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PERFORMANCE OF SLURRY INFILTRATED FIBROUS CONCRETE (SIFCON) WITH SILICA FUME

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ABSTRACT

SIFCON in our country in the construction of several structures that demand high standards of strength coupled with superior performance and durability. SIFCON possesses several desirable properties such as high strength and ductility. It also reveals a very high degree of ductility as a result of which it has superior stability under dynamic, fatigue and repeated loading. The main objective of this study is to determine the effect of silica fume in slurry infiltrated fibrous concrete on compressive strength, split tensile strength, flexural strength and toughness. Experimental programme was carried out to study the performance of SIFCON containing 10% of fibre content with different percentage of silica fume (5%, 10%, 15%, 20% and 25%) partially replaced by cement on compressive strength and split tensile strength. From the test results 15% of silica fume showed that optimum value in compression and tension. Compared to all other replacement level and FRC mix. Flexural test of reinforced SIFCON beam specimen of size 1.2 x 0.1 x 0.2 m containing optimum 15% of silica fume with various percentage of fibre content (6%, 8% and 10%) were tested under flexure to enhance the performance of silica fume based slurry infiltrated fibrous concrete. The results showed that SIFCON beam contains 10% fibre content exhibits excellent energy absorption and ductility characteristics among all other SIFCON and FRC specimens.

Key words: Silica fume, SIFCON**,** Toughness, FRC, Ductility factor.

INTRODUCTION

SIFCON is a high-strength, high-performance fabric containing a especially excessive extent percent of metallic fibres in comparison to SFRC. It is also every now and then termed as 'excessive-extent fibrous concrete'. The starting place of SIFCON dates to 1979, whilst Prof. Lankard carried out vast experiments in his laboratory in Columbus, Ohio, USA and proved that, if the proportion of metal fibres in a cement matrix can be elevated notably, then a cloth of very high strength could be received, which he christened as SIFCON. The

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matrix in SIFCON has no coarse aggregates, however a high cementitious content material. However, it may include quality or coarse sand and additives, which include fly ash, micro silica and latex emulsions. The matrix fineness must be designed so as to properly penetrate (infiltrate) the fibre network positioned in the moulds, considering otherwise, massive pores may additionally shape leading to a extensive reduction in properties.

SIFCON was invented in USA in the year 1983 by Lankard[1] and investigated the primary properties of SIFCON along with load-deflection curve, compressive and flexural strengths, impact and abrasion resistance. Yazici et al.[2,15] studied the effect of incorporating excessive quantity of class C fly ash on mechanical properties of SIFCON and conclusions have been drawn that increases flexural strength and toughness of SIFCON due to higher percentage of fibre content. Katkhuda et al.[3] studied the isolated effect of silica fume on tensile, compressive and flexure strengths on high strength lightweight concrete. The results showed that the tensile, compressive strengths increased with incorporation of silica fume. Dagar[4] investigated the performance of SIFCON and indicated that the formation of cracks does not extended through the entire width of specimen in SIFCON compared to ferrocement composite and ultimate tensile strength depends upon the mix proportion and percentage of fibre content. Thomas and Mathews[5] indicated that 5% of fibre content yield higher compression, tension and flexural strength Among three different percentage of steel and polypropylene fibres (4%, 5% and 6%) yield higher in SIFCON containing 5% fibre volume. Tuyan and Yazaici[6] investigated the pullout behaviour of SIFCON matrix and concluded that pullout peak load was increased with increasing diameter of fibres and also pullout toughness was increased with increasing fibre length, which is embedded in SIFCON. Parameswaran et al.[7] examined the behaviour of metal fibre mortar specimens having high quantity fraction of fibres within the range of 8%, subjected to flexure and reported that they possess flexural strength more than 40 N/mm^2. Sudarsana Rao et al.[8,14] tested SIFCON slabs under flexure and compared it with FRC and PCC slabs. It became reported that, SIFCON slabs display tremendous toughness characteristics under flexural loading in comparison to PCC and FRC slabs and the spacing of cracks have been found to decrease with increased volume of fibre content. Rao et al.[9] tested SIFCON slabs under impact loading revealed that the SIFCON slabs with 12% fibre volume fraction ehibit excellent performance in strength and toughness characteristics. Farnam et al.[10] investigate the triaxial compressive behavior of high strength concrete, high performance fibre reinforced concrete and SIFCON and found that increasing fibre volume increases the peak triaxial compressive strength.

