An Experimental Investigation on Rehabilitation of R.C. Beams Using Woven Roving Mat Fiber

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Abstract – *There is a keen need all over the world for strengthening and repairing of the damaged reinforced concrete structures. Recent advanced research proved that Fibre Reinforced Polymer (FRP) composites are attractive alternate to other traditional techniques in the field of strengthening and repairing of concrete elements. Synthetic Fibre Reinforced Polymers such as AFRP/CFRP/GFRP have been used for strengthening and retrofitting activity for the past 30 years. This Fibre Reinforced Polymers (FRP) wrapping improves the integrity of the structure there by acts as an outer strengthening layer to the structural elements. The main objective of the present experimental research is to access the behavior of the flexural member which is rehabilitated using of FRP materials wrapped in various patterns and layers. This research work was carried with the help of E-Glass fiber which is used as fiber reinforced polymer reinforcement for structural application to enhance the strength and stability of the different structural members. Woven roving mat were used in different layers and patterns to find the optimized method for retrofitting. The behavior of reinforced concrete beams rehabilitated using concrete jacketing technique is also studied. In this experimental study, concrete confirming to M20 grade is used. To maintain the same quality of concrete throughout the study, various test specimens were cast and standard tests like compression test, split tensile test, and modulus of rupture on hardened concrete were carried out, confirming to Indian Standards. Beams were wrapped with woven roving mat in single layer and double layer at bottom and sides to find the effect of wrapping in various layers and patterns to rehabilitate the beam. To find the effects on rehabilitation, the beam is subjected to initial crack load, which is obtained by testing the control specimen. The test results carried out throughout this study has proved that, the beam wrapped with woven mat provided at the bottom as double layer to ensure better performance under the static load and also the deflection at yield in linear form, ultimate and breaking loads are in good profile. This ensures the improvement in the ductility.*

Key Words: Fibre Reinforced Polymers (FRP), Rehabilitation, Wrapping, Woven roving mat, Deflection, Compressive Strength, Load.

1. INTRODUCTION

Fiber-reinforced polymer (FRP) is used as a structural engineering material in the field of civil engineering, strengthening concrete, steel, and wood structures. A variety of research has shown that the use of FRP in framed structure beams has greatly improved flexibility. FRP materials are well recognized as essential components of modern concrete structures. FRP materials improve structural performance in terms of stability, hardness, strength (including improved resistance against fatigue loading), and durability (Mandel 1982, Machida 1993, 1997, Hayes et al. 2000, Katz 1999, Nani 2000, Dezke 2001). Other factors include the possibility of large-scale production with high-quality control and relative economy.

Recent environmental degradation triggers the need to improve the lifespan of existing structures. The study of various methods of repair and rehabilitation, the methods of its application, and the rehabilitation of framed structures are undergoing extensive work. In recent years, the use of fiber wrapping has become more competitive for all structural components than for reinforced structural members. Fiber-reinforced polymer (FRP) therefore improves the integrity of the wrapping structure, thereby acting as an external reinforcement layer for the structural parts.

2. EXPERIMENTAL STUDY

2.1. MATERIALS AND MIX

2.1.1. Cement

In this study, grade 43 conventional Portland cement complying with IS 8112-1989 was used. The cement used has been tested for its physical properties in accordance with Indian standards. The properties of the cement used are shown in Table 1.

S. No.	Physical Properties	Values obtained	Requirements as per IS 8112-1989
1	Specific gravity	3.14	3.1-3.15
2	Normal Consistency	28.4%	------
3	Initial Setting Times	36 minutes	30 minutes(Min.)
4	Final Setting Times	340 minutes	600 minutes (Max.)
5	Compressive strength at 28 days	50.20 N/mm^2	43 N/mm^2 (Min.)

Table 1: Properties of Cement

2.2. Fine Aggregate

Used fine aggregate of natural origin, passed through a 4.75 mm sieve. The fine aggregate classification zone is zone II according to Indian standard specifications. The properties of the used fine aggregate are shown in Table 2.

