

Properties Exploration of Conventional Concrete after Silica Fume Supplementation

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Abstract: The enormous production of Ordinary Portland Cement is causing hazards to environment as well as reduction in natural sources though it is versatile materials and most important constituent of concrete. Due to this warning to ecosystem the researchers are directed to use industrial by products as supplementary cementitious material in usual manner in the present days in making concrete. In the experimentations, the silica fume is used as industrial by-product in normal concrete thereby increasing the mix design variables for which the mix proportioning is many-sided. The prime intention of this paper is to investigate the various mechanical properties essentially on workability and strength. Compressive strength, Slump and Compacting factor tests of silica fume concrete are performed for strength and workability respectively. For this paper 15 (five) mixes of silica fume concrete are cast for experiments. Various cement replacement levels by silica fume for three water-cementitious material ratios of 0.40, 0.45 and 0.50 are used in experiments whereas other mix design parameters are kept unvarying. The cement replacement levels by silica fume are 0%, 5%, 10%, 15% and 20% for three water-cementitious materials (w/cm) ratio of 0.40, 0.45 and 0.50. Compressive strengths, compacting factors and slumps are evaluated at different age levels like at 24 hours, 7 and 28 days for both 100 and 150 mm cubes.

Keywords: Silica fume, High strength concrete, high performance concrete, Strength.

I. INTRODUCTION

In the present days inclusion of mineral admixtures in the tailor made new generation concrete is a standard practice and the concrete making processes have undergone a fundamental change due to which the supplementary cementitious materials play a significant role to develop strength and other special properties. It is observed that the various parameters like w/c ratio, pore geometry and chemical composition of the cementitious materials control the properties of cement based materials and reported that the compressive, flexure and tensile strengths are improved with silica fume inclusion but the optimal replacement percentage is not invariable for the reason that it depends on the water-cementitious material (w/cm) ratio of the mix [1]. Numerous researchers reported that the strengths, durability, chemical and abrasion resistance, protection against corrosion and modulus of elasticity are increased due to inclusion of silica fume in concrete. But no distinctive conclusion of the optimal silica fume replacement percentage is obtained, even though various researchers have reported different replacement levels [1 - 3].

Silica fume, the industrial by-product used as alternate or supplementary pozzolanic materials like Fly ash, Rice husk ash, Ground Granulated Blast furnace Slag, and High Reactive Metakaolin which would lead to global sustainable development and lowest feasible ecological impact and direct to save energy [4]. Due to the inclusion of silica fume in concrete, advantages like durability, high strength and reduction in cement production are obtained and the optimal cement replacement percentage by silica fume ranged from 10 to 20 % is reported to obtain upper limit 28- days' strength of concrete [5 - 6]. Durability with other mechanical properties of concrete are improved due to incorporation of silica fume in concrete as the reaction among silica present in pozzolans and the free calcium hydroxide for the duration of the hydration of cement and accordingly forms additional calcium silicate hydrate (C - S - H) [7].

Mazloom et al. investigated the effects of different cement replacement levels by silica fume on different mechanical properties of high-strength concrete and observed that the different properties like compressive strength, strain due to creep, shrinkage, and secant modulus of elasticity, swelling and moisture movement are improved [8]. Rao investigated

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the effects of silica fume on a variety of properties of cement pastes and mortars like specific gravity, normal consistency of cement, air content and workability with different silica fume contents and reported that the use of silica fume lead the considerable change in the behavior of cement pastes and mortars[9]. N. K. Amudhavalli¹, Jeena Mathew² observed that the strength and durability characteristics have been improved appreciably due to addition of silica fume in concrete at different percentages. The authors surveyed that the flexural strength is improved more prominently than split tensile strength due to addition of silica fume and reported that the optimal values of compressive strength (7 and 28-days) and flexural strength are obtained at 10 – 15 % cement replacement levels by silica fume [10]. Various size and shape of aggregate have different effects on the development of high strength concrete. It is reported that the rounded shape and smaller sizes of aggregate should be used for high strength concrete than other sizes and shape correspondingly [11]. Addition of silica fume in concrete has a detrimental effect on workability (i.e. reduction in workability due to inclusion of silica fume) and consequently higher percentage of super plasticizer is required for addition of higher percentages of silica fume in concrete [12 – 13]. In this paper our attempt is made to inspect the different mechanical properties like compressive strength, slump, compacting factor of concrete incorporating silica fume taking into account three water-cementitious material ratios of 0.40, 0.45 and 0.50.

II. EXPERIMENTAL INVESTIGATION

2.1. Materials

2.1.1. Cement

For compressive strength levels, Ordinary Portland Cement of ACC brand of 43 grade is used in the present experimentations which surpasses BIS Specifications – IS: 8112-1989.

2.1.2. Fine Aggregate

Locally available natural river sand is used as per IS: 383-1970, having bulk density 2610 kg/m³. The properties of fine aggregate are shown below 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

2.1.3. Coarse Aggregate

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

2.1.4. Super Plasticizer

In order to improve 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 use for high range of water reductions up to 25% at same workability or to produce good quality concrete of low permeability. The properties of super plasticizer are shown below in Table 2.

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Table 2: 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

2.1.5. Silica Fume (Grade 920 D)

Silica fume used is in compliance to ASTM- C (1240-2000), supplied by “ELKEM INDUSTRIES” in the name of Elkem – micro silica 920 D. Silica fume is used as partial replacement of cement and the properties of silica fume are shown below in Table 3.

