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Study of Mechanical Properties of Slurry Infiltrated Fibrous Concrete (SIFCON)

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Abstract -*Slurry Infiltrated Fibrous Concrete (SIFCON), an exceedingly improved version of conventional fibre reinforced concrete (FRC), is a high performance concrete (HPC) endowed with unique properties in the areas of both strength and ductility. The primary constituents of SIFCON are steel fibres and cement-based slurry. SIFCON is cast using a preplacing technique in which fibres are placed in the mould or on a substratum and infiltrated with cement based slurry.The cement based slurry used in this study is a composition of cement, fly ash and sand, kept in constant proportion butthe hooked end steel fibres are added in various proportions, i.e. 4%, 6%, 8%, 10%. The aim of present investigation is to study the behaviour of SIFCON when subjected to flexure and compression loads. The results obtained from these tests were compared with those carried out on fibre reinforced concrete (FRC 1.5%) specimens. The investigations confirm the superior characteristics of SIFCON.*

Key Words: SIFCON, Fibre reinforced concrete, High performance concrete, steel fibres, cement slurry, fly ash.

1. INTRODUCTION:

Slurry Infiltrated Fibrous Concrete (SIFCON) is one of the recently developed construction material that can be considered as a special type of high performance fibre reinforced concrete (HPFRC) with higher fibre content.The primary constituent materials of SIFCON are steel fibres and cement based slurry. The slurry can contain only cement, cement and sand or cement and other additives like fly ash, silica fume etc. The matrix (cementitious slurry) plays an important role in SIFCON. It helps in transferring the forces between fibres and acts as a medium to keep the fibres interlocked. The fibres in SIFCON are subjected to frictional and mechanical interlock in addition to the usual bond with the matrix, this behavioural phenomenon of “Fibre lock” is believed to be responsible for its outstanding stress-strain properties

SIFCON is similar to FRC in the sense that it has discrete interlocking fibres that lend significant tensile properties to the composite matrix. In two aspects, however, it is different from normal FRC. In FRC, the fibre content usually varies from 1% to 3% by volume, whereas in SIFCON the fibre content varies from 4% to 20%. The matrix of SIFCON consists of low viscosity, cementitious slurry as opposed to regular concrete in FRC. These make the production of SIFCON far different from FRC. Unlike FRC, for which the fibres are added to the wet or dry concrete mix, SIFCON is prepared by infiltrating cement slurry into a bed of fibres preplaced and packed tightly in the moulds.

SIFCON is a unique construction material possessing high strength as well as large ductility and far excellent potential for structural applications when accidental or abnormal loads are encountered during services. SIFCON has been used successfully for refractory applications, pavement overlays, and structures subjected to blast and dynamic loading. Because of its highly ductile behavior and far superior impact resistance, the composite has excellent potential for structural applications in which accidental or abnormal loads such as blasts are encountered during service.

The following factors affect the strength of SIFCON:-

a. Slurry strength
b. Fiber volume
c. Fiber alignment
d. Fiber type

2. MATERIALS USED:

The materials used in the preparation of concrete and FRC are cement, sand, coarse aggregates, steel fibres and water.The materials used for preparing SIFCON are cement, sand, fly ash, steel fibre, super plasticizer and water.

2.1 Cement

Ordinary Portland cement of 53 grade, manufactured by Maihar Cement conforming to IS 12269:1987has been used in the present investigation. The specific gravity of cement is 3.15.

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2.2 Fine aggregate

Locally available natural river sand which passes through 4.75mm sieve and having specific gravity of 2.65 (conforming to Zone II of IS 383:1970) has been used.

2.3 Coarse aggregate

Machine crushed broken stone, angular in shape, was used as coarse aggregates. Two fraction of coarse aggregates were used, 20mm and 10mm size having specific gravity of 2.82 and conforming to table 2 of IS: 383-1970.

2.4 Water

Clean potable water which is available in college campus has been used.

