Experimental study on effect of external bonding of SIFCON laminate on RC beams

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Abstract - *Slurry infiltrated fibrous concrete (SIFCON) is one of the starting late made movement material that can be considered as a kind of high performance fiber reinforced concrete with higher fiber content. The present investigation emphasizes on the impact of use of SIFCON laminates as an externally bonded strengthening material on reinforced concrete beams. The study presents an experimental investigation on flexural behaviour of RC beams with precast SIFCON laminates. The concrete beams have been designed to obtain a concrete grade of M25. For laminates steel fibres (straight) of diameter 1mm are used with the fibre volume fraction of 9% and aspect ratio of 60. Concrete beam of size 150mm X 150mm X 700mm and laminate of size 150mm X 20mm X 700 mm were casted and tested under static loading to study the load deformation behaviour. A total of nine beams were casted out of which three of them are control beams (CB). The next three beams were bonded with SIFCON laminate to the bottom side of beam(SF1) and next set of beams were loaded upto 70% of ultimate load and then then bonded with SIFCON laminate (SF2). Results indicate that the strengthening of RC beams with SIFCON laminates has significantly improved the load carrying capacity and cracking behaviour of the beam.*

Key Words: **SIFCON, Flexural strength, Steel Fibre, Reinforced concrete beam**

1.INTRODUCTION

SIFCON (Slurry Infiltrated Fibrous Concrete) is new construction material which has high strength as well as large ductility and excellent potential for structural applications when accidental (or) abnormal loads are encountered during services. SIFCON is a high-strength, high-performance material containing a relatively high volume percentage of steel fibres as compared to Fibre Reinforced Concrete. It is also sometimes termed as 'high-volume fibrous concrete.

SIFCON is designed to give optimized performance characteristics for the given set of materials, usage and exposure conditions, consistent with requirement of costs, service life and durability. ACI has defined high performance concrete as a concrete meeting special combinations of performance and uniformity requirements that cannot always be achieved routinely using conventional constituents and normal mixing, placing, and curing practice. The development of high performance concrete is directly related to a number of recent technological milestones, in particular the discovery of the extraordinary dispersing action of superplasticizer, use of micro fillers like silica fume and fly ash, ability of fibres of different types, properties etc. The addition of steel fibers to high performance concrete makes it highly ductile and improves the energy absorption capacity.

The origin of SIFCON dates to 1979, when Prof. Lankard carried out extensive experiments in his laboratory 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.

SIFCON is made by preplacing short discrete filaments of steel (Steel Fibers) in to the moulds to full volume or to the desired part, consequently shaping an arrangement of network system. The matrix in SIFCON has no coarse aggregates, but a high cementitious content. However, it may contain fine or coarse sand and additives such as fly ash, micro silica and latex emulsions.

Proportions of cement and sand generally used for making SIFCON are 1: 1, 1:1.5, or 1:2. Cement slurry alone can also be used for some applications. Generally, fly ash or silica fume equal to 10 to 15% by weight of cement is used in the mix. The water-cement ratio varies between 0.3 and 0.4, while the percentage of the super plasticizer varies from 2 to 5% by weight of cement. The percentage of fibres by volume can be anywhere from 4 to 20%, even though the current practical range ranges only from 4 to 12%.

Even though, SIFCON is a recent construction material, it has found application in the areas of pavement repairs, repair of bridge structures, safe vaults and defense structures due its excellent absorption capacities

2. MATERIALS AND METHODS

2.1Material Properties

2.1.1 Cement

- Ordinary Portland cement of 53 grade
- Specific gravity – 3.14
- Normal consistency – 32 %
- Initial setting time – 90 minutes

2.1.2 Fine Aggregate

- Locally available M sand
- Specific gravity – 2.54

2.1.3 Coarse Aggregate

- Crushed angular aggregate
- Specific gravity – 2.63

2.1.4 Steel Bar

- Fe500 type of steel is used
- 8 mm # 2 no @ bottom

2.1.5 Steel Fiber

- Type of Steel fibre: straight fibre
- Diameter of steel fibre: 1 mm
- Aspect ratio 60

