ISSN 1996-3343

Asian Journal of Applied Sciences

http://knowledgiascientific.com

Knowledgia
SCIENTIFIC
A Place to Publish Outstanding Research

Asian Journal of Applied Sciences 7 (4): 232-239, 2014
ISSN 1996-3343 / DOI: 10.3923/ajaps.2014.232.239

Flexural Behaviour of Slurry Infiltrated Fibrous Concrete (SIFCON) Composite Beams

K. Parthiban, K. Saravanarajamohan and G. Kavimukilan
School of Civil Engineering, SASTRA University, Thanjavur, 613 401, Tamilnadu, India

Corresponding Author: K. Parthiban, School of Civil Engineering, SASTRA University, Thanjavur, 613 401, India Tel: 0091-99440 82810 Fax: 0091-4362-264120

ABSTRACT

Slurry Infiltrated Fibrous Concrete (SIFCON) is a high volume Fibre Reinforced Concrete (FRC) with significant improvement in the properties such as strength, durability, ductility and toughness. Fibre reinforced concrete has a wide variety of structural application, in which the ductility depends on the amount of fibres present in the concrete. This work reports on the experimental study concerning the flexural behavior of Slurry Infiltrated Fibrous Concrete (SIFCON) composite beams and to investigate the influence of volume percentage of SIFCON on strength and stiffness characteristics of Reinforced Cement Concrete (RCC) and fibre reinforced concrete beams under flexural loading. A total of thirteen beams with an effective span of 1000 mm were casted and tested to study the load deformation characteristics, ductility related parameters, ultimate moment capacity and failure criteria. The reinforced cement concrete and fibre reinforced concrete beams were casted with partial replacement with SIFCON in the tension zone. The effect of various volume of SIFCON (10, 20, 30, 40 and 50%) in the beam on the flexural strength was investigated. The beams were evaluated for flexural strength, compositeness between RCC and FRC with SIFCON under static loading. Herein, full SIFCON, full RCC and full FRC beams were also examined for comparison. The results illustrate that the composite beams holds improved flexural strength, deflection resistance behavior and performed comparatively with full SIFCON. The RCC composite beam has the strength of 25% more than the conventional concrete beam, whereas the FRC composite shows an increase of 45%.

Key words: Slurry infiltrated fibrous concrete, composite beams, fibre reinforced concrete, fibre volume

INTRODUCTION

Concrete is widely used as a construction material. Due to its specialty of being cast into any shape, it has replaced the old construction methods of stone and brick masonry. Nevertheless, concrete has many demerits like poor ductility, less tensile strength and low impact resistance. SIFCON has been classified as an excellent type of FRC with high volume of fiber. In conventional FRC, the fiber content usually varies from 1-3% (by volume), in SIFCON it varies from 4-25% (Naaman and Baccouche, 1995). Compared with cement concrete, SIFCON is distinct in mixing and its consistency and also superior in its energy absorption capacity, strength and ductility (Sudarsana Rao *et al.*, 2009). These strengths may get affected due to the alignment of the fibres (Stiel *et al.*, 2004). Homrich and Naaman (1987) also examined the SIFCON composites under compression and tension to study its stress-strain characteristics and elastic modulus. The behaviour of SIFCON and its crack pattern with high volume of fibres was studied by Yan *et al.* (2002). The use of fine sand might significantly improve the strength and stiffness characteristics of SIFCON and also reduction in cost (Naaman and Najm, 1991). The use of SIFCON in beam-column joints of the frame was investigated by Thirugnanam *et al.* (2001). The performance of SIFCON beams was studied by Naaman *et al.* (1992) and found that the use of SIFCON purged the use of shear reinforcements in RC beams. Based on the above quoted literatures, the work has been framed to study the flexural behavior and the load-deformation characteristics of RCC and FRC beams composited with SIFCON at various volume levels. The results are compared with the full RCC, FRC and SIFCON beams taken as the controlled specimens.

