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Study of High Performance Concrete with Silica Fume and Glass Fibre

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Abstract – **This paper presents the effect of silica fume and glass fibre in High Performance Concrete (HPC). In this study, High Performance Concrete mixes with silica fume of 0%, 10%, and 20% with addition of glass fibre of diameter 14µ and 12mm length at various percentages as 0%, 0.3%, and 0.6% by the volume of cement on M75 grade of concrete. The mix proportions of concrete had a constant binder of 0.26 and superplasticizer was added based on the required degree of workability. For each mix standard sizes of cubes, cylinders and prisms as per Indian Standards were cast and tested for compressive strength, split tensile strength and flexural strength at the age of 28 days. The addition of silica fume shows early strength gaining property and that of glass fibre control the cracking due to shrinkage. The results are satisfactory for the use of 10% silica fume and 0.3% glass fibre in producing High Performance concrete.**

Keywords : **High Performance Concrete, Silica fume, Glass fibre**

I. Introduction

Concrete is the most widely used construction material in the world, mainly due to its favourable features such as durability, versatility, satisfactory compressive strength, cost effectiveness and availability. The concrete being the main construction materials, it is being used in various applications and the strength of concrete varies below 60 MPa. Only for special applications the concrete grade can be increased to 60 MPa and above. These special applications of HPC cannot be achieved by Ordinary Portland Cement (OPC). It is achieved not only by reducing water cement ratio but also by replacement of cement with some mineral admixture like Silica fume, Ground Granulated Blast Furnace Slag, Metakaolin, Fly ash, etc and also with chemical admixtures. The term HPC is used for concrete mixture which possesses high workability, high strength, high modulus of elasticity, low permeability, etc. The substantial reduction of quantity of mixing water is the fundamental step for making HPC in the range below 0.3 (w/c ratio).

The initial interest in the use of silica fume was mainly caused by the strict enforcement of air-pollution control measures in various countries to stop release of the material into the atmosphere. Silica fume is a pozzolanic material which is a by-product of the silicon smelting process. Silica fume is known to produce a high strength concrete and is used in two different ways: as a cement replacement, in order to reduce the cement content and as an additive to improve concrete properties. Therefore, utilization of silica fume together with fly ash provides an interesting alternative and can be termed as high strength and high performance concrete. The use of fibre in concrete increases the mechanical properties such as compressive strength, tensile strength of concrete to some extent. Hence the flexural behaviour can be increased to some extent. It also possesses the ability to reduce plastic shrinkage in concrete. Cem-Fill Anti Crack Fibre was introduced in this study.

The objective of this work is to study the behaviour of High Performance Concrete with silica fume and glass fibre. Hence in the present work the effect of silica fume on the development of HPC and the quantity of glass fibre required to control cracks are studied.

Malathy, R. *et al* (2007) carried out an experimental work to study the effect of silica fume on plastic shrinkage cracking of HPC. Specimens were tested under hot dry environmental conditions. Finally, it was observed that optimum percentage of replacements were 0.3% volume fraction fibres were required for 10% silica fume replaced concrete with the w/b ratio of 0.3. Silica fume increases strength and life of concrete especially durability, but it also requires glass fibres to arrest plastic shrinkage cracks. Hariharan, A.R. *et al* (2011) reported that the strength development of high strength concrete containing fly ash and silica fume. The mix with 40% fly ash showed the maximum strength of 60.2 MPa compared to all other Fly ash replacements. The silica fume with 6% replacement showed maximum strength of 61.2MPa compared to 10% silica fume. Silica fume compensates the low early strength of concrete with high CaO fly ash. Vinayagam, P. (2012) formulated the simplified mix design procedure for HPC by combining BIS and ACI code methods of mix design. The optimum percentage of cement replacement by silica fume was 10% for the test conducted in M80 and M100 grades of concrete. It was observed that mixes containing silica fume showed lesser value of pH and percentage of saturated water absorption also lower when compared to mixes containing without silica fume.

II. Experimental Programme

A. Materials

1. Cement

The Ordinary Portland Cement of 53 Grade conforming to IS 12269 – 1987 was used in this study. The specific gravity, initial and final setting of OPC 53 grade were 3.15, 30 and 600 minutes respectively.

2. Fine Aggregate

Locally available river sand conforming to grading zone II of IS 383 –1970. Sand passing through IS 4.75mm Sieve will be used with the specific gravity of 2.65.

