2) Silica fume is much cheaper then cement therefore it very important form economical point of view.
3) Silica fume is a material which may be a reason of Air Pollution this is a byproduct of some Industries.
4) Use of micro silica with concrete decrease the air pollution.
5) Silica fume also decrease the voids in concrete.
6) Addition of silica fume reduces capillary.
7) Absorption and porosity because fine particles of silica fume reacts with lime present in cement.

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