Retrofitting of RC Beam using SIFCON(Slurry Infitrated Fibre Concrete) Panels

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***Abstract* – *The aim of the research is to present the experimental results concerning the cyclic behavior of reinforced concrete (RC) beams, which is externally retrofitted with slurry infiltrated fibrous concrete laminates. This study mainly deals with a method for retrofitting of reinforced concrete beams using High Performance Fiber Reinforced Cementitious Composites (HPFRCCs). The use of SIFCON matrix in compression zone of flexural member leads to improve ductility and energy absorption capacity of the member. SIFCON laminates are directly bonded to the bottom face of the beam by epoxy adhesive and are tested under compression cyclic loading. Nine beams of size 150 mm width x 300 mm depth x 1200 mm length with effective span of 1000 mm are cast and tested in the laboratory. The laminates of size 150 mm width x 25 mm depth x 1200 mm length are bonded beneath the bottom. Three beams were retrofitted with SIFCON laminates, three beams were strengthened with SIFCON laminates and remaining three beams were tested under compression cyclic loading as control specimen.*

***Key Words*: Reinforced concrete beam, Retrofitting, Slurry infiltrated fiber, Epoxy, SIFCON, HPFRCC**

1. INTRODUCTION

Slurry infiltrated fiber concrete (SIFCON) can be considered as a special type of concrete with high fiber content. This matrix usually consists of cement slurry or flowing mortar. SIDCON can be used in areas where high ductility and resistance to impact are needed. The use of SIFCON matrix in compression zone of flexural member leads to improve ductility and energy absorption. SIFCON contains relatively high cement and sand generally used for making SIFCON are 1:1, 1:1.2 and 1:2 cement slurry. The use of SIFCON matrix in compression zone of a flexural member leads to improve ductility and energy absorption. Applying pressure to fresh SIFCON minimizes the voids, the ultimate strength and absorbed energy if SIFCON confined concrete is very similar to the results of GFRP confined concrete. The comparison shows that SIFCON confinement method can be noted as a vying method with respect to the well-known FRP confinement technique.

1.1 Objective

- Determination of compressive strength of normal concrete and SIFCON
- Determination of flexural strength of SIFCON laminates.
- To check the deformation properties of control beams.
- Retrofitting of RCC beam using SIFCON panels.
- Rehabilitation of RCC beam using SIFCON panels

1.2 Scope

A new idea to retrofit with SIFCON panels and suggest their future scope in improving construction practices.

1.3 Methodology

- Literature review
- Collection of materials
- Initial tests on materials
- Casting of cubes and panels
- Preparation of beams and SIFCON panel with optimum percentage of steel fiber
- Flexural testing
- Retrofitting
- Analysis of results

2. MATERIALS USED

2.1 Cement

In this study ordinary Portland cement-grade 53 was used. Specific gravity and standard consistency is 3.12 and 34%. Initial setting time of cement is 74 minutes.

2.2 Fine Aggregate

For this study we used manufactured sand it should be free from impurities. The specific gravity of used aggregate was 2.6

2.3 water

The water fit for drinking is used for this experiment.

2.4 Steel Reinforcement

The high yield strength (HYSD) bars having yield strength of 415 N/mm^2 were used as reinforcement in the concrete. The longitudinal tension reinforcement used was HYSD bars of 8 mm diameter and the hanger bars were high yield strength bars of 6 mm diameter and 6 mm diameter mild steel bars are used for making stirrups

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2.5 Steel Fiber

In this study crimped steel fibers were used. Steel fibers were obtained from steel wools private limited Nagpur. The properties and specification of steel fibers are fibers begin to function in a structural supportive manner when the concrete matrix starts to crack, just like traditional reinforcement.

Table -1: properties of steel fiber

SL. NO	Properties	Specification
1	Type	Crimped
2	Tensile strength (Mpa)	1196
3	Length (mm)	30
4	Diameter (mm)	.50
5	Aspect ratio	60

2.6 Admixture

The admixture used for this study was master rheobild 1123. It is found that the admixture improves workability of concrete along with a decrease in water cement ratio.