2.1.6 Admixture

- Super plasticizer: CONPLAST SP – 430

2.2 Testing method

The experimental study consists of casting of three sets of Reinforced Concrete beams. In the first set the flexural beams were cast using M25 concrete which are taken as the control beam designated as CB.
In the second set of beams, three flexure beams with M25 concrete were casted and then bonded with SIFCON laminate at the tension face of the beam(SF1).
In the third set of beams, three flexure beams with M25 concrete were casted. The beams after 28 days of curing were then loaded upto 70% of ultimate load and then then bonded with SIFCON laminate at the tension face of the beam (SF2).
All the three sets were casted, cured and tested for ultimate load.

3. EXPERIMENTAL PROGRAM

3.1 Casting of SIFCON Laminate

SIFCON laminates of size 150 × 20 × 700 mm were casted for bonding at the bottom face. Straight Steel fibres with 1 mm diameter and 60 aspect ratio was used for this purpose. The volume fraction adopted was 9%. The proportion of cement to sand was taken as 1:1 with water cement ratio of 0.4. super plasticizer of 0.6% 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. Making process of SIFCON is different from Fibre Reinforced Concrete.
The fibres were placed inside the mould manually and the cement sand slurry was then poured into the mould evenly above the preplaced fibres. The specimen is removed from mould after 24 hours of casting and was allowed to cure for a period of 28 days.

Fig 3.1 Casted SIFCON Laminate

3.2 Casting of RC Beams

All the testing specimens for the flexural beams are to be cast using M25 concrete mix with proportion 1:1.54:3.09 having the dimensions of 150 x 150 x 700 mm. A total of nine reinforced concrete beams were casted with water cement ratio of 0.45. Fe 500 bars with 8mm diameter were used for reinforcing the beam. Concrete was placed in layers and adequate compaction was carried out. To check targeted concrete compressive strength after 28 days, three cubes will be cast and tested to ensure getting the designed compressive strength. Moulds were allowed to dry for 24hrs and then hardened specimens were de-moulded and kept in water for curing for 28 days.

Fig 3.2: Casting of beams

3.3 Strengthening of SIFCON laminate to beam

Six numbers of SIFCON laminates of 20 mm thick are used for external strengthening of the RC beams. To obtain good adhesion, it is essential to have a clean sound substrate. All laitance, oil, grease etc. shall be cleaned by grinding, wire brushing, chipping, sand blasting or chemical etching. The soffit of the beams and bonding face of SIFCON laminates are made rough by wire brush and it is thoroughly cleaned to remove all dirt and debris.

After surface preparation, a two - part epoxy adhesive (Cerabond EP) with paste like consistency is used to bond laminates to the beam soffits. The base and hardeners are weighed in the ratio of 1:1 proportion and is thoroughly mixed to get a uniform colour. The mixed material is applied on the prepared concrete surface with stiff bristled brush. The laminate is then placed on the top of epoxy resin coating and held in position by dead weights. 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 3.3: Epoxy Resin

Fig 3.4: Beam bonded with SIFCON Laminate

3.3 Testing of Beams

After the 28 days of curing period, the beam surface was cleaned and checked for visible cracks. Before testing, the member was checked for dimensions and a detailed visual inspection was made with all information carefully recorded. Beams are tested in Two - point bending and are tested till the ultimate load is reached. At each stage of loading, the deflections are measured. The crack development and propagation are monitored and marked during the progress of the test. 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. Cracking and failure mode was checked visually, and a load-deflection plot was prepared.

Fig 3.5 Testing of beams

3.4 Loading of RC Beams

The beam was cleaned and placed on the flexural testing machine. The breaking load of control specimen was found out. The other two beams were stressed with 70% of the safe load obtained from the testing of control beam. And then the distressed beams were strengthened with the 20mm thick SIFCON laminates. The strengthened beams were cured for 7 days. Two-point load was applied to the beam specimen until it breaks and the failure load was noted.

