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Use Of precast SIFCON Laminates For Strengthening of RC Beams

Mr. Yogesh N. Dhamak[1] *Prof. Madhukar R. Wakchaure*[2]
P.G. Student, Department of civil Engineering
Taluka- Sangamner, District-Ahmednagar
Maharashtra, INDIA
E mail- yogeshdhamak@gmail.com
Associate Professor, P.G.Co-ordinator AVCOE sangamner
AVCOE sangamner, Taluka- Sangamner, District-Ahmednagar
Maharashtra, INDIA
E mail- mrw12@rediffmail.com

Abstract- **Slurry infiltrated fibrous concrete (SIFCON) is a novel type of high performance fibre reinforced concrete made by infiltrating steel fibre bed with a specially designed cement based slurry. Laboratory experiments have shown that SIFCON is an innovative construction material possessing both high strength and large ductility. In the present study, the use of SIFCON has been investigated as an externally bonded strengthening material on reinforced concrete beams The experimental programme has been carried out to study the behaviour of flexural RC beams with precast SIFCON laminates. A total number of twenty one specimens of size 150mm x 300mm x1800mm corresponding to four test series are cast and tested under static loading to study the load deformation behaviour and ductility associated parameters. The concrete beams has been designed to obtain a concrete grade of M20.For laminates the fibre volume fraction was 7% and 10%. The steel fibres used in the study were hooked end steel fibres having 0.6mm diameter and aspect ratio of 50. Previous results indicate that the strengthening of RC beams with SIFCON laminates has significantly improved the cracking behaviour in terms of significant increase in first crack load and the formation of larger number of finer cracks. The stiffness, ductility and energy absorption are found to be increase to a great extent when the beams are strengthened by three face confinement (bottom & side faces).**

Keywords- Flexural strength; Load deflection response.

I INTRODUCTION

Reinforced concrete structures often have to face modification and improvement of their performance during their service life. The main contributing factors are change in their use, new design standards, deterioration due to corrosion in the steel caused by exposure to an aggressive environment and accident events such as earthquakes. In such circumstances there are two possible solutions: replacement or strengthening. Full structure replacement might have determinate disadvantages such as high costs for material and labor, a stronger environmental impact and inconvenience due to interruption of the function of the structure e.g. traffic problems. When possible, it is often better to repair or upgrade the structure by strengthening. In the last decade, the development of strong epoxy glue has led to a technique which has great potential in the field of upgrading structures. Basically the technique involves gluing steel plates or fibre reinforced polymer (FRP) bars to the surface of the concrete. A promising new way of resolving this problem is to selectively use advanced composites such as High Performance Fibre Reinforced Cementitious Composites (HPFRCCs). With such materials novel repair, retrofit and new construction approaches can be developed and that would lead to substantially higher strengths, seismic resistance, ductility, durability while also being faster and more cost - effective to construct than conventional methods. Normally HPFRCCs available in the market .

SIFCON is a high-strength, high-performance material containing a relatively high volume percentage of steel fibres as compared to steel fibre reinforced concrete (SFRC). It is also sometimes termed as 'high- volume fibrous concrete'. The origin of SIFCON dates to 1979, when Prof. Lankard carried out extensive experiments in his laboratory in Columbus, Ohio, USA and proved that, if the percentage of steel fibres in a cement matrix could be increased substantially, then a material of very high strength could be obtained, which he christened as SIFCON. While in conventional SFRC, the steel fibre content usually varies from 1 to 3 percent by volume, it varies from 4 to 20 percent in SIFCON depending on the geometry of the fibres and the type of application. The process of making SIFCON is also different, because of its high steel fibre content. While in SFRC, the steel fibres are mixed intimately with the wet or dry mix of concrete, prior to the mix being poured into the forms, SIFCON is made by infiltrating a low-viscosity cement slurry into a bed of steel fibres 'pre-packed' in forms / moulds. The matrix in SIFCON has no coarse aggregates, but a high cementitious content. However, it may contain additives such as fly ash, micro silica and latex emulsions. The matrix fineness must be designed so as to properly penetrate (infiltrate) the fibre network placed in the moulds, since otherwise, large pores may form leading to a substantial reduction in properties. A controlled quantity of high - range water -reducing admixture (super plasticizer) may be used for improving the flowing characteristics of SIFCON. All types of steel fibres, namely, straight, hooked, or crimped can be used. The HPFRCCs were developed in the 1990's to improve performance characteristics of fibre reinforced concrete *(Naaman and Reinhardt 1995).*

II METHODOLOGY

A.Material Properties

[a] Concrete

All the testing specimens for the flexural beams are to be cast using M20 concrete having the dimensions of 150 x 300 x 1800 mm. To check targeted concrete compressive strength after 28 days, three cubes will be cast and tested to ensure getting the designed compressive strength.