S. No.	Physical Properties	Values
1	Specific gravity	2.45
2	Fineness Modulus	2.10
3	Water Absorption	0.64%
4	Bulk Density	1544 kg/m^3
5	Free Moisture Content	0.11%

Table 2: Properties of fine aggregate

2.3. Coarse Aggregate

Used coarse granite crushed stone from local quarries. The maximum size of the coarse aggregate used was 20 mm. Coarse aggregate properties were determined in accordance with Indian standard specifications. The properties of the used coarse aggregate are shown in Table 3.

S. No.	Physical Properties	Values
1	Specific Gravity	2.64
2	Fineness Modulus	7.62
3	Water Absorption	0.40%

4	Bulk Density	1480 kg/m^3
5	Free Moisture Content	0.21%
6	Aggregate Impact Value	11.10%
7	Aggregate Crushing Value	24.21%

Table 3: Properties of coarse aggregate

2.4. Water

Potable water without salt was used for pouring and hardening the concrete according to the recommendations of IS: 456-2000.

2.5. Fibre Reinforced Polymers

For the study, commercially available fiberglass mat E fibers were used. The woven mat used in this study is shown in Figure1.

Figure 1 Woven Roving Mat

2.6. Mix Proportion

The concrete mixture was developed according to IS 10262-2009 for the concrete grade M20. A constant water / cement ratio of 0.45 was used. The relationship between the various ingredients used in the concrete mix is shown in the Table 4.

Materials required	Cement	Fine Aggregate	Coarse Aggregate	Water/ Cement	Super Plasticizer
eight in kg/m^3	340	544	1054	153	3
Proportion	1	1.60	3.10	0.45	1% of weight of cement

Table 4: Ratio of Ingredients used in Concrete Mix

2.7. Beam Specification

A total of 10 beams were cast and tested on a static load system. Of the 10 beams, 2 beams were tested as controls, and the remaining 08 beams were rebuilt with fiberglass winding using a single, double at the bottom and single, double at the bottom with shear sides and externally coated wicks, 2 numbers in each, respectively. Details of reinforced beams with various external cladding schemes are presented in the Table 5. The beam has been designed as a reinforced section capable of withstanding a minimum ultimate load of 40.00 kN. Details of the supplied fittings are shown in Figure 2. The beam consists of two rows of HYSD bars with a diameter of 12 mm at the bottom as tensile reinforcement. Two more rows of rods with a diameter of 12 mm were placed at the top as hangers. To support the stiffeners and act as shear stiffeners, 6 mm diameter brackets were used, positioned 150 mm from center to center.

