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To Study a Strengthening of RC Beam Using Carbon Fibber Reinforced Polymer Sheets

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ABSTRACT

Now a day it is common observation that structures are unable to give service as much as they are expected as per design. This is because of deterioration of the concrete and reinforcements caused by environmental factors and the widespread application of de-icing salts, or due to an increase in applied loads. The Retrofitting can be used as a cost-effective alternative to the replacement of these structures and is often the only feasible solution. Carbon Fibre Reinforced Polymers (CFRP) sheets or plates are well suited to this application because of their high strength-to-weight ratio, good fatigue properties, and excellent resistance to corrosion. A lot of research has been done on the FRP as reinforcement in concrete beams. However, the amount of research conducted on FRP as a sheet & laminate is quite less. So in the thesis, effect of CFRP on RC beams as a retrofitting material is studied. Also comparative effect of laminates with sheets having equivalent area is studied.

Key words: Carbon Fibre Sheet, Reinforced Concrete, Epoxy Resin.

1. INTRODUCTION

An increasing number of reinforced concrete structures have reached the end of their service life, either due to deterioration of the concrete and reinforcements caused by environmental factors and the widespread application of de-icing salts, or due to an increase in applied loads. These deteriorated structures may be structurally deficient or functionally obsolete, and most are now in serious need of extensive rehabilitation or replacement. Strengthening can be used as a cost-effective alternative to the replacement of these structures and is often the only feasible solution. Fibre Reinforced Polymers (FRP) sheets or plates are well suited to this application because of their high strength-to weight ratio, good fatigue properties, and excellent resistance to corrosion. Their application in civil engineering structures has been growing rapidly in recent years, and is becoming an effective and promising solution for strengthening deteriorated concrete members. Because FRPs are quickly and easily applied, their use minimizes traffic disruption and labour costs and can lead to significant savings in the overall costs of a project.

1.2 FIBRE REINFORCED COMPOSITES (FRC)

Composite can be defined as ‘two or more dissimilar materials which when combined are stronger than the individual materials.’ Composites can be both natural and synthetic (or man-made) and as materials technology moves toward more sustainable solutions, the focus on the use of organic, or natural materials, especially as reinforcements, increases each year.

Wood is a good example of a natural composite which is a combination of cellulose fiber and lignin. The cellulose fibre provides strength and the lignin is the "glue" that bonds and stabilizes the fibre. Reinforced concrete is another example of composite in which concrete and steel combines to create structures that are rigid and strong. This is a classic composite material where there is a synergy between materials. In this case, synergy means that the composite (or combination) of materials is stronger and performs better than the individual materials. Concrete is rigid and has good compression strength, whilst steel has high tensile strength. The result is a structure that is strong in both tension and compression.

Composites are of two types, one is particle based & other is fibre based. Fibre based composites are used for civil engineering applications which is composed of fibers' and resins. Two main types of polymer used for resins: thermosets and thermoplastics. The thermosetting polymers used in the construction industry are the polyesters and the epoxies. There are many thermoplastic resins used in composite manufacture: Polyolefins, polyamides, vinylic polymers, polyacetals, polysulphones, polycarbonates, polyphenylenes and polyimides. Resin systems such as epoxies and polyesters have limited use for the manufacture of structures on their own, since their mechanical properties are not very high when compared to, for example, most metals. However, they have desirable properties, most notably their ability to be easily formed into complex shapes.

Fibers are added to increase the load-carrying capability of the composite material. The fibers may occupy anywhere from 40 percent to 70 percent (by volume) of the material. These fibers have relatively small diameters. For example, a typical graphite fibre diameter is on the order of 5 to 7 micrometers, while glass fibers are usually larger, on the order of 15 to 20 micrometers. A wide range of amorphous and crystalline materials can be used as the fibre. In the construction industry the most common fibre used is glass fibre (there are 4 types of glass fibers: E-glass, AR-glass, A-glass and high strength glass). Carbon fibre, of which there are 3 types (Type I, II, III) can be used separately or in conjunction with the glass fibre as a hybrid to increase the stiffness of a structural member or the area within a structure, so that the stiffness exceeds the value that can be obtained by using glass fibre. These materials have extremely high tensile and compressive strength but in 'solid form' these properties are not readily apparent. This is due to the fact that when stressed, random surface flaws will cause each material to crack and fail well below its theoretical 'breaking point'. To overcome this problem, the material is produced in fibre form, so that, although the same number of random flaws will occur, they will be restricted to a small number of fibers with the remainder exhibiting the material's theoretical strength. Therefore a bundle of fibers will reflect more accurately the optimum performance of the material. However, fibers alone can only exhibit tensile properties along the fiber's length, in the same way as fibers in a rope. It is when the resin systems are combined with reinforcing fibers such as glass, carbon and aramid, those exceptional properties can be obtained. The resin matrix spreads the load applied to the composite between each of the individual fibers and also protects the fibers from damage caused by abrasion and impact. High strengths and stiffness's, ease of mulding complex shapes, high environmental resistance all coupled with low densities, make the resultant composite superior to metals for many applications.

