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A Study on Preparing Of High Performance Concrete Using Silica Fume and Fly Ash

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ABSTRACT
The main objective of this study was to investigate the physical properties of High Performance Concrete (HPC) using silica fume and fly ash as mineral admixtures along with the addition of glass fibres. High Performance Concrete (HPC) mixes incorporated various doses of silica fume (0%, 5%, 7.5%, 10% and 12.5%) as partial replacement of cement. Another concrete mixes incorporated various doses of silica fume (0%, 5%, 7.5%, 10% and 12.5%) and 10% fly ash as partial replacement of cement. For all the above mixes a 0.3% of glass fibres is added by volume fraction. The HPC mix, grade M75 with a water-cement ratio of 0.26 is adopted and it is designed as per ACI 211.4R-08.To improve the workability of concrete, super plasticizer of 0.8% by weight of cement is added. The mechanical behaviour were expressed in terms of compressive, split-tensile and flexural strength. The experimental results show that the specimens containing 10% silica fume and 0.3 % glass fibres and another mix containing 10% silica fume, 10% fly ash and 0.3 % glass fibres experienced higher mechanical properties compared to that of the control specimen.

Keywords:- *Compression Strength, Fly Ash , Flexural strength, Silica Fume, Split-tensile strength.*

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I. Introduction

1.1 General

High performance concrete is used for concrete mixture which possess high workability, high strength, high modulus of elasticity, high density, high dimensional stability, low permeability and resistance to chemical attack.

Normal concrete relatively have low strength and elastic modulus are the result of high heterogeneous nature of structure of the material, particularly the porous and weak transition zone, which exists at the cement paste-aggregate interface. By densification and strengthening of the transition zone, many desirable properties can be improved many fold. A substantial reduction of quantity of mixing water is the fundamental step for making HPC. Reduction of w/ c ratio will result in high strength concrete. But reduction in w/ c ratio to less than 0.3 will greatly improve the qualities of transition zone to give inherent qualities expected in HPC.

To improve the qualities of transition zone, use of silica fume is also found to be necessary. Silica fumes becomes a necessary ingredient for strength above to 80 MPa. The best quality fly ash and GGBS may be used for other nominal benefits. Inspite of the fact that these pozzolanic materials increase the water demand, their benefits will out weigh the disadvantages. The crux of whole problem lies in using very low w/ c ratio, consistant with high workability at the time of placing and compacting. Adopting w/ c ratio in the range of 0.25 to 0.3 and getting a high slump is possible only with the use of superplasticizer. Therefore, use of appropriate superplasticizer is a key material in making HPC.

1.2 Silica Fume

Silica fume is obtained from ELKEM INDIA PVT LTD.

1.2.1 Physical Properties of Silica Fume

The physical properties of Silica Fume (SF) are the particle size, colour, oversize, specific gravity, etc. are explained briefly:-

Particle Size: - SF particles are smooth, spherical size is 1/100 the diameter of Portland cement particle and average particle diameter lies between 0.1 to 0.2 micron range.

Fineness:- the specific surface area of SF as measured by nitrogen absorption method usually lies between 13sq.m/g to 28 sq.m/g. Generally the SF has the fineness value of about 22 sq.m/g.

Colour:- The colour of SF depends on carbon content, lower the carbon content of SF, the lighter is shade of grey. Usually, ferrosilicon furnaces manufacturing low silicon content alloys shoe darker silica fume.
Specific Gravity: - The specific gravity of SF produced from high quality silicon and high grade ferrosilicon alloys typically ranges between 2.2 and 2.3.

1.2.2 Chemical Properties of Silica Fume

Table 1 Chemical Properties of Silica Fume

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
LOI	1.7

1.3 Fly ash

Flyash is collected from Mettur Thermal Power Plant (MTTP) Mettur. Specific Gravity is 1.89. The properties of fly ash are shown in table 2.

