

Effect of Silica Fume on Strength and Durability Parameters of Concrete

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ABSTRACT:

Ordinary Portland cement (OPC) is one of the main ingredients used for the production of concrete and no alternative in the civil construction industry, and is a versatile and relatively high cost material. Large scale production of cement is causing environmental problems on one hand and depletion of natural resources on other hand. This threat to ecology has led to researchers to use industrial by products as supplementary cementations material in making concrete.

The main parameter investigated in this study is M20 grade concrete with partial replacement of cement by silica fume by 0, 5, 10, 15 and by 20%. This paper presents a detailed experimental study on Compressive strength, split tensile 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 indicate that use of Silica fume in concrete has improved the performance of concrete in strength as well as in durability aspect.

KEYWORDS:

Silica fume, durability, Compressive strength, Split tensile strength, Acid resistance.

I. INTRODUCTION :

Concrete is a widely used construction material for various types of structures due to its structural stability and strength.

The usage, behaviour as well as the durability of concrete structures, built during the last first half of the century with Ordinary Portland Cement (OPC) and plain round bars of mild steel, the ease of procuring the constituent materials (whatever may be their qualities) of concrete and the knowledge that almost any combination of the constituents leads to a mass of concrete have bred contempt. Strength was stressed without a thought on the durability of structures. The Ordinary Portland Cement (OPC) is one of the main ingredients used for the production of concrete and has no alternative in the civil construction industry. Unfortunately, production of cement involves emission of large amounts of carbon-dioxide gas into the atmosphere, a major contributor for greenhouse effect and the global warming, hence it is inevitable either to search for another material or partly replace it by some other material.

The search for any such material, which can be used as an alternative or as a supplementary for cement should lead to global sustainable development and lowest possible environmental impact. Substantial energy and cost savings can 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 some of the pozzolanic materials which can be used in concrete as partial replacement of cement. A number 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 encouraging. Addition 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%. Cement replacement up to 10% with silica fume leads to increase 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 additional calcium silicate hydrate (C – S – H), which improve durability and the mechanical properties of concrete. In this paper suitability of silica fume has been

discussed by replacing cement with silica fume at varying percentage and the strength parameters were compared with conventional concrete.

II. EXPERIMENTAL INVESTIGATION:

2.1. Materials :

2.1.1. Cement:

Ordinary Portland Cement of Anjani brand of 53 grade confirming to IS: 4031 (Part 4) : 1988 was used in the present study. The properties of cement are shown in Table 1.

Table 1: Properties of Cement

Sl. No	Property	Result
1.	Normal Consistency	32%
2.	Initial Setting time	45 mins
3.	Specific Gravity	3.15
4.	Fineness of cement	5%

2.1.2. Fine Aggregate

Natural sand as per IS: 383-1987 was used. Locally available River sand having bulk density 1860 kg/m³ was used. The properties of fine aggregate are shown in Tab 2.

Table 2: Properties of fine aggregate

Sl. No	Property	Result
1.	Specific Gravity	2.7
2.	Fineness modulus	3.12
3.	Grading zone	IV

2.1.3. Coarse Aggregate:

Crushed aggregate confirming to IS: 383-1987 was used. Aggregates of size 20mm and 12.5 mm of specific gravity 2.84 and fineness modulus 8.47 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 fine aggregate are shown in Table 3.

Table 3: Properties of silica fume

Specific Gravity	2.2
Bulk Density	576, (Kg/m ³)
Size , (Micron)	0.1
Surface Area , (m ² /kg)	20,000
SiO ₂	(90-96)%
Al ₂ O ₃	(0.5 -0.8)%

*As per manufacturers manual

2.2. Mix Proportioning:

Concrete mix design in this experiment was designed as per the guidelines specified in ACI234R – 96 “Guide for the use of silica fume in concrete” by ACI committee

234(7).All the samples were prepared using design mix. M25 grade of concrete was used for the present investigation. Mix design was done based on I.S 10262-1982. The Table 6 shows mix proportion of concrete (Kg/m³).

