Evaluation of Shear Behaviour of RC Beams Using CFRP

B. Srudhira, M. Anil kumar, K. J. Brahma Chari

Abstract: Carbon Fiber Reinforced Polymer (CFRP) wrapping technique is one of the best techniques to improve the strength of the structure without destroying the whole structure. In this study, the experimentation has been carried out on four Reinforced Concrete beams of different sheet widths of the CFRP fabric and tested under four-point loading using a loading frame. The U-type wrapping with different width on four Reinforced Concrete beams of size 1.5 m × 0.38 m × 0.23 m have been used in this study as parameters. The shear behavior of the CFRP wrapped Reinforced Concrete beams through the load vs. deflection response and crack pattern subsequently compared the same with conventional beams. It has been concluded that CFRP wrapped reinforced concrete beams have shown significant shear strength when compared to conventional beams.

Index Terms: CFRP, Four-point loading, Shear strength, and Reinforced concrete beams.

I. INTRODUCTION

The present world is emerging as the construction world with lots of concrete structures that are buildings, bridges, and dams. It can be used to make it economical for structures.Fiber reinforced polymer (FRP) is a composite material generally consisting of different types of carbon fiber reinforced polymer (CFRP), aramid fiber reinforced polymer (AFRP), glass fiber reinforced polymer (GFRP) in the polymeric matrix.Carbon fiber reinforced polymer is a popular technique used for shear strengthening has been applied to many structural elements like beams, columns, and slabs etc., this research focused on CFRP consisting of flexible sheets.Carbon fiber reinforced polymer is a very strong, light fiber reinforced plastic which contains carbon fibers. It can be used where ever we require and high strength and rigidity.These CFRP sheets are bonded by using epoxy adhesive. The failures that occur due to shear reinforcement, load, and corrosion, the use of construction materials will be reduced. By this, the construction cost will also be reduced.This paper deals with the effects of CFRP wrapping to the concrete beams for strengthening, providing stiffness to the beams in various orientations of the fibers along the axis of the beams. The use of the flexible carbon fibers sheets wrapped around U-type of reinforced concrete beams to increase their shear and flexural strength.

In this study, the comparison of CFRP wrapped beams with the conventional reinforced concrete beam was done.

Revised Manuscript Received on April 09, 2019.

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An experiment to obtain a better understanding of the behavior and to improve the data base of the influence of the depth size to the ultimate load carrying capacity. They concluded maximum axial strain in CFRP strips is concentrated along the shear crack. The strip having the highest axial strain value at the middle of the shear span[1]. The beam strengthened with more than one layer of CFRP laminate unnecessarily increased strengthening time and cost by more than one layer of CFRP laminate. The major literature of the study is to strengthen the beam using CFRP laminate provides a solution for extending the service life of concrete structures [2]. Nineteen understrength reinforced concrete beams retrofitted and tested to failure. Pre-cracking in beams observed prior to the retrofitting. Strength and stiffness in the existing concrete beams increased when bonded to the web and tension face with CFRP sheets [3]. An experiment on FRP plates for finding the better strength bonding capacity of the material for eliminating corrosion and heavyweight observed in steel plates. They concluded that the actual shear strength of the beams is governed by bond stress, strengthening scheme and strengthening direction [4]. On major possible failures observed on the CFRP strengthening mechanism. The beam with CFRP fabrics and the beam with CFRP strips have different failures modes. The failure of the CFRP fabric occurs due to fabric rupture and the failure of the CFRP strips caused by delamination underneath the epoxy. The study demonstrates the feasibility of using epoxy-bonded CFRP to restore or to increase the load carrying capacity in Shear of RC beams[5]. From the various authors observed that by applying carbon fiber sheets in existing reinforced concrete members are improved shear capacity and also studied the behavior of R.C. members [6].

II. RESEARCH SIGNIFICANCE

To further understand the behavior of shear strengthening using externally bonded CFRP sheets as the shear failure, the following objectives of this research have been established:

- To investigate the shear behavior and modes of failure of RC beams with shear deficiencies after strengthening with CFRP sheets.
- To study the effect of various CFRP sheets width types and crack failure configurations on the shear behavior of the beam.To increase the externally bonded to the
- To propose design approaches that are based on experiments and analytical studies.

III. MATERIALS

In this study, we had done the performance and structural behavior of the specimens by using the materials.