Ipeka et al.[11] through his experimentations on prisms pronounced that boom in pre-setting pressure suggests improvement in the flexural electricity and durability value. A most flexure strength of 67.5 MPa turned into accomplished when pre-putting stress given became 15 MPa. Kaikea et al.[12] tested development inside the mechanical properties of HPFRC with the alternate in mineral admixture and fibre concentration, and mentioned that flexural durability of HPFRC is 33 times higher than plain concrete. Wang and Maji[13] examined the shear properties of SIFCON under pure torsion and obtained the shear resistance properties.

From the above literatures, it is able to be mentioned that studies on the flexural electricity characteristics of SIFCON beams were very rare. Flexural behaviour is a completely critical issue in case of beams as in realistic programs they should withstand numerous flexural loads. As a result there is a want to behavior experimentations on SIFCON beams under flexure.

The aim of the research is to decide experimentally the flexural strength, load-deflection response and strength absorption capability for SIFCON beams with 6, 8 and 10% fibre quantity fraction. In this study, cement has been replaced by partial replacement of fly ash so as to minimise the shrinkage as well as heat of hydration problems and henceforth reduce the negative effects of global warming.

EXPERIMENTAL

An experimental program was carried out to provide a excessive volume fibre reinforced concrete known as slurry infiltrated fibrous concrete consists of fibres and partial replacement of cement with silica fume slurry mix is infiltrated right into a bed of preplaced fibres inside the mould. To improve the workability of concrete composite with the aid of excessive range water reducing admixture during mixing of slurry. It accommodates of casting of cubes of size a 100 X 100 X 100 mm for compressive strength, cylinders of 100 mm diameter and 200 mm top for split tensile strength and reinforced beam of length 1200 x 100 x 200 mm for flexural strength of SIFCON specimens. The reinforcement details of beam specimens are given below in Fig. 1. The substances used, mix proportions and method of casting and trying out are defined below.

Materials used

Cement

Ordinary Portland cement of 53 grade conforming to IS: 12269 were used. The specific gravity of cement was found to be 3.15.

Silica fume

Silica fume conforming to ASTM C 1240 and the specific gravity of silica fume was found to be 2.21.

Table 1: Chemical composition of cement and silica fume

S. No.	Chemical composition (%)	Cement	Silica fume
1	Silica (SiO_2)	21.8	97
2	Alumina (Al_2O_3)	6.6	0.2
3	Ferric oxide (Fe_2O_3)	4.1	0.5
4	Calcium oxide (CaO)	60.1	0.2
5	Magnesium oxide (MgO)	2.1	0.5
6	Sodium oxide (Na_2O)	0.4	0.2
7	Potassium oxide (K_2O)	0.4	0.5
8	Sulphuric anhydride (SO_3)	2.2	0.15
9	Loss on Ignition (LOI)	2.4	-

Fine aggregate

Locally available river sand passing through 4.75 mm sieve was used. The fineness modulus of fine aggregate was found to be 2. 43% and specific gravity was found as 2.71.

Fibre

Hooked end steel fiber of diameter 1.00 mm and length of 30 mm giving aspect ratio of 30 was used. Fibers were oriented in the form in random manner.

Reinforcement

All the four beams were reinforced. 12 mm diameter Fe 415 grade steel rods for main reinforcement and 6 mm diameter bars for shear reinforcement with 6 mm diameter 2-legged stirrups spaced at 100 mm c/c. The beam reinforcement details were shown in Fig. 1

Water

Fresh water available from local sources was used for mixing and curing of SIFCON.

Super plasticizer

To improve the workability of SIFCON, CONPLAST- 430, a high-range water reducing agent has been used.

Mix proportions

SIFCON slurry consisted of cement and fine sand mixed in the proportion of 1:1 by weight and water cement ratio of 0.4. Hand compaction was done to ensure complete penetration of the slurry into the bed of pre-packed fibres. The cement was replaced by silica fume (5, 10, 15, 20 and 25%) slurry containing 10% of fibre content were used for optimization of silica fume in SIFCON mix. The reinforced SIFCON beams were also cast and tested under flexure. Cement was partially replaced by optimum percentage of silica fume for making slurry with different percentage of fibre content are illustrated in Table 2. High range water reducing admixture of 2% by weight of cement was added to improve the workability and flow ability of the slurry into the fibre bed.

