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Advanced Structural Material – Micro Silica

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ABSTRACT:

Maintenance, Repair and Rehabitation of existing cement concrete structures involves a lot of problem leading to significant expenditure. Inthe recent past, there has been considerable attention for improving the properties of concrete with respect to strength and durability,especially in aggressive environments. High performance concrete (HPC) appears to be a better choice for strong and durable structures.Suitable addition of mineral admixture such as silica fumes (SF), ground granulated blast furnace slag and fly ash in concrete improves the strength and durability of concrete due to considerable improvement in the microstructure of concrete composites, especially at the transition zone .Very few studies have been reported in India on the use of Silica fumesfor the development of High performance concrete and also durability characteristics of these mixes have not been reported. In order to make quantitave assessment of different cement replacement levels with SF on strength and durability properties for M60, M7O and M110 grades of High performance concrete trail mixes and to arrive at the maximum levels of replacement of cement with SF, investigations were taken. This paper reports on the performance of High performance concrete. Trail mixes having different replacements levels of cement with Silica fumes. The strength and durability characteristics of these mixes are compared with the mixes without Silica fumes. Compressive strengths of 60 MPa, 70 MPa and 110 MPa at 28days were obtained by using 10 percent replacement of cement with silica fumes. The results also show that the silica fumes concrete possess superior durability properties.

INTRODUCTION:

Silica fume (SF) is a by-product of the smelting process in the silicon and Ferro- silicon industry. The reduction of high- purity quartz to silicon at temperatures up to 2,000 C produces SiO2 vapours, which oxidizes and condense in the low- temperature zone to tiny particles consisting of non-crystalline silica. By-products of the production of silicon metal and the ferrosilicon alloys having silicon contents of 75% or more contain 85–95% non-crystalline silica.

The by-product of the production of ferrosilicon alloy having 50% silicon has much lower silica content and is less pozzolanic. Therefore, SiO2 content of the silica fume is related to the type of alloy being produced Silica fume is also known as micro silica, condensed silica fume, volatilized silica or silica dust.The silica fume is collected in very large filters in the baghouse and then made available for use in concrete. Silica fume has historically been available in three basic product forms: undensified, slurried, and densified. There is no data available, after many years of testing, to show that any one of the product forms will perform better in a concrete mixture than any of the others. Slurried silica fume is no longer available in the U.S. market. Undensified silica fume is available but it is not frequently used in ready-mixed or precast concrete. Undensified silica fume is primarily used in pre-bagged products such as grouts or repair mortars.

Densified silica fume is produced by treating undensified silica fume to increase the bulk density up to a maximum of about 400 to 720kg/m3. This increase in bulk density is usually accomplished by tumbling the silica-fume particles in a silo, which causes surface charges to build up. These charges draw the particles together to form weak agglomerates. Because of the increased bulk density, this material is more economical for truck transportation Densified silica fume works very well in concrete. However, one caution when working with this product form is to ensure that the mixing is adequate to break up the particle agglomerations. Mixing in some types of mixers such as those that are used in dry mix shotcrete, roof tiles, or other applications where coarse aggregate is not present may not be adequate to break up the agglomerations. In those situations, an undensified silica fume may be more appropriate.

2. METHODS OF USING SILICA FUME IN CONCRETE:

As an admixture:

Small quantities of silica fume, 5 to 10 percent by weight of cement, can be added to concrete. The result- in loss in slump is compensated for either by the addition of more

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water or the use of superplasticizers. In either case, there is a marked increase in compressive strength as compared with the control mix. This is particularly so with the use of superplasticizer.

As a partial replacement for cement:

Silica fume can be used as a partial replacement for cement. The percentage replacement may vary from 0 to 30 percent. Though this does not change the weight of the cementitious materials, there is an increase in the water demand because of the extreme fineness of silica fume. In order to maintain the same water- (cement plus silica fume) ratios, superplasticizers are used to maintain the required slump. This approach also results in an increase in compressive strength at the age of 3 days and thereafter

2.1. APPLICATIONSOF SILICA FUMES:

• High Performance Concrete (HPC) containing silica fume— for highway bridges, parking decks, marine structures and bridge deck overlays which are subjected to constant deterioration caused by rebar corrosion current, abrasion and chemical attack. Silica fume will protect concrete against dicing salts, seawater, and road traffic and freeze/thaw cycles. Rebar corrosion activity and concrete deterioration are virtually eliminated, which minimizes maintenance expense.

