Experimental Study to Investigate Effect of Glass Fiber on Mechanical Properties of Silica Fume Concrete

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Abstract— Silica fume can be used as partial replacement of cement which leads to low environmental impact and energy saving. The advantages like high strength, durability and reduction in cement production are obtained due to incorporation of silica fume. Further, the use of glass fibres in concrete is being broad in current time due to its advantages like reduction in permeability, increasing fatigue strength, improved durability and toughness. In this experiment, we have studied mechanical and durability properties of M20 grade concrete containing silica fume 5%, 10% and 15% as a partial replacement of cement with addition of 0%, 0.5% and 1% of glass fibers by weight of cement. Tests results indicated that inclusion of silica fume and glass fibre in concrete it enhanced the compressive strength, Split tensile strength, flexural strength, acid attack resistance. It also seen that maximum strength is obtained at 10% partial replacement by silica fume and 1% glass fibre content.

Keywords: Silica Fume, Glass Fibre and Glass Fibre Reinforced Concrete

I. Introduction

Portland cement is the most significant constituent of concrete. Its massive production is triggering the environmental problems as well as the depletion of natural resources. Rapid advancement in environmental awareness and its probable hazardous effects has led the researchers to use industrial by-products as supplementary cementitious material to produce concrete. Among these by-products silica fume is used for increasing compressive strength of concrete by partly substituting cement with it.

Silica fume is derivative of the smelting phenomena in silicon and ferrosilicon industry. It is considered as a pozzolanic admixture and is very effective in improving the mechanical properties. Ref. [1] Compressive strengths of 100 MPa to 150 Mpa can be easily obtained in laboratory by using silica fume with different super plasticizers. Ref. [2] Concrete has a brittle character and weak tensile behavior. Strength and ductility of concrete can be increased by the use of reinforcement in concrete, but it requires careful placement by skilled labor.

Alternatively, better solution may be provided by intrusion of fibers to concrete. Concrete becomes homogeneous and isotropic material after the addition of fibers. When concrete fails, the haphazardly distributed fibers facilitate in halting crack development and propagation, and therefore improving strength and ductility.

Ref. [3, 4] Fiber reinforced concrete consists of hydraulic cement, aggregates and reinforcing fibers. It is somewhat new material and has high tensile strength. It consists of composite and uneven scattered fibers. Uniform distribution of fibers increases the cracking strength of concrete. GFRC is significant cement based compound which employs fine sand, cement, water, admixtures and alkali-resistant glass fibers. Glass fibers are similar in role as steel reinforcement and are principal tensile-load carrying members.

Ref. [5, 6] Ghorpade studied the behavior of glass fibers in High Performance Concrete by using silica fume in different percentages and found that performance of concrete was improved at 1% fiber volume. On comparison between metakaolin and silica fume it was found that for a specific mixture metakaolin showed better workability than the silica fume. Also, the strength of MK amended concrete showed an increase in strength at all ages with the increase in replacement.

Ref. [7, 8] Compressive strength of concrete reinforced with steel fibers having 8% silica fume by weight of cement was found to be increased up to 32.4% at 1% fiber volume along with increase in tensile strength up to 74% at 1% steel fiber content. 0.5% polypropylene fiber in the silica fume mix enhances compressive strength, split tensile strength, flexural strength, and mainly the behavior of concrete in terms of impact loading.

Ref. [9] Impact of joint action of silica fume as well as limestone on strength improvement, porosity, pore-structure and organizational features of the system have been studied and it was recognized that total porosity of mortars was significantly increased when cement was replaced with finely ground limestone equal to 15%. Limestone reduces the porosity, if silica fume is replaced up to 8%. Increase in porosity is observed if silica fume is added more than 8 %. Ref. [10, 11] Polypropylene fibers had no significant effect on the modulus of elasticity and compressive strength of lightweight self-compacting concrete. However, by adding these fibers durability, tensile and flexural characteristics are improved. Ref. [12] Sadrmomtazia et. al., investigated the effects of silica fume on mechanical strength and microstructure of basalt fiber reinforced cementitious composites (BFRCC) and found favorable results.

