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# Experimental Investigation on Strength and Durability of Concrete Incorporated with Mineral Admixtures

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**Abstract:** ***Portland cement is the most essential ingredient of concrete and is a multipurpose and comparatively high price tag material. huge scale production of cement is causing environmental troubles on one hand and exhaustion of natural resources on other hand. This hazard to ecology has lead to researchers to make use of industrial by products as supplementary cementations material in manufacture concrete. The most important factor investigated in this evaluation is M20 grade concrete with partial replacement of cement by silica fume by 10, 15and by 20%. This paper presents a comprehensive experimental study on Compressive strength at age of 7 and 28 day. Durability study on acid attack was also studied and percentage of weight loss is compared with normal concrete. Test results signify that use of Silica fume in concrete has enhanced the performance of concrete in strength as well as in durability characteristic.***

**Keywords:** Silica fume, Compressive strength, Durability, Acid resistance

## 1. Introduction

Concrete is a commonly used construction material for a range of types of structures due to its structural stability and strength. The usage, behaviour as well as the durability of concrete structures, built for the duration of the last first half of the century with Ordinary Portland Cement (OPC) and plain round bars of mild steel, the simplicity of procuring the element materials (whatever may be their qualities) of concrete and the knowledge that roughly any combination of the constituents leads to a mass of concrete have bred condescension. Strength was stressed without a thought on the durability of structures. As a outcome of the liberties taken, the durability of concrete and concrete structures is on a southward journey; a journey that seems to have gained thrust on its path to self– destruction.

1) The Ordinary Portland Cement (OPC) is one of the main ingredients used for the production of concrete and has no substitute in the civil construction industry. Unfortunately, production of cement involves production of large amounts of carbon-dioxide gas into the atmosphere, a chief contributor for green house effect and the global warming, hence it is predictable either to search for an additional material or partly replace it by some other material.
2) The search for any such material, which can be used as an substitute or as a supplementary for cement should lead to global sustainable development and lowest feasible environmental impact considerable energy and cost savings can end result when industrial by products are used as a partial replacement of cement. Fly ash, Ground Granulated Blast furnace Slag, Rice husk ash, High Reactive Met kaolin, silica fume are a few of the pozzolanic materials which can be used in concrete as partial replacement of cement
3) A numeral of studies are going on in India as well as abroad to study the impact of use of these pozzolanic materials as cement replacements and the results are hopeful. Accumulation of silica fume to concrete has many advantages like high strength, durability and reduction in cement production. The optimum silica fume replacement percentage for obtaining maximum 28- days strength of concrete ranged from 10 to 20 %.
4) Cement replacement up to 10% with silica fume leads to enhance in compressive strength, for M20 grade of concrete. When pozzolanic materials are incorporated to concrete, the silica present in these materials react with the calcium hydroxide released during the hydration of cement and forms supplementary calcium silicate hydrate (C – S – H), which develop durability and the mechanical properties of concrete(6). In this paper appropriateness of silica fume has been discussed by replacing cement with silica fume at reliable percentage and the strength parameters were compared with conventional concrete.

## 2. Literature Review

N. K. Amudhavalli et al 2012; Effect of Silica Fume on Strength and Durability parameters of concrete was studied and found that Consistency of cement depends upon its fineness. Silica fume is having larger fineness than cement and greater surface area so the consistency increase significantly, when silica fume percentage increase. The standard consistency increases about 40% when silica fume percentage increases from 0% to 20%. The optimum 7 and 28-day compressive strength and flexural strength have been obtained in the range of 10-15 % silica fume replacement level. Increase in split tensile strength beyond 10 % silica fume replacement is almost inconsequential whereas achieve in flexural tensile strength have occurred even up to 15 % replacements. Silica fume seems to have a more prominent effect on the flexural strength than the split tensile strength. When compared to other mix the loss in weight and compressive strength percentage was found to be reduced by 2.23 and 7.69 when the cement was replaced by 10% of Silica fume [1]. H. Rahmani, A.A. Ramazanianpour, T. Parhizkar et, al; 'Contradictory Effects Of Silica Fume Concretes In Sulfuric Acid Environments'. In this investigation the initial mass of samples was determined under saturated surface dry (SSD) conditions at the age of 28 days. Then, the specimens were immersed in sulfuric acid solutions. The measurements of mass change of samples at SSD condition were taken weekly within the first and second months and monthly afterwards until 11 months except for the third, fifth and seventh week and eighth and tenth month. During measurement, the samples were rinsed with tap water, brushed lightly with a plastic brush to remove loose particles and then measured for their SSD masses [2].