Table -2: properties of admixture

property	Value
Specific gravity	1.24
Aspect	Dark brown free flowing liquid
PH	<6
Chloride ion content	>0.2%

3. Experimental Program

3.1 Mix proportioning of concrete

M25 grade concrete mix is designed as per standard design procedures using the properties of the materials used. The M25 mix is designed as per IS-10252-2009

Table -3 Mix proportion

Grade designation	M25
Type of cement	OPC 53 grade
Assumed water/ cement ratio	0.4
workability	75 mm (slump)
Maximum cement content	450 kg/m^3
Proportion	1:1.39:2.52

3.2 Mix proportioning of SIFCON

Table -4 mix proportion

Ratio of cement to sand	1:2
Assumed water / cement ratio	0.4
Density of mortar	2080 Kg/cum

3.3 Design of beam

In this study the RCC beams were designed using M25 grade concrete and fe415 steel. The dimensions of the beams were designed with the standard design procedure in Limit state method. The beam is designed as per IS 456:2000. Since maximum length of beam by flexure is 1 m adopting the length of beam as 1.2 m, the breadth of the beam is assumed to be 0.15 m. Providing 8 mm diameter 2 longitudinal bars at tension zone, 6 mm diameter bars as stirrup holders at compression zone and provide 6 mm diameter 2 legged stirrups @ 100 mm c/c

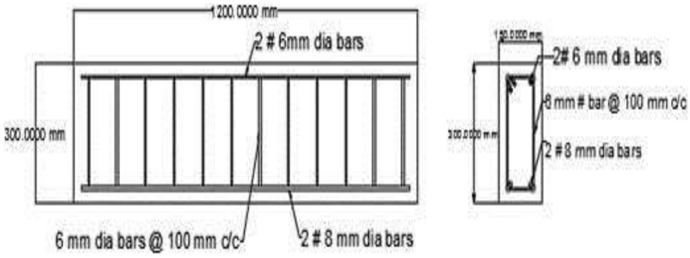

Fig -1: Detailing of Steel Reinforcement

3.4 Casting of cubes

The cubes of size 150 mm x 150 mm x 150 mm where casted at different percentage of steel fibres such as 0%, 5%, 6%, 7%, 8%, 9%, 10%, 11%, 12%. For each percentage of steel fiber, 3 cubes where cured for 28 days.

3.5 Casting of RC beam

The concrete mix proportion was 1:1.389:2.52 with water cement ratio 0.40. Ordinary Portland cement (OPC) 53 grade, M sand confirming to zone II as per IS 2386(Part I) 1963 and coarse angular aggregate of 20 mm size confirming to zone II were used as the concrete ingredient. The beams are designed as under reinforced section(as per IS 456-2000), reinforced with high yield strength deformed bars of two 8 mm diameter on tension side and two numbers of 10 mm diameter hanger bars and 6 mm diameter 2 legged stirrups at 100 mm c\c throughout the span. A total of nine beams of size 150 mm width x 300 mm depth x 1200 mm length with effective span of 1000 mm where casted. Three beams as control beam, three as retrofitting beam and three as strengthened beam.

3.6 Loading on beams

The simply supported concrete beam was loaded by two point loading placed along the span of the beam. Loading was done such that the load was increased until flexural failure took place. The loading was done such that the load was increased until flexural failure took place. The loading was done using a hydraulic loading frame of capacity about 100 tons. The load was applied gradually to the first crack formation, and then the load is released. The cracked portion that is the bottom of the beam is attached by SIFCON panel using glues. Then the beam is pre-loaded to its maximum capacity for retrofitting beams, and the strengthening beams are attached by the SIFCON panel before loading.

Fig -2: Loading frame

Fig -3: Testing of beam

3.7 Deflection measurement

The deflection of the beam during flexural bending was calculated using deflection gauge set at the bottom middle point of the beam. The maximum deflection of the beam is obtained from the centre of the beam. The gauge was placed such that it was supported by a stand placed at the bottom gauge. Deflection was shown soon after the increase in the load acting in the beam. Deflection was noted for every increase in 10 KN up to the formation of initial cracks on the beam.

3.8 Strengthening

Strengthening is done using SIFCON laminates. Laminates of 25 mm thick are used for strengthening the RC beams. After the surface preparation the adhesive Nitobond EP no more nails paste like consistency is used to bond laminates to the beam soffits. The SIFCON laminates which were casted earlier were placed over the beam and held in correct position by dead weights. For gluing, the beams are inverted and the Laminates are placed at the top. But when it comes to the field application the laminates has to be bonded to the soffit of the beam. The laminates have to be fixed after proper gluing at the bottom of the beam and can be jacked up.

Fig -4: Attaching panel using Adhesive

4. RESULTS AND DISCUSSIONS

4.1 Compression test

The compressive strength test results for 9.0 percentage gives better results, when the volume fraction and consequent fiber content increases, the infiltration of cement matrix into the fiber reduces and this will resulted in reduction of strength for higher volume fraction of steel fiber.