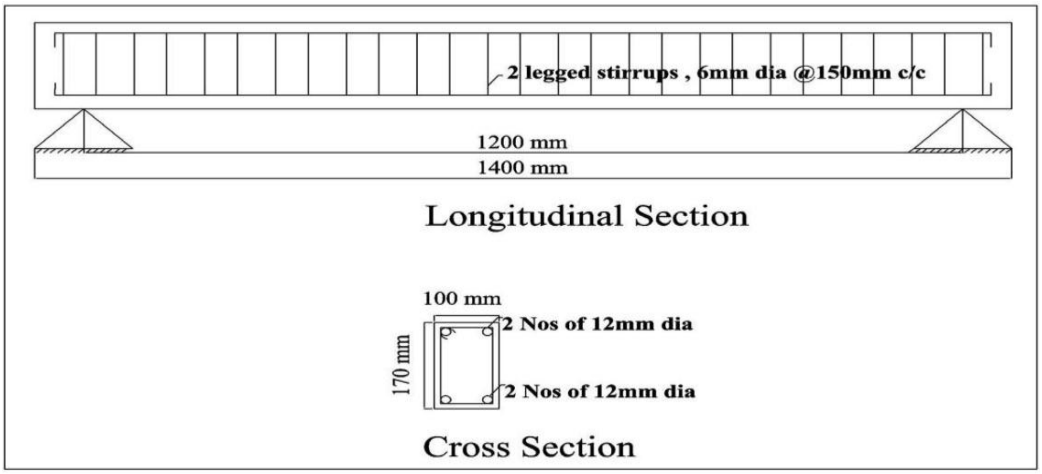

Figure 2 Reinforcement Details

Sr. No.	Specimen Designation	Cross Section (mm)	Effective Span (mm)	Description of Specimen
1.	CC	100 × 170	1200	Conventional RC Beam
2.	RWB1	100 × 170	1200	Rehabilitate with Glass Woven Mat at the bottom with one layer.
3.	RWB2	100 × 170	1200	Rehabilitate with Glass Woven Mat at the bottom with two layers.
4.	RWBS1	100 × 170	1200	Rehabilitate with Glass Woven Mat at the bottom and sides all-round in shear zone one layer.
5.	REJ1	150 × 220	1200	External Jacketing - Rehabilitated with external jacketing using 2 No. of 10mm diameter @ top and bottom and 6mm diameter stirrups spaced @ 175mm c/c. Cast with M20 grade concrete.

Table 5: Designation of beam rehabilitated using FRP wrapping & external jacketing

3. RESULTS AND DISCUSSION

3.1. Compressive Strength Test

Expressed samples of 15 numbers of concrete cubes measuring 150 mm × 150 mm × 150 mm were casted. The compressive strength of the three control cube samples was calculated without wrapping. The rest of the cubes were wrapped in a woven mat in a single and double layer, each with three cubes, respectively. The compressive strength values obtained from the experimental study are shown in Table 6. Comparison of compressive strength values is shown in Figure 3.

Sr. No.	Specimen	ressive strength in N/mm²
1.	CC-Conventional	22.57
2.	WB1 (Woven Roving Mat Wrapped - Single Layer)	24.75
3.	WB2 (Woven Roving Mat Wrapped - Double Layer)	27.31

