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Flexural Behaviour of SIFCON Beams

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Abstract

Slurry Infiltrated Fibrous Concrete (SIFCON) is an exceptional type of FRC with high fiber content. The matrix usually holds cement-sand slurry or fluent mortar. SIFCON is advantageous by its excellent energy absorption capacity, greater strength and high ductility. This paper reports on the flexural behaviour of SIFCON-RC composite beams. Composite beam (SIFCON-RC) comprises of 2 layers with RC as the top and SIFCON as the bottom layer. To improve the strength, wear resistance and durability of the concrete a small fraction of short crimped fibers (NOVOCON 1050) with aspect ratio 50 is used in the study. Totally 12 beams of size 1.0 x 0.1x 0.2m are cast and tested. The effect of various volume of SIFCON (20, 30, 40, and 50%) in SIFCON-RC beam on the flexural strength is investigated. Diagonal tension failure is noted in all the specimens. SIFCON-RC composite beam with 40% SIFCON behaves well and the load versus deflection at yield point is compared with the 100% RC beam using the software ANSYS. The analytical results are reasonable which shows that the efficiency of the modelling of the SIFCON beams.

Keywords— SIFCON, RC Beam, Flexural strength, Crack pattern, Deflection, ANSYS software

1. Introduction

Concrete is the most extensively used material in Civil Engineering and is the primary component in most infrastructures. In the foreseeable future, there seems to be no alternative to concrete as a construction material. Although strength of concrete is most important, it is also necessary that the concrete is durable, workable and provide a good service life. For example, in prestressed concrete bridges, the concrete should have not only high strength but also limited shrinkage and creep properties. For bridges, offshore structures, highway and airport pavements and machine foundations, concrete should possess high fatigue strength. For nuclear containers exposed to very high temperatures, the concrete must have high resistance to thermal cracking. All these requirements made the engineers to think seriously and to find out the appropriate technology for improving the performance of concrete[1]. Increase in demand and decrease in supply of aggregates for the production of concrete results in the need to identify new sources of aggregates [2]. SIFCON gains importance because it eliminates the use of coarse aggregate. The principle of sustainable construction development requires prudent use of natural resources with best quality. SIFCON could be the one better solution [3].

Strengthening of existing RC framed buildings for improving seismic resistance is a challenging engineering problem. Many of the existing buildings are found to have inadequate strength, ductility, or stiffness because they were designed and built when modern seismic requirements did not exist. Various strengthening techniques such as addition of infill walls, various precast panel walls, steel bracings, and concrete jacketing of frame members or a combination of them are being used for such buildings in practice. Even beam length can be increased but increase in length increases the self-weight. The basic aim of strengthening techniques is to upgrade strength, ductility and stiffness of the member and/or the structural system as a whole.

2. SIFCON

SIFCON is one better solution, in which the material is altered to increase the strength, ductility and stiffness of the member. Slurry infiltrated fibrous concrete (SIFCON) is a rather new construction material. It could be considered as an exceptional type of FRC with high fiber content. The matrix usually holds cement-sand slurry or fluent mortar. In conventional FRC, the fiber content usually varies from 0.5-2% by volume in SIFCON it varies from 3-20%. SIFCON is unique in its consistency and the method of mix preparation [4]. In FRC the fibers are premixed where as in SIFCON the fiber bed is prepared and the slurry is infiltrated into it. Some typical reasons for using SIFCON because it can understand

- Seismic and wind loads
- Blast mitigation
- Corrosion

Over the last few years, there has been a worldwide increase in the use of different materials, to make the structure seismic resistant. One important application of this is SIFCON (Slurry Infiltrated Fibrous Concrete) when existing internal transverse reinforcement is inadequate. The main thrust of this study has been aimed at characterizing the strength and durability of SIFCON[5]. However, the vast majority of all columns in buildings are rectangular columns. Therefore, their strengthening and rehabilitation need to be given attention to preserve the integrity of building infrastructure.

- The structural rehabilitation community is in search of techniques and materials that are reliable, fast, cost effective and easy to implement.

- A large number of unaffected structures in seismic regions require retrofitting to avoid future loss of property.

- Therefore, an effective and a cheap solution is needed for shear strengthening the existing captive columns in RC frames without confining reinforcement.

SIFCON have the following properties:

- Excellent energy absorption capacity.
- Highly ductile and greater Strength.

The steps involved in SIFCON mix preparation are

- Fiber placement
- Dry mixing
- Slurry preparation
- Slurry infiltration
- Finished SIFCON beam

3. Methodology

The methodology adopted in the investigation is shown in Figure 1.

