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RETROFITTING OF REINFORCED CONCRETE BEAMS BY USING CARBON FIBRE REINFORCED POLYMER SHEETS

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ABSTRACT

In day todays life, it is an important to modify, repair, rehabilitation or reconstruction of existing structures because of various factors like bond failure between beam and column joint, corrosion which leads deterioration, natural disasters etc. These factors results in cracking of our structures, i.e the structures becomes inservicible. Hence the modification of these structures is required. This paper shows an experimental study on RC beams retrofitted using unidirectional and bi-directional CFRP sheet. The main objective of this study is to investigate the behaviour of RC beams after retrofitting with CFRP sheets.

Keywords: Retrofitting, Flexural strength, Crack Pattern, Deflection, RC Beams etc.

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1. INTRODUCTION

Retrofitting is the technique of repair and rehabilitation to make structures more resistant to seismic activity, shaking of earth's surface etc. Replacement of the full structure leads various disadvantages like labour charges, cost of the building material etc. It also leads inconvenience because of improper function of a structure e.g. traffic jams. This work is about an effect of CFRP sheets having different thicknesses over the RC beams by using experiments. Corrosion of the reinforcement and deterioration of the structures in RC structures are common problems and many researchers finding an alternative materials and techniques of rehabilitation and many solutions have been put forwarded since a long times and there remains always a demand for looking to use new materials and techniques for repair and rehabilitation of the structures. Retrofitting with the CFRP sheets as external reinforcement plays a great role in a civil engineering.

2. MATERIALS USED

2.1. Cement

An OPC of Grade 43 satisfying all the requirements of IS 8112:1989 is utilized in this context. It was tested for its physical properties as per Indian Standard specifications.

Table 1 Characteristics of cement

S.No	Characteristics	Value obtained	As per IS:8112
1	Specific gravity	3.15	2.5-3.5
2	Standard Consistency (%)	32	30
3	Fineness (kg/m^2)	245	275
4	soundness(mm)	3	10
5	Initial setting time (min.)	50	30
6	Final setting Time (min.)	260	600
7	Compressive strength 7days (N/mm2)	26	23 (Min)
	14 days(N/mm2)	35	33 (Min)
	28 days(N/mm2)	46	43 (Min)

2.2. Sand

Sand used in this study was locally available with fineness modulus of 2.19 and specific gravity of 2.69 has been used.

2.3. Coarse Aggregate

Maximum size of Aggregates of 20mm having specific gravity of 2.74 were used and grading zone of aggregates was Zone II as per IS specifications.

2.4. Water

Clean tape water used that was free from suspended particles and chemical substance admixture also used during mixing.

2.5. Carbon Fibre Sheets

CFRP is having high strength, durability and one more thing it is easy to install. It is commonly used whenever high strength and rigidity is needed. Both Unidirectional and bi-directional carbon fibre sheets with different thickness were used as a retrofitting material to the beams.

Table 2 Properties of CFRP sheet.

Fiber material	High strength carbon
Areal Weight	245 gm/m2
Fabric width	500 mm
Ultimate Tensile Strength	3800 Mpa
Tensile Modulus	>2750Mpa