Table 6: Compressive Strength Values

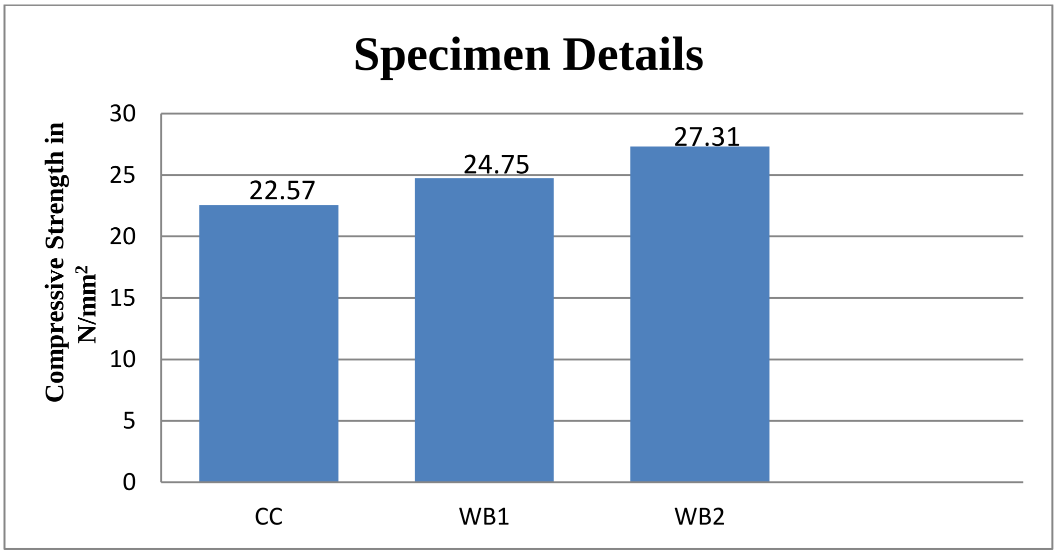

Figure 3 Comparisons of Compressive Strength Values

3.2. Split Tensile Strength

Nine specimens of concrete cylinders with a diameter of 150 mm and a height of 300 mm were cast. The two-stage tensile strength of three test cylinder samples was calculated without winding. The remaining cylinder was wrapped in a single-layer and double-layer woven mats, each with three cylinders, respectively. The values of the relative tensile strength obtained from the experimental study are shown in Table 7. Figure 4 shows a comparison of tensile strength values divided for different fiberglass wrapping.

Sr. No.	Specimen	plit Tensile Strength in N/mm²
1.	CC-Conventional	2.75
2.	WB1 (Woven Roving Mat Wrapped - Single Layer)	3.30
3.	WB2 (Woven Roving Mat Wrapped - Double Layer)	4.07

Table 7: Split Tensile Strength Values

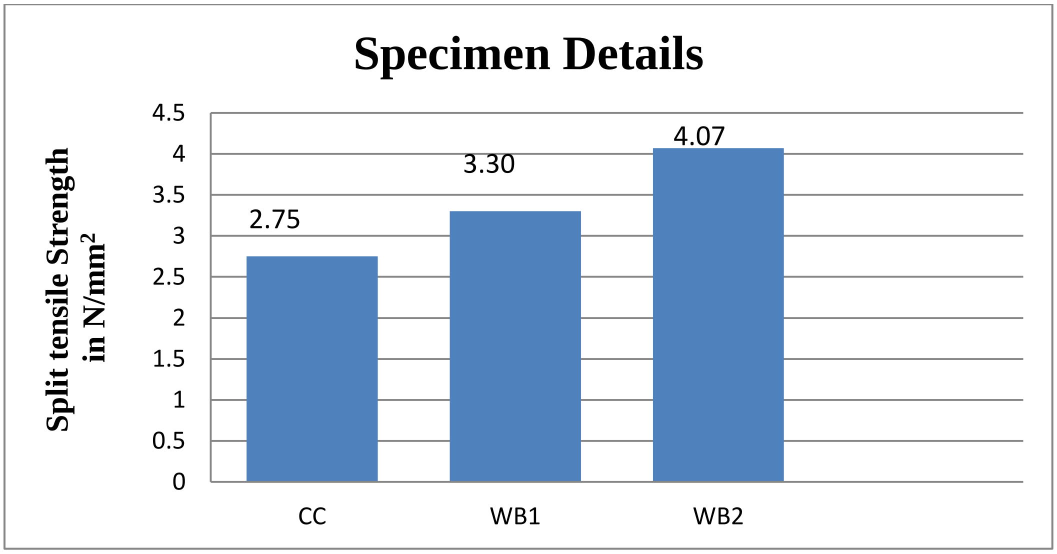

Figure 4 Comparisons of Split Tensile Strength Values

3.3. Modulus of Rupture

Samples of concrete prisms with dimensions of 500 mm × 100 mm × 100 mm were cast. A total of 9 prisms were cast, three of which were tested as a control, and the remaining prisms were wrapped with a woven mat in single and double layers, since each prism had three prisms, respectively. The rupture modulus values obtained from the experimental study are shown in Table 8. Figure 5 shows a comparison of the gap modulus values.

Sr. No.	Specimen	Modulus of Rupture (N/mm²)
1.	CC-Conventional	3.39
2.	WB1 (Woven Roving Mat Wrapped - Single Layer)	3.69
3.	WB2 (Woven Roving Mat Wrapped - Double Layer)	4.09