4. RESULTS AND DISCUSSIONS

4.1 Flexural Test Result

Flexural strength is one measure of the tensile strength of concrete. The variation of deflection with load increment was noted for all the set of beam. The first crack loads are obtained by visual examination only. The ultimate load is obtained corresponding to the load beyond which the beam would not sustain additional deformation at the same load intensity. The average value of ultimate load carrying capacity of all set of beams is shown in the table 4.1.

Table 4.1 Experimental result of RC beam

Beam	Ultimate load (kN)	Deflection (mm)
CB	61.4	1.35
SF1	68.3	3.41
SF2	63.05	3.65

From the obtained result it is clear that strengthening of beams with laminates increases the load carrying capacity of beams. There is a significant increase in strength at all the load levels by externally bonding SIFCON laminates.

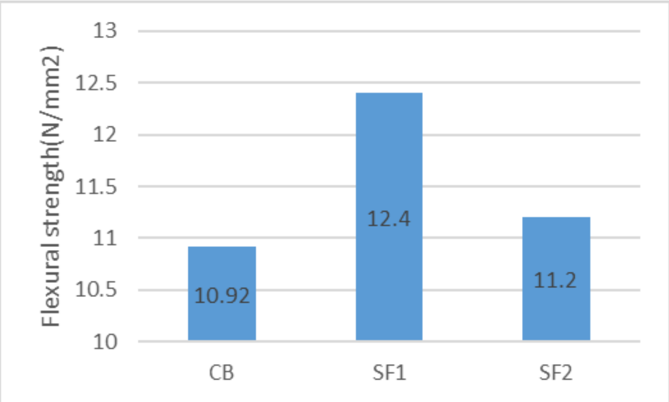

Fig 4.1: Flexural Strength of beam

It can be seen that flexural strength for SF1 has 13.55% more strength than control beam. Also flexural strength of SF2 has 2.56%. Also it is clear from table 4.1 that even after loading of 70% of the ultimate load of the beam the set SF2 can bear more than the ultimate load of the control beam.

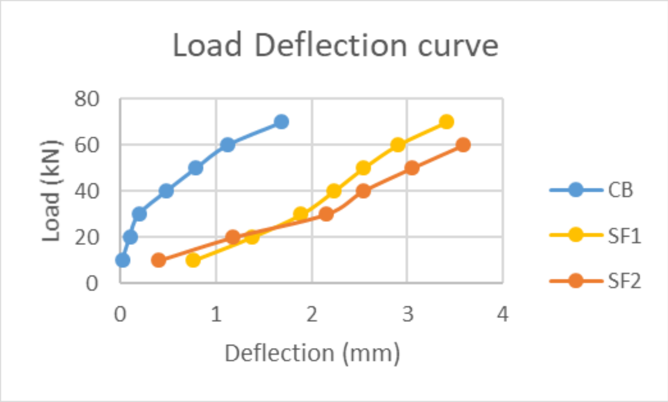

Fig 4.2: load deflection curve

5. CONCLUSION

Based on the experimental investigation the following conclusions were drawn.

- SIFCON laminates properly bonded to the tension face of RC beams can enhance flexural strength substantially.
- The flexural strength of RC beams with laminates on bottom face was found to be 13.55% more than that of conventional RC beams.
- The flexural strength of 70% loaded RC beams with laminates on bottom face was found to be 2.56% more than that of conventional RC beams.
- Retrofitting beams with materials such as SIFCON, significantly increases the flexural strength of distressed beams. Therefore, by strengthening the beam, performance of the weak structure can be improved.
- Additionally, no minimum concrete cover is needed to prevent corrosion of the reinforcement, if laminates are provided.
- Flexible epoxy system will ensure that the bond line does not break before failure and participate fully in the structural resistance of the strengthened beams.

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