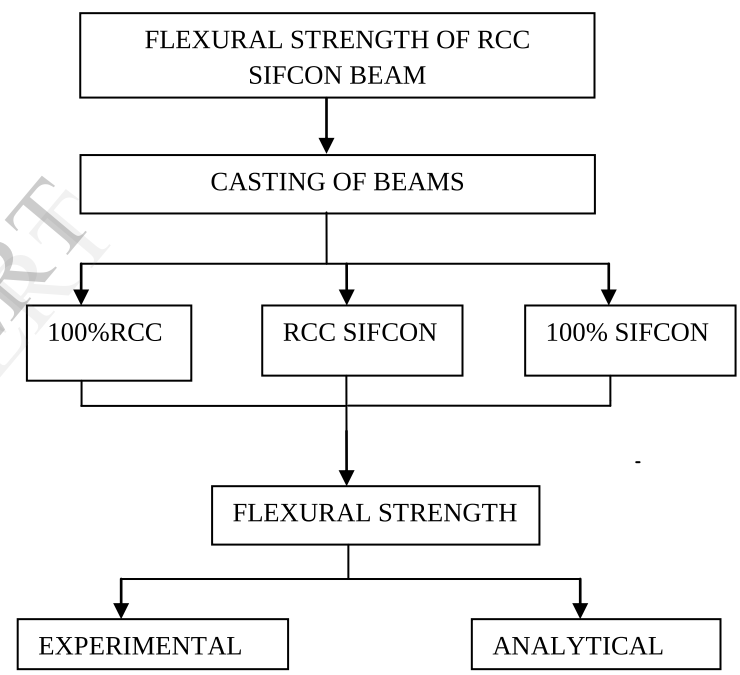

Figure 1. Methodology adopted

All the beams are reinforced with 4 nos. of 10 mm diameter Fe 415 grade steel- two number at bottom and two number at top and 6 mm diameter 2 legged stirrups at 100 mm c/c. Figure 1 shows the reinforcement details of the beam specimen.

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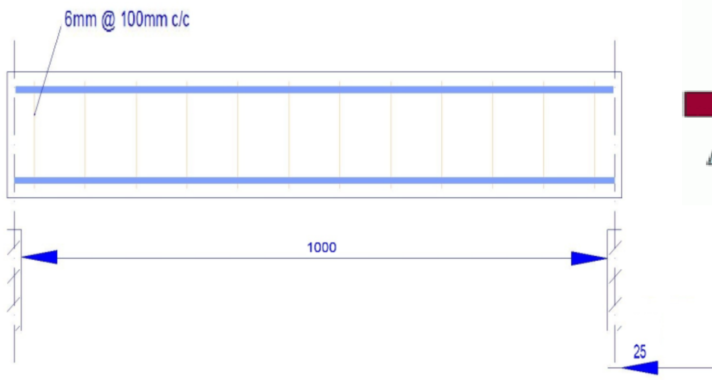


Figure 2 Reinforcement details

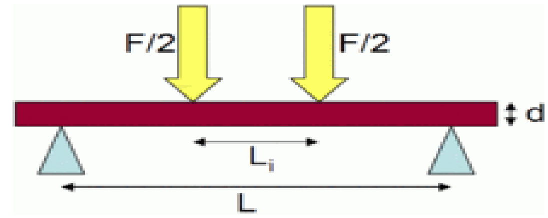
The mould is arranged properly and placed over a smooth surface. The sides of the mould exposed to concrete are oiled well to prevent the side walls of the mould from absorbing water from concrete and to facilitate easy removal of the specimen. The reinforcement cages are placed in the moulds and cover between cage and form provided is 20 mm. Cement mortar block pieces are used as cover blocks. The concrete contents such as cement, sand and water are weighed accurately and mixed. The mixing is done till uniform mix is obtained. Then the steel fibers are placed into the mould .The concrete is made infiltrated through the fiber bed immediately after mixing. The test specimens are remoulded at the end of 24 hours of casting. They are cured in water for 28 days. After 28 days of curing, the specimens are dried in air and white washed. Flexural tests have been conducted for all 12 beams under two point loading.

4. Results and Discussion

In most field applications, SIFCON is subjected to bending stress, at least partially. Hence, the behaviour under flexural loading plays an important role in field applications.

A. Flexural Strength

It is measured by testing beams under 2 point loading (also called 4 point loading including the reactions). Beam Dimensions: 1. m length × 0.1 m breadth x 0.2 m height. Figure 3 shows the loading position of the beams.



$$\sigma = \frac{3F(L - L_i)}{2bd^2}$$

Figure 3. Beam under two point load

Where
F = the load applied to a sample of test length *L*, width *b*, and thickness *d*.