2.5 Superplasticizer

In present study, CONPLAST SP 430 G8, a high range water reducing admixture from FOSROC is used to increase the workability of slurry. It gives water reductions of up to 25%. It is based on sulphonated naphthalene polymers and is a brown liquid instantly dispersible in water. It complies with IS: 9103 and ASTM-C-494 Type 'G'. It has a specific gravity of about 1.25 – 1.27.

2.6 Fly ash

Class F fly ash conforming to IS 3812 Part -1 2003, collected from Maihar Cement, Maihar (which procures it from SGTPS, Birsinghpur) has been used. The chemical composition is presented in Table – 1.

Table – 1 Chemical composition of fly ash

S. No.	Test parameter (%)	Test result
1	Loss of ignition(LOI)	3.8
2	SiO_2	62.4
3	Al_2O_3	27.2
4	Fe_2O_3	3.8
5	CaO	0.6
6	Na_2O	0.26
7	K_2O	0.88

2.7 Steel Fibres

Hooked end steel fibres manufactured by Stewols India (P) Ltd., NAGPUR conforming to ASTM A-820M 06, Type I cold drawn wire were used in the present study. The properties of fibre are presented in Table – 2.

Table – 2 Properties of fibres

Parameter	Value
Diameter(D)	0.5mm
Length(L)	35 mm
Aspect ratio L/D	70
Unit weight	7850 kg/m^3
Tensile strength	1100 MPa
Strain at failure	< 4%

Figure – 1 Hooked end steel fibre

3. MIX PROPORTIONS AND CASTING OF SPECIMENS:

The SIFCON specimens were casted and compared with fibre reinforced concrete (FRC 1.5%) to study the compressive strength and flexural strength. The fibres are dispersed in a random manner to the volume fraction. Three layer techniques was used for incorporating the steel fibers in the matrix, it involved initial placing and packing of the fibers in the mould only up to one-third depth, followed by infiltration of the slurry up to this level. The process was repeated until the entire mould was filled. Compaction by hand tamping was used to ensure complete penetration of the slurry into the fibre pack. 24 hours after casting, the cubes and beams were demoulded and cured in water for 7 and 28 days.Four volume percentages – 4%, 6%, 8% and 10% were used in making the SIFCON specimens. The slurry used for infiltration consisted of cement and sand mixed in the proportion of 1:1 by weight. Fly ash equal to 20% by weight of cement was used. The water-cement ratio was kept constant at 0.4, and CONPLAST SP430 G8 was kept at 2% (percentage by weight of cement). FRC was obtained by simply adding 1.5 % volume fraction of fibres in the conventional concrete (M30, 1:1.78:3.14) with w/c ratio of 0.48. Mix proportions are presented in Table – 3.

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Table – 3 Mix proportions

Mix designation	Cement	Sand	Coarse aggregate	Fly ash by wt. of cement (%)	w/c ratio	SP by wt. of cement (%)	Fibre by volume (%)
FRC 1.5%	1	1.78	3.14	-	0.48	-	1.5
SIFCON4%	1	1	-	20	0.4	2	4
SIFCON6%	1	1	-	20	0.4	2	6
SIFCON8%	1	1	-	20	0.4	2	8
SIFCON10 %	1	1	-	20	0.4	2	10

4. TEST PROGRAMME:

4.1 Compression test

The experimental work was carried out by casting cubes of size 150 x 150 x 150mm to find the compressive strength. A compression testing machine of 240 Tons capacity with a least count of 1 Ton was used for testing the compressive strength of the specimens. Before testing, specimens are removed from water after specified curing time and the excess water is wiped out from the surface, the specimen is aligned centrally on the base plate of the testing machine. Now, load is applied gradually without shock and continuously at the rate of 140 kg/cm^2/minute till the specimen fails.

4.2 Flexure test

The experimental work was carried out by casting beams of size 100mm x 100mm x 500mm to find the flexural strength. A Universal testing machine of 100 ton capacity with a least count of 20 kgf was used for testing the flexural strengthof the specimensusing centre point loading system. Flexural tests of moist cured specimens shall be made as soon as practical after removal from moist storage. Load the specimen continuously and without shock up to the breaking point.