Table 2 Chemical Composition of Fly ash

Chemical Properties	Fly Ash
SiO_2+Al_2O_3+Fe_2O_3,min% by weight	90.50
SiO_2+Al_2O_3+Fe_2O_3,min% by weight	90.50
SiO_2, min% by weight	58.00
CaO max % by weight	3.60
SO_3, max % by weight	1.80
Na_2O, max % by weight	2.00
L.O.I, max % by weight	2.00
MgO, max %by weight	1.91

1.4 Glass Fibres

Table 3 Properties of Glass Fibres

Density	2.6 t/m^3
Elastic modulus	73 GPa
Tensile strength	1700 MPa
Number of fibers	220 million / kg
Filament diameter	14µ
Specific gravity	2.6
Length	6 mm
Aspect ratio	857:1
Specific surface area	105m^2/kg

Fig. 1 Glass Fibres

II. Mix Design

2.1 General

The concrete used in this study was proportioned to attain strength of **75 MPa**. ACI committee recommendation has been used for M75 design The mixes MSG1, MSG2, and MSG3 were obtained by replacing 5, 7.5 and 10 percent of the mass of cement by Silica Fume. Then mix MSFG1, MSFG2 and MSFG3 were obtained by replacing the mass of cement by the above percentage of Silica Fume and with 10% of Fly Ash. The water cement ratio (w/c) is taken as 0.26**.** The mix design has been adopted as per ACI 211.4R-93.

2.2 Material Properties

Characteristic compressive strength = 75 MPa
Maximum size of aggregate used = 12.5 mm (passing through and retained on 10 mm sieve).
Specific gravity of cement = 3.15
Specific gravity of fine aggregate = 2.65
Specific gravity of coarse aggregate = 2.77
Dry rodded bulk density of FA = 1701.11 kg/m^3
Dry rodded bulk density of CA = 1692.73 kg/m^3
Slump assumed = 50-75 mm

2.3 Calculation Of Weight Of Coarse Aggregate

From Table 4.3.3 of ACI 211.4R-93,
Fractional volume of oven dry rodded CA = 0.68 m^3
Weight of CA = 1692.73 x 0.68 = 1151.06 kg/m^3

2.4 Calculation Of Quantity Of Water

From Table 4.3.4 of ACI 211.4R-93,
For CA of 12.5 mm and slump of 50-75 mm
The mixing water = 148 ml
Void content of FA for this mixing water = 35 %
Void content of fine aggregate,

$$V= 1 - \{\frac{dry\ rodded\ of\ FA}{density\ of\ water * Gfa}\}* 100$$

V = 35.81 %
Adjustment in mixing water = (35.81 – 35) x 4.55 = 3.686 ml
Total water required = 148 + 3.686 = 151.686 ml.

2.5 Calculation Of Weight Of Cement

Target mean strength f_{cr} = 75 + 9.65 = 84.65 MPa (12277.4 Psi)
Water / cement ratio = 0.26
Weight of cement (Kg) = 583.41 kg/m^3

2.6 Calculation Of Fine Aggregate

CEMENT = 583.41 / (3.15 x 1000) = 0.1852 m^3
WATER = 151.686 / (1 x 1000) = 0.152 m^3
CA = 1151.06 / (2.77 x 1000) = 0.416 m^3
Entrapped air = 2%
Total volume = 0.1852 + 0.152 + 0.416 + 0.02 = 0.773 m^3
Volume of FA = 1 – 0.773 = 0.227 m^3
Weight of FA = 0.227x2.65x1000 = 601.55 kg/m^3

2.7 MIX RATIO

Therefore, the mix ratio adopted is; **1 : 1.03 : 1.973 : 0.26**

Table 4 Mix Proportions

Mix	% Silica Fume	% Fly Ash	% Glass Fibre	W/C Ratio
MSG1	5	0	0.3	0.26
MSG2	7.5	0	0.3	0.26
MSG3	10	0	0.3	0.26
MSG4	12.5	0	0.3	0.26
MSFG1	5	10	0.3	0.26
MSFG2	7.5	10	0.3	0.26
MSFG3	10	10	0.3	0.26
MSFG4	12.5	10	0.3	0.26
C	0	0	0	0.26

III. Experimental Investigation

3.1 General

Strength studies on HPC (M75) were conducted by means of compressive, tensile and flexural strength for 28 days respectively.