1.3. NEED FOR THE STUDY

Following characteristic studies are of interest

- Comparison of experimental results, for beams without FRP, with various layers FRP by testing the beams in flexure.
- To prepare the load vs deflection curve using the experimental values.

1.4.SCOPE OF THE STUDY

- Various type of research works have been done on flexural and strength behavior of concrete beams with fiber reinforced polymer.
- But most of them are using carbon fibers which are high strength, and the beams were reinforced in tension zone with CFRP reinforcement.

1.5.MATERIAL PROPERTIES

Cement, fine aggregates, coarse aggregates, reinforcing bars are used in casting of beams, and cement slurry with bonding agent for grouting is used for retrofitting of these beams. The specifications and properties of these materials are as under:

1.5.1Cement

Ordinary Portland cement of 53 grades from a single lot was taken for the study. The physical properties of cement as obtained from various tests. All the tests are carried out in accordance with procedure laid down in IS: 8112-1989.

1.5.2Fine Aggregates

The sand used for the experimental works was locally procured and conformed to grading zone III. Sieve Analysis of the Fine Aggregate was carried out in the laboratory as per IS 383-1870. The sand was first sieved through 4.75mm sieve to remove any particle greater than 4.75 mm sieve and then was washed to remove the dust.

1.5.3Coarse Aggregates

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Crushed stone aggregate (locally available) of 20mm are used throughout the experimental study.

1.5.4Water

Fresh and clean water is used for casting the specimens in the present study. The water is relatively free from organic matter, silt, oil, sugar, chloride and acidic material as per Indian standard.

1.5.5Reinforcing Steel

HYSD steel of grade Fe-415 of 10mm and 8mm diameters were used as longitudinal steel. 10mm dia bars are used as tension reinforcement and 8mm bars are used as compression steel. 8mm diameter bras are used as shear stirrups.

1.5.6 CFRP material

For retrofitting of CFRPs sheets & laminates were used. Laminates have cross section of 50.8 X 1.4 mm & sheets have 300 X 0.1176 mm.

(A) Laminate

(B) Sheet

Fig.1.1 CFRP materials used in the experiment

2. MATERIAL TESTING REPORT

Sl.No	Description	Cement	FA	CA
1	Specific gravity	3.134	2.670	2.680
2	Fineness modulus	4%	2.850	-
3	Water absorption	-	1.02%	2.37%
4	Impact value	-	-	17%

2.1 Compressive Strength of Mortar Cube

SL.No	Mix ratio	Period of curing(days)	Compressive strength(N/mm^2)
1	1:1.46	7	42
2	1:1.46	14	49
3	1:1.46	28	55

2.2 Compressive Strength Test

Cube specimens of size 150X150X150mm are to be cast for the mix proportion. After curing for required period the specimen were tested using compressive testing machine. The curing periods were was 7days, 14 days and 28days.Compressive strength test was found by the following formula:

$$\text{Compressive strength (N/mm}^2\text{)} = \frac{\text{max .load (N)}}{\text{cross sectional area (mm}^2\text{)}}$$

