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Study on Fibre Reinforced Silica Fume Concrete

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ABSTRACT

Today concrete is most widely used construction material because of ease of construction and its properties like compressive strength, flexural strength, and durability. It is difficult to point out another material of construction which is as versatile as concrete. It is so closely associated now with every human activity that it touches every human being in his day to day living. It is well known that plain concrete is very good in resisting compressive forces but found to be weak against tensile forces. It has the qualities of flexibility and ability to redistribute stresses, but possesses a low specific modulus, limited ductility and little resistance to cracking. There are so many new types of admixtures have been developed in recent years to improve the strength and workability properties of concrete. The use of pozzolonic materials is as old as that the art of concrete construction which changes functional needs of a structure. This interest arises due to the collection of these materials from various countries and to strict the enforcement of pollution control and to stop dispersing this hazardous pozzolonic material in to the atmosphere. Pozzolonic materials by and large can be used to replace a part of cement in all construction works. In this class of materials silica fume is one, which can replace cement up to 20 %. The literature available regarding the properties of composite material including concrete, silica fume, fibre is rare. So we used to these components in various proportions to evaluate the flexural and compressive strength of concrete. The structural behavior of steel fibre reinforced silica fume concrete under compression and flexure is studied by conducting tests on standard controlled specimens. The use of fibre in the concrete improves its property especially flexural strength and the addition of silica fume to concrete further improves its compressive strength.

Key Words- ***High strength concrete, Water cement ratio, Fly ash***

INTRODUCTION

There is a general agreement among various researches regarding the use of silica fume to improve various properties of fresh and hardened concrete[1]. It is also a matter of common concern regarding the use of super plasticizers to maintain the workability of concrete. It is agreed that silica fume has less gain in strength at seven days and rapid gain at later ages. The flexural strength, elastic modulus, toughness and the steel concrete[1] bond increases for silica fume concrete. After conducting the tests for strength, permeability and freeze – thaw resistance on concrete containing silica fume for using overlays, a conclusion has come out that concrete containing silica fume at a low replacement rate and water cement ratio 0.4 or less can provide satisfactory strength and low permeability for bridge deck overlays with a minimum thickness of 32 mm. Shear strength[6] of plain concrete beams with silica fume in axial compression[2] has increases with strength of concrete.

Steel fibres impart ductility to over reinforced beams and increases the ultimate concrete strain[3]. The use of steel fibre permits high yield strength and crack width and deflection is being controlled within acceptable limits. The steel fibre permit substantial increase in bending moment to be developed before a particular width of crack occurs. The improvement of crack control due to addition of fibres was more pronounced with deformed bars than with plain bars. The addition of fibres of 1.75% by volume resulted in nearly crack free beam at service load. Even at ultimate, fibres were more

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effective in reducing deformations and increasing flexural stiffness.[4] Fibre reinforced [5]concrete is very much effective in resisting the flexural tensile stresses as compared to compressive stresses. The optimum percentage of fibre – fly ash reinforced concrete[1] cam ne 0.5% - 1.0% of fibres and 20% - 30% of fly ash.

STRENGTHENING MATERIALS – SILICA FUME

The abrupt increases in population day by day increased the demand for construction. The non availability of the materials required for construction entrusted the development of new building materials. At present, the alternative building materials like flyash, metakaolin, ground granulated blast furnace slag are used for partial replacement for cement or extra addition in concrete. In similar way, Silica fume which is a byproduct resulting from the reduction of high volumes of ue of cement in concrete. The super fines nature of silica fume which is having surface area of 15000-20000 m^3/kg and high content of silicon dioxide enhances the pozzolonic action. Silica fume can be used as:

- Partial replacement for cement in same percentage of weight of concrete.
- Addition to concrete to improve the concrete properties

This can be either blended with cement or directly added to concrete.

