RESEARCH ARTICLE OPEN ACCESS

Effects of Silica Fume in Conventional Concrete

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ABSTRACT
The production of tailor made high strength and high performance concrete are made by incorporating silica fume into the normal concrete and it is a routine one in the present days. The mix proportioning is intricate and the design parameters are increased due to the incorporation of silica fume in conventional concrete. The aim of this paper is to look into the different mechanical properties like compressive strength, compacting factor, slump of concrete incorporating silica fume. In this present paper concrete incorporating silica fume are cast for 5 (five) mixes to perform experiments. Different percentages of silica fume are used for cement replacement in order to carry out these experiments at a single fixed water-cementitious materials ratio keeping other mix design parameters constant. The cement replacement level by silica fume was 0%, 5%, 10%, 15% and 20% for a constant water-cementitious materials (w/cm) ratio for 0.50. 100 and 150 mm cubes are used to determine the compressive strengths for all mixes at the age levels of 24 hours, 7 and 28 days. Besides the compressive strengths other properties like compacting factor, slump of concrete are also determined for five mixes of concrete.
***Keywords* -** Silica fume, High strength concrete, High performance concrete, Strength. Slump.

I. INTRODUCTION

Silica Fume Is A By-Product Derived During The Production Of Elemental Silicon Or An Alloy Containing Silicon And It Is Very Fine Non-Crystalline Silica Produced In Electric Arc Furnaces As Defined By The American Concrete Institute (ACI). Many Researchers Made Extensive Experiments Around The World And Observed That The Incorporation Of Silica Fume In Concrete Improves The Different Mechanical Properties Like Concrete Strengths, Modulus Of Elasticity, Durability, Corrosion Protection, Chemical And Abrasion Resistance. But No Unique Conclusion Regarding The Optimum Percentages Of Cement Replacement By Silica Fume Is Obtained, Although Some Researchers Have Reported Different Replacement Levels [1, 2 And 3]. Bhanja And Sengupta [4, 5 And 6] Investigated The Effect Of Silica Fume On The Compressive And Tensile Strength Of High Performance Concrete (HPC) And Developed Mathematical Model Using Statistical Methods To Predict The 28-Days Compressive Strength Of Silica Fume Concrete With Water- Cementitious Material (W/Cm) Ratios Ranging From 0.3 To 0.42 And Cement Replacement Percentages By Silica Fume From 5 To 30. The Authors Observed That Optimum Cement Replacement Percentage By Silica Fume Is Not Constant At All Water-Binder Ratios But Depends On Water Content Of Mix. The Authors Also Reported That Compressive Strength Of Silica Fume Concrete Depends On W/Cm, Total Cementitious Material Content And Cement-Admixture Ratio. Song Et Al. [7] Predicted The Diffusivity Procedure Of High Strength Concrete Based On A Microstructure Model And Key Factors Which Influence The Diffusivity Are As Water-To-Binder Ratio, Silica Fume Replacement ratio, and degree of hydration and reported that incorporation of silica fume reduce the diffusivity and makes the microstructure of concrete denser. Mazloom et al. [8] surveyed the effects of different levels of silica fume on fresh and mechanical properties of high-strength concrete and evaluated that the various properties like compressive strength, secant modulus of elasticity, strain due to creep, shrinkage, swelling and moisture movement are improved. Rao [9] experimented to investigate the influence of silica fume on various properties of cement pastes and mortars like air content, specific gravity, normal consistency of cement, and workability of mortar with different silica fume contents and showed that incorporation of silica fume lead the significant change in the behavior of cement pastes and mortars. Katkhuda*1, Hanayneh2 and Shatarat1 experimented to investigate the isolated effect of silica fume on compressive, tensile and flexure strengths on high strength lightweight concrete and showed that the compressive, tensile and flexure strengths increased with silica fume incorporation but the optimum replacement percentage is not constant because it depends on the water–cementitious material (w/cm) ratio of the mix [10]. To obtain the high strength concrete rounded shape and smaller sizes (10 mm and 5mm) of aggregates should be used than other shape and sizes respectively [11]. Higher percentage of super plasticizer would be used in silica fume concrete for higher percentage of cement replacement by silica fume to overcome the adverse effect on workability [12, 13]. In this paper our endeavor is made to inspect the different mechanical properties like compressive strength, permeability, porosity, density, modulus of elasticity, compacting factor, slump of concrete incorporating silica fume considering a single water-cementitious material ratio of 0.50.