Table 2: Mix proportions of SIFCON specimens

S. No.	Nomenclature of mix	Cement content (%)	Silica fume (%)	Fine Aggregate (%)	Fibre content (%)	W/C ratio	Super plasticizer (%)	Mode of vibration
1	SF5SIF10	95	05	100	10	0.4	2	Hand tamping
2	SF10SIF10	90	10	100	10	0.4	2	Hand tamping
3	SF15SIF10	85	15	100	10	0.4	2	Hand tamping
4	SF20SIF10	80	20	100	10	0.4	2	Hand tamping
5	SF25SIF10	75	25	100	10	0.4	2	Hand tamping
6	SF15SIF6	85	15	100	6	0.4	2	Hand tamping
7	SF15SIF8	85	15	100	8	0.4	2	Hand tamping
8	SF15SIF10	85	15	100	10	0.4	2	Hand tamping

Method of casting

Initially the mould is placed on a smooth surface and the sides of mould are oiled so as to enable easy removal of specimen. Cement, silica fume, sand, water and superplasticizer are weighed accurately and mixed for making slurry. Fibres are weighed according to the percentage by volume and SIFCON beams were made by using three layer technique. This technique follows the filling of fibres to one–third depth of mould and then slurry being poured to the pre-placed fibres upto this layer. Compaction was done to ensure complete infiltration of slurry into fibre pack. The process is repeated till the entire mould was filled and compacted. After 24 hrs of casting, beams were demoulded and cured in water for

28 days. After curing days, specimens were dried in air and painted in white so as to get clear visibility of cracks.

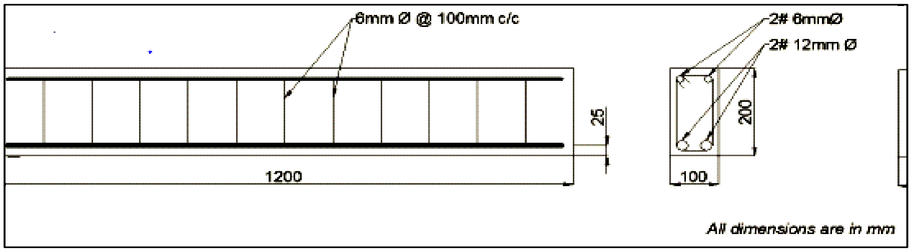

Fig. 1: Beam reinforcement details

Fig. 2: Casting of SIFCON beam

Test program

Compressive strength test

The compressive strength of concrete is the most common performance measure in designing building and other structures. The compressive test on cubes were conducted on a computerised compressive testing machine of capacity 3000KN.

Split tensile strength

The split tensile strength on cylinders were conducted on a computerised compressive testing machine of capacity 3000KN, the test specimens were placed horizontally between two platens. Load was gradually applied till failure of the specimen.

Flexural strength

Casting of three reinforced SIFCON beams of size 1.2 × 0.1 × 0.2 m with variation in fibre concentration as 6, 8 and 10% by volume and FRC (1%) specimens. The flexural test of beams were conducted on a computerized universal testing machine (UTM) of capacity 1000 kN. Loads were applied gradually in increasing rate till the failure of specimen and the maximum load applied to the specimen at failure and also yield and ultimate loads and their corresponding were recorded.

RESULTS AND DISCUSSION

Compressive strength

The compressive strength results of slurry infiltrated fibrous concrete (SIFCON) with silica fume are shown in Fig. 3(a). It can be seen from the table that the strength increased with the increase of silica fume replacement and at certain percentage of replacement the strength values get reduced. Furthermore at all percentage of replacement, the strength value gets increased when compared to FRC specimen (Control mix).

Split tensile strength

The test results shown in Fig. 3(b), that the split tensile strength gets gradually increased upto 15% of silica fume replacement after that the strength was decreased slightly. When compared to FRC specimen the strength of SIFCON specimens yield higher strength at all replacement level of silica fume in SIFCON when compared to FRC specimen.

