Experimental Study on Strengthening of RC Beam with Sifcon Laminates

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Abstract- *Now a day's natural and manmade disaster like Earthquake, Cyclone etc., plays an important role in the behaviour of structures. Hence the structures has to be designed in a good manner which resists higher seismic and impact forces. Strengthening of existing RC framed buildings for impacting 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 build when modern seismic requirements did not exist. SIFCON posses high strength, improved ductility, impact resistance and enhanced energy absorption capacity, so it is used as an option for strengthening the conventional reinforced concrete beam. The main thrust of the study has been aimed at characterizing the flexural strength of the beam strengthened with precast SIFCON laminate externally. Slurry infiltrated fibrous concrete (SIFCON), an exceedingly improved version of conventional fibre reinforced concrete (FRC), is a unique construction material having unique properties in the areas of both strength and ductility. SIFCON being a new kind of fibre reinforced composite material, limited literature is available regarding its application as structural element. In the present study, investigations are carried out to study the behaviour of reinforced concrete beams with SIFCON laminates. Experimental programmes have to be carried out to study the behaviour of flexural and shear RC beams with precast SIFCON laminates. The concrete mixes for RC beams have to be designed to obtain a concrete grade of M30. The steel fibres used in the study were hooked end fibres having 0.6mm diameter and aspect ratio of 60.*

I. INTRODUCTION

Concrete is remarkably strong in compression but it is equally weak intension. Hence, the use of plain concrete as a structural material is limited to situations where significant tensile stresses and strains do not develop. SIFCON is the extension of conventional FRC that differs in terms of fabrication and composition. In FRC, the fibre content varies from 1 to 3 % by volume whereas, in SIFCON, the fibre content varies from 6 to 20 %.SIFCON is prepared by cement slurry into a mixing of fibres. SIFCON, a high performance material containing a relatively high volume percentage of steel fibres as compared to steel fibre reinforced concrete. SIFCON is a high performance material that possesses excellent mechanical properties coupled with greater energy absorption characteristics.

SIFCON possess properties such as strength (compression, tension, bending and shear), ductility, toughness, durability, stiffness and energy absorption capacity under cyclic loads.
These properties are achieved through an optimized combination of matrix properties, fibre reinforcing parameters and fibre content.

Some of special properties of SIFCON are as follows,

- It has maximum value of shear strength
- It has high modulus of elasticity
- It exhibits an extreme ductility behavior under compression monotonic and high amplitude cyclic loading.
- It has a larger strain capacity
- Flexural Strength found to be very high.

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.

II. COLLECTION OF MATERIALS

a) Ordinary Portland Cement of 53 grade will be used
b) Fine aggregate passing through 300µ sieve will be for SIFCON laminates
c) Natural river sand or M sand will be used as fine aggregate for beams
d) Coarse aggregate of size 12mm to 20mm will be used for conventional concrete beam
e) 12 mm and 6 mm diameter Fe500 HYSD bars will be used as main reinforcement and shear reinforcement respectively
f) Steel fibres of length 30 mm and 0.6mm diameter will be used (Aspect ratio 60)
g) Potable drinking water will be used for mixing and curing the concrete

III. MATERIAL PROPERTIES:

3.1 Cement

The cement used is ordinary Portland cement of 53-grade conforming to IS 12269. The cement should be fresh and of uniform consistency. Where there is evidence of lumps or any foreign matter in the material, it should not be used. The cement should be stored under dry conditions and for as short duration as possible.

3.2 Aggregates

A) Fine Aggregates:

M Sand shall be obtained from a reliable supplier .It should be clean, hard, strong, and free of organic impurities and deleterious substance. It should inert with respect to other materials used and of suitable type with regard to strength, density, shrinkage and durability of mortar made with it. Grading of the sand is to be such that a mortar of specified proportions is produced with a uniform distribution of the aggregate, which will have a high density and good workability and which will work into position without segregation and without use of high water content. The fineness of the sand should be such that 100% of it passes standard sieve No.8.The fine aggregate which is the inert material occupying 60 to 75 percent of the volume of mortar must get hard strong nonporous and chemically inert. Fine aggregates conforming to grading zone II with particles greater than 2.36 mm and smaller than 150 mm removed are suitable.

B) Normal Weight Coarse Aggregate:

Machine crushed hard granite chips of 67% passing through 20 mm sieve and retained on 12 mm sieve and 33% passing through 12 mm and retained on 10 mm sieve was used as coarse aggregate throughout the work.

3.3 Water

Water used in the mixing is to be fresh and free from any organic and harmful solutions which will lead to deterioration in the properties of the mortar. Salt water is not to be used. Potable water is fit for use mixing water as well as for curing of beams

3.4 Details of Mould

Beam mould - 2000 mm x 150 mm x 250 mm

Laminate mould - 500 mm x 100 mm x 50 mm

IV. RESULTS AND DISCUSSION

4.1 Behaviour of Beams

In most field applications, SIFCON is subjected to bending stress, at least partially. Hence, the behavior under flexural loading plays an important role in many applications. An experimental investigation was carried out to study the behavior of flexure RC beam specimens under cyclic loading. The parameters like first crack load and ultimate load carrying capacity were observed.