## 3. Experimental Investigation

### 3.1. Materials

#### 3.1.1. Cement

Ordinary Portland Cement of Ultratech brand of 43 grade confirming to IS: 12269-1987(9) was used in the current study. The properties of cement are shown in Table 1

**Table 3.1:** Properties of Cement

| S. No | Properties | Obtained Results | Values as per IS:12269 |
|---|---|---|---|
| 1. | Fineness | 4.3% | <10% |
| 2. | Consistency | 33% | |
| 3. | Initial Setting Time | 52 min | >30 min |
| 4. | Final Setting Time | 260 min | <600 min |
| 5. | Specific gravity | 2.9 | <3.15 |

#### 3.1.2 Fine aggregate

Fine aggregates are materials passing through as IS sieve which is less than 4.75mm. They are filler materials between the coarse aggregate. The most important function of the fine aggregate is to provide workability and uniformity in the mixture.

#### 3.1.3 Coarse aggregate

Material which is held on BIS test sieve no.4.75mm is termed as a coarse aggregate form the main matrix of the concrete. The broken stone is by and large utilized as a coarse aggregate. As per IS 383:1970 coarse aggregate, maximum size 20 mm is suitable for concrete work.

#### 3.1.4 Silica Fume

Silica fume is a **byproduct in the carbothermic reduction of high-purity quartz** with carbonaceous materials like coal, coke, wood-chips, in electric arc furnaces in the production of silicon and ferrosilicon alloys. Because of its extreme fineness and high silica content, silica fume is a very effective pozzolanic material.

**Table 2.2:** Chemical composition of Silica Fume (IS 15388-2003)

| Chemical Composition | Percentage (%) |
|---|---|
| Calcium oxide, CaO | 0.59 |
| Magnesium oxide, MgO | 0.36 |
| Ferric oxide, $Fe_2O_3$ | 1.57 |
| Sodium oxide, $Na_2O$ | 0.47 |
| Aluminium oxide, $Al_2O_3$ | 0.2-5.0 |
| Phosphorus pentoxide, $P_2O_5$ | 0.27 |
| Silicon dioxide, $SiO_3$ | 91.45 |

### 3.2. Mix Proportioning

The concrete prepared for the experimental procedure is of M-20 grade nominal mix (1 : 1.5 : 3). Water cement ratio is kept constant at 0.55 as prescribed by IS code 456:2000. Cement of density 1440 kg/m³ will be used. Fine aggregate of density 1540 kg/m³ and Coarse aggregate of density 1600 kg/m³ is used. For making blends containing Silica Fume (SF) is replaced with cement in some percentage by weight. Table below shows the various mix proportions for the M20 grade concrete for the experimental procedure.

**Table 3.3:** Mix (1) Conventional Concrete

| Cement (per $m^3$) | Fine Aggregate (per $m^3$) | Coarse Aggregate (per $m^3$) | Water ( per $m^3$) |
|---|---|---|---|
| 411 Kg | 706.5 Kg | 1369.5 Kg | 226.05 Kg |

**Table 3.4:** Mix (2)- Concrete with Admixture ( 10 % Silica fume + Dr fixit) – (CWA10)

| Cement (per $m^3$) | Fine Aggregate (per $m^3$) | Coarse Aggregate (per $m^3$) | Water (per $m^3$) | Silica fume (per $m^3$) |
|---|---|---|---|---|
| 370 Kg | 706 Kg | 1369.5 Kg | 224.406 Kg | 41 Kg |