L= centre to centre distance of the supports.

Li= inner span.

Table 1 presents the flexural strength of the tested beams. The flexural strength is computed using the average load of two specimens in each category.

Table.1 Flexural strength of different beam specimens

Sl.No	**RC (%)**	**SIFCON (%)**	**Peak Load (kN)**	**Flexural Strength (N/mm²)**
1	100	-	54.95	14.42
2	-	100	72.6	19.06
3	80	20	71.1	18.66
4	70	30	72.9	19.14
5	60	40	88	23.10
6	50	50	73.15	19.20

B. Crack Pattern

Regarding the crack pattern diagonal tension failure is noted in all the specimens. The diagonal crack starts from the last flexural crack and turns gradually into a crack more and more inclined under the shear loading as noted in Fig. Such a crack comes not proceed immediately to failure, although in some of the longer shear spans this either seems almost to be the case or an entirely new and flatter diagonal crack suddenly causes failure. More typically, the diagonal crack encounters resistance as it moves up into the zone of compression becomes flatter and stops at some point such as that marked 1 in Figure 4. With further load, the tension crack extends gradually at a very flat slope until finally sudden failure occurs, possibly from point 2. Shortly before reaching the critical failure point at 2 the more inclined lower crack 3 will open back, at least to the steel level and usually cracks marked 4 will develop.

Figure 4. Beam failure pattern

C. Load vs Displacement:

Even though SIFCON has typically higher compressive strength than normal concrete, its uniqueness is much more important in the area of energy absorption, ductility and toughness [6]. A great energy absorbing capacity and a ductile mode of failure make SIFCON suitable and perfect for applications involving impact, blast, and earthquake loading. The load versus deflection behaviour of different specimens is shown in Figure 5. It can be seen that 40%SIFCON-60%RC and 50% SIFCON-50%RC composite beams have lesser displacement than rest of the beams. The stiffness is also higher for 40%SIFCON-60%RC composite beam

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Table.2 Load Vs displacement

Load (kN)	Deflection(mm)					
	RC 100%	SIFCON 100%	SIFCON 20%	SIFCON 30%	SIFCON 40%	SIFCON 50%
0	0	0	0	0	0	0
10	0.24	0.56	0.35	0.08	0.1	0.11
20	0.65	1	0.75	0.31	0.34	0.37
30	1.14	1.46	1.25	0.66	0.54	0.79
40	1.6	1.9	1.78	1.04	0.8	1.32
50	9.8	2.36	2.3	1.42	1.15	1.76
60		2.9	2.84	1.86	1.48	2.3
70		6.8	6.2	7.3	2.52	
80					3.6	

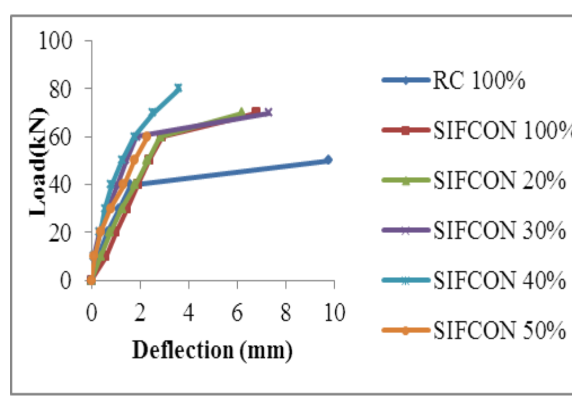

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Figure 5 . Load Vs Displacement Behaviour

D. SIFCON volume (%) Vs Modulus of Elasticity

The modulus of elasticity of all the beam specimens is found individually from the Stress Vs Strain graph of each beam. Table 3 presents the modulus of elasticity of the beams with various SIFCON ratios. It is observed that there is a gradual increase in modulus of elasticity with increase in SIFCON volume from 20% to 40% . At 50% there is a sudden drop in the Young's modulus.

Table.3 Modulus of elasticity of various beams

SL.NO	RC (%)	SIFCON (%)	Modulus of Elasticity(N/mm²)
1	100	-	23158
2	-	100	20953
3	80	20	21349
4	70	30	32633
5	60	40	39067
6	50	50	28282

E. Modelling of beam using ANSYS

The experimental investigation on different types of beams with and without SIFCON shows better results for 40% SIFCON-60% RC composite beam. An attempt has been made to model the same behaviour using the FEM software ANSYS. Beam with 40% SIFCON-60% RC has been modelled and the deflection behaviour at yield point is compared with the 100% RC beam. Table 4 shows the comparison between experimental and analytical results. The results are reasonable and the difference is less than 10%. The model of the beam and its meshing are shown in Figures 6 and 7, respectively. The deflection behaviour of the beams with 100% RC is shown in Figure 8 and the Figure 9 shows the deflection behaviour of 40% SIFCON.