MATERIALS AND METHODS

Materials: In the preparation of specimens, Ordinary portland cement of 53 grade, locally available River sand (passing through 4.75 mm IS sieve), coarse aggregate (20 mm maximum size) and steel fibers with an ultimate tensile strength of 1050 N mm^{-2} were used. The fibers are of length 50 mm and diameter 1 mm and henceforth, the aspect ratio is 50. SIFCON beams were produced to study the strength development of different SIFCON volume ratios (10, 20, 30, 40 and 50%) and the results were compared with full SIFCON, full RCC and full FRC beams. The cement mortar was prepared with the ratio of 1:1 by weight of cement and sand, with a water-cement ratio of 0.50 and their details are given in Table 1. The strength-related properties such as flexural strength, stress-strain relationship were also observed.

Casting of test specimens: Wooden moulds of required size were prepared to cast the beams. The moulds have been coated with waste oil initially in order to remove the specimen easily. The steel

Table 1: Mix proportioning of the beam specimens under various replacement levels

Beam designation	RCC (%)	FRC (%)	SIFCON (%)	w/c ratio
CB01	100	-	-	0.50
CB02	-	-	100	0.50
CB03	-	100	-	0.50
SS01	90	-	10	0.50
SS02	80	-	20	0.50
SS03	70	-	30	0.50
SS04	60	-	40	0.50
SS05	50	-	50	0.50
SS06	-	90	10	0.50
SS07	-	80	20	0.50
SS08	-	70	30	0.50
SS09	-	60	40	0.50
SS10	-	50	50	0.50

CB01: Reinforced concrete beam (Controlled beam), CB02: Slurry infiltrated fibrous concrete beam (Controlled beam), CB03: Fibre reinforced concrete beam (Controlled beam), SS01: SIFCON 10% volume and RCC 90% volume, SS02: SIFCON 20% volume and RCC 80% volume, SS03: SIFCON 30% volume and RCC 70% volume, SS04: SIFCON 40% volume and RCC 60% volume, SS05: SIFCON 50% volume and RCC 50% volume, SS06: SIFCON 10% volume and FRC 90% volume, SS07: SIFCON 20% volume and FRC 80% volume, SS08: SIFCON 30% volume and FRC 70% volume, SS09: SIFCON 40% volume and FRC 60% volume, SS10: SIFCON 50% volume and FRC 50% volume

Fig. 1: Steel fibers preplaced in the mould before pouring of slurry

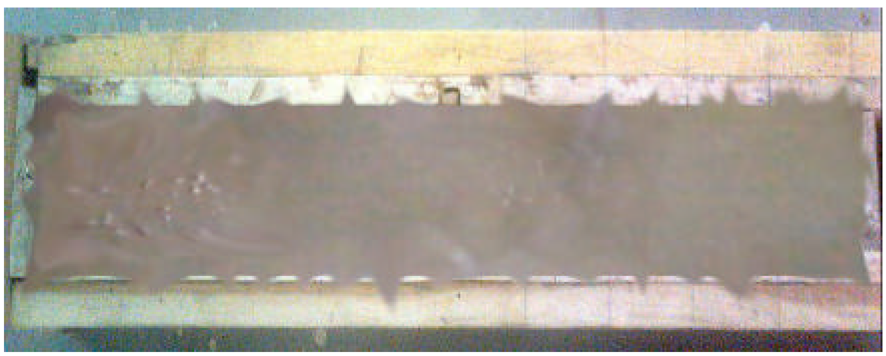

Fig. 2: SIFCON composite beam casted in the mould

fibres of random orientation were placed in the mould for the required depth (Fig. 1) and the cement sand slurry was prepared in the mean time was then poured into the mould evenly above the preplaced fibres.

All the beams were reinforced with 2 nos. of 12 mm diameter Fe 415 grade steel as tension reinforcement and 2 nos. of 10 mm diameter as compression reinforcement with 6 mm diameter 2-legged stirrups at 150 mm c/c. Over the SIFCON bed, RCC or FRC was poured to the required depth as shown in Fig. 2. The specimens were removed from the moulds after 24 h of casting and were allowed to cure for a period of 28 days. After removing from the curing tank, they were allowed to dry and then coated with white paint in order to get clear visibility of the cracks. Grids with 2 cm spacing were also marked after white washing.