3. Coarse Aggregate

Locally available crushed blue granite stones conforming to graded aggregate of nominal size 12.5 mm as per IS 383-1970 with the specific gravity of 2.77.

4. Silica Fume

Silica Fume was obtained from Elkem India (P) Ltd., Navi Mumbai conforming to ASTM C 1240 as mineral admixture in dry densified form.

5. Glass Fibre

Glass Fibre available in the market was used in this experimentation. The length of the fibre is 12mm and the diameter of 14μ with the specific gravity of 2.6.

6. Water

Casting and curing of specimens were done with the potable water that is available in the college premises.

7. Superplasticizer

A commercially available Sulphonated naphthalene formaldehyde based super plasticizer (Conplast SP 430) was used as chemical admixture to enhance the workability of the concrete.

B. Mix Proportions

In this study, control specimen (MCS) was designed as per ACI 211.4R-93 to achieve M75 grade of concrete. Silica Fume was used to replace Ordinary Portland Cement

Table I Concrete Mix Proportions

Mix	MCS	MSF1	MSF1G3	MSF1G6	MSF2	MSF2G3	MSF2G6
Cement (kg/m^3)	583	525	525	525	466	466	466
FA (kg/m^3)	602	602	602	602	602	602	602
CA (kg/m^3)	1151	1151	1151	1151	1151	1151	1151
SF (%)	0	10	10	10	20	20	20
GF (%)	0	0	0.3	0.6	0	0.3	0.6
Water (lit/m^3)	151	151	151	151	151	151	151
Superplasticizer (lit/m^3)	4.7	4.7	4.7	4.7	4.7	4.7	4.7

at various levels of 0%, 10%, 20% and the glass fibre of 0%, 0.3%, 0.6% were used. The mix proportions of different mixes are shown in Table I.

C. Casting And Testing Of Specimens

For each mix of concrete three number of concrete cubes, cylinders and prism were cast and tested as per IS 516-1959. To obtain a homogenous mix, aggregates were mixed and binders (cement, FA, SF, GF) were added to the system. After remixing, water was added to the dry mix. Finally, superplasticizer was introduced to the wet mixture. Cube specimens were used to determine the compressive strength, cylinder specimens were used to determine the split tensile strength and prism specimens were used to determine the flexural strength. After casting, the mould specimens were left in the casting area for 24 hours then demoulded and allowed for wet curing. The specimens were cured for 28 days period to determine the compressive, split tensile and flexural strengths.

III. Results and Discussion

A .Compressive Strength

The cube compressive strength results at 28 days for different replacement levels such as 0%, 10%, and 20% of cement with silica fume and 0%, 0.3% and 0.6% of glass fibre are presented in Table II. The development of Compressive Strength with ages for the above different mixes was plotted in the form of graph as shown in Figure1. The cube compressive strength was observed as 89.1 N/mm^2 for 10% SF and 0.3% GF there is an increase of strength by 12.5% when compared to control specimen and for the same with 10% SF and 0% GF there is an increase of strength by 4%. The compressive strength development is due to the pozzolanic reaction of silica fume and the presence of glass fibre. The rapid rate of strength development is due to the fact that for lower water-binder ratio, the cement particles are held at closer interval than for higher water-binder ratios. Also due to the action of silica fume on calcium hydroxide, more gel is formed. These two factors enhance the formation of a continuous system of gel, which provides better development of strength at early ages since, silica fume starts react with calcium hydroxide and produces C-S-H gel immediately.

Table II Compressive Strength Results

Mix	% of SF	% of GF	28 Days (N/mm^2)
MCS	0	0	79.2
MSF1	10 0	0	85.4
MSF1G3	10 0	0.3	89.1
MSF1G6	10 0	0.6	86.7
MSF2	20 0	0	87.0
MSF2G3	20 0	0.3	85.2
MSF2G6	20 0	0.6	82.5

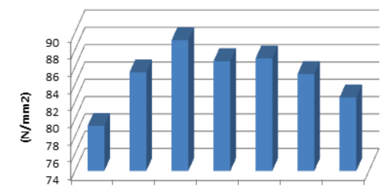

Fig. 1 Comparison of Compressive Strength at 28 days of various mixes

B. Split Tensile Strength

The split tensile strength results of mixes at the age of 28 days for different replacement levels such as 0%, 10% and 20% of cement with Silica fume and 0%, 0.3% and 0.5% of Glass fibre are presented in Table III. The development of Split tensile strength with ages for the above different mixes was plotted in the form of graph as shown in figure2. The cylinder split tensile strength was observed as 6.330 N/mm^2 for 10% SF and 0.3% GF there is an increase of strength by 4.4% when compared to control specimen and for the same with 10% SF and 0% GF there is an increase of strength by 2%. From the test results it was observed that the maximum split tensile strength is obtained for mix with 10% SF and 0.3% GF.