A. Cement

Cement is a binder for used construction. The Cement is blended with calcium silicates and calcium aluminates, which are grounded into the fine powder and with the addition of small percentages of the gypsum. The ordinary Portland cement of 53 grade conforming to the IS code 8112 was used for entire work.

B. Fine aggregates

The river sand particles are used as the fine aggregates according to the recommendation of IS- 383. The fine aggregates are sieved and removed the deleterious materials which are present in it.

C. Coarse aggregates

The coarse aggregates were used to form our university batching plant and were confined to the IS-383 was used. The flakiness and elongation index was maintained. Depending on the arresting of the voids were casting with 10 mm and 20 mm of coarse aggregates was used combined with 40% of 10 mm and 60% of 20 mm sizes from the total weight of the aggregates done after the mix design confirming to the IS- 456:2000.

D. Carbon fiber reinforced polymer (CFRP)

It is a very strong, light fiber reinforced plastic which contains carbon fibers. It can be used where ever we require and high strength and rigidity. Fig. 1 shows CFRP. Carbon fiber reinforced polymer is popular a type of shear strengthening technique has been applied to many concrete structural elements like beams, columns, and slabs etc.,

Fig. 1: Carbon Fiber Reinforced Polymer sheet &Epoxy Resin

E. Epoxy resin

Epoxy is a hardening agent which works to cure it into the very strong adhesive. CFRP sheets are bonded by using epoxy adhesive. Fig.1 to shows Araldite LY556 and hardener HY951 mix proportion 100gms:10gms

IV. EXPERIMENTAL WORK

A. Test Specimens

This experimental study deals with the casting of 4 beams with the cross section 1.5m × 0.23m × 0.38m. The beam design was made according to the IS codes. The four beams were cast and cured for the 28 days. The M25 mix design is used for the casting of the beams. The 12mm Ø bars are used in tension reinforcement and 10mm Ø bars are used in the compression zone. According to the specific design for each beam based on the IS code, stirrups are designed by Specimen details are as follows, Fig. 2 shows the layout of the conventional beam. Fig 3 shows the beam of u- type CFRP wrapping with the 100mm spacing and 50mm width of the strip.The mix proportions are shown in Table I.

Table I: Mix design

Grade	Cement (Kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	w/c ratio	Water Lt/m^3
M25	384	790.3	1073.3	0.47	198

This type of reinforced concrete beam using CFRP wrapping 50mm width distance and 100mm spacing This type of reinforcement is analyzed for the sake of observing the crack pattern of shear failure in RCC beam. Fig. 3 shows the layout of 4- stripped CFRP concrete beam.

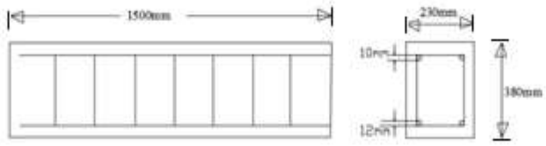

Fig.2: Layout of conventional reinforced concrete beam

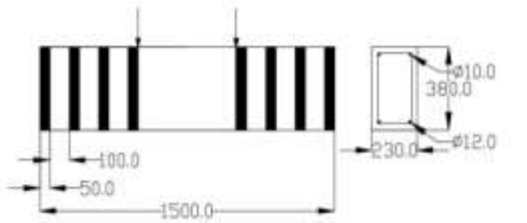

Fig.3: The layout of 4-stripped CFRP concrete beam

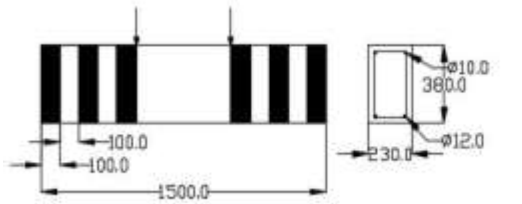

Fig.4: Layout 3-stripped CFRP concrete beam

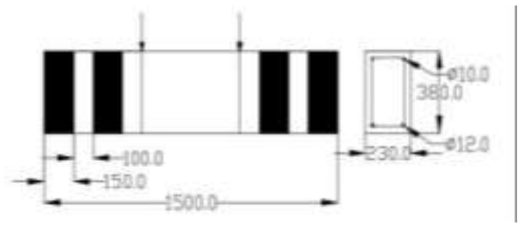

Fig.5: The layout of 2-stripped CFRP concrete beam

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The reinforced concrete beams consist of CFRP strips of size 100 mm and spacing of 100 mm. Fig. 4 shows the layout of 3 stripped CFRP concrete beam.