Loading arrangement and testing: All beam specimens were simply supported and static load was applied through two symmetrically placed concentrated loads, placed at one-third span as shown in Fig. 3. The load was applied gradually in the increasing rate, up to and over the ultimate loads. The central deflections were recorded for each load increment. The load at the first crack and the corresponding deflection was observed.

Behaviour under flexural loading: In most of the applications, SIFCON was subjected to bending, at least partially. Therefore, its flexural behavior plays a vital role in the field applications.

Fig. 3: Loading arrangement of the beam specimen before testing

Flexural test was conducted for all specimens under two point loading. The beams were simply supported over an effective span of 1000 mm under four point bending and the loads were incremented under static behaviour. The strain rosettes were placed under the load points and the strain at each level has been measured for every increment of loading. The vertical mid-span deflections were measured with a mechanical dial gauge of 0.01 mm accuracy. During the process of loading, the development of the cracks and its propagation were monitored.

RESULTS AND DISCUSSION

The results of the experimental investigation are presented in Table 2. Naaman and Baccouche (1995) reported that SIFCON contains 4-25% of fibres. But, in this work, the use of fibres in SIFCON composite beams has been limited to 12%. This is due to the less cross sectional area of the beam specimens and it may be increased for larger area. Typical load-deformation relationships of the beam specimens for RCC and FRC composites are presented in Fig. 4. From the test results, it has been observed that in SIFCON-RCC composites, the increase in the depth of SIFCON increases the load carrying capacity of the Beam specimens and decrease in the deflection of the beam (Sudarsana Rao *et al.*, 2009) in which SS04 mix has higher load carrying capacity of 88 kN and also shows comparatively less deflection of 8.70 mm. This is similar in the case of SIFCON-FRC composites, where SS09 mix takes 101.05 kN with the central deflection of 9.91 mm. More will be the rigidity of the member, if less is the displacement which ultimately increases the load carrying capacity. The ultimate load carrying capacity of the beam specimens and their corresponding first crack load is presented in Fig. 5. From the test results, it is distinct that the displacement for 100% RCC is too high. The maximum displacement is getting reduced with increase in SIFCON volume.

Table 2: Summary of the beams test results under flexure loading

Beam designation	Load at first crack (kN)	Deflection at first crack load (mm)	Yield load (kN)	Deflection at yield load (mm)	Ultimate load (kN)	Deflection at ultimate load (mm)
CB01	9.95	1.50	57.50	4.50	68.85	36.51
CB02	11.75	2.02	62.00	5.00	72.60	13.00
CB03	9.60	1.50	64.15	5.00	72.60	33.07
SS01	8.95	1.35	59.50	4.75	70.16	21.20
SS02	9.10	1.25	65.45	5.00	72.90	17.01
SS03	9.50	1.50	69.30	6.76	71.10	10.67
SS04	9.20	1.60	86.85	7.90	88.00	8.70
SS05	9.20	1.51	70.10	4.10	73.15	4.30
SS06	9.10	1.45	63.00	4.80	74.20	7.20
SS07	9.15	1.30	88.15	5.80	92.05	11.70
SS08	9.90	1.50	65.70	5.00	69.00	13.00
SS09	9.75	1.50	96.10	7.30	101.05	9.91
SS10	8.65	1.80	71.65	6.90	77.30	13.20