5. RESULTS & DISCUSSION:

5.1 Compressive strength

The results of cube compressive strength for 7 days and 28 days curing are given in Table-4, and the corresponding graphis shown in Figure-2 resp. A comparative chart for compressive strength at 28 days is shown in Figure-3.

Table – 4 Compressive strengths at 7 and 28 days

S. No.	Designation of Mix	Average compressive strength at 7 days (N/mm^2)	Average compressive strength at 28 days (N/mm^2)
1	FRC 1.5%	33.07	48.77
2	SIFCON4%	40.62	63.28
3	SIFCON6%	49.87	74.45
4	SIFCON8%	53.01	83.97
5	SIFCON10%	63.43	96.50

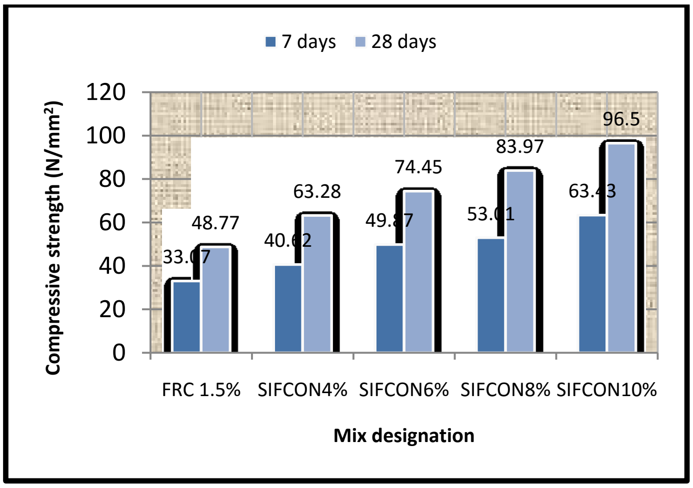

Figure-2 Compressive strength at 7 & 28 days

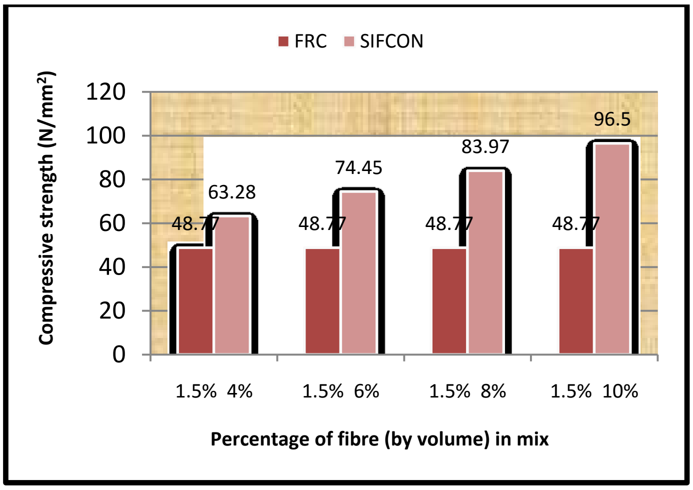

Figure – 3 Comparison of compressive strength of specimens at 28 days

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5.2 Flexural strength

The results of flexural strength for beams at 7 days and 28 days curing are given in Table-5, and the corresponding graph is shown in Figure-4 resp. A comparative graph for compressive strength at 28 days is shown in Figure-5.

Table – 5 Flexural strengths at 7 and 28 days

S. No.	Designation of Mix	Average flexural strength at 7 days (N/mm²)	Average flexural strength at 28 days (N/mm²)
1	FRC 1.5%	3.98	6.46
2	SIFCON4%	7.15	13.01
3	SIFCON6%	12.79	20.68
4	SIFCON8%	14.68	23.28
5	SIFCON10%	16.42	27.34