II. Material used

A. Cement:

Ordinary Portland cement 53 grade will be used in the present study which surpasses IS 8112-1989 Specifications.

B. Fine Aggregate:

Natural sand as IS 383-1970 will be used as fine aggregate.

C. Coarse Aggregate:

Crushed aggregate conforming to IS 38 conforming to IS 383-1970 will be used as coarse aggregate.

D. Glass Fibres:

Gf's are procured from Thane, Maharastra.

E. Silica Fume:

Silica fume will be used as partial replacement of cement in this study. Chemical properties of silica fume are as below in table. It is procured from Guru Corporation, Ahmedabad.

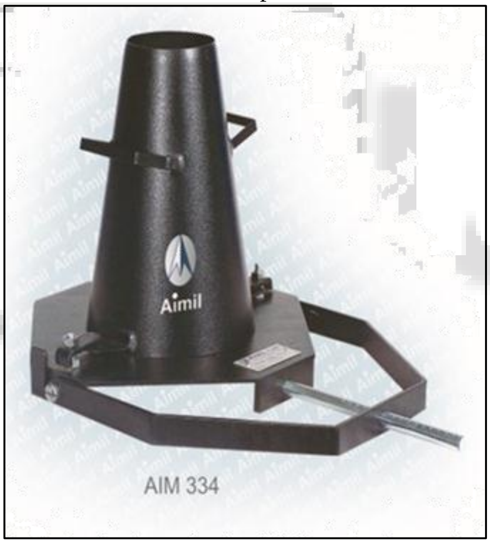
Chemical Parameter	Silica Fume (%)
SiO_2	97.1
Al_2O_3	0.4
Fe_2O_3	0.3
CaO	0.3
MgO	0.0
SO_3	0.2
Total alkalies (Na_2O)	0.0
Loss of ignition	1.7

III. EXPERIMENTAL PROGRAM

All the specimens were cast containing cubes, beams, and cylinders were tested at 28 days. The water cement ratio was kept 0.5 for all mixes. The mix proportion was as given below:

W/C	CEMENT	FINE AGGREGATE	COARSE AGGREGATE
0.5	394 KG	693 KG	1109.7 KG

For workability, we have performed slump test after proper mixing of concrete for all the replacements.



After specified curing age, the compressive strength of cubes, split tensile strength of cylinders and flexural tensile strength of beams were tested as per guidelines of standard IS: 516-1959. For compressive strength, 24 cubes of size 150×150×150 mm were cast. Testing was done on compression testing machine as shown in Figure 1. At each age strength was calculated after taking average of strength of 3 specimens as per the relation:-

Compressive strength (N/mm^2) = load / area.

For testing split tensile strength, the specimens of 200 mm length and 100 mm diameter was used. Total 24 cylinders were cast and the specimens were tested in same compression testing machine (Figure 2). At each age, strength was calculated after taking average of strength of 3 specimens as per the relation:-

Split tensile strength (N/mm^2) = $2P / DL$

Where P = failure load

D = Diameter of cylinder = 100 mm

L= Length of cylinder = 200 mm

Flexural strength is also a measure of tensile strength of concrete. For testing, total 24 beams of size 500×100×100 mm were. The flexural strength specimens was tested under four point loading according to IS: 516-1959. Effective span of beam was 450 mm. Average of 3 specimens were tested at each age to obtain the flexural strength. Test setup is as shown in Figure 3. Flexural strength was calculated as per the relation:-

Flexural strength (N/m^2) = $p\,l / bd^2$

Where,

p = failure load

l = c/c distance 500mm

b = width of the specimen = 100 mm

d = depth of the specimen = 100mm

Acid attack test in Hydrochloric acid is also performed to predict durability of concrete. For this purpose, firstly all the concrete specimens were cured in potable water for 28 days and the cleaned and again cured in 5% solution of HCL for 28. The, weight loss after the acid cure is noticed.

