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FLEXURAL BEHAVIOUR OF RC BEAMS WRAPPED WITH CARBON FIBRE REINFORCED POLYMER

C. Sudha[1], P. R. Kannan Rajkumar[1], M. Jegan[2]
[1]Department of Civil Engineering, SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu, India
[2]Centre for Advanced Concrete Research, Department of Civil Engineering, SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu, India
E-Mail: sudhac@srmist.edu.in

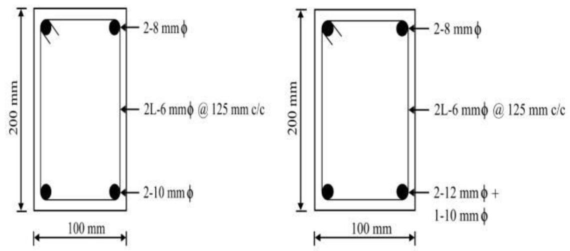
ABSTRACT

Fiber-reinforced polymer (FRP) composites are broadly utilized in advanced concrete technology given their dominance over outmoded steel reinforcements. These materials have high strength limit and consumption obstruction and can be utilized as the fundamental fortifications in mix with glues and safe havens to fortify strengthened reinforced concrete (RC) beam members. The preliminary objective of this investigation is to study performance of RC beams by using Carbon Fibre Reinforced Polymer (CFRP). The different strengthening configurations are considered (balance section, under reinforced section with the use of Carbon Fibre Reinforced Polymer (CFRP). Eight reinforced concrete beams with and without CFRP were cast and tested to find the flexural performance of M30 and M40 grade concrete. The beam is tested under the two-point loading and the failure load was measured, and it is analysed. The load carrying capability of beam increases in flexure with CFRP wrapping indicates that the depth of the section can be reduced without compromising on the deflection. This indicated that wrapping of beam with CFRP increase the flexural strength of RC beam in multifold.

Keywords: carbon fibre reinforced polymer, balanced section, under reinforced section, flexural behaviour.

1. INTRODUCTION

Now a days, there is lot of researches are ongoing about the repair and rehabilitation of reinforced members by using polymer wraps, sheets and laminates. Among the most commonly used polymer wraps, carbon fibre reinforced polymer (CFPR) becomes more efficient and can be easily used in the repair and strengthening works of RC beams [1]. The traditionally available repair and strengthening systems has been replaced by polymer wrap repair and strengthening system due to its high efficiency over a long period of time. The experimental results about load, deflection and failure lodes are based on the type of beams repaired and also based on the repair mechanism used in it [2]. In this investigation, the effect of carbon fibre reinforced polymer has been investigated for under reinforced beam section and also for balanced reinforced beam sections. Up gradation to seismic zones of cities and towns in India has developed the need of finding new retrofitting strategies. Generally, two methods of the retrofit strategies like local and global retrofit strategies are adopted. The local retrofit strategies are applied to individual elements of a building. The global retrofit strategies adopted for the building as a whole may be safe against a lateral load. In the present study, local retrofitting strategy to retrofit RC structural elements like beams and columns with Fibre Reinforced Plastic (FRP) wraps were studies [3]. The studies were performed on the RC beams to assess performance of the carbon fibre reinforced wrapping in flexural, shear and axial compression loading [4]. The results of the investigations are presented. Figure-1 represents cross section of test beams with reinforcements.



(a) Under reinforced (b) Balanced section

Figure-1. Cross section of test beams with reinforcement.

2. MATERIALS AND MIX DESIGN

2.1 Cement

Ordinary Portland Cement (OPC) of 53 grade (IS: 12269 (2003) [5] is used for the casting of beams. The specific gravity of cement is 3.15.

2.2 Ground Granulated Blast Furnace Slag (GGBS)

GGBS is the by-product produced during the manufacturing of steel which is very finer compared to cement and can be used in concrete as a substitute of cement which acts as a binder in concrete. This GGBS can increase the reaction in cement and hence can be used to reduce the setting time if required without affecting the strength parameters. The GGBS used are confirming to IS code (IS 10289:1987) [6]. The specific gravity of GGBS is 3.12.

2.3 Fine Aggregate

Fine aggregate compatible with ASTM code (ASTM C33 / C33M - 18) gradation confines with fineness modulus of 2.5 and with specific gravity of 2.57

was used [7]. Locally available sand which passes through 4.75 mm sieve as per IS code (IS: 383 (1970)) provisions were used as fine aggregate [8]. The specific gravity of fine aggregate is 2.78.

2.4 Coarse Aggregate

Coarse aggregates were used of size 12.5mm to attain maximum particle packing density. The locally available aggregates were used for casting. The specific gravity of coarse aggregate 2.80. The water absorption of coarse aggregates is 0.57.

2.5 Water

The locally available ground water was used for the development of concrete and also for curing purpose.