3.2 Compressive Strength Test

The test is carried out on 150x150x150 mm size cubes, as per IS: 516-1959. The test specimens are marked and removed from the moulds and unless required for test within 24 hrs, immediately submerged in clean fresh water and kept there until taken out just prior to test. A 2000 KN capacity Compression Testing Machine (CTM) is used to conduct the test. The specimen is placed between the steel plates of the CTM and load is applied at the rate of 140 Kg/Cm^2/min and the failure load in KN is observed from the load indicator of the CTM.

Compressive strength = (Load / Area) N/mm^2

Table 5 Compressive Strength Results

Mix	% Silica Fume	% Fly Ash	% Glass Fibre	28 Days N/mm^2
MSG1	5	0	0.3	68
MSG2	7.5	0	0.3	70
MSG3	10	0	0.3	78
MSG4	12.5	0	0.3	73
MSFG1	5	10	0.3	67
MSFG2	7.5	10	0.3	71
MSFG3	10	10	0.3	81
MSFG4	12.5	10	0.3	77
C	0	0	0	69

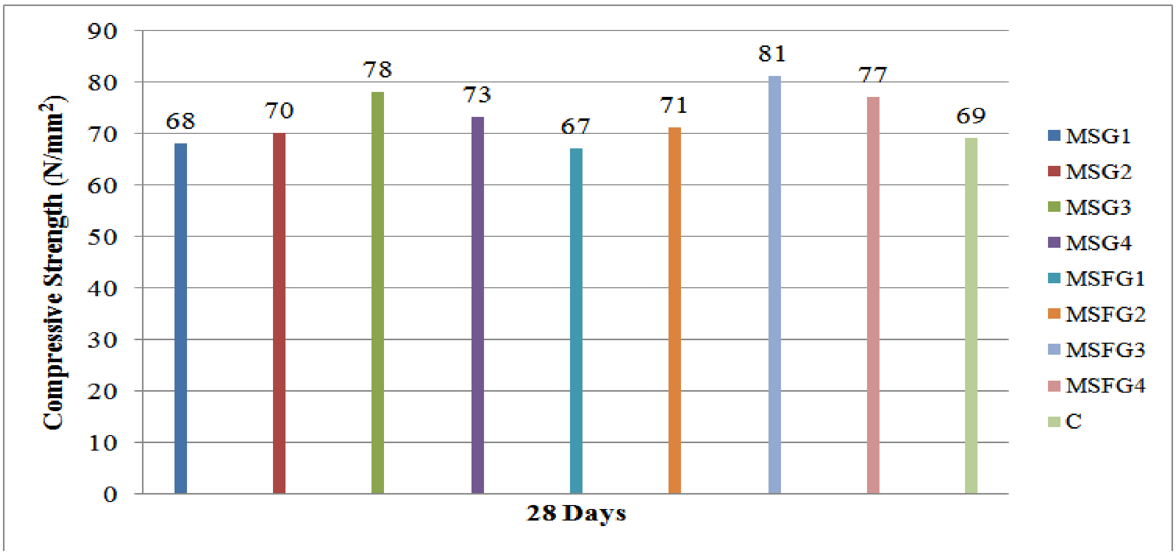

Fig. 2 Graphical Representation of Compressive Strength of Cube at 28 Days.

3.3 Split Tensile Strength Test

The splitting tensile strength of concrete cylinder was determined based on 516-1959. The load shall be applied nominal rate with in the range 1.2 N/(mm^2/min) to 2.4 N/(mm^2/min)

$$\text{Split Tensile Strength} = \frac{2P}{\pi LD}$$

Table 6 Split Tensile Strength Results

Mix	% Silica Fume	% Fly Ash	% Glass Fibre	28 Days N/mm^2
MSG1	5	0	0.3	5.092
MSG2	7.5	0	0.3	5.410
MSG3	**10**	0	**0.3**	**6.040**
MSG4	12.5	0	0.3	5.729
MSFG1	5	10	0.3	5.729
MSFG2	7.5	10	0.3	6.366
MSFG3	**10**	**10**	**0.3**	**6.684**
MSFG4	12.5	10	0.3	6.040
C	0	0	0	5.729