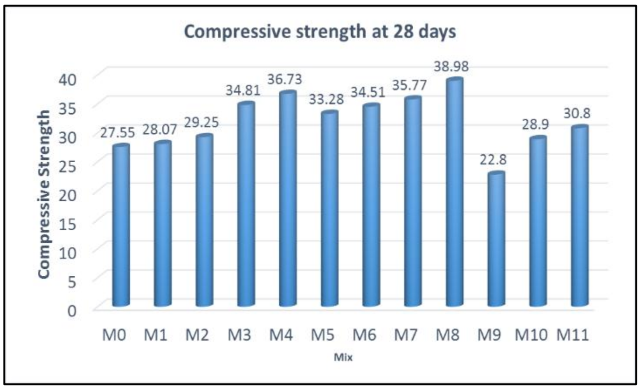
IV. RESULTS AND DISCUSSION

A. *Compression Strength Test:*

Compressive strength of concrete without and with glass fibers and silica fume was tested at the age of 7 days and 28 days. With increase in fiber content and SF an increase in compressive strength was observed, at both curing ages. Maximum increase in strength was observed at 1.0% of glass fibers and 10% SF with strength at 28 days curing age as 38.98 N/mm2. The compressive strength values of various mixes with different fiber percentages and at different curing ages is as shown in Table 1.

Mix	Compressive Strength @ 7 days	Compressive Strength @ 28 days
M0	18	27.55
M1	18.52	28.07
M2	19.71	29.25
M3	23.22	34.81
M4	24.41	36.73
M5	22.42	33.28
M6	23.46	34.51
M7	24.11	35.77
M8	26.55	38.98
M9	14.25	22.8
M10	16.2	28.9
M11	16.8	30.8

Table 1: Effect of Glass Fibers and SF on Compressive Strength of Concrete Mixes.

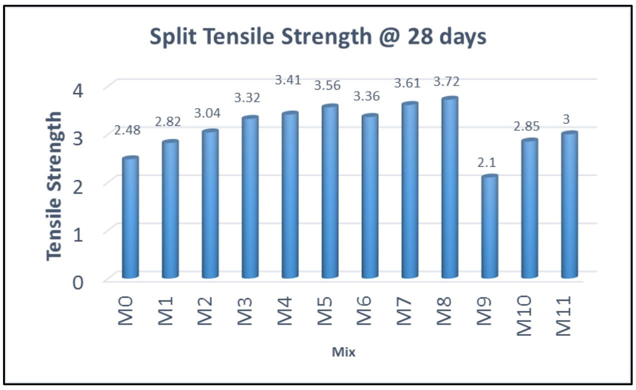


B. *Split Tensile Strength*

Split tensile strength of concrete without and with glass fibers are tested at the ages of 28 days. Similar to compressive strength results, maximum increase in strength was observed at 1% of glass fibers and 10% SF with strength at 28 day curing age as 3.72 N/mm2. The split tensile strength values of various mixes with different fiber percentages and at different curing ages is as shown in Table 2.

Mix	Tensile strength
M0	2.48
M1	2.82
M2	3.04
M3	3.32
M4	3.41
M5	3.56
M6	3.36
M7	3.61
M8	3.72
M9	2.1
M10	2.85
M11	3.00

Table 2: Effect of GF and SF on Split Tensile Strength of Concrete Mixes.



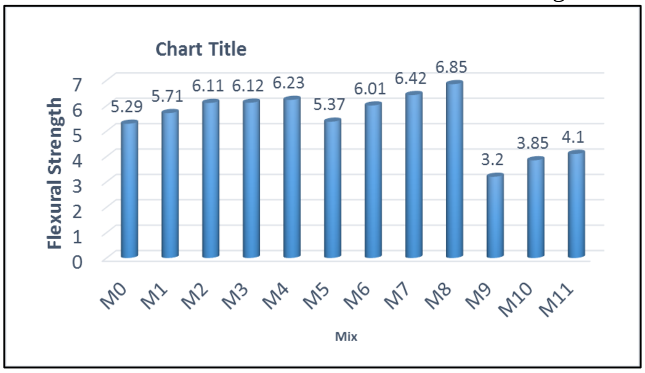
C. *Flexural Strength*

Flexural strength of concrete without and with glass fibers are tested at the ages of 28 days. Similar to compressive strength results, maximum increase in strength was observed at 1% of glass fibers and 10% SF with strength at 28 day curing age as 6.85 N/mm2. The flexural strength values of various mixes with different fiber percentages and at different curing ages is as shown in Table 3.