STRENGTHENING MATERIALS – FIBRE

Fibre is a small piece of reinforcing material possessing certain characteristic properties. They can be circular or flat. It is often described by a convenient parameter called “aspect ratio”. The aspects ration of the fibre is the ratio of its length so its diameter. Steel fibre is one of the most commonly used fibres. These fibres are sued in concrete as crack arrestor and would substantially improve its static and dynamic properties. This type of concrete is known as fibre reinforced[5] concrete. Conventional concrete possesses a very low tensile strength. Limited ductility and little resistance to cracking. As a result, concrete is subjected to brittle fracture. In the past attempts have been made to import improvements in tensile properties of concrete members by way of using conventional reinforced. And also by applying restraining techniques. Although both these methods provides tensile strength to the concrete members. The diameter of steel fibre may varies from 0.25 mm to 0.75 mm. it has been extensively used in various types of structures, particularly for overlays of roads, airfield pavements and bridge decks.

STATEMENT OF THE PROBLEM

A review of the previous literature has stressed the need of using silica frame which is hazardous industrial was and steel fibres beneficially without sacrificing the important properties of concrete i.e. strength, workability and durability etc. It is understood that the proper introduction of silica fume and fibres in concrete improves both mechanical properties and durability. There is a need of research and development in this direction to mainly study the variation of compressive strength and flexural strength of concrete with partial replacement of silica fuame and mixing steel fibres in various proportions. Table 1 shows some of interested properties of constituent materials, which are used in this study.

Table 1: Details of Constituent Materials

Cement	Type OPC 43 Grade cement Specific gravity 3.15
Fine Agrregate	River Sand
Coarse Aggregate	20 mm nominal
Silica frame	Specific gravity 2.15 Specific surface area range (m^2/kg) 15000 - 20000
Steel fibre	Diameter 0.4 mm Length 32 mm Aspect ratio 80
Mix Proportion	1:2:4 by weight
Water cement ratio	0.55

EXPERIMENTAL PROGRAM

There are three techniques of incorporating silica fume relative to cement in the concrete mix.

- Addition to cement; it is used when special concrete with high strength is required.
- Partial replacement of cement by equal weight of silica fume (1:1 replacement). It is used when the purpose is to save the cement content which usually results in high quality concrete.

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- Partial replacement of cement by less weight of silica fume. Since concrete yields higher quality with 1:1 replacement, it is possible to use filica fume to reduce the cost for comparable quality by reducing the cement content and replacing it with a lesser amount of silica fume

MIXING & CASTING

Silica fume, fibre cement, fine aggregate[2] and course aggregate are taken in their proportions by weight and required amount of water added, mixed thoroughly in the mixer. Fibre is sprinkled over the mix uniformly. The fresh concrete was smoothly transferred into the mould in three stages and compacted with the help of tamping rod. After the casting the top surface of the mould is levelled using a trowel Mechanical mixer of rotating drum type has used for mixing of concrete. The capacity of mixer is of quarter bag of cement.

For compressive strength 15 X 15 X 15 cm cast iron moulds are used. The moulds were initially tightened and the inner sides of the moulds were thoroughly oiled. Care was taken to see that there was no leakage thought the joints. For flexural strength 10 X 10 X 40 cm cast iron moulds were used. The inner parts of the moulds were thoroughly oiled.

The specimens were demoulded after 24 hours of casting and placed in a curing tank of 28 days, after curing period, the specimens were removed from tank and white washed for better visibility of cracks. Table 2 shows the nomenclature used for each proportion of silica fume and fibre in though out the study.

Table 2: Designation of Concrete Mixes[3]

Percentage of Fibre		0	0.5	1.0	1.5	2.0
Percentage of silica fume	0	M 0/0	M 0/0.5	M 0/1.0	M 0/1.5	M 0/2.0
	5	M 5/0	M 5/0.5	M 5/1.0	M 5/1.5	M 5/2.0
	10	M 10/0	M 10/.0.5	M 10/1.0	M 10/1.5	M 10/2.0
	15	M 15/0	M 15/0.5	M 15/1.0	M 15/1.5	M 15/2.0
	20	M 20/0	M 20/0.5	M 20/1.0	M 20/1.5	M 20/2.2

TESTING – COMPRESSIVE STRENGTH

COMPRESSIVE TESTING MACHINE of 200 kN has been used for testing.