• **High-strength concrete enhanced with silica fume—**provides architects and engineers with greater design flexibility. Traditionally used in high-rise buildings for the benefit of smaller columns high- strength concrete containing silica fume is often used in precast and prestressed girders allowing longer spans in structural bridge designs.

• **Oil Well Grouting—**whether used for primary (placement of grout as a hydraulic seal in the well-bore) or secondary applications (remedial operations including leak repairs, splits, closing of depleted zones); the addition of silica fume enables a well to achieve full production potential. Besides producing a blocking effect in the oil well grout that prevents gas migration, it provides these advantages such as (i) Improved flow, for easier, more effective application; (ii) dramatically decrease permeability, for better control of gas leakage; and (iii) lightweight

• **Repair Products—**silica fume is used in a variety of cementitious repair products. Mortars or grouts modified with silica fume can be tailored to perform in many different applications—overhead and vertical mortars benefit from silica fume's ability to increase surface adhesion. Silica fume significantly improves cohesiveness making it ideal for use in underwater grouts, decreases permeability in grouts used for post-tensioning applications and increases the resistance to aggressive chemicals

• **Refractory and Ceramics—**the use of silica fume in refractory castables provides better particle packing. It allows for less water to be used while maintaining the same flow characteristics. It also promotes low temperature sintering and the formation of mullite in the matrix of the castable. This produces a castable that has a low permeability to avoid gas, slag and metal penetration. Castables incorporating silica fume are stronger than non-silica fume containing castables especially at high temperatures with higher density they attain lower porosity and are more volume stable.

3. SIGNIFICANCE AND OBJECTIVES:

The objective of the present investigation is to investigate the workability, strength and durability characteristics for HPC mixes of grade M60, M70 and M110 by replacing 0, 2.5, 5, 7.5, 10, 12.5 and 15 percent of the mass of cement with SF and using a superplasticizer. Also, an attempt is made to find the optimum cement replacement level by SF for better strength and durability characteristics of HPC. Hence, in the present investigation more emphasis is given to study the strength and durability properties of HPC using SF and superplasticizer so as to achieve better concrete composite and also to encourage the increased use of SF to maintain ecology

4. EXPERIMENTAL PROGRAMME:

Experimental investigations have been carried out on the M60, M70 and M110 HPC specimens to ascertain the workability, strength and durability related properties.

4.1.Materials used:

•Ordinary Portland cement, 53 Grade conforming to IS: 12269-1987.
•Silica fume as mineral admixture in dry densified form obtained from ELKEM INDIA (P) LTD., MUMBAI conforming to ASTM C-1240.

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•Superplasticizer(chemical admixture) based on Sulphonated naphthalene Formaldehyde condensate - CONPLAST SP430 conforming to IS: 9103-1999 and ASTM C – 494
•Locally available quarried and crushed blue granite stones conforming to graded aggregate of nominal size 12.5mm as per IS:383-1970 with specific gravity 2.82 and fineness modulus 6.73 as Coarse aggregates (CA)
•Locally available Karur river sand conforming to Grading zone II of IS: 383-1970 with specific gravity 2.60 and fineness modulus 2.96 as fine aggregates (FA).
•Water: Drinking water supplied to Coimbatore city from Siruvani dam for concreting and curing..