Abbreviations are defined under Table 1

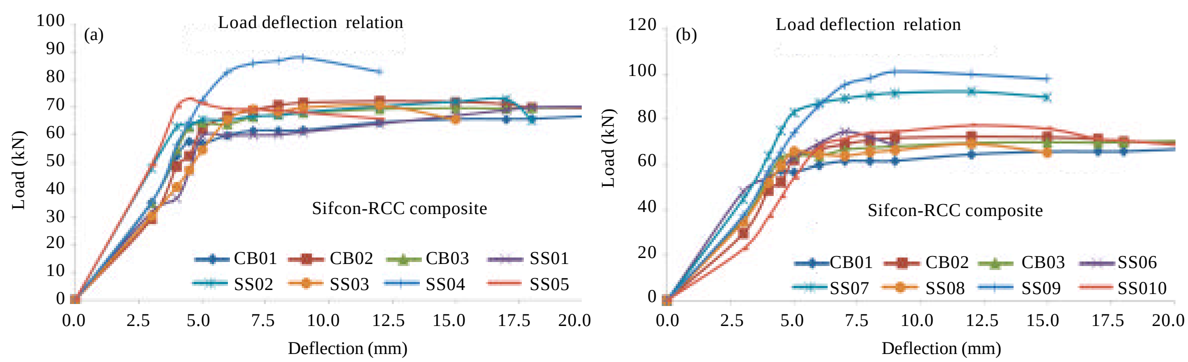

Fig. 4(a-b): Load-deformation characteristics of beam specimens under flexural loading, (a) SIFCON-RCC composites and (b) SIFCON-FRC composites

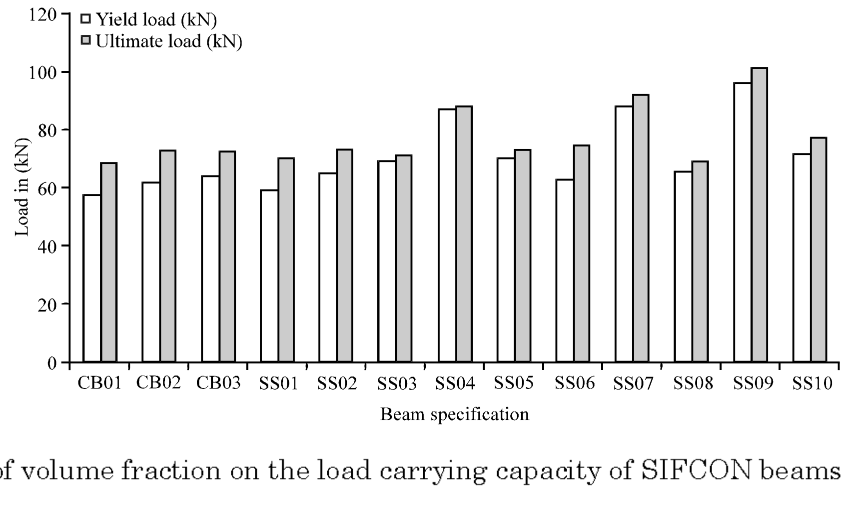

Fig. 5: Effect of volume fraction on the load carrying capacity of SIFCON beams

Similar performance has been observed in the case of FRC composites also. The orientation of the fibres also plays a significant role in the load carrying capacity of the SIFCON, in which the randomly oriented fibres produced the maximum load carrying capacity (Stiel *et al*., 2004) which was evident from the test results.

The flexural strength of the beam specimens are summarized in Table 3. The beams were subjected to flexural cracking, followed by diagonal cracking. This transition takes place under inclined shear loading as shown in Fig. 6. Such cracks do not proceed instantly to collapse, but in some larger shear spans this seems to be the instance or an exclusively fresh and flatter diagonal crack all of a sudden causes failure. The beams were subjected to diagonal cracks at the bottom which indicates the shear deficiency of the beam and while propagating to the compression zone, this becomes flatter and discontinues at some point, whereas, Naaman *et al*. (1992) reported that the availability of stirrups may be completely eliminated with the use of SIFCON in flexural

Table 3: Load carrying capacity and flexural strength of different beam specimens

Beam	Peak load (kN)	Flexural strength (N mm^{-2})
CB01	68.85	17.21
CB02	72.60	18.15
CB03	72.60	18.15
SS01	70.16	17.54
SS02	72.90	18.23
SS03	71.10	17.78
SS04	88.00	22.00
SS05	73.15	18.29
SS06	74.20	18.55
SS07	92.05	23.01
SS08	69.00	17.25
SS09	101.05	25.26
SS10	77.30	19.33