Table 1 M20 Mix proportion

Cement	**Sand**	**Course Aggregate**	**Water**
372 Kg/m^3	713 Kg/m^3	1065 Kg/m^3	191
1	1.92	2.86	0.50

[b] Steel Bar

To cast the beam specimen, Fe500 type of steel is to be used which is having the yield tensile strength 500 MPa.

Use 12 mm # 3 no @bottom ,

8 mm # 2 no @ Top and

6 mm # @ 200 mm c/c as a stirrups.

[c] SIFCON laminate

Hook end steel fibres of 0.6 mm diameter and aspect ratio of 50 are used to cast SIFCON laminates. fibre volume fraction is 7% and 10%.cement,mocro silica and fly ash were used for making cement slurry with the mix proportion 1:0.2:0.5.water binder ratio was about 0.45.super plasticizer of 1.5% is used to increase the workability of the cement based slurry so as to facilitate easy infiltration of cement slurry in to the fibre matrix. Laminate of size 1800 mm X 150mm X 20 mm and 1800 mm X 300 mm X20 mm were cast for bottom face and side face respectively. wooden moulds were used to cast the laminates. Initially the fibres were placed in the mould to its full capacity and then the cement based slurry is made to infiltrate in to the mould. The laminates were demolded after 24 hours and were cured for 28 days.

Table 2 Casting sequence of beam specimens

Sr. No	**Beam Design ation**	**Laminate confinement**	**Numbe r of Beams**
01	CB	No confinement	03
02	CB 1	Bottom face Confinement	06
03	CB 2	Side face Confinement	06
04	CB 3	Three face confinement(bott om & side faces)	06

Table 2 Casting sequence of laminates

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Sr. No	Laminate Designation	Size	No.of laminates For fibre vol. 7 %	No.of laminates For fibre vol. 10 %
01	SIFCON 1	1800 X 150 X 20 mm	6	6
02	SIFCON 2	1800 X 300 X 20 mm	12	12

B. Strengthening procedure of SIFCON to beam

The concrete surface is made rough by wire brush and it is thoroughly cleaned to remove all dirt and debris. The epoxy resin and hardener are weighed in the ratio of 1:1 and mixed thoroughly and applied over the concrete surface. The laminate is then placed on the top of epoxy resin coating such that the warp direction of the fabric is kept along the longitudinal reinforcement of the beam. During hardening of the epoxy, a constant uniform pressure is applied to ensure good contact between the epoxy, the concrete and the laminate. Concrete beams with laminate are cured for 7 days at room temperature before testing.

Fig.1 Casting of SIFCON laminates

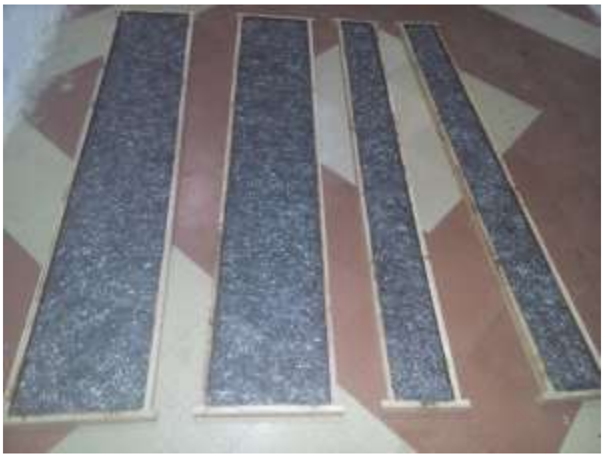

Fig.2 Moulds with fibers

c. Test setup and procedure

The testing procedure for the entire specimen was same. After the curing period of 28 days was over, the beam surface was cleaned and white washed for clear visibility of cracks. Before testing, the member was checked for dimensions and a detailed visual inspection was made with all information carefully recorded.