**Table 3.5:** Mix (3) Concrete with Admixture (15% Silica Fume + Dr fixit)- (CWA15)

| Cement (per $m^3$) | Fine Aggregate (per $m^3$) | Coarse Aggregate (per $m^3$) | Water (per $m^3$) | Silica Fume (per $m^3$) |
|---|---|---|---|---|
| 349.35 Kg | 706.5 kg | 1369.5 Kg | 224.406 Kg | 61.65 Kg |

**Table 3.6:** Mix (4) Concrete with 20% Silica Fume + Dr fixit-(CWSF20)

| Cement (per $m^3$) | Fine Aggregate (per $m^3$) | Coarse Aggregate (per $m^3$) | Water (per $m^3$) | Silica fume (per m3) |
|---|---|---|---|---|
| 329 Kg | 706.5 Kg | 1369.5 Kg | 224.406 Kg | 82 Kg |

### 3.3. Test for Workability of Fresh Concrete

Slump test is a test conducted that measures the workability of concrete. It gauges the consistency of concrete in that particular bunch. The test is performed with the slump cone apparatus to check the consistency of fresh concrete. Table and figure below shows slump cone test results for each sample and line diagram of comparison of slump.

**Table 3.7:** Slump cone test Results

| S. No | Remark | Slump Value (mm) |
|---|---|---|
| 1. | No replacement | 38mm |
| 2. | 10 % Cement Replaced by Silica Fume | 45mm |
| 3. | 15% Cement Replaced by Silica Fume | 48mm |
| 4. | 20% Cement Replaced by Silica Fume | 50mm |
| 5. | 10 % Cement Replaced by RHA | 42mm |

### 3.4 Experimental Procedure

The specimen of standard cube of (150mm x 150mm x 150mm) were used to determine the compressive strength of concrete. Three specimens were tested for 7 & 28 days with each proportion of silica fume replacement. Totally 30 cubes were cast for the strength parameters and 15 cubes for acid attack test. The constituents were weighed and the materials were mixed by hand mixing. The water binder ratio (W/B) (Binder = Cement + Partial replacement of silica fume) adopted was 0.55 and weight of Dr fixit was estimated as 2% of weight of water. The concrete was filled in different layers and each layer was compacted. The specimens were remolded after 24 hrs, cured in water for 7 & 28 days, and then tested for its compressive strength as per Indian Standards.

## 4. Test Results and Discussions

Results of fresh and hardened concrete with partial replacement of silica fume are discussed in evaluation with those of standard concrete.

**Table 4.1:** Results of Compressive Strength

| Mix | % of Silica Silica Fume added % | Compressive Strength(N/mm$^2$) | |
|---|---|---|---|
| | | 7 days | 28 days |
| M1 | 0 | 14.733 | 19.66 |
| M2 | 10 | 19.43 | 22.43 |
| M3 | 15 | 17.33 | 23.54 |
| M4 | 20 | 18.01 | 21.01 |

### 4.1 Compressive Strength

The maximum compression strength at the 7$^{th}$ day was found in the sample 2 (CWSF10) 19.43 N/mm$^2$ in which Cement replaced by 10% Silica Fume (SF), whereas the minimum compression strength was found in sample 3 (CWRHA15) 17.33 N/mm$^2$ in which Cement replaced by 15% Silica Fume.

**Figure 4.1:** Compressive Strength Test

The maximum compression strength at the 28$^{th}$ day was found in the sample 3 (CWSF15) 23.54 N/mm$^2$ in which Cement was not replaced by any of the admixtures, whereas the minimum compression strength was found in Sample 1(CC) in which cement was Not replaced.