TESTING – FLEXURAL STRENGTH

Beams used for flexural Strength were 100 X 100 X 400 cm on UNIVERSAL TESTING MACHINE of capacity of 400 kN has been used as per the specifications of relevant codes.

INTERPRETATION AND DISCUSSION – COMPRESSIVE STRENGTH

Specimens were tested for compression and ultimate compressive strength was determined from failure load. The values of compressive strength of 3 specimens for each category and average value are given in Table 3.

Curves were plotted against average compressive strength and percentage of volume of silica fume is given in fig. 1.

From those curves, it can be seen that in the specimens without fibres, compressive strength increases up to 10 % replacement of cement by silica fume. It decreases sharply for 20% replacement of cement by silica sume.

Similar trend can be seen fibre reinforced[5] silica fume concrete specimen whose strength increases with the addition of silica fume up to 10 % of cement replacement. The maximum increase in the specimens with 10% of silica fume content for all percentage of fibres used. The Table 4 given shows the percentage increased/decreased in the compressive strength of fibre reinforced silica fume concrete over the corresponding strength of fibre reinforced plain concrete.

It can also be seen that addition of fibre decreases the compressive strength of specimens without silica fume where as it decreases marginal for specimens with silica fume.

Table 3: Results of 28 day cube compressive strength test

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Specimen designation	28 day cube compressive strength (N/mm²)				Stregnth ratio
	Specimen 1	Specimen 2	Specimen 3	Average	
M 0/0	28.13	28.65	27.82	28.20	1.00
M 5/0	33.59	35.16	34.90	34.55	1.23
M 10/0	38.75	39.23	40.67	39.55	1.40
M 15/0	33.56	32.28	36.82	34.22	1.21
M 20/0	26.20	24.23	21.57	24.00	0.85
M 0/0.5	31.89	32.34	31.77	32.00	1.13
M 5/0.5	34.49	32.23	32.28	33.00	1.17
M 10/.05	35.29	36.46	34.90	35.55	1.26
M 15/0.5	32.12	33.05	30.08	31.75	1.13
M 20/0.5	26.84	29.23	25.26	27.11	0.96
M 0/1.0	19.65	20.36	21.82	20.61	0.73
M 5/1.0	22.96	23.49	21.05	22.50	0.80
M 10/1.0	25.32	24.13	25.13	24.86	0.88
M 15/1.0	25.89	26.23	25.19	25.77	0.91
M 20/1.0	17.86	18.25	14.53	16.88	0.60
M 0/1.5	19.35	19.58	20.38	19.77	0.70
M 5/1.5	27.05	27.61	25.32	26.66	0.95
M 10/1.5	29.65	28.36	26.95	28.32	1.00
M 15/1.5	22.87	23.10	24.53	23.50	0.83
M 20/1.5	16.32	15.46	13.85	15.21	0.54
M 0/2.0	10.26	11.57	12.34	11.39	0.40
M 5/2.0	13.56	14.31	12.12	13.33	0.47
M 10/2.0	16.51	18.34	18.46	17.77	0.63
M 15/2.0	12.76	12.64	12.10	12.50	0.44
M 20/2.0	11.56	9.23	8.31	9.70	0.34

Table 4 : Percentage increase / decrease in compressive strength of FRSFC over plain concrete

Percentage of silica fume		5	10	15	20
Percentage of fibre	0.0	22.52	40.25	24.35	-14.89
	0.5	3.13	11.09	-0.78	-15.30
	1.0	9.71	20.62	25.04	-18.10
	1.5	34.85	43.25	18.87	-23.07
	2.0	17.03	36.01	9.75	-14.84

INTERPRETATION AND DISCUSSION – FLEXURAL TENSILE STRENGTH

Flexural tensile strength test was conducted on prism, two point loading and ultimate flexural tensile strength was determined from the failure loads as discussed earlier. The values of flexural tensile strength for 3 specimens and average values are given in Table -5. A curve is plotted against average flexural tensile strength and percentage of fibres used was shown in the Fig – 2. From this, it can be seen that fibres are very much effective in increasing the flexural tensile strength of composite. It is observed that at 1.0% fibres, there is maximum strength is observed.