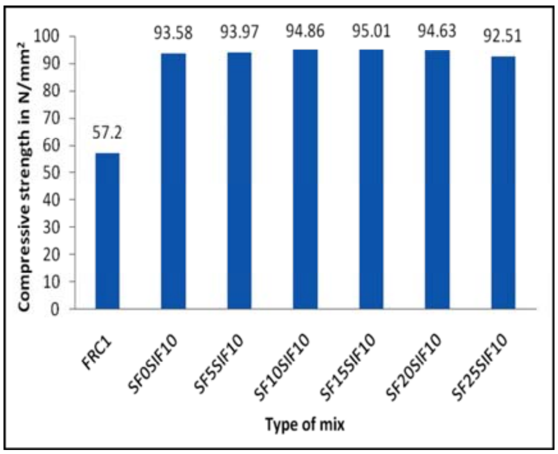

Fig. 3(a): Type of mix vs Compressive strength

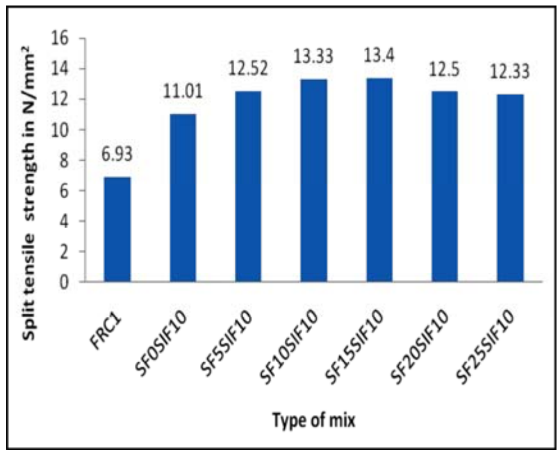

Fig. 3(b): Type of mix vs Split tensile strength

Flexural strength

The flexural strength of reinforced SIFCON beam containing 6% was higher value compared to SIFCON containing 8% and 10%. The flexural strength gets affected, because of slurry strength, method compaction and orientation of fibres. The test result was shown in Fig. 4(b).