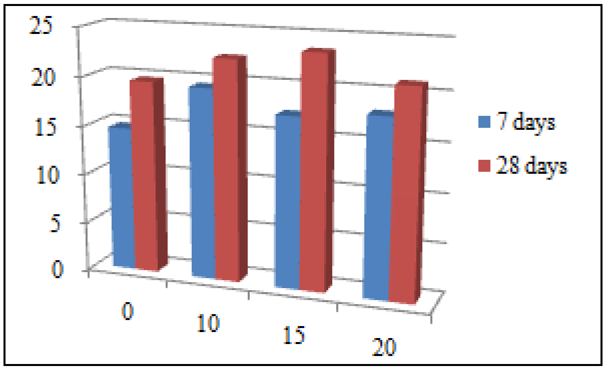


**Figure 4.2:** Effect of silica fume on compressive strength of concrete

### 4.2 Durability Test

### 4.2.1 Acid Resistance

Cubes of sizes 150mm were cast and cured for 28 days. After 28 days curing cubes were taken out and allowed for drying for 24 hours and weights were taken. For acid attack 5% dilute hydrochloric acid is used. The cubes were to be immersed in acid solution for a period of 30 days. The concentration is to be maintained throughout this period. After 30 days the specimens were taken from acid solution. The surface of specimen was cleaned and weights were measured. The mass loss and strength of specimen due to acid attack was determined.

The action of acids on concrete is the renovation of calcium compounds into calcium salts of the attacking acid. These reactions destroy the concrete structure. Thus replacement of silica fume is found to have increased the durability against acid attack. This is due to the silica present in silica fume which combines with calcium hydroxide and reduces the amount susceptible to acid attack.

**Table 4.2:** Effect of Acid Attack on Weight and Compressive Strength Of Cubes

| Specimen | Cube Weight before Acid | Cube Weight after Acid | % Loss of Weight |
|---|---|---|---|
| Conventional Concrete | 8.7 | 8.1 | 2.29 |
| CWSF10 | 8.7 | 8.4 | 3.4 |
| CWSF15 | 8.7 | 8.4 | 3.4 |
| CWSF20 | 8.5 | 8.3 | 2.3 |

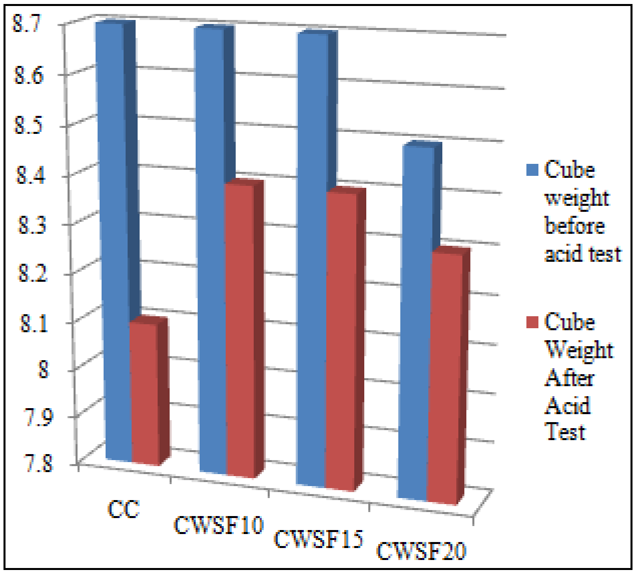


**Figure 4.3:** Comparison of Cube Weight before and After Acid Test

## 5. Conclusions

Consistency of cement depends upon its fineness. Silica fume is having greater fineness than cement and greater surface area so the consistency increases greatly, when silica fume percentage increases. The normal consistency increases when silica fume percentage increases from 0% to 20%. The optimum 7 and 28-day compressive strength have been obtained in the range of 10-15 % silica fume replacement level.. When compared to other mix the loss in weight was found to be reduced by 2.84 when the cement was replaced by 10% of Silica fume.

## 6. Future Scope

1) The Experimental work can be done by various other proportions and ratios of admixtures in the concrete mix design.
2) The experimental investigation of basic properties of concrete is done on 7, & 28 days, further it can be done for longer period i.e. 56, 90, and 180 days.
3) The experiment can be done with different water cement ratios in future.
4) The experiment can be done using other wastes present in the environment which are needed to be disposed off containing cementitious properties.

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