Research Paper Engineering

Pozzolanas- Evaluation of Silica Fume For Use in Concrete

Dr Deepa A Sinha | Associate Professor, Structural Engineering Dept, BVM Engineering College, Vallabh Vidyanagar, Anand, Gujarat, India.

ABSTRACT

Replacing cement by pozzolanic material like fly ash, silica fume, blast furnace slag and metakaolin , not only its strength gets enhance but serviceability and durability characteristic can also be improve. The addition of silica fume to a mix, along with appropriate chemical admixtures, often improves its plastic properties such as workability, pumpability, cohesion and adhesion, and gives reduced bleeding and a very fine surface finish.. In this paper the engineering properties of Silica fume for use in Concrete is discussed.

KEYWORDS Supplementary cementing material, Engineering properties, Mechanical properties, Durability properties

Introduction

Silica fume, also known as microsilica 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 and consists of spherical particles with an average particle diameter of 150 nm. The main field of application is as pozzolanic material for high performance concrete. [1]

Silica fume is a co-product of the ferrosilicon and silicon alloy industry. Silica fume is a byproduct resulting from the reduction of high purity quartz with coal in electric arc furnaces the production of silicon and ferro-silicon alloys. Silica fume is also collected as a byproduct in the production of other silicon alloys such as ferro chromium, ferro manganese, and ferro magnesium and calcium silicon.

Silica fume concrete has proved particularly beneficial in areas where the structures are subjected to severe environmental attack. These include hazardous ground conditions, marine exposure, chemical attack or physical degradation such as abrasion or erosion. The concrete can also be designed to give very high strength as well as increased electrical resistivity. The term high performance concrete (HPC) and high strength concrete (HSC) is often associated with silica fume concrete. The addition of silica fume to a mix, along with appropriate chemical admixtures, often improves its plastic properties such as workability, pumpability, cohesion and adhesion, and gives reduced bleeding and a very fine surface finish. [1]

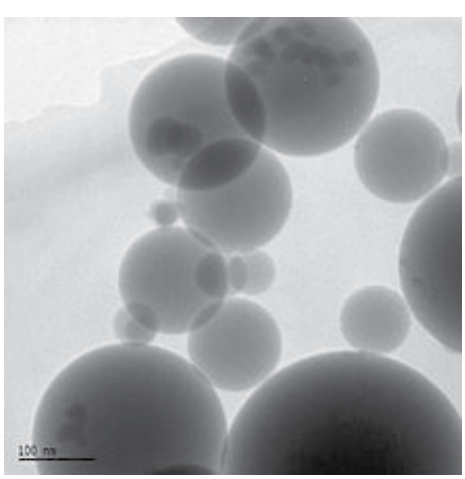

Fig. 1 SEM photo of silica fume



Fig. 2 Raw silica fume

Physical properties

- Specific gravity of silica fume is 2.2 and its particle shape is spherical.
- The specific surface area of silica fume can be measured with the BET method or nitrogen adsorption method. It typically ranges from 15 to 25 m2/gm
- Bulk density varies from 500 to 700 kg/m³.
- Its colour varies from light to dark grey which depends on the process in the manufacturing and is influenced by some parameters such as wood chip composition,furnace temperature, ratio of wood chip to the coal used, exhaust temperature, and type of metal produced.
- Particles retained on 45 micron Sieve:- Max 10% as per IS.
- Silica fume is an ultrafine airborne material with spherical particles less than 1µm in diameter, the average being about 0.1 µm. This makes it approximately 100 t i m e s smaller than the average cement particle. (2),

Chemical Composition

Table 1 Chemical composition [2]

Ingredients	% by weight
SiO_2	90.3
$A1_20_3$	0.8
Fe_20_3	1.7
CaO	0.1
MgO	1.0
L.O.I	2.1

Engineering properties

Loss on ignition:- As per IS Max 6 %.
Moisture content:- As per IS limits Max. 3.0%.
Silicon dioxide as per IS limits 85%.

Hydration mechanism
As the concrete hardens, the chemical reaction of silica fume takes place over from the physical effects. In addition to the pozzolanic reaction between the amorphous silica in silica fume and calcium hydroxide produced by the hydration of Portland cement, silica fume contributes to the progress of hydration of latter material. This contribution arises from the extreme fineness of the silica fume particles which provide nucleation sites for calcium hydroxide. Thus the amount of binder (C-S-H gel) is increased, which both increases the early strength and reduces the permeability by densifying the matrix of the concrete. Silica fume dissolves in a saturated solution of calcium hydroxide within a few minutes. Therefore, as soon as enough Portland cement has hydrated to result in saturation of the pore water with calcium hydroxide, calcium-silicate-hydrate is formed on the surface of silica fume particles. Since silica fume has a very high surface area and a high content of reactive silicon-di-oxide, it is more reactive than other supplementary materials such as FA and GGBFS, the reaction proceeds, initially, at high rate. This increased reactivity is found to push the hydration of the C_3S fraction of the cement initially, thus creating more calcium hydroxide, and that the reaction rates settle down to more normal rates beyond 2 days. For example, when the mass of silica fume was 10% of the total mass of cementitious material, one-half of the silica fume was observed to react in 1 day; the two-thirds during the first 3 days. However, subsequent reaction was very slow, only three-quarters of the silica have hydrated at 90 days. [(1), (2)]