Compressive Strength in N/mm^2

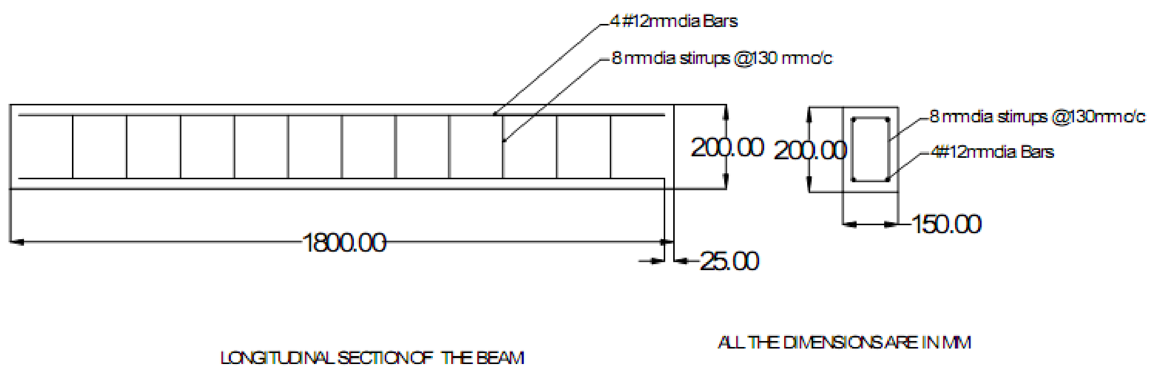
Specimen	Control concrete		
	7days	14 days	28days
1	13.50	16.12	20.15
2	13.25	16.25	20.22
3	13.60	16.20	20.27

2.3 Split Tensile Test

Cylinder specimen of size 300mm height and 150mm diameter are to be cast for the mix proportion. After curing for required period the specimen were tested using compressive testing machine. The curing periods are 7days, 14 days and 28days and tested to find the split tensile of concrete and the result obtained is being tabulated below.

Cylinder Split Tensile Strength

Specimen	Control concrete (N/mm^2)		
	7days	14 days	28days
1	1.41	1.65	1.90
2	1.30	1.92	2.18
3	1.32	1.76	1.86



2.4 BEAM APPLIED WITH TWO LAMINATES

2.4.1Control beam

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First fresh RC beam specimen has been loaded in a two point test set up as described in previously. This test has been carried out on the RC beams prior to the application of any FRC. The set up ensures pure bending in the central portion of the beam. The beams have been loaded with equal force on the two load points until the beams deformed did not take any further load. It may be noted that the beam sections were under-reinforced. Therefore, steel had yielded in all the specimens. The damage in the beams started with bending cracks in the central region of the beam as shown in fig4.1, first crack was observed at 32 KN. As load reached 56 KN more cracks were

observed. Almost all cracks were vertical & near top & bottom edge sub cracks were generated connecting to main crack. First crack generated between left point load & beam center. Second crack was just inside the right point load. Third & fourth crack generated was between center point of beam & right point load. Fifth crack was just outside of right point load. Sixth crack was in between third & fourth crack. At 88 KN spalling started.

Major cracking was observed at 90 KN. Beam stopped taking load at 90 KN. Final deflections at the center was 82.65 mm.