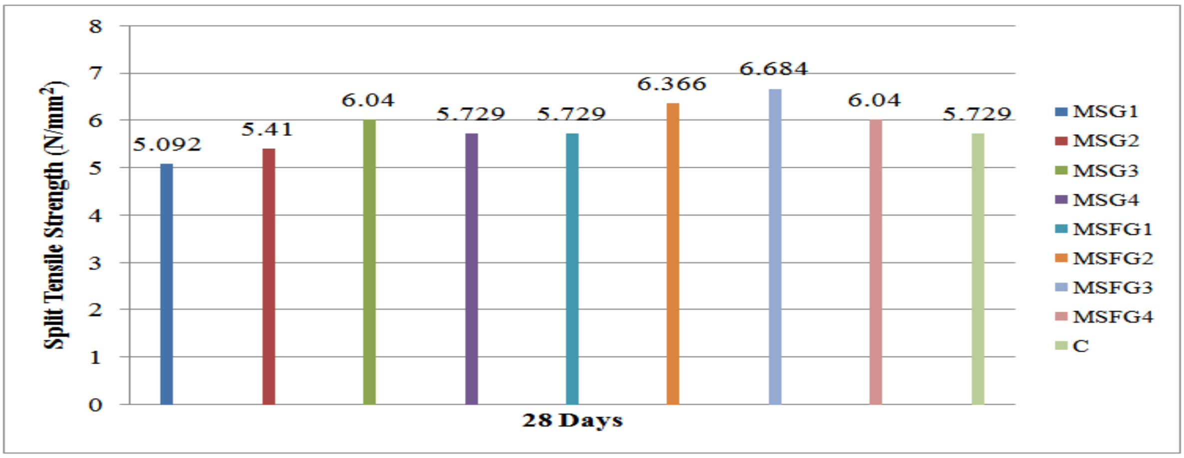

Fig. 3 Graphical Representation of Split Tensile Strength of Cylinder at 28 Days.

3.4 Flexural Strength Test

The flexural strength of concrete prism was determined based on IS: 516 –1959. Place the specimen in the machine in such a manner that the load is applied to the upper most surface as cast in the mould along two lines spaced 13.3cm a part. Apply load without shock and increase continuously at a rate of 180 kg/min and it is increased until the sample fails. Measure the distance between the line of fracture and nearest support.

If a > 13.3cm then

$$\text{Modulus of rupture } f_b = \frac{P \ x \ l}{b \ x \ d^2}$$

If a < 13.3

$$f_b = \frac{3P \ x \ a}{b \ x \ d^2}$$

If a < 11, Discard the specimen

Where,

P = Maximum load applied to the specimen in kN.

L= Supported Length in mm.

d = Depth of the specimen mm, and

a = Distance of the crack from the nearest support.

Table 7 Flexural Strength Results

Mix	% Silica Fume	% Fly Ash	% Glass Fibre	28 Days N/mm^2
MSG1	5	0	0.3	4.551
MSG2	7.5	0	0.3	4.866
MSG3	**10**	**0**	**0.3**	**5.179**
MSG4	12.5	0	0.3	4.748
MSFG1	5	10	0.3	4.238
MSFG2	7.5	10	0.3	5.023
MSFG3	**10**	**10**	**0.3**	**5.337**
MSFG4	12.5	10	0.3	4.866
C	0	0	0	4.395