The reinforced concrete beams consist of CFRP strips of size 150 mm and spacing of 100 mm Fig. 5 shows the layout of the 2 stripped CFRP concrete beam.

B. Casting of Specimens

The cubes were tested for compressive strength to check the grade of concrete M25. The cubes of dimension 150mm× 150mm × 150mm are used for compressive strength of concrete. The mix design was made according to the code of practice IS: 10262-2009. the slump was maintained 100mm to check the slump test. Fig. 6 shows the slump cone test.

Fig. 6: Slump cone test

The reinforcement detailing of the beam. All the four beams were casted in the mold of M25 grade and the maximum size of aggregate 20 mm was used as shown in Fig. 7. The steel reinforcement in the tension zone and compression zones are 12 mm diameter and 10 mm. stirrups of 8mm diameter were used. The casting of the beam was shown in Fig. 8.

Fig. 7: Providing reinforcement

Fig. 8: The casting of conventional reinforced concrete beam

V. RESULTS AND DISCUSSION

All beams were tested on the loading frame under four-point loading. The conventional beam designed with shear reinforcement failed at a load of 160 KN. The failure of the first crack appeared at a load of 92 KN. The cracks mitigated from the tension zone to the mid span of the beam. Shear cracks increase when the load increases. The conventional specimen failed in shear at the load of 160kN.

Fig. 9: Test setup of beam

Table II: Experiment Results

Beam Designation	First crack Load P (kN)	Deflection (mm)	Ultimate load (kN)
Conventional beam	92	16.7	160
CFRP Beam 1 (4 strips)	116	20.1	170
CFRP Beam 2 (3 strips)	138	19.2	180
CFRP Beam 3 (2 strips)	160	13.7	209

The deflection at the ultimate load is 16.7mm. The test setup of the beam was shown in Fig. 9. The load Vs Deflection curve for the conventional beam under four-point loading is shown in Fig. 10. The experimental results are shown in Table II.

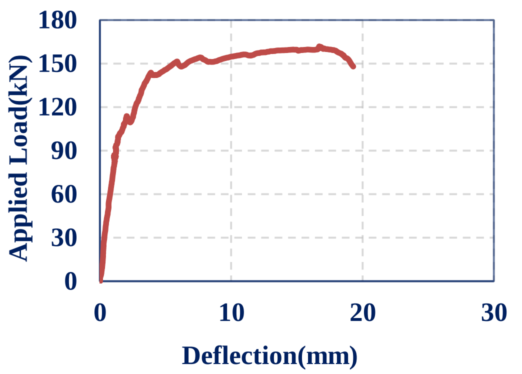

Fig.10: Load vs deflection curve of the conventional beam under four-point loading

A. 4- Stripped CFRP wrapped beam:

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The four strips of CFRP sheets of size 50 mm is wrapped to the beam with a spacing of 100 mm. The epoxy is used to bond the CFRP sheets to the beam. Specimen failed at the ultimate load of 170 kN. The deflection at the ultimate load is 20.1 mm. the 4-stripped CFRP wrapped beam is shown in Fig. 11. The load Vs deflection curve for the 4-stripped CFRP wrapped beams under four-point loading is shown in Fig. 12.

Fig. 11: 4-Stripped CFRP wrapped beam

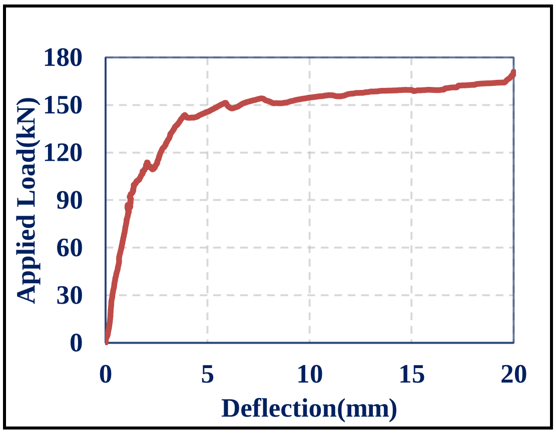

Fig. 12: Load deflection curve of four strips of cfrp wrapping of the beam.