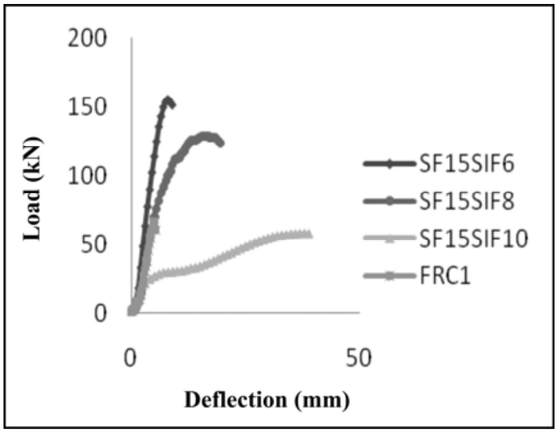

Fig. 4(a): Load vs Deflection

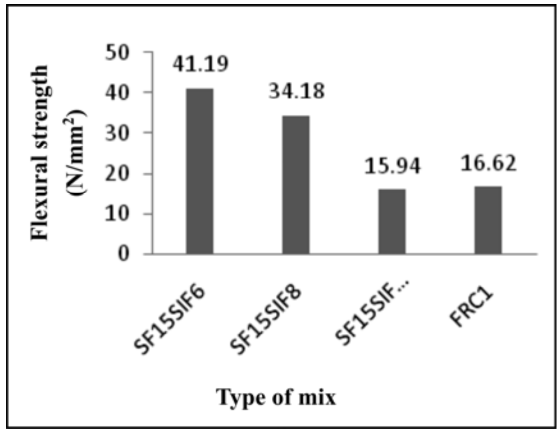

Fig. 4(b): Type of mix vs Flexural strength

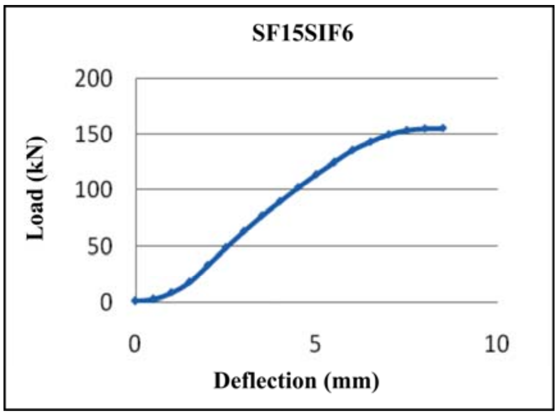

Fig. 5(a): Load vs Deflection

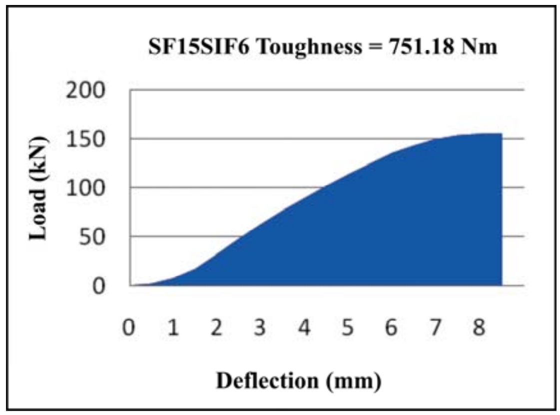

Fig. 5(b): Load vs Deflection

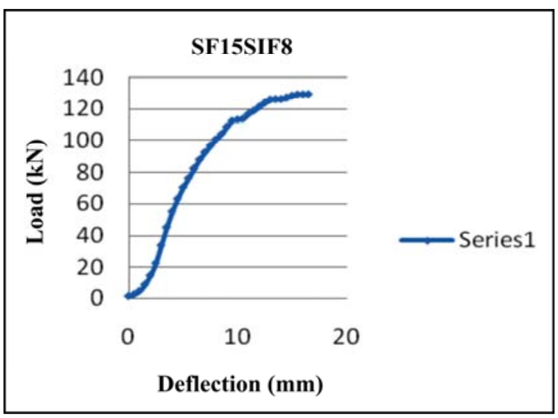

Fig. 6(a): Load vs Deflection

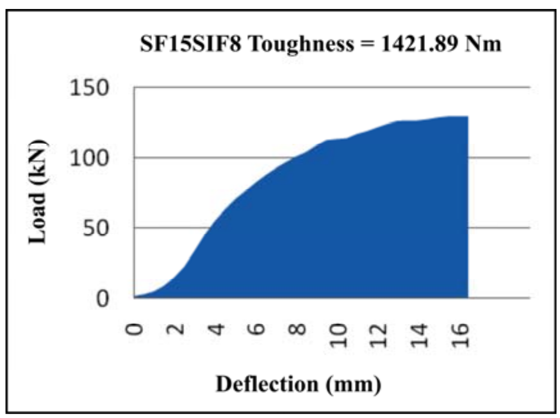

Fig. 6(b): Load vs Deflection

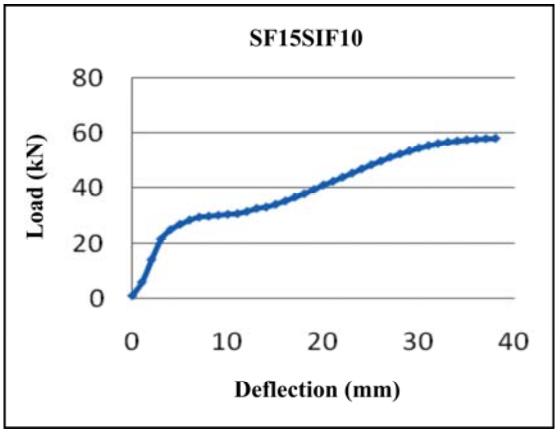

Fig. 7(a): Load vs Deflection

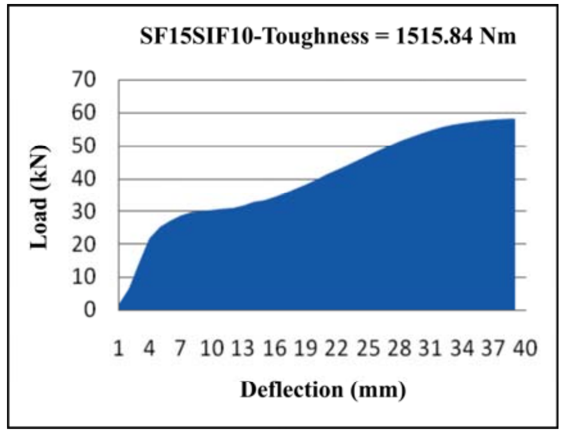

Fig. 7(b): Load vs Deflection

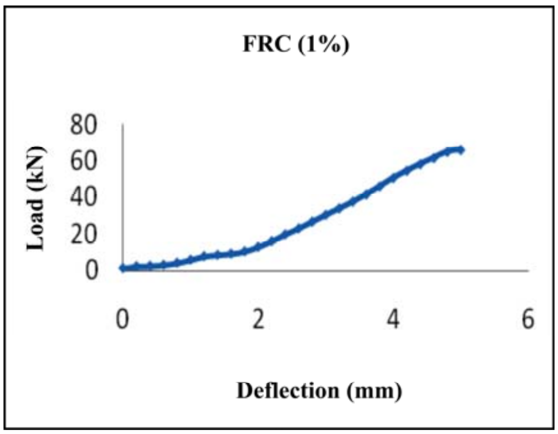

Fig. 8(a): Load vs Deflection

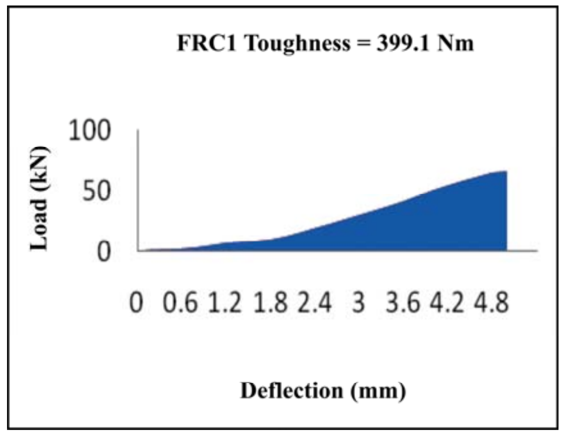

Fig. 8(b): Load vs Deflection

Toughness

The toughness was calculated from load deflection curve. The area under load deflection curve of different mixes were presented in Table 3. The energy absorption characteristics of SIFCON containing 10% of fibre content performed well among all other SIFCON specimens. When compared to FRC mix, SIFCON specimens yields more energy, because of incorporation of higher volume of fibre content enhances the properties SIFCON mix. Fig. 9(a) shows the types of mix vs toughness.

Ductility factor

Table 3 illustrated the ductility factor of various mixes. The increased percentage ductility factors were observed 22.74%, 70.04% and 96.03% in SIFCON containing 6, 8 and

10 percentage of fibre content by volume fraction with respect to FRC specimen. It was observed that the ductility was increased due to increased percentage of fibre content. It was found that fibre plays a vital role to enhance the ductile properties of composites.

Table 3: Behaviour of SIFCON with silica fume under flexure

S. No.	Nomenclature of mix	Flexural strength (N/mm^2)	Ductility factor	% Increase w.r.t FRC	Energy absorption (Nm)	% Increase w.r.t. FRC
1	SF15SIF6	41.19	3.40	22.74	751.180	7.45
2	SF15SIF8	34.18	4.71	70.04	1421.89	103.39
3	SF15SIF10	15.94	5.43	96.03	1515.84	116.83
4	FRC (1%)	16.62	2.77	-	699.10	-