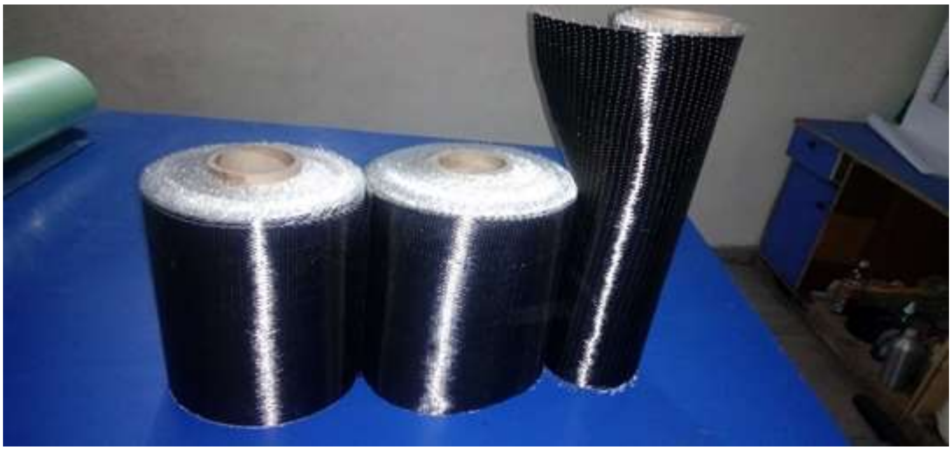
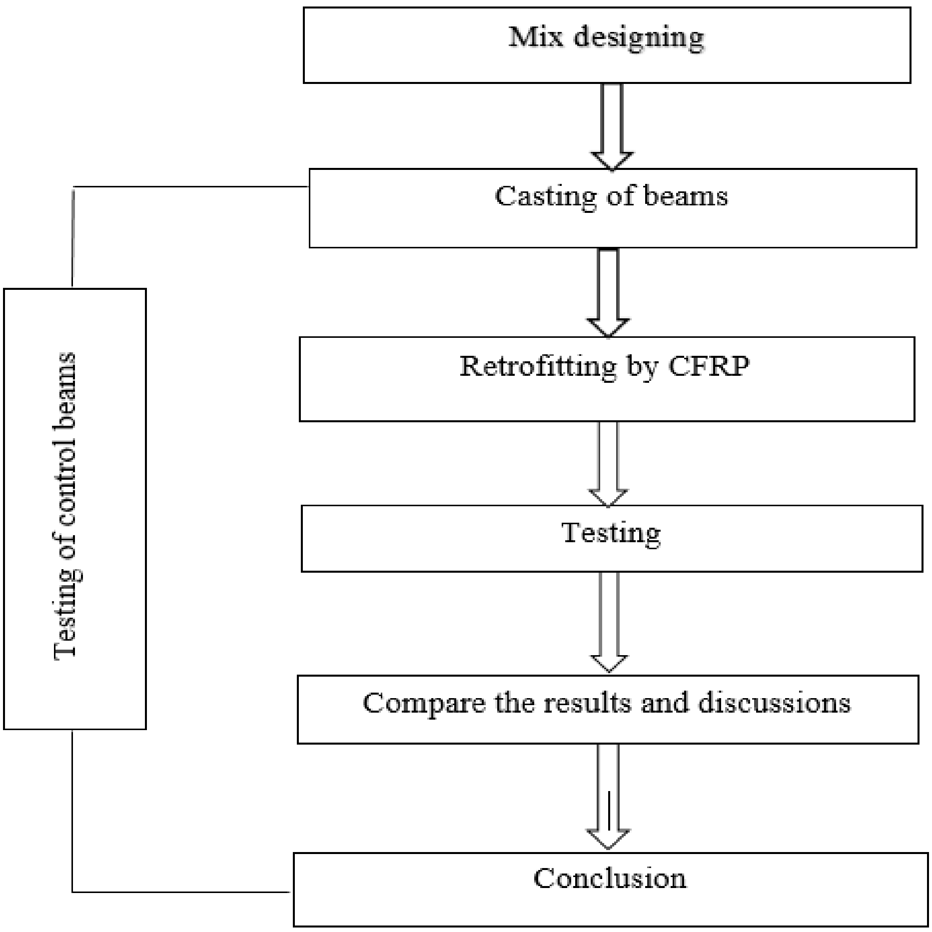


Figure 1 Uni-directional and bi-directional Carbon fibre sheets.

2.6. Epoxy

Epoxy resin with hardener was used as a bond purpose between concrete surface and carbon fiber sheet. The epoxy resin primer is mixed as per the guidance of manufacturer's instructions. And the mixing is carried out in a plastic container having base hardener ratio (Base: Hardener =3.33Kg: 1Kg) i.e, hardener 30% of epoxy resin. After the uniform mixing, epoxy resin is applied to the concrete surface of RC Beams.