Mix	Slump in mm
M0	110

M1	100
M2	95
M3	105
M4	98
M5	95
M6	95
M7	90
M8	90
M9	85
M10	79
M11	71

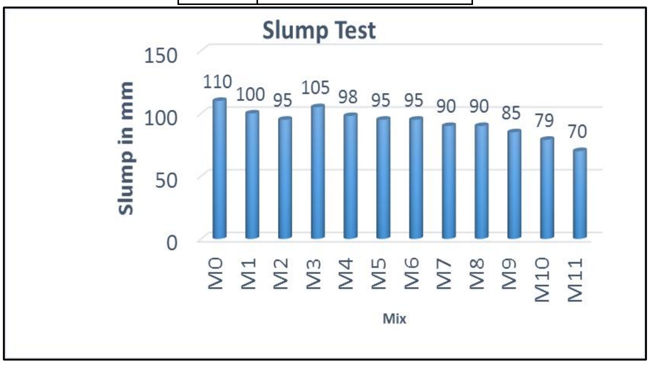
Table 3: Effect of Gf and SF on Flexural strength



D. Slump Test

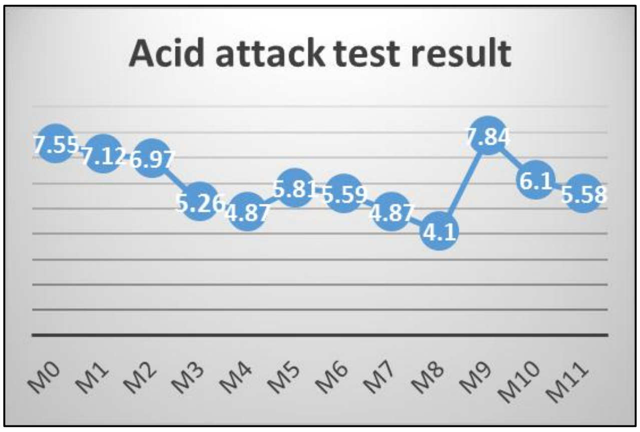
Slump test show that inclusion of GF and SF decrease the workability of concrete mixes. The slump values of various mixes with different GF and SF content showed shown in Table 4.

Mix	Flexural Strength
M0	5.29
M1	5.71
M2	6.11
M3	6.12
M4	6.23
M5	5.37
M6	6.01
M7	6.42
M8	6.85
M9	3.2
M10	3.85
M11	4.1



E. Acid Attack Test Results:

Weight loss for 1% GF and 10% SF is minimum, also notice that durability is improved in GFRC compared to control mix.



V. CONCLUSION

- It identified that Silica fume and Glass fibre can be used in concrete as they improve mechanical properties.
- The workability of concrete is decreased by inclusion of glass fibre and silica fume in concrete.
- Compressive strength of GFRC is increased by 42% compared to control mix at 10% SF and 1% GF.
- Split tensile strength of GFRC is increased by 50% compared to control mix at 10% SF and 1% GF.
- Flexural strength of GFRC is increased by 29.5% compared to control mix at 10% SF and 1% GF.
- Hence, optimum dosage of silica fume is 10% by weight of cement and for glass fibre is 1% by weight of cement.
- Durability in acid test is also improved due to inclusion of GF and SF in optimum dosage.
- Further addition of SF and GF more than optimum dosage reduces the mechanical properties of concrete.

VI. FUTURE SCOPE

- Another types of supplementary cemetery materials can be used with replacement of cement.
- Other durability tests can be done like sulphate attack test, rapid chloride penetration test, water permeability test etc.

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