Table 5: Flexural Strength Results

Designation	28 day beam flexural strength (N/mm²)				Ratio
	Specimen 1	Specimen 2	Specimen 3	Average	
M 0/0.0	4.38	3.88	3.56	3.94	1.00
M 10/0.0	4.96	5.68	5.92	5.52	1.40
M 10/0.5	6.54	6.97	6.29	6.60	1.68
M 10/1.0	8.26	7.84	8.02	8.04	2.04
M 10/1.5	5.86	5.93	5.97	5.92	1.50
M 10/2.0	4.89	4.21	5.03	4.71	1.19

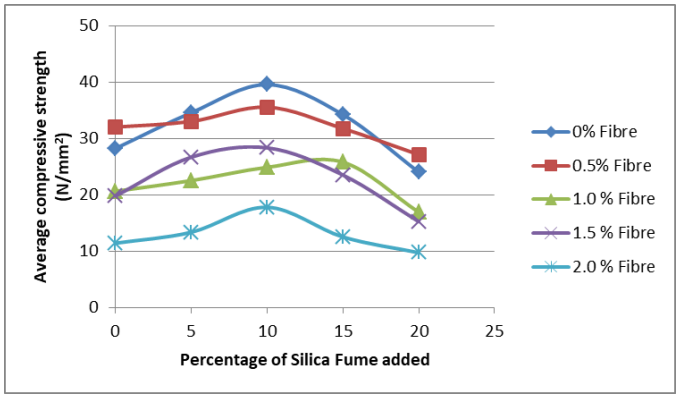

Figure 1: Compressive Strength envelope for different percentages of fibre

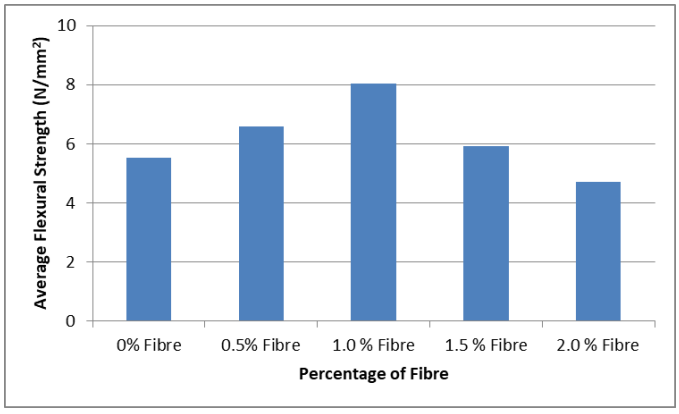

Figure 2: Flexural tensile Strength envelope for optimum percentage of silicafume

CONCLUSIONS

From the Limited study conducted on the fibre reinforced silica fume concrete, following conclusions can be drawn:

- In general, Silicafume concrete shows a higher compressive strength and fibre reinforced concrete shows a higher flexural strength than the plain concrete.
- Fibre reinforced concrete is very much effective in resisting the flexural tensile stresses as compared to compressive stresses.
- For all percentage of fibre addition, it is observed that maximum strength is obtained at 10% of silica fume replacement.
- Maximum value of 28 days cube compressive strength obtained as 35.55 N/mm^2 for 10% silica fume and 0.5% steel fibre mix. (M 10/0.5)

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- Maximum value of 28 days beam flexural strength obtained as 8.04 N/mm^2 for 10% silica fume and 1.0% steel fibre mix (M 10/1.0)
- Workability of concrete will also get enhanced due to the addition of silica fume, which is required especially in higher percentage of fibre content.

The optimum values of silica fume and fibre contents are found. However, more detailed micro level studies need to be conducted before adopting the new composite material.

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