Table 8: Modulus of Rupture Values

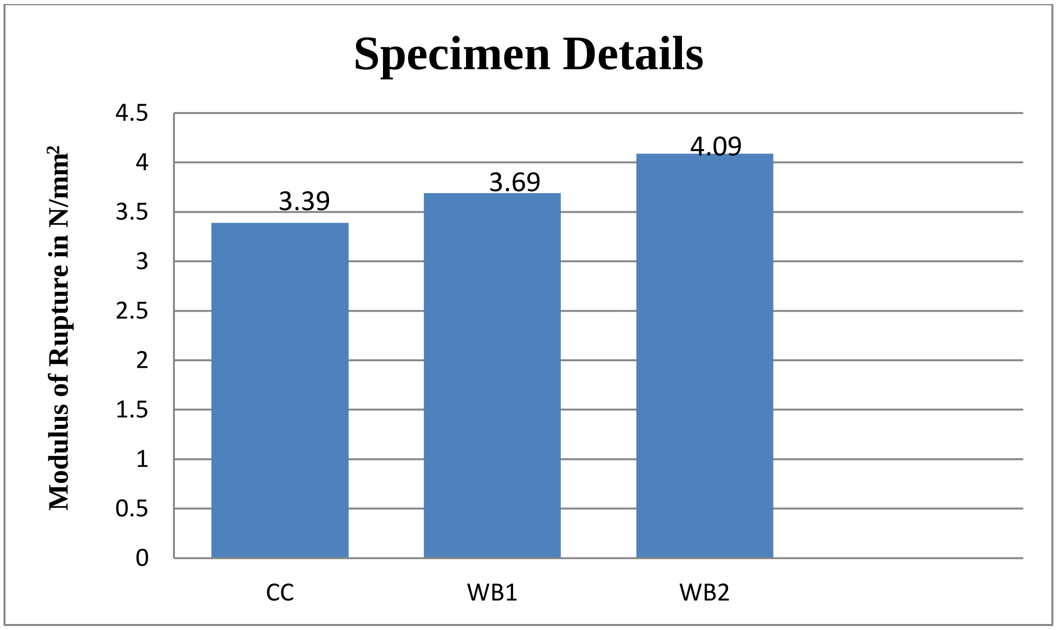

Figure 5 Comparisons of Modulus of Rupture Values

3.4. Load Carrying Capacity

Studies on beams rehabilitated using woven roving mat and external jacketing is carried out, and the load carrying capacity of the beam rehabilitated using woven roving FRP and external jacketing is compared with the control beam. Comparison of load carrying capacity of beams rehabilitated using woven roving FRP is given in Figure 6.

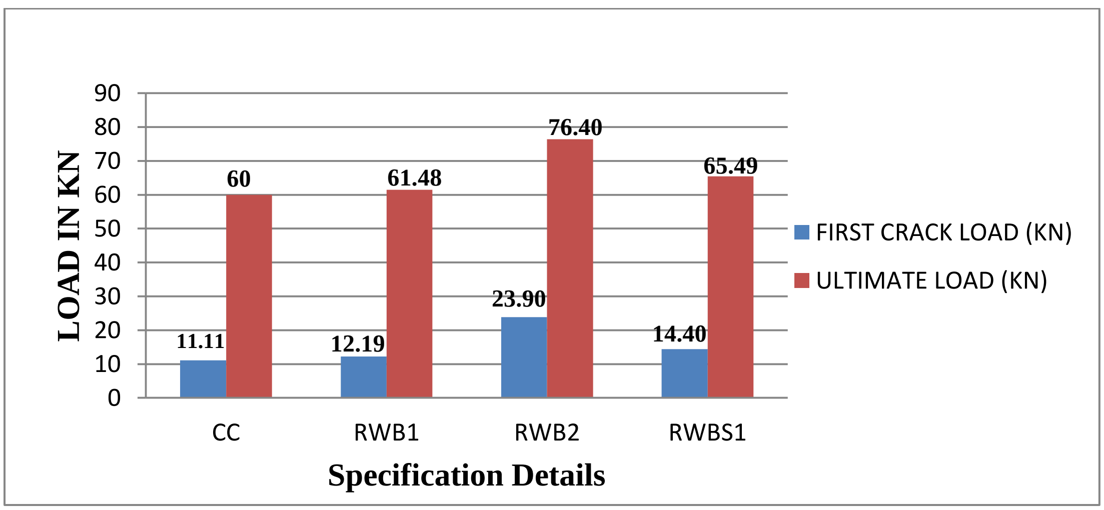

Figure 6 Comparison of Load Carrying Capacity of Rehabilitated beams using woven FRP