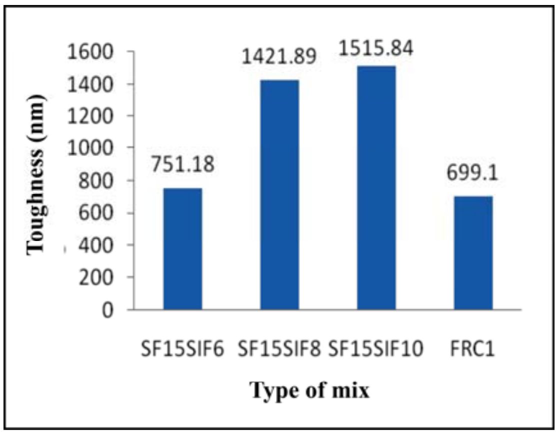

Fig. 9(a): Type of mix vs Toughness

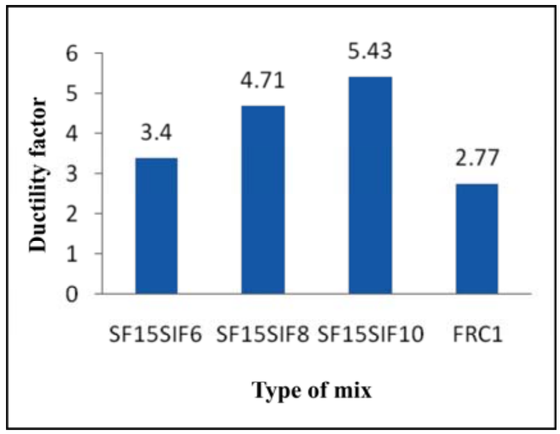

Fig. 9(b): Type of mix vs Ductility factor

Load deflection response

The load deflection curve is shown in Fig. 4(a). From the results observed in SIFCON containing 6% of fibre content yields higher first crack and ultimate load when compared to all other specimens. It reveals that increased percentage of fibre content in silica fume based SIFCON decreases the load carrying capacity.

Cracking and failure pattern

It was noticed that the formation of cracks in SIFCON beams does not extend the full width of beam in all SIFCON beams. The cracks width was decreased with incorporation of higher percentage of fibre content (10%) among all other SIFCON beams, because of increase in percentage of fibre content will take place more crack-bridging. The propagation of cracks was observed to be slower in SIFCON beams when compared with FRC beam. The cracking and failure pattern was shown in Fig. 10.

Table 4: Maximum deflection at first crack load and ultimate load

S. No.	Nomenclature of mix	First crack load (kN)	Deflection at first crack (mm)	Ultimate load (kN)	Deflection at ultimate load (mm)
1.	SF15SIF6	48.75	2.5	155.45	8.0
2.	SF15SIF8	45.05	3.5	129.2	16.5
3.	SF15SIF10	29.65	7.0	58.05	38.0
4.	FRC (1%)	10.35	1.8	66.45	5.0

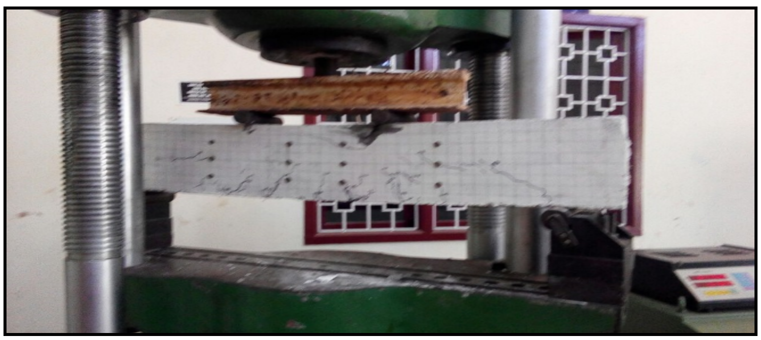

Fig. 10: Crack pattern

CONCLUSION

Based on the test results obtained from the experimental programmes the following conclusions are drawn.

(i) It is observed that the utilization of silica fume is well accepted for replacing cement with silica fume in the production of concrete composites because the incorporation of silica fume in SIFCON enhancing the mechanical properties.

(ii) It improves the consistency and workability of fresh slurry, because an extra capacity of fines is added to the mixture. Silica fume modify the microstructure of concrete and reduce its voids thereby increasing the load carrying capacity.

(iii) The effect of silica fume replacement in SIFCON increases the compressive and split tensile strength and the maximum strength attained at 15% replacement compared to all other replacement level of silica fume and FRC specimens.

(iv) The test results shows that SIFCON beam containing 10% of fibre content yields higher energy absorption and ductility characteristics among all other SIFCON specimens and FRC specimen.

(v) The increase in energy absorption capacity of SIFCON specimens is about 7.45 to 116.83% and ductility factor ranges from 22.74 to 96.03% when compared with FRC specimen

(vi) It was concluded that toughness and ductility factor were increased and flexural strength was decreased with increased volume of fibre content in SIFCON when compared among all SIFCON specimens.

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