Combinational Study of Mineral Admixture and Super Plasticizer in Usual Concrete

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ABSTRACT:

Now a days the tailor made high strength and high performance concrete embodied with silica fume into the normal concrete are being widely used all over the world and it is a common practice in the present days. The presence of silica fume makes the mix proportioning difficult and increase the design parameters in conventional concrete. The principal object of this paper is to observe the several mechanical properties like compressive strength, compacting factor, and slump of silica fume concrete. In this present paper silica fume concrete are cast for 5 (five) mixes to execute experiments. Various percentages of silica fumes are used for cement replacement to carry out these experimentations at a single unchanging water-cementitious materials ratio keeping other mix design variables unvarying. The various cement replacement levels by silica fume are 0%, 5%, 10%, 15% and 20% for a single water-cementitious materials (w/cm) ratio of 0.50. Different sizes like 100 and 150 mm cubes are used to find out the compressive strengths for all mixes at age levels of 24 hours, 7 and 28 days. Except the compressive strengths, other properties like compacting factor, slump of concrete are also resoluted for five mixes of concrete. To overcome low workability problem, high range water reducer chemical admixture is used.

KEYWORDS: *Silica fume, high strength concrete, high performance concrete and strength.*

I. INTRODUCTION

Silica fume is very fine non-crystalline silica derived in electric arc furnaces and it is a by-product resulting during the manufacture of elemental silicon or an alloy containing silicon as defined by the American Concrete Institute (ACI). Numerous researchers made widespread experiments around the world and observed that the incorporation of silica fume in concrete develops the various mechanical properties like concrete strengths, durability, modulus of elasticity, corrosion protection, chemical and abrasion resistance. But no sole conclusion regarding the optimum percentage of cement replacement by silica fume is obtained, while some researchers have reported different replacement levels [1, 2 and 3]. Bhanja and Sengupta experimented silica fume concrete to observe the effect of silica fume on compressive and tensile strength of high performance concrete (HPC) and the mathematical model using statistical methods was developed for prediction of 28-days compressive strength of silica fume concrete with water- cementitious material (w/cm) ratios ranged from 0.30 to 0.42 and cement replacement by silica fume from 5 to 30 %.

The authors observed that optimum cement replacement level by silica fume is not constant for 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 [4, 5 and 6]. Song et al. observed the diffusivity procedure of high strength concrete on the basis of a microstructure model and water-to-binder ratio, silica fume replacement ratio, and degree of hydration are the key factor which control the diffusivity and reported that incorporation of silica fume decrease the diffusivity and makes the microstructure of concrete denser [7]. Mazloom et al. investigated the effects of various levels of silica fume on fresh and mechanical properties of high-strength concrete and reported that the various properties like compressive strength, shrinkage, swelling, secant modulus of elasticity, strain due to creep and moisture movement are enhanced [8].

Rao experimented to investigate the influence of silica fume on various properties of cement pastes and mortars like air content, normal consistency of cement, specific gravity and workability of mortar with different silica fume contents and reported that incorporation of silica fume lead the considerable change in the behavior of cement pastes and mortars [9]. Katkhuda[*1], Hanayneh[2] and Shatarat[1] experimented to observe the isolated effect of silica fume on compressive, flexural and tensile strengths on high strength lightweight concrete and showed that the compressive, flexural and tensile strengths enhanced with silica fume incorporation but the optimal replacement percentage is not invariable because it depends on the water–cementitious material (w/cm) ratio of the mix [10]. Yaqub* and Bukhari reported that smaller sizes (10 mm and 5mm) and rounded shape of coarse aggregates should be used to obtain the high strength concrete than other sizes and shape respectively [11]. It is reported that to overcome the unfavorable effect on workability, higher percentage of super plasticizer would be used in silica fume concrete for higher percentage of cement replacement by silica fume [12, 13]. In this paper our effort is made to examine the different mechanical properties like compressive strength, slump, compacting factor of silica fume concrete taking into account of a single fixed water-cementitious material ratio of 0.50.

II. AIMS AND OBJECTIVES OF THE PRESENT EXPERIMENTATION

To observe the different mechanical properties i.e., compressive strength, compacting factor and slump of concrete incorporating silica fume at different replacement levels of cement by silica fume.

III. SCOPE OF THE PRESENT WORK

High-strength and high performance concrete of grade M60, the replacement levels of cement by silica fume are selected as 0%, 5%, 10%, 15% and 20% for 100 and 150 mm cubes for testing.