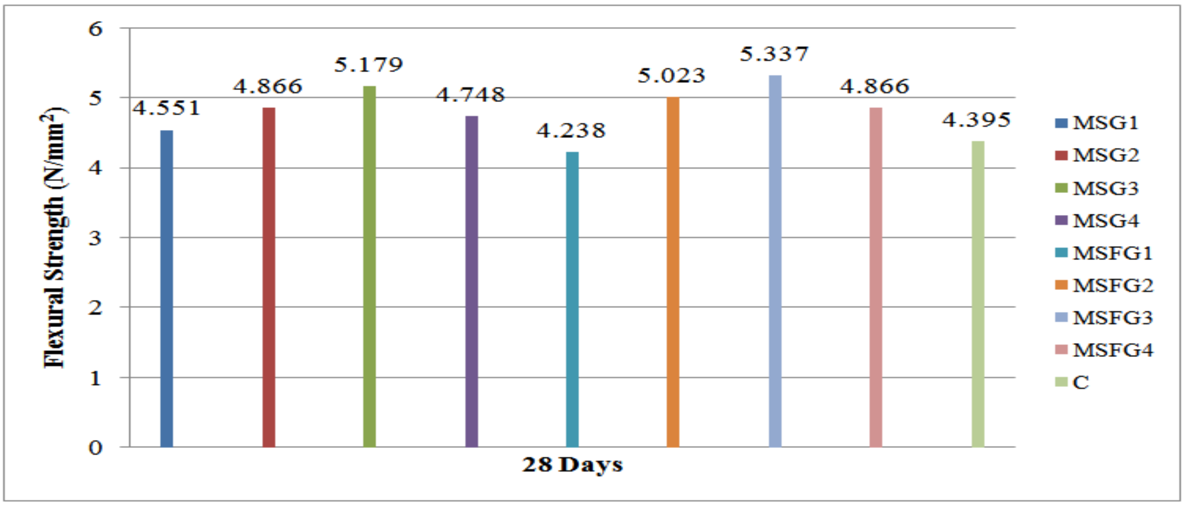

Fig. 4 Graphical Representation of Flexural Strength of Prism at 28 Days.

IV. Conclusion

4.1 General

In this paper the effect of silica fume on compressive strength on high strength concrete was studied by carrying out. The silica fume was replaced by 0%, 5%, 10% and 12.5% for water-binder ratio of 0.26. And also for the constant replacement of fly ash by 10% along with the above mentioned replacement. The following conclusions were obtained,

4.2 Strength Studies

- The results of the present investigation indicate that other mix design parameters remaining constant, silica fume incorporation in concrete results in significant improvements in compressive strengths.
- The super plasticizer demand of concrete containing Fly Ash and Silica Fume increases with increasing amount of fly ash and silica fume. The increase is primarily due to the fineness of the fly ash and silica fume.
- The optimum 28-day compressive strength has been obtained in the range of 10% silica fume replacement level and adoption of constant 0.3% glass fibres (MSG3).
- The compressive Strength of mix MSG3 is 1.13 times higher than that of the conventional mix.
- The optimum 28-day compressive strength for another mix is obtained in the range of 10% silica fume, 10% fly ash and 0.3% glass fibres (MSFG3).
- The compressive Strength of mix MSFG3 is 1.17 times higher than that of the conventional mix.
- The optimum 28-day split tensile strength has been obtained in the range of 10% silica fume replacement level and adoption of constant 0.3% glass fibres (MSG3).
- The split tensile strength of mix MSG3 is 1.05 times higher than that of the conventional mix.
- The optimum 28-day split tensile strength for another mix is obtained in the range of 10% silica fume, 10% fly ash and 0.3% glass fibres (MSFG3).
- The split tensile strength of mix MSFG3 is 1.17 times higher than that of the conventional mix.
- The optimum 28-day flexural strength has been obtained in the range of 10% silica fume replacement level and adoption of constant 0.3% glass fibres (MSG3).

- The flexural strength of mix MSG3 is 1.18 times higher than that of the conventional mix.
- The optimum 28-day flexural strength for another mix is obtained in the range of 10% silica fume, 10% fly ash and 0.3% glass fibres (MSFG3).
- The flexural strength of mix MSFG3 is 1.21 times higher than that of the conventional mix.
- As the age of concrete increases, the compressive strength also increases. Silica Fume concrete attains high strength and also the concrete containing silica fume with fly ash.
- It is proved that the high strength concrete can be obtained by lowering the water-cement ratio and the workability can be maintained by the use of super plasticizers even for very low water-cement ratio.

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