4.2.Mix proportions:

Mix proportions are arrived for M60, M70 and M110 grades of concrete based on Absolute volume method of mix design by replacing 0, 2.5, 5, 7.5, 10, 12.5 and 15 percent of the mass of cement by SF and the material requirements per code

5. MIXING AND PLACING CONSIDERATIONS:

5.1 Handling the micro silica:

Because of its extreme fineness, micro silica presents handling problems. A cement tanker that could ordinarily haul 35 metric tons of cement accommodates only 7 to 9 tons of dry micro silica and requires 20 to 50 percent more time for discharging. Some producers mix micro silica with water on a pound-for-pound basis ton form a slurry that is transportable in tank trailers designed to handle liquids. The water of the slurry replaces part of that ordinarily added to the mix. One supplier prepares a slurry which, used at the rate of 1 gallon per 100 pounds of cement, will provide aboutn5 percent micro silica by weight of cement. In 1984, that supplier was quoting a price of $1.70 per gallon at a plant in West Virginia. In Canada, patented methods have been used to densify the micro silica for shipment to ready mix producers. Some concrete producers also use the loose micro silica just as it is collected.

5.1.2 Water requirements of the mix:

When no water reducing agent is used, the addition of micro silica to a concrete mix calls for more water to maintain a given slump. Water content can be held the same by using a water reducer or super plasticizer along with the micro silica. Water reducing agents appear to have a greater effect on micro silica concrete than on normal concrete. Thus water demand for given micro silica concrete can be controlled to be either greater or smaller than for the reference concrete.

5.1.3 Placing and finishing, curing:

The gel that forms during the first minutes of mixing micro silica concrete takes up water and stiffens the mixture, necessitating adjustment of the timing of charging and placing. Scandinavian researchers have concluded that micro silica concretes often require 1 to 2 inches more slump than conventional concrete for equal workability. When cement content and micro silica dosage are relatively high, the mixture is so cohesive that there is virtually no segregation of aggregates and little bleeding. This may cause problems for floors or slabs cast in hot, windy weather because there is no water film at the surface to compensate for evaporationPlastic shrinkage cracking can readily develop unless precautions are taken. It is important to finish the concrete promptly and apply a curing compound or cover immediately. With lean concrete mixes or mixes containing fly ash replacement of cement, different effects have been reported. For example, Reference 4 reports that mixes with less than 380 pounds of cement per cubic yard plus 10 percent micro silica are both more cohesive and more plastic so no extra water is needed to maintain slump.

6. TEST RESULTS :

Workability tests such as slump test, compaction factor test and Vee-Bee consistometer test were carried out for fresh concrete as per IS specifications, keeping the dosage of superplasticizer as constant at 3 % by weight of binder. For hardened concrete, cube compression strength test on 150mm size cubes at the age of 1 day, 3 days, 7 days, 14 days,28 days and 56 days of curing were carried out using 3000 KN capacity AIMIL compression testing machine as per IS:516-1959. Also, compression strength and split tensile strength tests on 150mm x 300mm cylinders and flexural strength tests on 100mm x 100mm x 500mm beams were carried out on 28 days cured specimens as per IS specifications. The stress-straingraph for HPC is obtained using compressometer fitted to cylinders during cylinder compressive strength test for finding Modulus of Elasticity for HPC mixes.

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6.1. Durability Related Tests:

The durability related tests such as Saturated Water Absorption (SWA) test, Porosity test, Sorptivity test, Permeability test, Acid resistance test, Sea water resistance test, Abrasion resistance test and Impact resistance test were carried out on hardened concrete specimens at the age of 28 days of curing.

6.1.1Test for Saturated Water Absorption & Porosity:

The water absorption was determined on 1OOmm cubes as per ASTM C-642 by drying the specimens in an oven at a temperature of 105° C to constant mass and then immersing in water after cooling to room temperature. The specimens were taken out of water at regular intervals of time and weighed. The process was continued till the weights became constant (fully saturated). The difference between the water saturated mass and oven dry mass expressed as a percentage of oven dry mass gives the SWA. The SWA of concrete is a measure of the pore volume or porosity in hardened concrete, which is occupied by water in saturated condition. It denotes the quantity of water, which can be removed on drying a saturated specimen. The porosity obtained from absorption tests is designated as effective porosity. It is determined by using the following formula.Effective Porosity = (Volume of voids I Bulk volume of specimen) x 100The volume of voids is obtained from the volume of the water absorbed by an oven dry specimen or the volume of water lost on oven drying a water saturated specimen at 105° C to constant mass. The bulk volume of the specimen is given by the difference in mass of the specimen in air and its mass under submerged condition in water.