4.2 Load Behaviour

The maximum load level was increased. The beam specimen was loaded with two point loading. The specimen must be carefully aligned with the axis of loading device. The load was increased and decreased in each stage. The first crack load for conventional beam and strengthened beams was found to be 28 kN and 39kN respectively. The ultimate load carrying capacity of strengthened beams was found to be 57 kN whereas the corresponding value for conventional beam were 72kN. The comparison of first crack load and ultimate load for conventional beam and strengthened RC beams were shown in Figure 4.1 and Figure 4.2 respectively

4.1.3 Test Results

Table 4.1 Test Results

Beam	First crack Load	Ultimate Load
Conventional	28kN	57kN
Strengthened	39kN	72kN

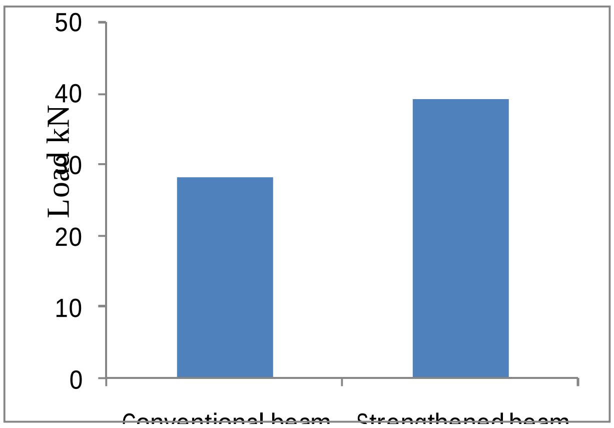

Figure 4.1 Comparison of First Crack load

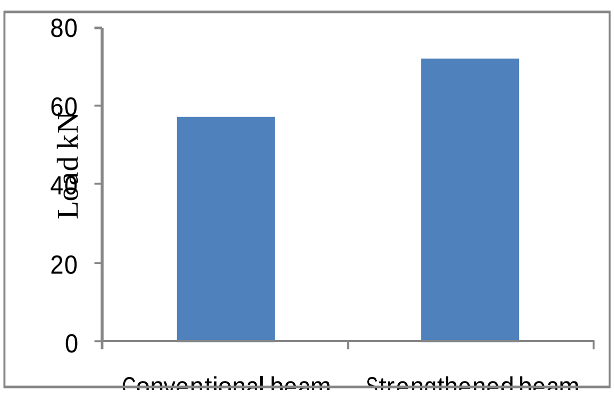

Figure 4.2 Comparison of Ultimate load

4.1.4 Behavior and Mode of Failure

Conventional beam and strengthened beam have failed in flexure more by yielding steel for RC beams, crushing and spalling of concrete takes place after the yieliding of steel in tension zone. Behavior of RC beams under two point loading are listed below,

i. The ultimate load was observed 57kN. More number of cracks have been observed during final failure of the specimen

ii. In strengthened specimen ultimate load was observed 72kN. Less number of cracks have been observed during the final failure of the specimen. This may be due to laminate confinement in bottom face.

Flexural beam with laminate suffers lesser damage as compared to control specimen. The failure pattern of the conventional beam is shown in Figure 4.3 and strengthened RC beam is shown in Figure 4.4

Figure 4.3 Failure pattern in conventional beam

Figure 4.4 Failure pattern in strengthened RC beam

4.1.5 MODULUS OF RUPTURE

Table 4.2 Modulus of Rupture

Beam	Maximum load(P)	Modulus of Rupture(f_b)
Conventional beam	57kN	0.0214 kN/mm^2
Strengthened beam	72kN	0.027 kN/mm^2

$$f_b = (P \times l) / (b \times d^2)$$

Here,

P = Maximum load applied to the specimen

l = length of the specimen

b = Measured width of the specimen

d = Measured depth of the specimen

f_b for conventional beam = $(57 \times 1500) / (100 \times 200^2)$

= 0.0214 kN/mm^2

fb for strengthened beam = $(72 \times 1500) / (100 \times 200^2)$

= 0.027 kN/mm^2

V. CONCLUSION

Based on the results obtained from the experiments, the following conclusions are drawn:

1. SIFCON laminates properly bonded to the tension face of the RC beams can enhance the flexural strength substantially. The SIFCON strengthened beams exhibit an increase in flexural strength based on volume fraction and aspect ratio.

2. At any given load level, the deflections are increased significantly thereby increasing the stiffness for the strengthened beam.

3. A flexible epoxy system will ensure that the bond line does not break before failure and participate fully in the structural resistance of SIFCON.

The tests results are compared with that of conventional RC beam subjected to similar loading condition.

1. The first crack load of strengthened beam was found to be greater than that of conventional flexural beam.

2. The ultimate load carrying capacity of strengthened beam was found to be higher than that of conventional flexural beam.

From the test results it can be seen that SIFCON strengthened beams perform well in all aspects when compared to conventional beam. Hence, SIFCON proves to be an effective material to enhance the strength and for the repair or strengthening of RC beams.

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