2.6 Super Plasticizers

In this study, polycarboxylate polymers based chemical admixture with pH of 7.20, chloride ion content as 0.0079%, solid content as 33.72% and relative density at 25° as 1.08 g/cc was used.

2.7 Carbon Fibre Reinforced Polymer (CFRP)

Carbon Fiber Reinforced Polymers (CFRP) are used for the production of aerospace components, automobile components, Sports kits and in manufacturing of bicycle parts. The CFRP sheets used in this investigation are with thickness of 1.2mm, width of 50 mm and has elastic modulus of 165 GPa. The carbon sheets are available in the form of roll as shown in Figure-2 and properties are shown in Table-1. The ultimate stress of the carbon sheets are found out by testing the sheets in tension testing machine at a rate of 2 mm/min.

Figure-2. Carbon fibre reinforced polymer with adhesive.

Table-1. CFRP properties.

Properties (Carbon Fibres and epoxy)	Longitudinal (0º)	Transverse (90º)
Tensile Strength, MPa	1860	65
Tensile Modulus of Elasticity, GPa	145	9.4
Ultimate Tensile Strain (%)	1.2	0.7

3. EXPERIMENTAL INVESTIGATION

For carrying out experimental investigation, concrete mixes of grade M30 and M40 were prepared by mixing fine aggregate and coarse aggregate in a dry state and after 1 minute of mixing, cement and GGBS were added in the mixer machine and dry mixed for another 1 minutes Now water along with SP was added in the mixer and mixed for 5 minutes until all the ingredients in concrete were uniformly mixed. Once the mixing was completed, then cubes of size 150mm and beams were cast and made to cure for 24 hours. After 24 hours curing, cube and beam specimens were demoulded and allowed for water curing for 28 days as per IS: 516 (1959) [9]. The mix proportions used in this study and strength were followed as per IS10262-2019 [10] is shown in Table-2. Before the testing the CFRP was wrapped on the beam and allowed to cure. The experimental investigation was conducted on six beams as tabulated in Table-2.

Table-2. Specifications of beam.

ID	Description
B1	Controlled beam M30 (Balanced section)
B2	Controlled beam M30 (Under Reinforced section)
BB1	Beam strengthened with CFRP sheet for M30 (Balanced section)
BU1	Beam strengthened with CFRP sheet for M30 (Under Reinforced section)
B3	Controlled beam M40 (Balanced section)
B4	Controlled beam M40 (Under Reinforced section)
BB2	Beam strengthened with CFRP sheet for M40 (Balanced section)
BU2	Beam strengthened with CFRP sheet for M40 (Under Reinforced section)

The beams were prepared by using M30 and M40 grade concrete has cross-sectional dimension of 100 mm x 200 mm and length of 1200 mm with a span of 1000mm. High Yield Strength Deformed (HYSD) bars were used in this investigation. In the beam, at tension face 2 numbers of 12 mm dia bar was used and in compression face 2 numbers of 10 mm dia bars were used. The cover used in the beam is 25 mm on all sides. Two legged stirrups with 6 mm diameter mild steel was used as shear reinforcement with 100 mm spacing (IS: 456 (2000)) [11].

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Table-3. Mix Proportions and properties of concrete.

Mix	Cement (kg/m^3)	GGBS (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	Water (kg/m^3)	SP (kg/m^3)	Slump (mm)	Compressive Strength (MPa)
M30	230	120	857	1083	155	2.1	145	38.8
M40	282	95	951	979	155	3.44	130	49

The beams B1 and B2 are control beams of M30 whereas B3 and B4 are M40. Beams were tested by using two point loading setup as displayed in Figure-4. The deflection in the mid span of beam was measured by using dial gauges during the application of load. The two-point load was applied and the deflections were observed [12]. The loading was applied on the beam at the rate of 5kN upto the failure of beam. The failure load in the beam was recorded and compared [13].

After strengthening the beams by using CFRP sheets, the beams BB1, BB2, BU1 and BU2 were tested. The beam has been strengthened by applying CFRP sheets on the tension face of the beam by wet layup process. The load was not identical to BB1, BU1, BB2 and BU2. Before applying CFRP sheets in the beam, the surface preparation need to be done. The surface of the beam is coated with primer and made to cure for 24 hours. After 24 hours of curing, two epoxy components were coated on beam and CFRP sheets were placed on the surface of beam such that orientation of fibres in CFRP sheets were along the tensile direction [14]. The two point loading setup of the beam is displayed in Figure-3. The beams were tested under static loading and the failure mode of balanced section and under reinforced section are displayed in Figure-5 and Figure-6. The failure was primarily due to difficult interfacial stress that surpasses frictional resistance of adhesive [15, 16].