B. 3- Stripped CFRP wrapped beam:

Three strips of CFRP sheets of size 100 mm is wrapped to the beam with a spacing of 100 mm. specimen failed at the ultimate load of 180 kN. The deflection at the ultimate load is 19.2 mm. the 4-stripped CFRP wrapped beam is shown in Fig. 13. The load Vs deflection curve for the 3-stripped CFRP wrapped beams under four-point loading is shown in Fig. 14.

Fig. 13: 3-Stripped CFRP wrapped beam

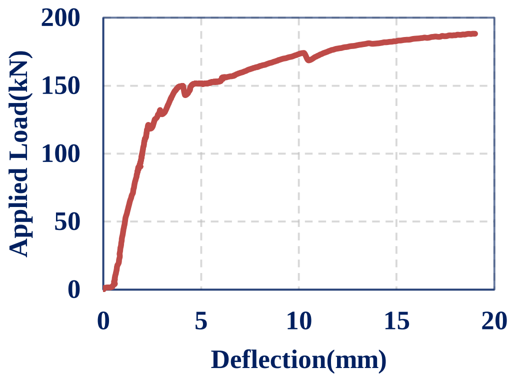

Fig. 14: Load vs deflection three strips of cfrp wrapping of beam

C. 2- Stripped CFRP wrapped beam:

The two strips of CFRP sheets of size 150 mm is wrapped to the beam with a spacing of 100 mm. specimen failed at the ultimate load of 209 kN. The deflection at the ultimate load is 13.7 mm. the 2-stripped CFRP wrapped beam is shown in Fig. 15. The load Vs deflection curve for the 2-stripped CFRP wrapped beams under four-point loading is shown in Fig. 16.

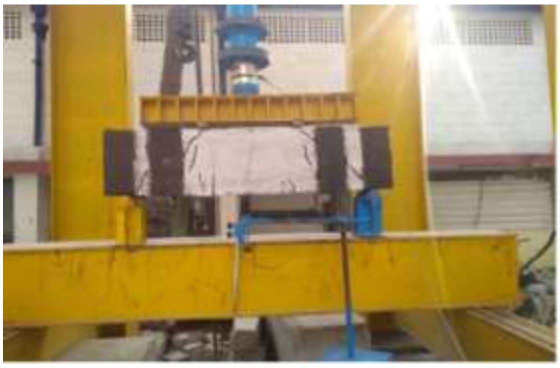

Fig. 15: 2-Stripped CFRP wrapped beam

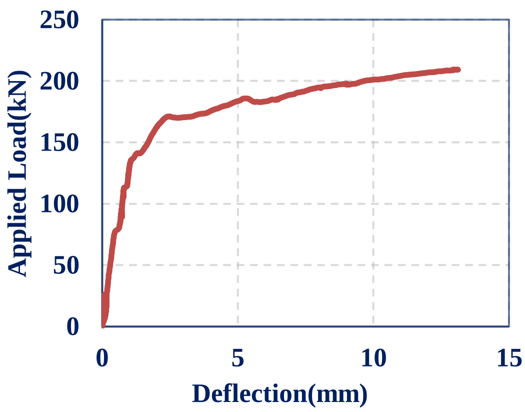

Fig. 16: Load vs deflection two strips of cfrp wrapping of beam

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VI. CONCLUSION

Based on the experimental studies that were carried out on the conventional concrete beam and Beams wrapped with CFRP U-strips, the following are the observations obtained from the results.

- The load Vs deflection behavior of the CFRP wrapped beams are better performed when compared to the conventional beam.
- The load carrying capacity of the CFRP wrapped beams are higher than the conventional beam.
- Among the 3 CFRP wrapped beams, the 2- stripped beam shows higher strength than the other 2 beams.
- Shear crack width of the 2- stripped CFRP beam has clearly shown the shear resistance capacity of CFRP is less when compared to the remaining 2 CFRP beams.
- Two stripped CFRP has controlled the shear cracks and their patterns when compared with other two beams.
- Therefore, CFRP wrapping should be useful for the structural members due to its high strength.

It is concluded that the CFRP wrapped beams shows better performance than the conventional beam.

ACKNOWLEDGMENT

The constant support and encouragement of Koneru Lakshmaiah Educational Foundation is gratefully acknowledged. This work wouldn't have been completed without the University Support and we're forever thankful. Our special thanks to Head of the Department, Civil Engineering for providing us with adequate facilities, ways,and means by which we can complete this project work. We thank teaching, non-teaching members and friends of the Civil Engineering Department for supported or partially supported.

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