3. METHODOLOGY



Design concrete mix M30 of 1:1.77:2.89 by weight is used. In this context, the water cementaceous ratio of 0.45 was used. Before the casting of RC-beams, only three cubes were cast and were tested for compressive strength (at the age of 28 days). The average compressive strength of the three concrete cubes was 26.81 N/mm2. HYBDbars of 12 mm dia diameter in tension zone and 10mm diameter in compression zone were used and 8mm diameters were used as shear reinforcement.

4. CASTING OF RC-BEAMS

Twelve beams were cast. The dimensions of all the specimens were identical and were identical in shape i.e' rectangular having dimensions 1000mm in length and 300mm x 150mm in cross section. The rectangular moulds were prepared using boiling water-proof plywood as shown in figure 3. For designing the beams, the design mix ratio was used. Fig.2 shows rectangular reinforment cage which consists 12 mm diameter of two bars as tension reinforcement at the soffit of the beam and 10 mm diameter of two bars as compression reinforcement and 8mm diameter for rings as shear reinforcement with c/c spacing 100mm.Twelve beams were cast in which three of them as control beams and rest nine beams were retrofitted. The first three beams were tested in four points loading for failure. The rest nine beams were tested in four-point loading until cracks appeared on them and these cracked beams were unloaded and retrofitted the cracked beams with unidirectional and bi-directional CFRP sheets having different thicknesses.

Figure 2 Reinforcement cage

Figure 3 Plywood moud

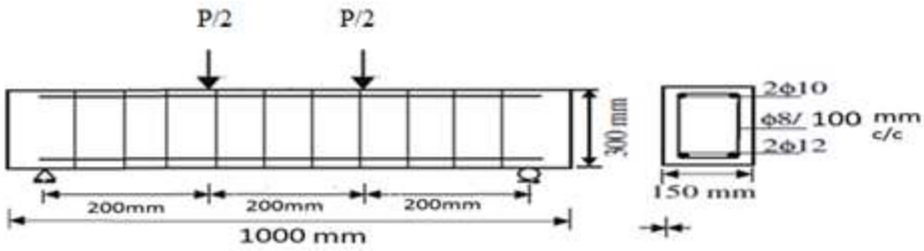


Figure 4 Geometry, Detail of reinforcement and loads of the beams.

Figure 5 Casting of RC Beam

5. RETROFITTING OF BEAMS

All the four sides of the beams were wrapped with CFRP sheet used full wrapping technique as the method of retrofitting. Before applying the epoxy primer, the surface of the beams was made rough so as to get better bond between concrete surface and CFRP sheet. Wire brush is used for roughing the surface of RC- beam and then surface was cleaned with clean water to remove the dirt. And the mixing is carried out in a plastic container having base hardener ratio (Base: Hardener =3.33Kg: 1Kg) i.e, hardener 30% of epoxy resin. The epoxy resin primer is mixed in a plastic container as shown in fig.6 as per the guidance of manufacturer's instructions. After the uniform mixing, epoxy resin was applied to the concrete surface of RC Beams. After that, CFRP sheets were applied on the top coating of the epoxy resin and the sheet on the beam was pressed to eliminate entrapped air bubbles. This retrofitting of beams is done under room temperature. Before testing the Retrofitted beams, they were cured for 2 days at room temperature.

Mixing of Epoxy Resin Application of epoxy resin Retrofitted Beams

Figure 6 Retrofitting of Beams.