IV. EXPERIMENTAL INVESTIGATION

4.1. Materials

4.1.1. Cement

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

4.1.2. Fine Aggregate

Locally available River sand (i.e. natural sand) as per IS: 383-1970 is used, the bulk density of which is 2610 kg/m^3. The properties of fine aggregate are shown 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

4.1.3. Coarse Aggregate

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

4.1.4. Silica Fume (Grade 920 D)

Silica fume used is compliant to ASTM- C (1240-2000) which is supplied by “ELKEM INDUSTRIES” is named Elkem – micro silica 920 D and also the cement is partially replaced by silica fume. The properties of silica fume are shown in tabular form in Table 2.

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

4.1.5. Super Plasticizer

In these experimentations for development of the workability of concrete, super plasticizer-CONPLAST-SP 430 with the form of sulphonated Naphthalene polymers in compliance to IS: 9103-1999 and ASTM 494 type F is used. Conplast SP 430 has been specially formulated to report high range of water reductions up to 25% without losing workability or to turn out high quality concrete of lesser permeability. The properties of super plasticizer are shown below 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

4.2. Mix Proportioning

In these experiments the mixes of concrete are intended as per the guidelines specified in I.S. 10262-1982 though some restriction is mandatory by restricting the amount of cementitious material content is equal to 450 Kg/m^3. The Table 4 shows mix fraction of concrete (Kg/m^3):

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	400	639.800	1121.070	200	0.815 – 0.840

V. TEST RESULTS AND DISCUSSION

Table 5: Compressive strength and fresh concrete properties

W/c m	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			
0.5	400	0	18.07	30.52	44.2	19.20	32.60	48.00	0.00	25,25,23	0.815
		5	21.63	36.63	45.11	23.70	38.00	55.33	0.50	18,15,15	0.84
		10	29.93	39.56	57.45	30.30	40.78	58.00	1.00	22,20,18	0.82
		15	32.74	40.60	60.20	33.60	40.80	57.20	1.30	20,25,21	0.80
		20	37.04	40.11	60.46	38.10	43.33	61.00	1.75	15,20,18	0.83

In this paper experiments are executed for 5 (five) mix of concrete embodied with undensified silica fume. Due to use of smaller size of coarse aggregate (i.e. 12.5 mm) in the experiments, better bonding at the interfacial zone is occurred between coarse aggregates and paste matrix, because of exposure of larger surface area for smaller size of coarse aggregates. As a result, the interfacial zone between coarse aggregate and paste matrix is more strengthened and denser, so strength in silica fume concrete is higher than concrete without silica fume. Different cement replacement levels by silica fume (i.e. 0%, 5%, 10%, 15% and 20%) are used to carry out the experiments at a fixed constant water-cementitious materials ratio of 0.40 but at the same time other design mix parameters are keeping constant. Compressive strengths are observed at different age levels (i.e. at 24 hours, 7 and 28 days) for 150 mm and 100 mm cubes for all mixes. Experiments are also executed to survey the results of other properties like compacting factor and slump for all mixes of concrete. It is investigated from experimental results that at all cement replacement levels by silica fume (i.e. at 5 %, 10%, 15% and 20%) and at all age levels (i.e. at 24 hours, 7 days and 28 days), compressive strengths are higher than concrete without silica fume. It is evident from experimental results that higher compressive strengths of 100 mm cubes are obtained than 150 mm cubes at all age and cement replacement levels by silica fume. It is also determined that the maximum compressive strength is found at 20% cement replacement by silica fume. It is found that 28 days compressive strength is 60.46 MPa and 61.00 MPa for 150 mm and 100mm cubes respectively at 20% cement replacement by silica fume but for control concrete (i.e. concrete without silica fume) it is 44.20 MPa and 48.00 MPa respectively. For workability, compacting factor and slump value ranges from 0.815 to 0.84 and 15 to 25mm respectively are obtained. The values of slump show the mixes are cohesive in nature.

VI. CONCLUSIONS

The highest value of compressive strength is obtained at all age levels (i.e. at 24 hours, 7 and 28 days) at 20% cement replacement by silica fume. Slump value may be increased by increasing the dosages of superplasticizer without hampering the strength for further investigation but the range of compacting factor from 0.815 to 0.84 is good for using concrete in the field in control system. Higher compressive strength is reported as per IS code recommendations that the concrete incorporated with silica fume is high strength concrete (HSC). During the testing of cubes at 28 days, it is found that the failure plane of cubes cut the aggregates but not along the inter facial zone. Hence it is concluded that the interfacial zone attained much higher strength than control concrete i.e. concrete without silica fume. It is seemed that improved pore structures at transition zone of silica fume concrete converted to it as high performance concrete but durability tests are yet to be surveyed.

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