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# Influence of Silica Fume on Normal Concrete

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**ABSTRACT :** The incorporation of silica fume into the normal concrete is a routine one in the present days to produce the tailor made high strength and high performance concrete. The design parameters are increasing with the incorporation of silica fume in conventional concrete and the mix proportioning is becoming complex. The main objective of this paper has been made to investigate the different mechanical properties like compressive strength, compacting factor, slump of concrete incorporating silica fume. In this present paper 5 (five) mix of concrete incorporating silica fume are cast to perform experiments. These experiments were carried out by replacing cement with different percentages of silica fume at a single constant water-cementitious materials ratio keeping other mix design variables constant. The silica fume was replaced by 0%, 5%, 10%, 15% and 20% for water-cementitious materials (w/cm) ratio for 0.40. For all mixes compressive strengths were determined at 24 hours, 7 and 28 days for 100 mm and 150 mm cubes. Other properties like compacting factor and slump were also determined for five mixes of concrete.
**Keywords** – Silica Fume, Compressive Strength, Concrete, High performance concrete, Slump.

## I. INTRODUCTION

The production of Ordinary Portland Cement (OPC), the main ingredient in normal concrete unfortunately, emits vast amounts of carbon-dioxide gas into the atmosphere which has major contributions to green house effect and thereby causing global warming; hence it is obvious to use either alternate or other materials as part replacement [1]. Some alternate or supplementary pozzolanic materials like Fly ash, silica fume, Rice husk ash, Ground Granulated Blast furnace Slag, and High Reactive Metakaolin can be used for cement as partial replacement in concrete and should lead to global sustainable development and lowest possible environmental impact and energy saving [2]. The advantages like high strength, durability and reduction in cement production are obtained due to the incorporation of silica fume in concrete and the optimum percentage replacement of silica fume ranging from 10 to 20 % to obtain maximum 28-days strength of concrete [3-4]. Durability and the other mechanical properties of concrete are improved when pozzolanic materials are incorporated in concrete because of the reaction between silica present in pozzolans and the free calcium hydroxide during the hydration of cement and consequently forms extra calcium silicate hydrate (C – S – H) [5]. N. K. Amudhavalli, Jeena Mathew showed that a part replacement of cement by silica fume at varying percentage has improved the performance of concrete in strength and durability aspect and reported that 10-15 % silica fume replacement level produce the optimum (7 and 28-days) compressive strength and flexural strength and it is seemed that silica fume have a more prominent effect on the flexural strength than the split tensile strength [6]. The incorporation of silica fume in concrete is useful to increase the compressive strength [7-10], decrease the drying shrinkage [9, 10], and the permeability [11]. Also the incorporation of silica fume in concrete is effective to increase the bond strength with the steel reinforcement [12, 13], and abrasion resistance [14]. Consequently, the use of silica fume concrete in civil structures is wide spreading [15, 16]. Nevertheless, the loss of workability due to the use of silica fume creates the difficulty to utilize silica fume concrete accurately [17]. The smaller sizes (10 mm and 5mm) and rounded shape aggregates should be used for high strength of concrete than other sizes and shape respectively [18]. Incorporation of silica fume in concrete has an adverse effect on workability and higher percentage of super plasticizer is needed for higher percentage of cement replacement by silica fume [1, 19]. In this paper our attempt have been made to investigate the different mechanical properties like compressive strength, compacting factor, slump of concrete incorporating silica fume considering a single water-cementitious material ratio of 0.40.

## II. EXPERIMENTAL INVESTIGATION

### 2.1 MATERIALS

#### 2.1.1 CEMENT

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

#### 2.1.2. FINE AGGREGATE

Natural sand as per IS: 383-1970 was used. Locally available River sand having bulk density 2610 kg/m3 was used. 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 |

**2.1.3. COARSE AGGREGATE**

Crushed aggregate confirming to IS: 383-1970 was used. Aggregates of size 12.5 mm of specific gravity 2.83 and fineness modulus 6.28 were used.

**2.1.4. SILICA FUME (GRADE 920 D)**

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

Table 2 SILICA FUME
CHEMICAL & PHYSICAL ANALYSIS REPORT

| **Sl.no.** | **CHEMICAL ANALYSIS** | **ANALYSIS** |
|---|---|---|
| 1. | SiO2 | 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/m3 |
| 4. | Specific Surface Area (by BET)* | 22.21 m2/kg |
| 5. | Accelerated Pozzolanic Activity Index with Portland Cement | 134.90% |