Table 4 Comparison between experimental and analytical results

SL. No	Material	Deflection at yield point(mm)	
		Experiment	ANSYS
1	RC Beam (100%)	1.6	1.59
2	Beam with 40% Sifcon	2.52	2.78

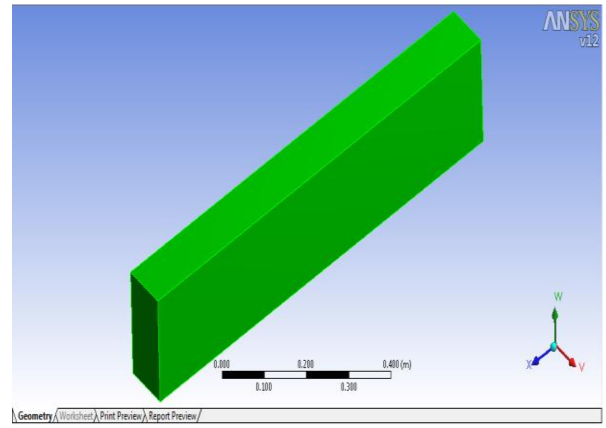

Figure 6. Model of beam in ANSYS

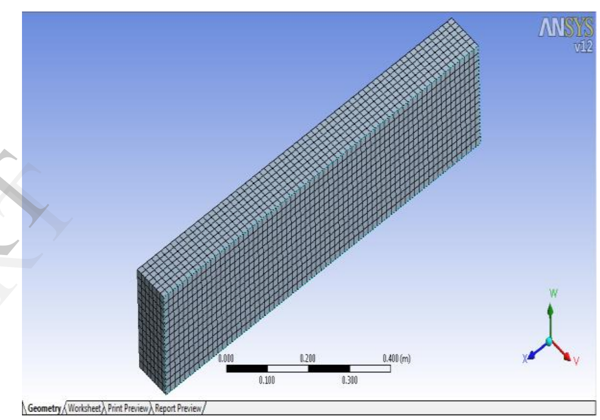

Figure 7. FEM Model of beam

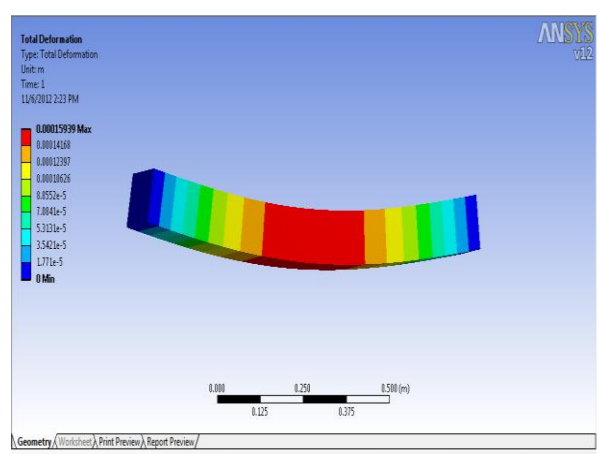

Figure 8. Deflection Behaviour of 100%RC Beam

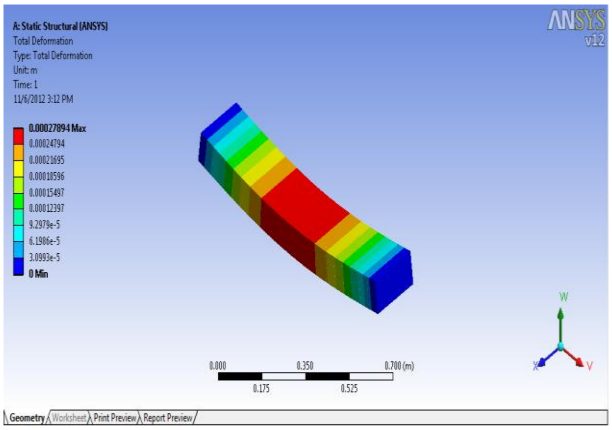

Figure 9.Deflection Behaviour of 40% SIFCON Beam

5. Concluion

This study deals with experimental and analytical investigation on flexural behaviour of SIFCON-RC composite beams. Based on the results the following conclusions are derived.

a) On comparing the flexural strength, SIFCON is better than RC.

b) When the volume of SIFCON increases from 20% to 100%, high flexural strength and high modulus of elasticity is achieved for 40% SIFCON.

c) The ANSYS model of SIFCON beams exhibits similar flexural behavior as in the experimental investigation.

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