Workability
The addition of silica fume brings about cohesiveness as well as improved boding between aggregates. This increase in cohesiveness is mostly advantageous but it also means that the concrete will have a lower slump. But when the mix is supplied with energy as in pumping, vibrating or tamping, the silica fume particles being spherical act as ball bearings and lubricate the mix giving it a greater mobility than ordinary concrete with similar slump. The high specific surface area of silica fume means that there will be an increased water demand and this is a reason why silica fume should always be used with plasticizers or superplasticisers. [(2)]

Placing and pumpability
Since silica fume concrete is more cohesive, it is therefore less susceptible to segregation than regular concrete, even in flowing concrete. The addition of small amounts of silica fume to a designed mix will act as a pumping aid, giving very good pumping characteristics. Another advantage of cohesiveness is that silica fume concrete will produce virtually no bleed water. The lack of bleed water means that finishing and curing can be started little earlier than the ordinary concrete. However, silica fume being a pozzolan requires calcium hydroxide to start the reaction and it takes place only after the cement has started reacting. The setting times for silica fume concrete are similar to those of ordinary concrete. [(2)]

Mechanical properties
Compressive strength
This is the first property associated with the silica fume Concrete. Many reports are available showing that silica fume when added to a concrete mix will increase the strength of that mix by 30% and 100%. But this is of course depend on type of mix, type of cement, amount of silica fume, the use of plasticizer and superplasticiser, w/c ratio, curing regime, etc. [(2)]

Tensile strength
The relationships between tensile, flexural and compressive strengths in silica fume are similar to those of ordinary concrete. Thus an increase in the compressive strength using silica fume will result in a proportional increase in the tensile and flexural strengths. [(2)]

Bonding
The improved packing contributed by the very small size of the particles silica fume will improve the contact surface and thus the bond, between the fresh silica fume concrete and the substrate such as reinforcement, old concrete, fibers and aggregates. This is property of silica fume is exploited in all applications especially in shotcreting. [(2)]

Shrinkage
The shrinkage of silica fume concrete is similar to that of normal concrete. However, due to the reduced rate of drying, shrinkage takes place at slower rate in silica fume concrete. This means that the observed shrinkage will be less in silica fume concrete than in normal concrete. [(2)]

Abrasion and erosion: High strength silica fume concrete show greatly improved resistance to abrasion and erosion. Therefore this property of silica fume concrete is being extensively used in applications where the concrete exposed to heavy abrasion, erosion and wear such as in dams-spillways, stilling basins roads, pavements, etc. [(2)]

Fire resistance
Tests have shown that under normal fire conditions, silica fume concrete do not behave any differently to normal concrete. The mechanism involved is probably on of high resistance to steam movement. If soaked concrete is tested in very intensive fire tests, where the low permeability of the silica fume concrete means that steam cannot escape, spalling occurs due to steam pressure. [(2)]

Durability properties
The main chemical and physical effects of silica fume addition to concrete are reduction in the content of calcium, potassium and sodium hydroxides and a refined pore structure in the hardened concrete. The major influence of the silica fume on the chemical and physiochemical durability of concrete is through the large change in the permeability, for water the reduction in permeability can be by a factor of between 10 and 100 time compared to control concrete.

The deterioration of silica fume concrete is demonstrably slower than comparable normal concrete. The neglect in mix design, quality control and curing of concrete may result in weaker and less durable concrete than normal. [(2)]

Sulfate resistance
The consensus is that resistance to sulfates (with the exception of ammonium sulfate), is improved by the use of SF as a partial cement replacement. There is a general indication in research that replacement should be limited to 15%. Silica fume concretes are as effective against sulfate attack as sulfate resisting PCs. Silica fume concretes are used where there are high concentrations of sulfates, for example for concrete piles adjacent to groundwater with high levels of sodium or calcium sulfates. [(2)]

Alkali-silica reaction
Three main factors (high alkali content, reactive aggregate and a source of water) are required for damaging alkali silica reaction to occur in concrete. Well dispersed silica fume binds alkalis and should thus prevent attack on reactive siliceous aggregates. The reduced permeability of silica fume concrete should also reduce the supply of water. silica fume has an excellent track record of use in Iceland where some of the aggregates are highly reactive A minimum of 8% silica fume by mass, as a percentage of the total binder, is recommended to minimize alkali-silica reaction. The recommendations apply only to silica fume with greater than 85% non-crystalline SiO_2 by mass. [(2)]

Heat of hydration
For a given 28 day strength, silica fume concrete will normally develop less heat than regular portland cement concrete. The reason is that the amount of cement is reduced which means that the total heat evolved early on is also reduced. The silica fume added starts reacting a little later after calcium hydroxide is released, and does not contribute as much as heat does

cement. Silica fume concrete is very sensitive to temperature variations while hardening. The rate of hydration, and with it a gain in strength will be reduced with low and dramatically accelerated with increase temperatures [2]

Advantages

- Silica fume improves the properties of fresh and hardened concrete
- Fresh concrete made with silica fume is more cohesive
- Silica fume reduces segregation and bleeding
- Silica fume improves the durability of concrete
- Lack of bleeding allows a more efficient finishing process [2]

Conclusion

Thus it can be concluded looking to the above properties that Silica fume can be used as a supplementary cementitous material.

REFERENCES

1. Santanu Bhanja and Bratish Sengupta, "Optimum Silica fume content and its mode of action of concrete" ACI (Material journal, September-October 2002, pp 407-412. | 2. Silica fume user manual |