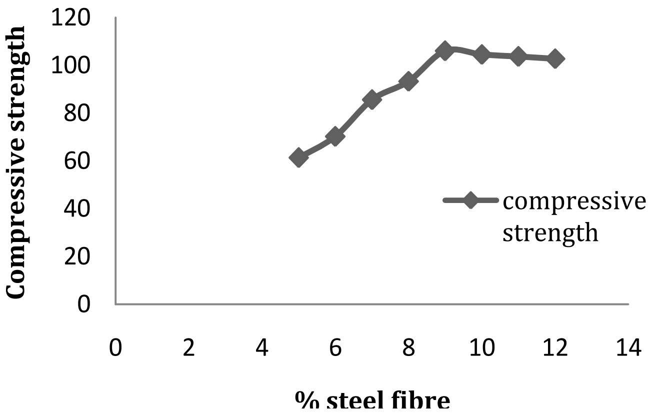

Chart -1: Compressive strength result

4.2 Flexural test result

The details of flexure (bending) test results for SIFCON laminates (100 X 25 X 500) are presented in table. The load-deflection curve has a short linear elastic response and a considerable let-up at the peak. The fiber length and fiber volume fraction influence key for strength and ductility.

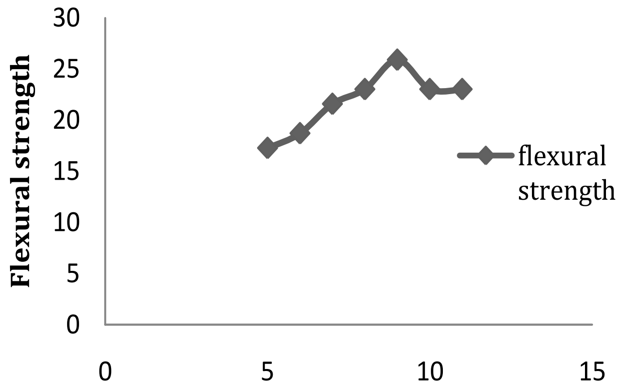

Chart- 2 Flexural strength results

4.3 Beam testing

The beams where tested under cyclic compression loading, the beams where designed for flexural and the flexural loading was done on the loading frame and flexural yield load was obtained from the deflection gauge. The three beams were tested under compression cyclic loading as control specimen, three beams were retrofitted with SIFCON laminates, and three beams were strengthened with SIFCON laminates. The ultimate loads are obtained corresponding to the load beyond which the beam cannot sustain additional deformation at the same load intensity.

Table -5 Experimental Result

Beam designation	First crack stage		Ultimate stage	
	Load (KN)	Deflection (mm)	Load (KN)	Deflection (mm)
Control beam	100	8	130	30
Control beam	100	11	130	34
Control beam	105	10	130	33
Retrofitted beam	100	14	150	50
Retrofitted beam	110	14	150	55
Retrofitted beam	115	13	155	55
Strengthened beam	130	18	170	65
Strengthened beam	140	20	180	70
Strengthened beam	140	20	170	70