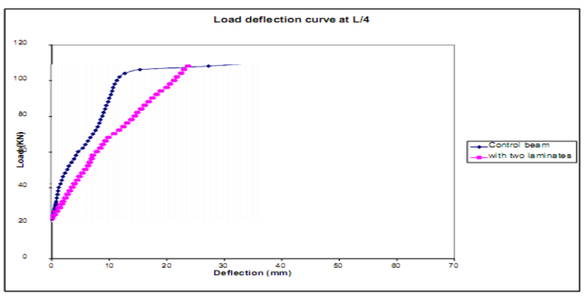

Fig 4.6 Graph of load deflection curve at L/4 from support

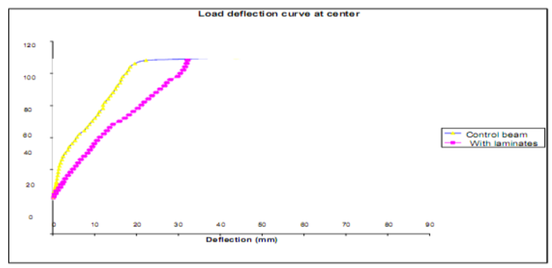

Fig 4.5 Graph of load deflection curve at the center of the beam

Testing of the beam with three laminates

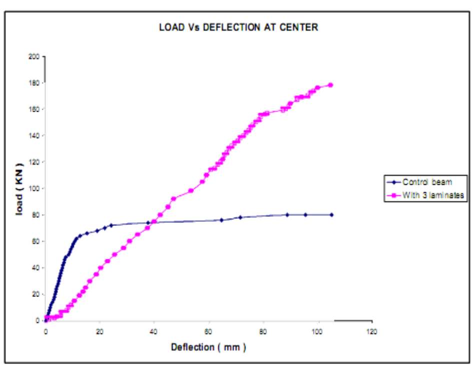

Fig 4.10 Load deflection curve at the center of the beam

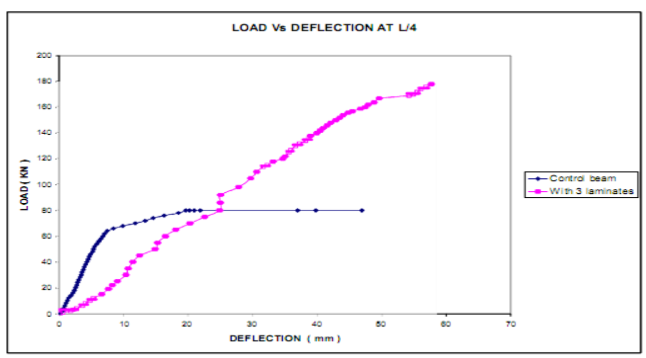

Fig 4.11 Load deflection curve at the L/4 from support of the beam

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BEAM APPLIED WITH

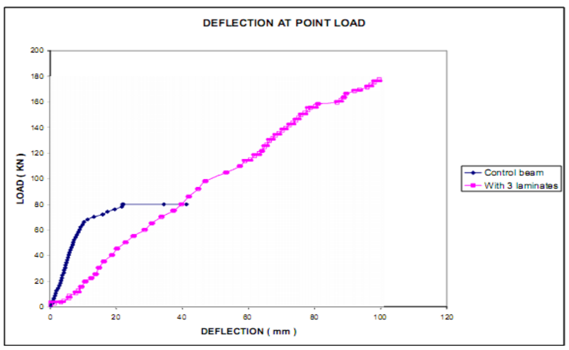


Fig 4.12 Load deflection curve under the point load of the beam

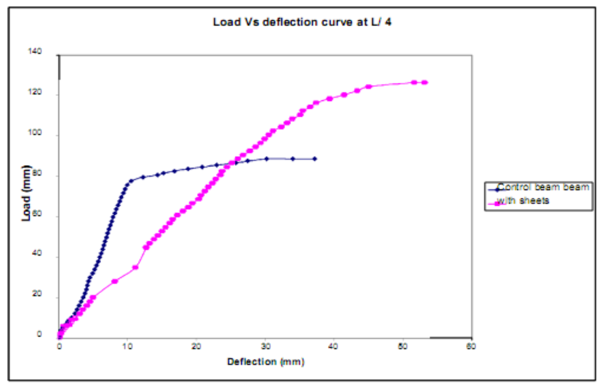
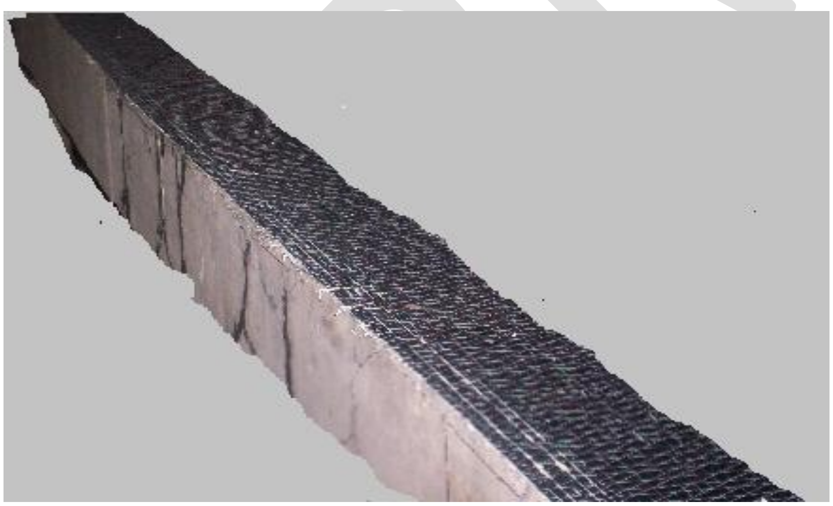