6. TESTING OF BEAMS

Both control and retrofitted beams were tested for flexural strength. Twelve beams were cast. For all the beams, the test procedure was same. The beams were cured for a 28 days. In twelve beams three beams were test for failure and rest nine beams were retrofitted with CFRP sheets and six beams were retrofitted with uni-directional CFRP sheets having thickness 0.2mm and 0.3mm and three beams were retrofitted with bi-directional CFRP sheets having thickness 0.4mm. For clear visibility of cracks on the surfaces of the beams, the surface of beams is cleaned with cotton. The arrangement of Four-point Loading is used for testing of beams because in arrangement, the maximum flexural stress is spread over the section of the beam between loading points and four point loading tends to the best choice if the material is not homogenous. Four point loading arrangement was done as shown in the fig.7 which consists of beam supported on the two steel rollers bearing 200mm from ends of the beams. The remaining portion 600 mm was divided into three equal parts of 200 mm as shown in the fig 7. Till the appearance of the first crack recorded on automatic UTM, the deflections of the beams were noted. Then the fracture load was recorded as the load at which load on the automatic UTM returned back. The average load of the three control specimens and average of nine retrofitted beams has been taken and the load – deflection graph was obtained. The deflection curve of each beam in four points loading is analyzed.

Figure 7 Experimental test set up

The deflections of each type of beams retrofitted with uni-directional and bi-directional CFRP sheets were compared with the control RC beams. Also the behaviour of load deflection was compared between beams retrofitted with unidirectional and bi-directional CFRP sheets having different thicknesses and the same reinforcement. It has found that the behaviour of the beams retrofitted with CFRP sheets is better than the control beams. The deflection lowers when retrofitted externally with CFRP sheets. It has also found that beams retrofitted with bi-directional CFRP sheets shows less deflection and high load bearing capacity than the beams retrofitted with uni-directional CFRP sheets. Also load bearing capacity increase with the thickness of CFRP sheets. The use of CFRP sheet shows less growth of crack formation.

Control beam Retrofitted Beam

Figure 7 Failure pattern of the beams

Since the full wrapping technique was used for strengthening of the beams, initially the cracks were not visible. As the increase in loading increases the propagation of the cracks but due to wrapping of CFRP sheets around the beams (uni-directional and bi-directional) leads less crack formation. The result shows that due to the application of the CFRP sheets around the beams are not only beneficial in flexure but shear in strengthening also. Fig. 8 shows the failure pattern.

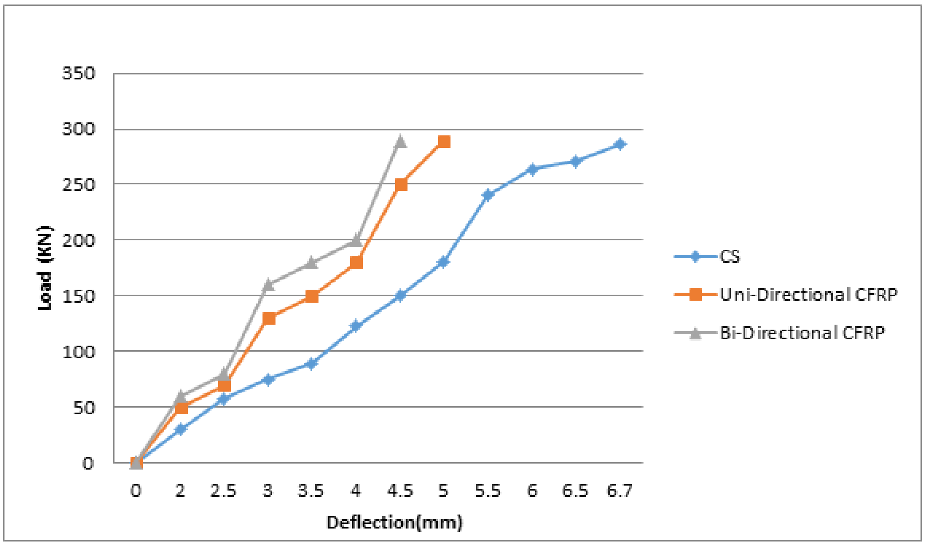


Figure 8 Load vs Deflection Graph

It has been found that less cracks appeared on the beams retrofitted with bi-directional CFRP having thickness 0.4mm as compared with the beams retrofitted with that of the uni-directional CFRP sheets having thickness 0.2mm and 0.3mm. The control beams shows the maximum deflections and less ultimate load carrying capacity. It is clear from the graph that all the beams retrofitted with CFRP sheets have better load deflection characteristics than the control beams.