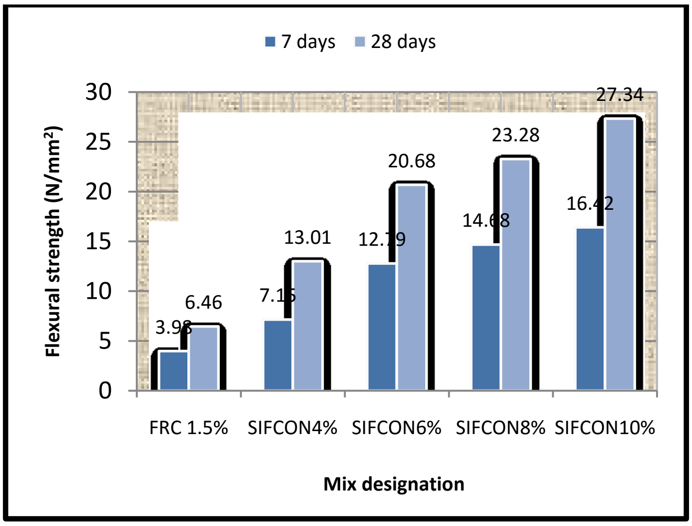

Figure – 4 Flexural strengths at 7 & 28 days

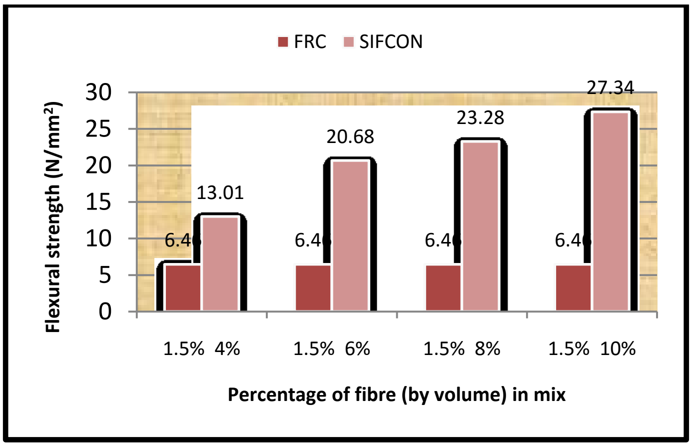

Figure – 5 Comparison of flexural strength of specimens at 28 days

It can be observed that the compressive & flexural strength of SIFCON mixes increases with increase in percentage volume of fibres. The compressive & flexural strength of SIFCON sample cubes are found to be much higher than FRC.

It is important to note that SIFCON material costs should not be compared on a one-to-one basis with the material costs of FRC since it would appear that SIFCON is prohibitively expensive. A total system or structure comparison needs to be considered. In applications where SIFCON would be practical, often the size of the main structural elements can be significantly reduced or other subsystems modified, resulting in the entire system being less costly than those using FRC.

During construction of SIFCON some of the problems encountered were:-

- Surface finishing
- Rusting
- Fibre placement
- Slurry placement

6. CONCLUSION

The compressive strength test result shows that the maximum strength is obtained when 10% fibre by volume was used to make SIFCON cubes. It is an increase of 97.87% with respect to compressive strength of FRC(1.5%)

The flexural strength test result shows that the maximum strength is obtained when 10% fibre by volume was used to make SIFCON beams. It an increase of 323.22% (fourfold) with respect to flexural strength of FRC(1.5%).

It is observed that compressive strength and flexural strength of SIFCON made from hooked end steel fibres are on higher side for SIFCON produced from 10% fibres as compared to that produced from 8%, 6% and 4% fibres. Hence the characteristic properties of SIFCON depend on volume of steel fibres in it. Higher volumes of fibres yield higher characteristic properties.

A fibre content of 10% was found to be optimum for making SIFCON specimens using the mix proportions reported in the thesis from the point of view of strength (flexure and compression).

The three layer technique used for incorporating fibres in the mould along with hand tamping proved effective during the casting of the SIFCON specimens, it was found to be easier and simpler than the single-layer technique.

SIFCON specimens exhibited greater ductility and greater resistance to cracking and spalling of concrete than FRC specimens.

In the present investigation after making a few trials with different volume fraction of fibres, it was observed that beyond 10% fibre volume (35mm length, A/R 70 hooked end steel fibre), placing of fibres manually in the mould was very tedious. Hence it can be concluded that using fibre volume beyond 10% is not practical, though using fibre volume beyond 10% may be tried with other types of fibres, with differing geometry.

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