Abbreviations are defined under Table 1

Fig. 6: Failure pattern of the beam specimen after testing

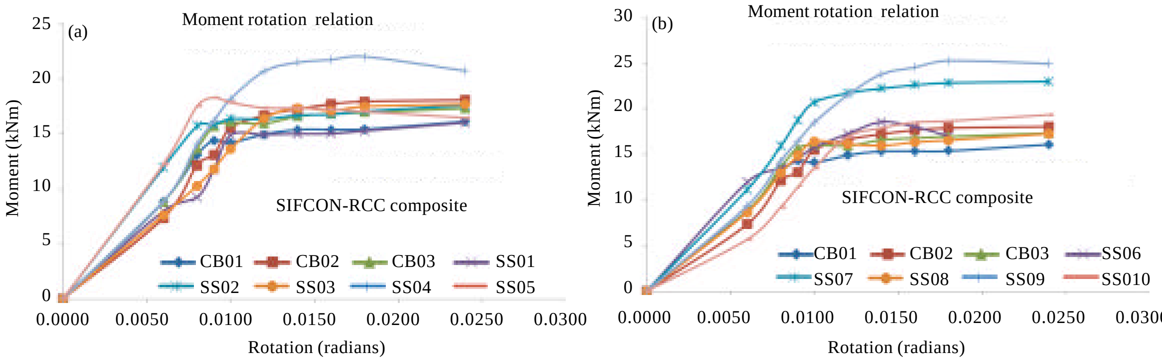

Fig. 7(a-b): Moment-rotation characteristics of the beam specimens (a) SIFCON-RCC composites and (b) SIFCON-FRC composites

members. On the application of the load, the rotation decreases with the increase in the depth of the SIFCON, this shows the increase in the rigidity of the member. The Moment-rotation relationship is presented in Fig. 7. The yield load of the beam specimens was found to be around 80% of its ultimate load and this gets increases with the increase in the depth of the SIFCON layer.

CONCLUSION

The flexural strength of plain concrete can be improved clearly by incorporating SIFCON and the addition of SIFCON in conventional concrete results in improvements in strength and ductility under static loading. The addition of SIFCON to the conventional concrete beams increased both the yielding and the ultimate loads by about 25% and an increase of 45% in the case of FRC composites. Increase in the depth of SIFCON showed positive effect in the reduction of beam deflection. The ductility factors for the beams increased significantly with the increase in the depth of the SIFCON. The addition of SIFCON in conventional concrete beams shows significant reduction in the number of cracks and their widths. Energy absorption capacity or toughness of reinforced concrete beams increases with the increase in the depth of SIFCON.

REFERENCES

Homrich, J.R. and A.E. Naaman, 1987. Stress-strain properties of SIFCON in compression. ACI SP-105, American Concrete Institute, Detroit, MI., USA., pp: 283-304.

Naaman, A. and H. Najm, 1991. Bond-slip mechanisms of steel fibers in concrete. ACI Mater. J., 88: 135-145.

Naaman, A.E., H.W. Reinhardt and C. Fritz, 1992. Reinforced concrete beams with a SIFCON matrix. ACI Struct. J., 89: 79-88.

Naaman, A.E. and M.R. Baccouche, 1995. Shear response of dowel reinforced SIFCON. ACI Struct. J., 92: 587-596.

Stiel, T., B.L. Karihaloo and E. Fehling, 2004. Effect of casting direction on the mechanical properties of CARDIFRC. Proceedings of the International Symposium on Ultra High Performance Concrete, September 13-15, 2004, Kassel, Germany, pp: 481-493.

Sudarsana Rao, H., N.V. Ramana and K. Gnaneswar, 2009. Behaviour of restrained SIFCON two way slabs part 1: Flexure. Asian J. Civil Eng. (Build. Housing), 10: 427-449.

Thirugnanam, G.S., P. Govindan and A. Sethurathanam, 2001. Ductile behaviour of SIFCON structural members. J. Struct. Eng., 28: 27-32.

Yan, A., K. Wu and X. Zhang, 2002. A quantitative study on the surface crack pattern of concrete with high content of steel fiber. Cement Concrete Res., 32: 1371-1375.