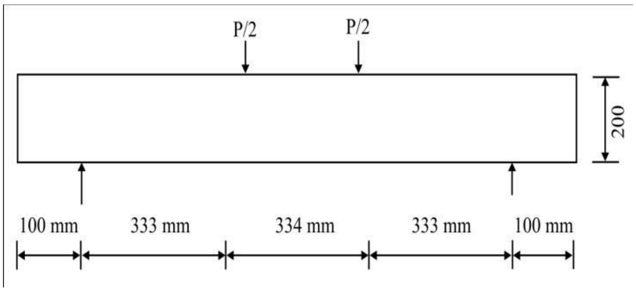

Figure-3. Testing with two-point load.

Figure-4. Beam loaded prior to test.

Figure-5. Cracked beam for balanced section.

Figure-6. Cracked beam for under reinforced section with CFRP.

4. DISCUSSION OF RESULTS

The experimental investigation has been carried out to find the ultimate load and cracking load and the results are tabulated in Table-4 and load vs deflection curve of M30 and M40 grade concrete are displayed in Figure-7 and Figure-8 respectively. On studying test results, it was found that for balanced section with CFRP in M30 grade concrete, ultimate load was 1.25 times higher than balanced section without CERP and deflection was higher for balanced section without CFRP whereas for under reinforced section with CFRP in M30 grade concrete, ultimate load and deflection were 1.53 times and 1.42 times respectively higher than balanced section without CERP. On analysing the strength factors of M40 grade concrete, ultimate load and deflection of balanced section with CFRP were 1.25 times and 1.41 times greater than balanced section without CFRP. However, for under reinforced section, ultimate load and deflection of under reinforced section with CFRP were 1.53 times and 1.54 times superior to under reinforced section without CFRP. From the both grade of concrete, it was found that the balanced section containing with CFRP and without CFRP performed better compared with under reinforced sections and also noted that the strength of concrete beam increases

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due to the presence of CFRP. The results obtained are in similar trends with results of Balamuralikrishnan *et al.* (2009) [17] and Hee Sun Kim *et al.* (2011) [18].

Table-4. Experimental results of different types of beams.

ID	Ultimate load (kN)	Deflection at Ultimate Load (mm)
B1	125	13.60
B2	64	6.2
BB1	156	12.1
BU1	98	8.8
B3	131	10.1
B4	72	6.1
BB2	164	14.2
BU2	110	9.4

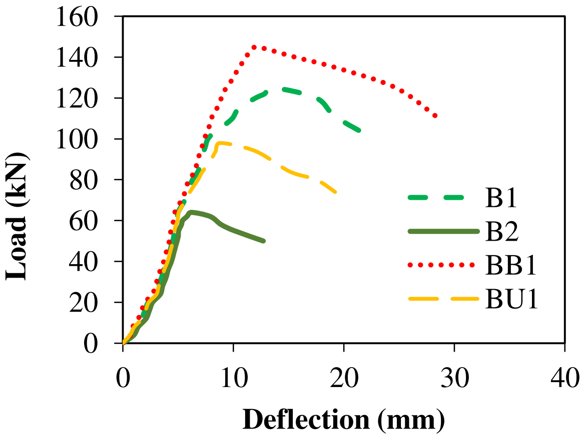

Figure-7. Load vs deflection curve M30 grade concrete.

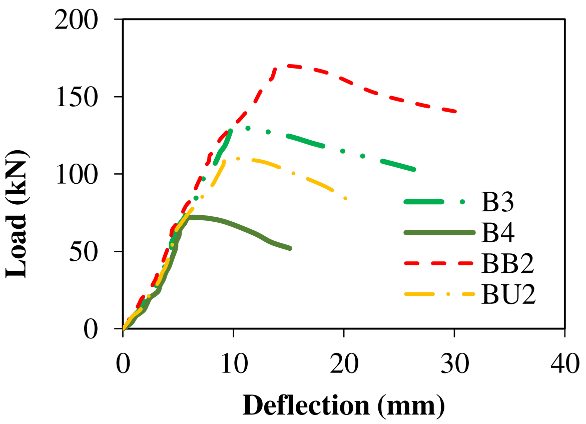

Figure-8. Load vs deflection curve M40 grade concrete.

5. CONCLUSIONS

On analysing test results of CFRP beam, the following conclusions were derived,

- For M30 grade of concrete, ultimate load of balanced section with CFRP is 22.06% higher than balanced section without CFRP whereas deflection of balanced section without CFRP is 11.67% higher than balanced section with CFRP.
- In under reinforced section of M30 grade concrete, ultimate load and deflection are 41.98% and 34.67% respectively increased on comparing with under reinforced section without CFRP.
- While validating ultimate load and deflection of balanced section with CFRP for M40 grade concrete, there was 22.37% and 33.74% higher compared to balanced section without CFRP respectively.
- The ultimate load and deflection of under reinforced section with CFRP was 41.76% and 42.58% increased for M40 grade concrete of under reinforced section without CFRP.
- This improved strength in CFRP wrapped section of both grade of concrete indicates that the bonding of CFRP with reinforced concrete is very strong with improved deflection properties and can be implemented for repairing of damaged beams.

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