II. EXPERIMENTAL INVESTIGATION

A. MATERIALS

- **CEMENT**

The cement used is Ordinary Portland Cement of ACC brand of 43 grade in the present study which surpasses BIS Specifications (IS 8112-1989) on compressive strength levels.

- **FINE AGGREGATE**

Locally available River sand i.e. natural sand as per IS: 383-1970 is used. The bulk density of sand is 2610 kg/m3. The properties of fine aggregate are shown in tabular form in Table 1.

Table 1: Properties of fine aggregate

Sl. No.	Property	Result
1.	Specific Gravity	2.61
2.	Fineness modulus	3.10
3.	Grading zone	II

- **COARSE AGGREGATE**

Crushed aggregate used is conforming to IS: 383-1970. The size, specific gravity and fineness modulus of coarse aggregate are used as 12.5 mm, 2.83 and 6.28 respectively.

- **SILICA FUME (GRADE 920 D)**

Silica fume used is conforming to ASTM- C (1240-2000) and it is supplied by "ELKEM INDUSTRIES" is named Elkem – micro silica 920 D. The cement is partially replaced by silica fume. The properties of silica fume are shown in Table 2. In support of particle morphology with elemental existence a Scanning Electron Microscopy (SEM) and EDAX Spectrum have been reported in Figure 1 and Figure 2 respectively.

Table 2
SILICA FUME- CHEMICAL & PHYSICAL ANALYSIS REPORT

Sl.no.	CHEMICAL ANALYSIS	ANALYSIS
1	SO_2	95.00 %
2	SO3	0.18 %
3	CL	0.12 %
4	Total Alkali	0.66%
5	Moisture Content	0.16%
6	Loss of ignition	1.92%
7	pH	7.90%

Sl.no.	PHYSICAL TESTS	ANALYSIS
1	Oversize **-** % retained on 45 μm sieve (wet sieved)	1.13%
2	Density – (specific gravity)	2.27
3	Bulk Density – (per ASTM) 187.91 kg/m^3	11.73 lb/ft^3
4	Specific Surface Area (by BET)*	22.21 m^2/kg
5	Accelerated Pozzo;anic Activity Index with Portland Cement	134.90%

*As per manufacturers manual

- **SUPER PLASTICIZER**

In this experimentfor improvement of the workability of concrete, super plasticizer- CONPLAST-SP 430 in the form of sulphonated Naphthalene polymers conforming to IS: 9103-1999 and ASTM 494 type F is used. Conplast SP 430 has been specially formulated to impart high range water reductions up to 25% without loss of workability or to produce high quality concrete of lower permeability. The properties of super plasticizer are shown in Table 3.

Table 3: Properties of super plasticizer

Sl.no.	PHYSICAL TESTS	ANALYSIS
1	Specific Gravity	1.224
2	Chloride content	NIL
3	Air entrainment	**11.73 lb/ft^3**

*As per manufacturers manual

- **MIX PROPORTIONING**

In this experiment the mix of concrete is designed as per the guidelines specified in I.S. 10262-1982 though some restriction is obligatory by restricting the amount of cementitious material content is equal to 450 Kg/m3. The Table 4 shows mix proportion of concrete (Kg/m3):

Table 4: Mix Proportioning

W/cm	Cement(Kg/m^3)	Fine Aggregate (Kg/m^3)	Coarse Aggregate (Kg/m^3)	Water (Kg/m^3)	Compacting factor
0.50	450	599.290	1050.080	225	0.821 – 0.880