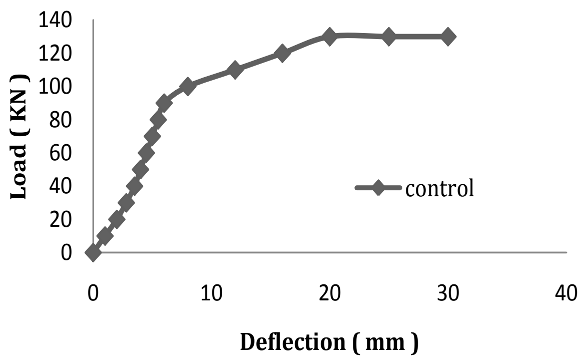

Chart -3 Load deflection of control beam

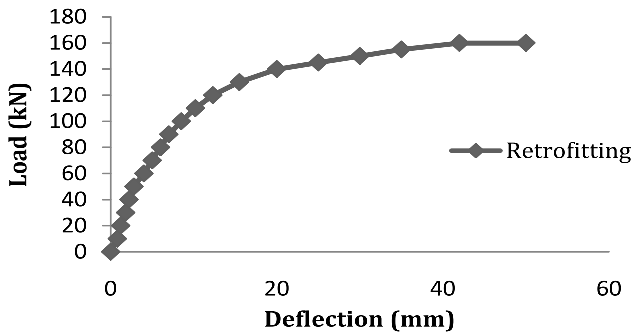

Chart – 4 Load deflection of Retrofitted beam

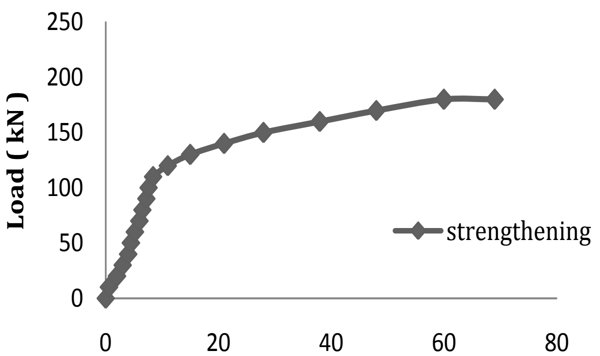

Chart -5 Load deflection of strengthened beam

From the above drawn graphs almost up to 100 KN, all the three beams, that is control beam, retrofitted beam and strengthened beam there is a linear variation of load and deflection. For the control beam after first crack the load carrying capacity reduces. For small increment of load large deflection is obtained. For the retrofitted beam after first crack the sudden widening of crack were restricted and 25 to 30% of load where taken than control beam. For the strengthened beam the SIFCON panel gives better support to the tension zone. After the first crack, then also it shows linear variation between load and deflection. The strengthened beam carries almost 60% load than control beam.

Fig -5: Retrofitted beam

4.4 Discussions

For initial loads the cracks obtained are identified by visual examination only. At experimental ultimate load level, the strengthened beams show an increase of 62% with respect to the control specimens and the retrofitted beams show an increase of 25% with respect to the control specimens.

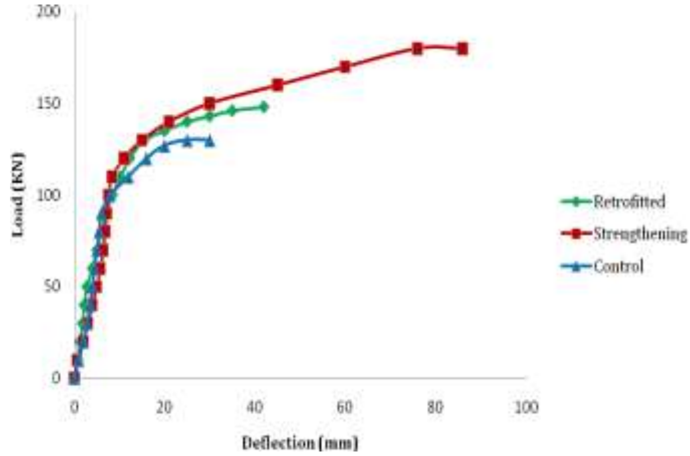

Chart -6 Comparing load deflection curves

Based on the experimental results, it is observed that the strength is increased at all levels, when the SIFCON laminates are bonded externally. This increase may be attributed to the increase in the composite moment of inertia of the section and to increase in tensile cracking strength of concrete due to confinement. Further, it is to be noted that the increase in load carrying capacity is possible only when other modes of failure do not interfere. Almost all the beams failed in flexure mode only. The beams showed significant flexural cracking and vertical deflection near to failure. Well-distributed closely spaced cracking was observed. None of the beams exhibited sudden brittle failure. Also the strengthened beams exhibit an increase in flexural capacity.

5. CONCLUSIONS

In this research the actual load carrying capacity of reinforced concrete beam is increased by the method of retrofitting using high performance fiber reinforced cementitious composites (HPFRCCs) called SIFCON, which are directly bonded to the tension side, on the soffit of the beam by epoxy adhesive and are tested under compression cyclic loading. The optimum percentage of SIFCON was obtained by compression testing and flexural testing. Cubes and panels (laminates) were casted and tested on different steel fiber volume were attained as optimum value. When the volume fraction and consequent fiber content increases, the penetration capacity of cement matrix into the fiber reduces and this could be the reason for reduction in strength for higher volume fraction.

The flexural strength of RC beam is significantly increased, when the HPFRCC laminates such as SIFCON, which is properly bonded to the tension face. The SIFCON strengthened beams show an increase in flexural strength of 62% with respect to control specimens and the retrofitted beams shows an increase of 25% with respect to the control specimens for laminates having volume fraction 9.0% and aspect ratio 60. All the beams strengthened with SIFCON laminates with optimum fraction 9.0 percent and aspect ratio 60, experience flexural failure. None of the beams shows improved ductility with respect to control beams because of the presence of metal fibers.

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