When all the beams retrofitted with CFRP sheets are considered it is found that the beams with 0.4mm CFRP sheet wrapping had a better load deflection behavior compared to the other retrofitted beams. It is found that retrofitting with CFRP sheets is more effective in improving the flexural strength of the beam. The first crack appeared at the load of 252 KN on the beam. Also to some extent, retrofitting of beams by using CFRP sheets (uni-directional and bi-directional) reduced the deflections of the beams.

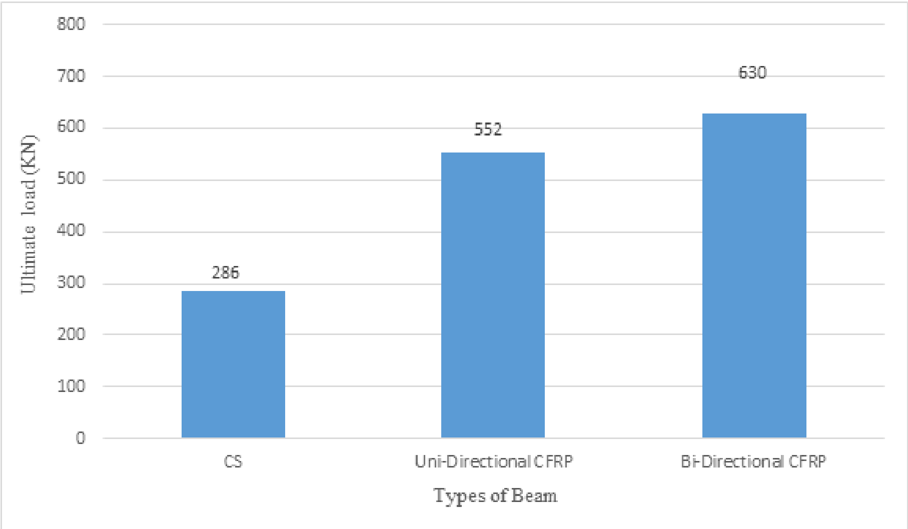


Figure 9 Comparison of Ultimate Load Capacity

From the fig.9, it is clear that retrofitting with CFRP sheets enhances the ultimate load capacity. The ultimate load of control beam was 286 KN, whereas the ultimate load of all the retrofitted beams had greater than 550 KN. The ultimate load capacity of the beams retrofitted with uni-directional and bi-directional CFRP sheet CFRP sheets increased by 93% and 120% respectively than the control RCC beam.

7. CONCLUSION

The flexural behaviour of reinforced concrete beams externally strengthened by CFRP sheets (uni-directional and bi-directional) having different thicknesses are studied in this experimental investigation. From the calculated strength values and the test results, the following conclusions are drawn:

- Due to strengthening of beams with CFRP sheets externally, The ultimate load bearing capacity and the flexural strength of the beams increased.
- The first Average crack load of control beams and retrofitted beams were found at 252 KN and above 500 KN respectively. The initial cracks in the retrofitted beams appeared at a higher load as compared to control beams.
- Due to the full wrapping technique around all the four sides of the RCC beams, the deflections of the beams also reduced.
- When compared the control RCC beams with the beams retrofitted with uni-directional and bi-directional CFRP sheet CFRP sheets, there increased ultimate load capacity by 93% and 120% respectively.
- Of course, the cost of the material is high but the beams retrofitted with CFRP sheets shows the maximum ultimate load capacity.
- Debonding between CFRP sheet and concrete occurs at high loads, there occurs debonding at 530 KN in case of uni-directional CFRP sheets whereas at 597 KN in bi-directional CFRP sheet, since CFRP sheets shows composite action.
- Cracks due to the loads were minimized by the application of the CFRP sheets externally on the beams that indicates serviceability of the cracked beams increases.
- It is found that the wrapping of CFRP sheets around all the four sides of beams is more effective in improving ultimate load capacity of beams and their flexural strength.

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