III. TEST RESULTS AND DISCUSSION

Table 5: Compressive strength of cube

W/cm	Cementitious material (Kg/m^3)	% of MA (SF)	Compressive Strength (MPa)						% of SP	Slump (mm)	CF
			150 mm cubes			100 mm cubes					
			24 Hrs.	7 days	28 days	24 Hrs.	7 days	28 days			
0.50	450	0	16.59	30.67	45.35	22.33	32.33	47.67	0.00	30,30,30	0.821
		5	19.41	35.26	48.00	22.50	37.00	55.70	0.25	25,22,24	0.835
		10	27.26	36.30	51.85	27.70	37.00	58.00	0.60	20,21,20	0.850
		15	30.37	38.22	52.15	32.23	39.27	56.00	0.90	20,22,24	0.843
		20	34.67	39.41	54.33	36.35	40.00	57.40	1.20	30,30,28	0.880

In this present paper experiments are performed for 5 (five) mix of concrete incorporating undensified silica fume. As smaller size of coarse aggregate have exposure of larger surface, better bonding of coarse aggregates with paste matrix at the interfacial zone is occurred due to which smaller size of coarse aggregate (i.e. 12.5 mm) is used in the experimentations. Subsequently higher strength is obtained at the interfacial zone between coarse aggregate and paste matrix therefore; strength in concrete is higher than control concrete (i.e. concrete without silica fume) as the interfacial zone is denser. Various cement replacement percentages by silica fume are used to carry out these experiments at a single constant water-cementitious materials ratio while other mix design parameters are kept constant.

The cement replacement percentages by silica fume are 0%, 5%, 10%, 15% and 20% for water cementitious materials ratio 0.40. Compressive strengths are determined at age levels of 24 hours, 7 days and 28 days for 100 mm and 150 mm cubes for all mixes. Experiments are also performed to determine the results of other properties like compacting factor and slump for five mixes of concrete. It is observed from experimental results that compressive strengths for all replacement levels of cement by silica fume (i.e. at 5 %, 10%, 15% and 20%) is higher than control concrete (i.e. concrete without silica fume) at all ages (i.e. at 24 hours, 7 days and 28 days).

Experimental results provide evidence that compressive strengths of 100 mm cubes are higher than 150 mm cubes at all age levels and cement replacement levels by silica fume. It is found that the maximum compressive strength is obtained at 20% cement replacement by silica fume. Higher compressive strength at 28 days of about 54.33MPa for 150 mm cube and 57.40 MPa for 100 mm cube are obtained at 20% cement replacement by silica fume. But in control concrete (i.e. concrete without silica fume) 28 days compressive strength is about 45.35 MPa for 150 mm cube and 47.67 MPa for 100 mm. It is observed that 28 days compressive strength is increased near about by 20% for 150 mm cubes and 60% for 100 mm cubes than control concrete i.e. without silica fume. For workability, compacting factor and slump value ranges from 0.82 to 0.88 and 20 to 50mm respectively. The value of slump showed the mixes are cohesive in nature.

IV. CONCLUSION

The optimum compressive strength is obtained at 20% cement replacement by silica fume at all age levels (i.e. at 24 hours, 7 and 28 days). Slump value may be increased by increasing the dosages of superplasticizer without hampering the strength for further investigation but the ranges of compacting factor from 0.82 to 0.88 and slump value from 20 to 50mm are also good for using concrete in the field in control system. Higher compressive strength resembles that the concrete incorporated with silica fume is high strength concrete (HSC) as per IS code recommendations. It is reported that improved pore structures at transition zone of silica fume concrete led to it as high performance concrete but durability tests are yet to be surveyed. During the testing of cubes at 28 days the failure plane of cubes cut the aggregates but not along the inter facial zone which is concluded that the interfacial zone attained much higher strength than control concrete i.e. concrete without silica fume.

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