After setting and reading all gauges, the load was increased incrementally up to the calculated working load, with loads and deflections recorded at each stage. Loads will then normally be increased again in similar increments up to failure, with deflection gauges replaced by a suitably mounted scale as failure approaches. This is necessary to avoid damage to gauges and although accuracy is reduced, the deflections at this stage will usually be large and easily measured from a distance. Similarly, cracking and manual strain observations must be suspended as failure approaches. Special safety precautions shall be taken; if it is essential to take precise deflection readings up to collapse. Cracking and failure mode was checked visually, and a load-deflection plot was prepared. The most commonly used load arrangement for testing of beams will consist of two-point loading as shown .

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Fig.3 Testing Set up

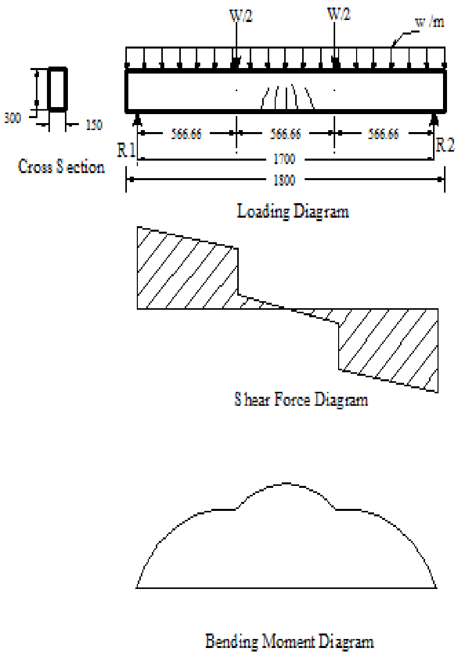


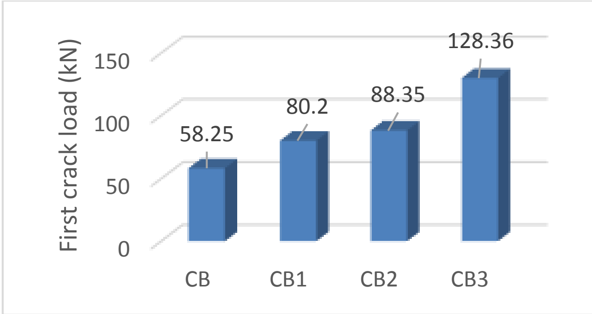
Fig.4
Shear force and bending moment diagram for two points loading

III RESULT AND DISCUSSION

1.First crack load-

Table 4. First crack load for 7%fiber volume

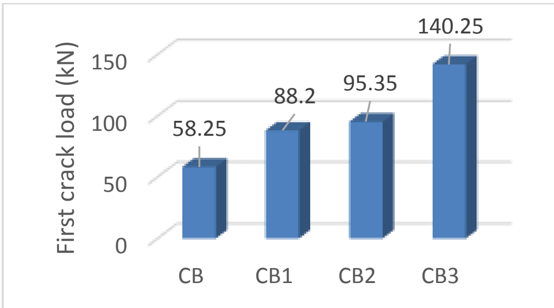
Beam	First crack load (kN)		
	A	B	C
CB	56.34	56	58.25
CB1	77.48	78.82	80.20
CB2	86.28	86.18	88.35
CB3	130.26	126.32	128.36



Graph 1. Comparison of first crack load (7% fiber volume)

Table 5.First crack load for10%fiber volume

Beam	First crack load (kN)		
	A	B	C
CB	56.34	56.80	58.25
CB1	85.40	83.50	88.20
CB2	94.10	94.25	95.35
CB3	142.11	138.15	140.25



Graph 2. Comparison of first crack load (10% fiber volume)

2.Ultimate load-

Table 6. Ultimate load for 7% fiber volume

Beam	Ultimate load(kN)		
	A	B	C
CB	71.60	70.22	73.15
CB1	129.25	126.50	130.18
CB2	177.20	175.23	178.45
CB3	188.20	186.30	186.50