6.1.2. Permeability Test :

Permeability is related to the durability of concrete, specially its resistance against progressive deterioration under exposure to severe climate. The tests for permeability were carried out on 1OOmm x 100mm cylinders as per IS:3085-1965,using a AIMIL Concrete permeability apparatus Cylinders are kept in permeability mould and tightly packedand sealed. Water pressure was applied at a pressure of 10kg/cm2over cylinders using air compressorTheCOFFICIENT OF PERMEABILITY (K) = Q

AT(H/L)

6.1.3. Impact Resistance Test:

The tests for impact resistance were carried out on specimens of size 152 mm diameters x 62.5mm thickness, using Drop weight testing machine. The specimens were kept on the base plate and centred. A drop hammer weighing 45 N was used to apply the impact load. The number of blows required by dropping a hammer through a height of 457mm to cause the ultimate failure was recorded.

STRENGTH RESULTS OF THE TRAIL MIX M60 GRADE

MIX	1	2	3	4	5	6	7
SILICA (%)	0	2.5	5	7.5	10	12.5	15
	CUBE	COMPRESSIVE	STRENGTH	(Mpa)			
7 DAY	47.52	52.33	56.33	58.56	63.14	60.11	57.28
14 DAY	54.74	57.07	61.11	62.72	73.07	69.89	67.76
28 DAYS	62.55	66.11	69.22	71.22	82.46	78.88	75.33
	CYLINDER	COMPRESSION	STRENGT	(Mpa)			
28 days	50.42	53.65	55.36	57.55	66.85	63.15	60.40

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STRENGTH RESULTS OF THE TRAIL MIX M70 GRADE

MIX	1	2	3	4	5	6	7
SILICA (%)	0	2.5	5	7.5	10	12.5	15
	CUBE	COMPRESSIVE	STRENGTH	(Mpa)			
7 DAY	57.52	59.33	65.90	69.78	70.14	69.11	67.28
14 DAY	64.74	67.00	70.12	73.11	75.07	69.89	65.76
28 DAYS	70.34	76.55	79.11	80.22	82.46	78.88	75.33
	CYLINDER	COMPRESSION	STRENGT	(Mpa)			
28 days	58.45	59.34	60.23	62.34	65.55	61.90	59.88

STRENGTH RESULTS OF THE TRAIL MIX M110 GRADE

MIX	1	2	3	4	5	6	7
SILICA (%)	0	2.5	5	7.5	10	12.5	15
	CUBE	COMPRESSIVE	STRENGTH	(Mpa)			
7 DAY	68.87	75.75	79.2	88.3	93.66	88.11	85.38
14 DAY	78.38	85.07	88.7	93.5	106.2	102.6	101.1
28 days	91.22	97.80	103.22	108.66	121.2	115.2	112.4
	CYLINDER	COMPRESSION	STRENGT	(Mpa)			
28 days	71.06	77.16	82.35	86.92	98.14	91.6	89.48

8. CONCLUSIONS:

1.Cement replacement level of 10 percent with SF in M60, M70 and M110 grades of HPC mixes is found to be the optimum level to obtain higher values of compressive strength, split tensile strength, flexural strength

2. The results of the strength and durability related tests have demonstrated superior strength and durability characteristics of HPC mixes containing SF. This is due to the improvement in the microstructure due to pozzolanic action and filler effects of SF, resulting in fine and discontinuous pore structure.

3.Even a partial replacement of cement with SF in concrete mixes would lead to considerable savings in consumption of cement and gainful utilization of SF. Therefore, it can be concluded that replacement of cement with SF up to 10 % would render the concrete more strong and durable. This observation is in par with the maximum limit of 1O % for mineral admixture in concrete mixes as recommended by IS: 456-2000.

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

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