Table 3: Silica fume chemical & physical analysis report

Sl.no.	CHEMICAL ANALYSIS	ANALYSIS
1	SO ₂	95.00 %
2	SO ₃	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
	Oversize - % retained on 45 μm sieve (wet sieved)	1.13%
	Density – (specific gravity)	2.27
	Bulk Density – (per ASTM) 187.91 kg/m ³	11.73 lb/ft ³
	Specific Surface Area (by BET)*	22.21 m ² /kg
	Accelerated Pozzogenic Activity Index with Portland Cement	134.90%

*As per manufacturers manual

2.2. Mix Proportioning

In these experiments mix design process of concrete is followed as referred to I.S. 10262-1982 though some restriction is imposed by restricting cementitious material content is 450 Kg/m³. Mix proportions of concrete are shown in Table 4:

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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
0.4	450	630.75	1097.23	180	0.814
0.45	450	609.298	1114.157	202.50	0.82 – 0.856
0.50	450	599.290	1050.080	225	0.821 – 0.880

III. TEST RESULTS AND DISCUSSION

Table 5: Compressive strength and workability properties

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			
0.40	450	0	23.70	30.67	49.48	26.00	36.33	55.67	0.50	12,15,20	0.812
		5	31.39	40.40	56.03	27.47	44.80	58.25	1.0	15,22,24	0.780
		10	34.44	40.26	62.67	29.84	38.0	60.78	1.6	20,20,20	0.824
		15	40.84	40.74	62.37	33.68	40.00	65.67	2.10	17,12,15	0.811
		20	45.04	38.10	67.72	46.67	42.00	71.33	2.6	18,20,21	0.814
0.45	450	0	22.96	33.20	51.12	24.33	35.00	53.33	0.50	18,20,17	0.820
		5	25.58	37.10	52.33	25.80	38.67	56.67	0.80	15,15,16	0.821
		10	28.40	37.63	55.33	28.90	37.67	59.33	1.10	20,25,26	0.856
		15	33.00	39.70	57.21	33.20	39.90	59.50	1.50	13,13,14	0.820
		20	37.48	40.11	61.55	40.80	40.97	62.95	1.90	15,16,18	0.856
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

The investigations are made in this present paper on 15 (fifteen) mixes of silica fume concrete by using undensified silica fume to cast concrete for experiments. In these experiment smaller size coarse aggregate of 12.5 mm is used due to larger exposed surface area of smaller size and as a result, bond at the interfacial zone between paste matrix and coarse aggregate is improved and concrete is more dense at interfacial zone. For this, the interfacial zone between paste matrix and coarse aggregate is more strengthening and thus high strength is observed in concrete incorporating silica fume than the concrete without silica fume.

These experiments are performed at water-cementitious material ratios of 0.40, 0.45 and 0.50 while other mix design parameters are keeping constant at several cement replacement levels by silica fume of 0%, 5%, 10%, 15% and 20%. Compacting factor and slump are recorded for fifteen mixes of concrete, shown in table 5. Low values of slump indicates that the nature of mixes are cohesive. Compressive strengths of 150 and 100 mm cubes for all mixes are shown in table 5 those are determined at the age levels of 24 hours, 7 days and 28 days. Experimental results represented in table 5 shows that for all age levels at 24 hours, 7 and 28 days and at 0 – 20% cement replacement level

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by silica fume, higher compressive strength is noticed than concrete without silica fume (i.e. control concrete). It is found from experimental results shown in table 5 that the 28 days compressive strengths for 150 mm and 100 mm cubes are 67.72 & 71.33 MPa, 61.55 & 62.95 MPa and 54.33 & 57.40 MPa at 20% cement replacement level by silica fume at water-cementitious material ratios of 0.40, 0.45 and 0.50 respectively. But the 28 days compressive strengths for 150 mm and 100 mm cubes are 49.48 & 55.67 MPa, 51.12 & 53.33 MPa and 45.35 & 47.67 MPa at zero percentage cement replacement level by silica fume (i.e. for control concrete) at water-cementitious material ratios of 0.40, 0.45 and 0.50 respectively.

It is observed that 28 days compressive strength is increased by 36.82%, 20.40% and 20% for 150 mm cubes and by 28.13%, 18.40% and 60% for 100 mm cubes than control concrete i.e. without silica fume at water-cementitious material ratios of 0.40, 0.45 and 0.50 respectively.

It is also investigated from experimental results that higher compressive strengths of 100 mm cubes are found out at all age and replacement levels than 150 mm cubes. It is reported that the optimal compressive strength is obtained at 20% cement replacement level by silica fume at all water-cementitious material ratio of 0.40, 0.45 and 0.50. We obtain the compacting factor ranges from 0.81 to 0.88 and the slump value ranges from 10 to 30 mm.

IV. CONCLUSION

From experimental results it is concluded that the optimal compressive strength is obtained at 20% cement replacement level by silica fume at all age levels of 24 hours, 7 and 28 days and low values of slump resemble that the mixes are cohesive in nature but the range of compacting factor is good for using concrete in field in control system. In further investigations, workability of concrete may possibly be increased by increasing the superplasticizer dosages without hampering strength of concrete. The concrete produced by incorporating silica fume in it, gained high values of compressive strength and silica fume concrete is termed as high strength concrete (HSC) as per IS code recommendations. It is assumed that as pore structures at transition zone of silica fume concrete is improved so it is familiarised as high performance concrete but durability tests are yet to be performed. It can be concluded that much higher strength is attained at interfacial zone than concrete without silica fume (i.e. control concrete) because during testing at 28 days, the failure plane cuts the aggregates of cubes but not along the interfacial zone.

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