Fig 4.19 Load deflection curve at L/4 from support of the beam

SHEETS



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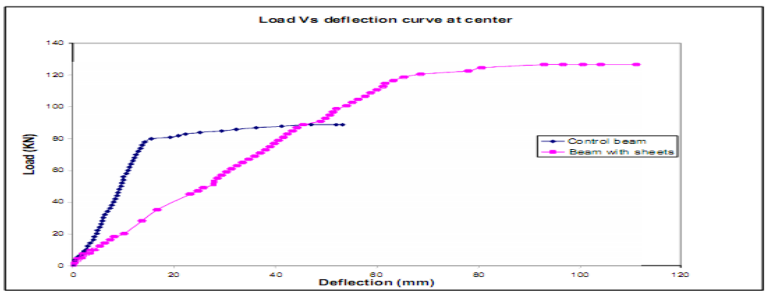

Fig 4.17 Load deflection curve at the center of the beam

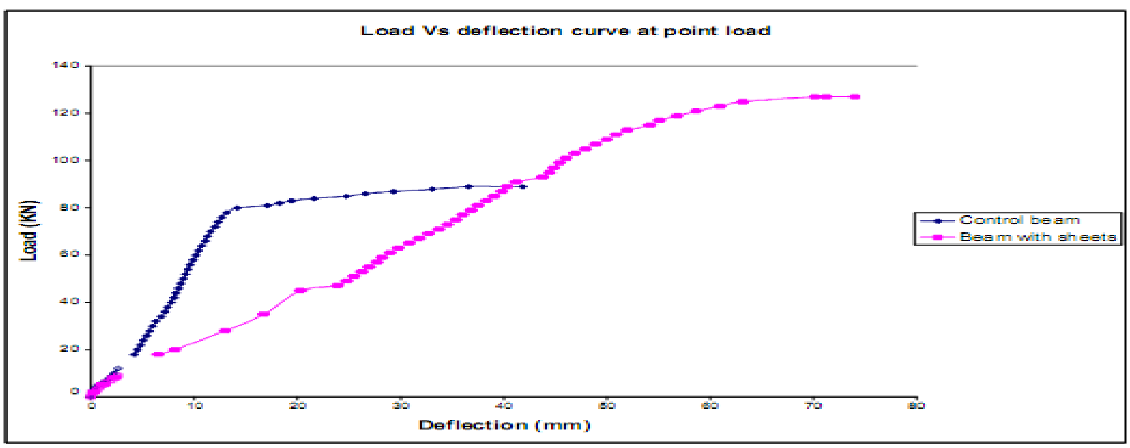

Fig 4.18 Load deflection curve under the point load of the beam

Comparison of Experimental Results

SL.No	Beam Type	Moment at First Crack kN-m	Max load (P in kN)	Max Deflection (mm)	Ultimate moment kN-m	% of Increase In Cracking Moment

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1	First fresh beam	22.5	90	82.65	31.25	
2	Beam with two laminates	27	108	49.8	32.4	20
3	Second fresh beam	20	80	105	26.25	
4	Beam with three laminates	44.5	178	104.6 8	54.51	122.5
5	Third fresh beam	22.25	89	53.17	30.25	
6	Beam with sheets	31.75	127	111.2 4	54.30	42.7

CONCLUSION

CFRP for retrofitting has proven itself to be a better feasible option than other methods. So the future prospects for the utilization of CFRP in Civil engineering infrastructure are good. Researchers around the world are now looking at the new and innovative ways of utilization of the same. Based upon the test results of the experimental study undertaken, the following conclusions may be drawn:

1. Load carrying capacity of retrofitted beam was significantly improved as compared to fresh beams.
2. Beam with two laminates at bottom has taken 20% more load than fresh beam.

3. Beam with three laminates at bottom has performed well as it has taken 122.5%more load than fresh beam.
4. Beam with sheets applied at bottom has shown 42.7% increase in load carrying capacity as compared to fresh beams.
5. Comparing beam applied with two laminates & beam applied with sheets having equivalent area, Sheets have taken 17.59% more load than laminates.
6. As compared to two laminates, failure of three laminates was quite satisfactory as there was partial peeling off.
7. Due to de bonding total utilization of strength of laminates was not achieved.

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