Table 4: Mix Proportioning

Sl. No	Material	Quantity (Kg/m ³)
1.	Cement (OPC)	383
2.	Fine Aggregate	546
3.	Coarse Aggregate	1187
4.	Water	191.6

2.3. Test for Workability of Fresh Concrete:

Workability is defined as the properties of freshly mixed concrete or mortar which determines the ease and homogeneity with which it can be mixed, placed, consolidated and finished. The workability was measured by conducting slump cone test and compaction factor test in accordance with IS: 1199-1959.

Totally 30 cubes and 30 cylinders 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 0.45 weight of binder. The concrete was filled in different layers and each layer was compacted. The specimens were demoulded after 24 hrs, cured in water for 7 & 28 days, and then tested for its compressive and split tensile as per Indian Standards.

2.4. Experimental Procedure:

The specimen of standard cube of (150mm x 150mm x 150mm) and standard cylinders of (300mm x 100mm) were used to determine the compressive strength, split Tensile strength. Three specimens were tested for 7 & 28 days with each proportion of silica fume replacement.

III. TEST RESULTS AND DISCUSSIONS :

Results of fresh and hardened concrete with partial replacement of silicafume are discussed in comparison with those of normal concrete.

Table 5: Results of Compressive strength and Split Tensile Strength

Mix	% of silica fume added	Compressive strength (N/mm ²)		Spilt tensile strength (N/mm ²)	
		7 days	28 days	7 days	28 days
M1	0	18.74	29.25	1.53	2.63
M2	5	18.21	25.33	1.06	2.11
M3	10	22.43	30.30	1.90	2.65
M4	15	19.07	24.66	1.10	2.23
M5	20	17.7	22.43	1.05	2.09

3.1. Compressive Strength:

The results of compressive strength were presented in Table 6. The test was carried out conforming to IS 516-1959 to obtain compressive strength of concrete at the age of 7 and 28 days. The cubes were tested using Compression Testing Machine (CTM) of capacity 2000Kn.

From Fig 1 the compressive strength is up to 22.43 N/mm² and 30.30 N/mm² at 7 and 28 days. The maximum compressive strength is observed at 10% replacement of silica fume. There is a significant improvement in the compressive strength of concrete because of the high pozzolanic nature of the silica fume and its void filling ability.

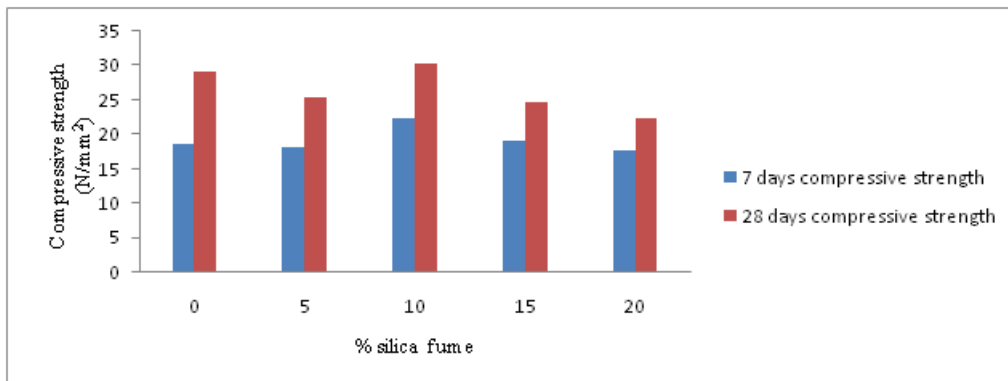


Fig 1. Effect of silica fume on compressive strength of concrete

3.2 Split Tensile Strength:

The results of Split Tensile strength were presented in Table 6. The test was carried out conforming to IS 516-1959 to obtain Split tensile strength of concrete at the age of 7 and 28 days. The cylinders were tested using Compression Testing Machine (CTM) of capacity 2000Kn.

From Fig 2 the increase in strength is 1.90N/mm² and 2.65N/mm² at 7 and 28 days. The maximum increase in split tensile strength is observed at 10% replacement of silica fume. The optimum silica fume replacement percentages for tensile strengths have been found to be a function of w/cm ratio of the mix. The optimum 28-day split tensile strength has been obtained in the range of 5–10%.