*As per manufacturers manual

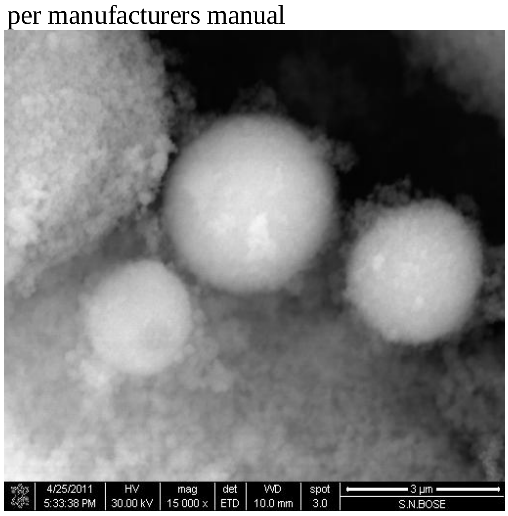

Figure 1: SEM Image of Silica Fume

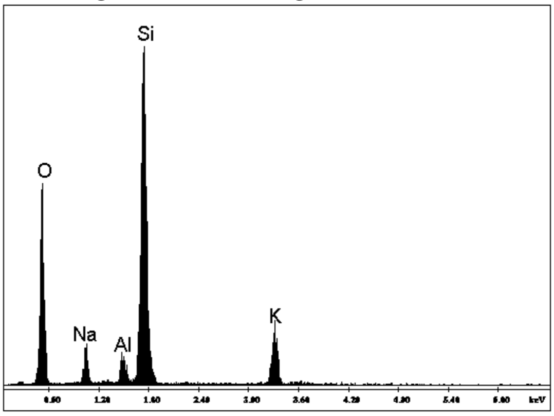


Figure 2: EDAX Spectrum of Silica Fume

**2.1.5. SUPER PLASTICIZER**

In this investigation super plasticizer- CONPLAST-SP 430 in the form of sulphonated Naphthalene polymers complies with IS: 9103-1999 and ASTM 494 type F was used to improve the workability of concrete. Conplast SP 430 has been specially formulated to give high water reductions upto 25% without loss of workability or to produce high quality concrete of reduced 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/ft3 |

*As per manufacturers manual

**2.2. MIX PROPORTIONING**

Concrete mix design in this experiment was designed as per the guidelines specified in I.S. 10262-1982. But some restriction is imposed 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/m3) | Fine Aggregate (Kg/m3) | Coarse Aggregate (Kg/m3) | Water (Kg/m3) | Compacting factor |
|---|---|---|---|---|---|
| 0.4 | 450 | 630.75 | 1097.23 | 180 | 0.814 |

## III. TEST RESULTS AND DISCUSSION:

| W/cm | Cementitious material (Kg/m3) | % 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 | 38.00 | 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 |

In this present paper 5 (five) mix of concrete incorporating undensified silica fume are cast to perform experiments. Smaller size of coarse aggregate (i.e. 12.5 mm) used for the experimentations because for smaller size of coarse aggregate larger surface area are to be exposed for better bonding with paste matrix at the interfacial zone. So strength in the interfacial zone between paste matrix and coarse aggregate is higher and hence strength in concrete is higher than normal concrete as density at transition zone is increased. The experiments were carried out by replacing cement with different percentages of silica fume at a single constant water-cementitious materials ratio keeping other mix design variables constant. The silica fume was replaced by 0%, 5%, 10%, 15% and 20% for water-cementitious materials ratio for 0.40. For all mixes compressive strengths were determined at 24 hours, 7 days and 28 days for 100 mm and 150 mm cubes. Experiments for other properties like compacting factor and slump were also performed to determine the results for five mixes of concrete. The experimental results showed that compressive strength for all replacements of silica fume (i.e. at 5 %, 10%, 15% and 20%) is higher than control concrete (i.e. concrete at zero percentage silica fume replacement level) at all ages (i.e. at 24 hours, 7 days and 28 days).

Experimental results showed that at all ages and replacement levels compressive strengths of 100 mm cubes are higher than 150 mm cubes. It was observed that the maximum compressive strength is obtained at 20% silica fume replacement levels and thereafter compressive strength is decreased. Higher compressive strength at 28 days of about 67.7 MPa for 150 mm cube and 71.33 MPa for 100 mm cube are obtained at 20% cement replacement by silica fume. But in normal concrete without silica fume at 28 days compressive strength of about 49.48 MPa for 150 mm cube and 55.67 MPa for 100 mm cube are obtained. It is observed that 28 days compressive strength is increased by 36.82% for 150 mm cubes and by 28.13% for 100 mm cubes than control concrete i.e. without silica fume. For workability we are concentrated to keep compacting factor 0.814 for all mix irrespective of slump. The slump value ranges from 20 to 50 mm. The value of slump showed the mixes are cohesive in nature.

## IV. CONCLUSION:

There is scope of increasing slump value by increasing dosages of superplasticizers without hampering the strength for further investigation but 0.814 compacting factor is also good for using concrete in the field in control system. Higher compressive strength resembles the concrete incorporating silica fume is high strength concrete as per IS code recommendations. Improved pore structures at transition zone for silica fume concrete resembles that it may be led to as high performance concrete but experiments for durability are yet to be investigated. 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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