Table III Split Tensile Strength Results

Mix	% of SF	% of GF	28 Days (N/mm^2)
MCS	0	0	6.062
MSF1	10	0	6.253
MSF1G3	10	0.3	6.330
MSF1G6	10	0.6	5.900
MSF2	20	0	6.125
MSF2G3	20	0.3	6.200
MSF2G6	20	0.6	5.890

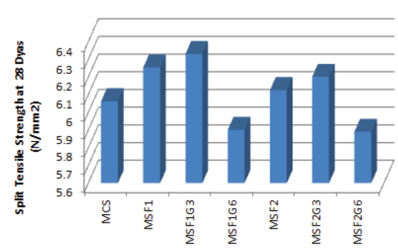

Fig. 2 Comparison of Split Tensile Strength at 28 days of various mixes

C. Flexural Strength

The Flexural Strength results of mixes at the age 28 days for different replacement levels such as 0%, 10% and 20% of cement with Silica fume are presented in Table IV. The development of Flexural Strength with ages for the above different mixes was plotted in the form of graph as shown in figure 3. The prism flexural strength was observed as 5.430 N/mm^2 for 10% SF and 0.3% GF there is an increase of strength by 9.4% when compared to control specimen and for the same with 10% SF and 0% GF there is an increase of strength by 5%. From the test results it was observed that the maximum flexural strength is obtained for mix with 10% SF and 0.3% GF. In the replacement of SF the mix with 10%SF+0.3%GF was observed that the maximum Flexural strength at the water-binder ratio of 0.26.

Table IV Flexural Strength Results

Mix	% of SF	% of GF	28 Days (N/mm^2)
MCS	0	0	4.963
MSF1	10	0	5.172
MSF1G3	10	0.3	5.430
MSF1G6	10	0.6	5.120
MSF2	20	0	5.260
MSF2G3	20	0.3	5.243
MSF2G6	20	0.6	4.890

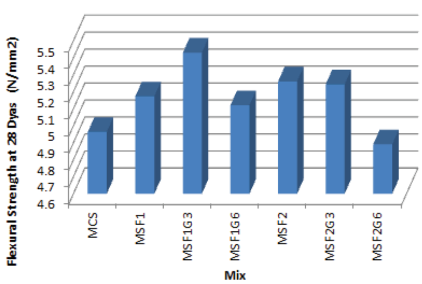

Fig. 3 Comparison of Flexural Strength at 28 days of various mixes

IV. Conclusion

The major objective of this experimental investigation is to use silica fume and glass fibre in High Performance Concrete and also reducing the cement content. Based on the present investigation the following conclusions are drawn:

1. The effect of silica fume and glass fibre in the High Performance Concrete are studied;
2. From the obtained results, 0.3% glass fibre can be taken as the optimum dosage, which can be used for giving maximum possible strength at the age of 28 days for glass fibre reinforced high performance concrete;
3. From the obtained results, 10% silica fume can be taken as the optimum dosage, which can be used for giving maximum possible strength at the age of 28 days for high performance concrete;
4. The percentage increase in compressive strength at 28 days of 10% silica fume with 0.3% glass fibre over control specimen without silica fume and glass fibre is 12.5%;
5. The percentage increase in split tensile strength at 28 days of 10% silica fume with 0.3% glass fibre over control specimen without silica fume and glass fibre is 4.4%;
6. The percentage increase in flexural strength at 28 days of 10% silica fume with 0.3% glass fibre over control specimen without silica fume and glass fibre is 9.4%;
7. The compressive, split tensile and flexural strength of other mixes are lower when compared to the mix with 10% silica fume and 0.3% glass fibre;
8. From the experimental results, the optimum percentage recommended as 0.3% glass fibre volume with 10% silica fume for achieving maximum benefits in compressive, split tensile and flexural strength.

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