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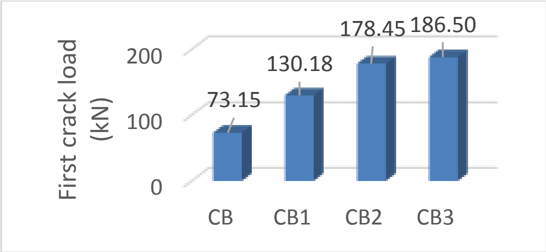
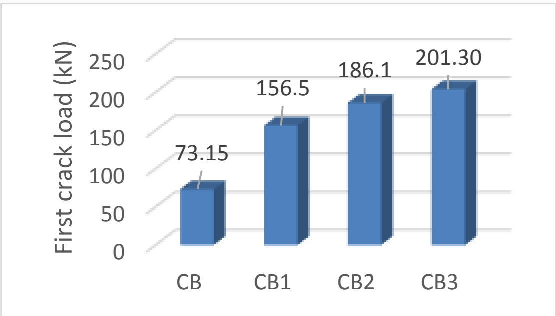


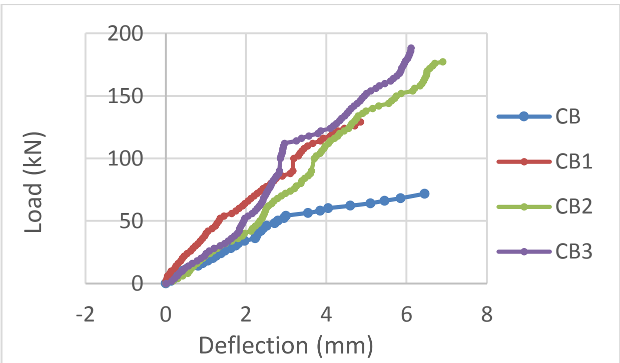
Graph 3.Comparison of ultimate load (7% fiber volume)

Table 7. Ultimate load for 10% fiber volume

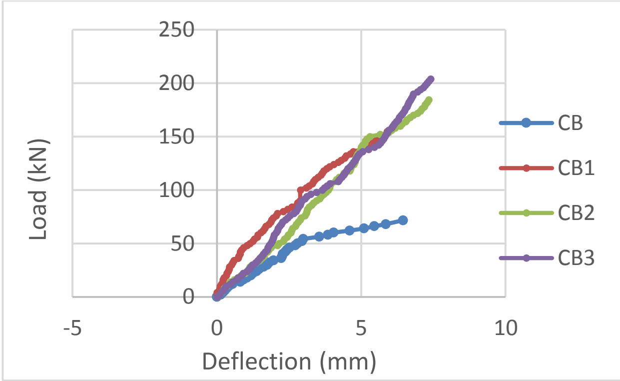
Beam	**Ultimate load (kN)**		
	A	**B**	**C**
CB	71.60	70.22	73.15
CB1	154.70	155.60	156.50
CB2	184.60	183.90	186.10
CB3	204.12	198.80	201.30



Graph 4. Comparison of ultimate load (10 % fiber volume)



Graph 5. Comparison of equivalent load deflection behavior for beams (7% fiber volume)



Graph 6. Comparison of equivalent load deflection behavior for beams (10 % fiber volume)

IV CONCLUSION

Based on the experimental investigation the following conclusions were drawn.

1. For 7 % fiber volume the first crack load is 37%, 53%, and 131% for bottom face, two side face, and three side faces respectively to that of the conventional control beam.
2. For 10 % fiber volume the first crack load is 51%, 67%, and 152% for bottom face, two side face, and three side faces respectively to that of the conventional control beam.
3. For 7 % fiber volume the ultimate load is 80%, 147%, and 162% for bottom face, two side face, and three side faces respectively to that of the conventional control beam.
4. For 10 % fiber volume the ultimate load is 116%, 157%, and 185% for bottom face, two side face, and three side faces respectively to that of the conventional control beam.
5. Flexural strengthening of the beam increases the ultimate load carrying capacity, but the cracks developed were not visible. Due to invisibility of the initial cracks' it removes the fear from the minds of occupants regarding the collapse. Even though after the failure of beams and excessive deflection beam do not fail suddenly due to the use of U-wrapping of SIFCON laminates.
6. By strengthening the beam, performance of the weak structure can be improved and it will protect many lives from sudden failure.

7. Additionally no minimum concrete cover is needed to prevent corrosion of the reinforcement, if laminates are provided.

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