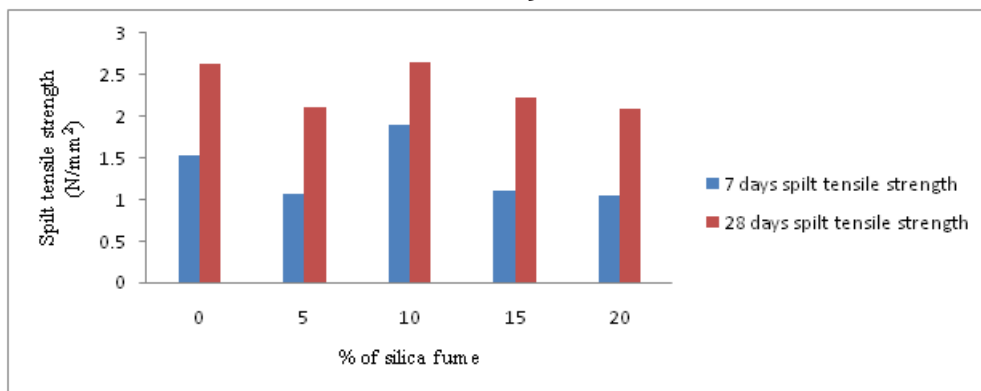


Fig 2 Effect of silica fume on split tensile strength of concrete

3.4 Durability Test:

3.4.1 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 specimen was tested in the compression testing machine under a uniform rate of loading 140Kg/cm² as per IS 516. The mass loss and strength of specimen due to acid attack was determined.

Acid attack:

The action of acids on concrete is the conversion of calcium compounds into calcium salts of the attacking acid. These reactions destroy the concrete structure. The percentage of loss in compressive strength was

10.51%, 9.12%, respectively. 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 6: Effect of Acid Attack On Weight And Compressive Strength Of Cubes

Sl. No	Silica fume %	Loss in Weight (%) At 30 Days	Loss in Compressive strength (%) At 30 Days
1	0	3.99	10.51
2	5	3.89	9.12
3	10	3.53	8.62
4	15	3.72	8.92
5	20	3.84	9.05

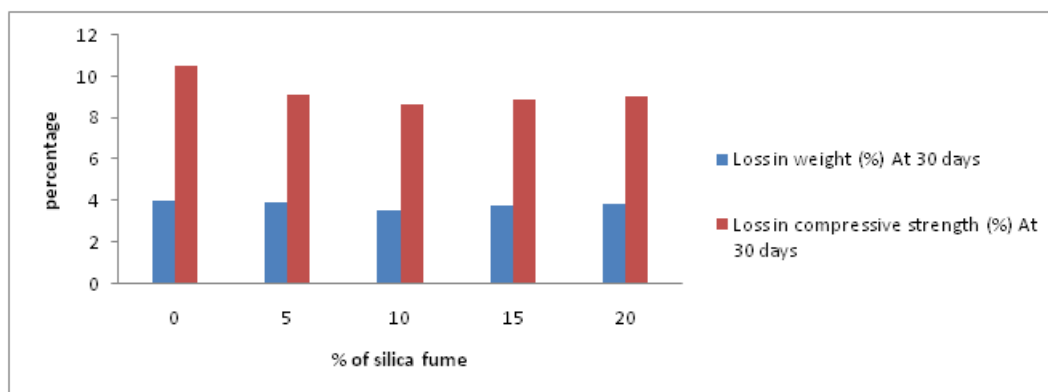


Fig 3 Effect of acid attack on weight and compressive strength of cubes

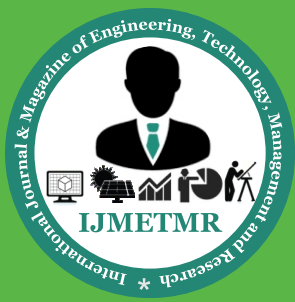
IV.CONCLUSIONS:

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 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 insignificant whereas gain in flexural tensile strength have occurred even up to 15 % replacements. Silica fume seems to have a more pronounced 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.

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