The load-carrying capacity of REJ1 is increased compared to the control. The first crack load and final load REJ1 are 12.30 kN and 66.80 kN, respectively indicates that the load behavior of REJ1 has increased. Figure 7 shows Comparison of load carrying capacity of beams rehabilitated using external jacketing.

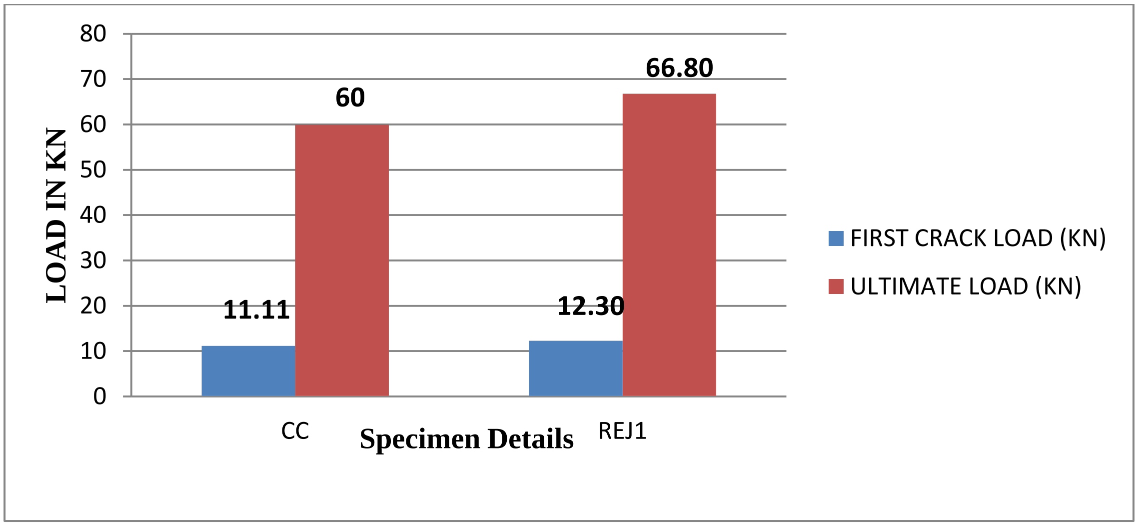

Figure 7 Comparison of load carrying capacity of rehabilitated beams using External Jacketing

4. CONCLUSIONS

4.1. Conclusions obtained from the study of companion specimens:

In all aspects of the test, the double wrap mat sample performed well under all conditions. Since the adhesion adapts to the concrete and does not collapse suddenly.

- According to the results of the compressive strength test of the cube, the double-layer wrapped cube sample reaches 27.31 N/mm^2 by woven, and CC has a value of 22.57 N/mm^2. In a double layer of woven roving, the strength increases by 21 % over CC.
- The split tensile strength of a typical concrete cylinder is 2.75 N/mm^2. This strength value increases by 20% and 48%, while the GFRP woven roving mat has single and double layer wrapped.
- The flexural strength test of a prismatic concrete specimen was 3.39 N/mm^2. When this prism is wrapped in single and double layer fiberglass woven roving mat, it increases flexural strength by 8.85% and 20.65% over Sample CC.

4.2. Conclusions obtained from the experimental study on rehabilitated beams:

- The flexural behavior of the reconstructed beam was significantly improved while the sample beam was wrapped with a two-layer woven mat (RWB2) placed at the bottom of the section. This beam can withstand a maximum load of 76.40 kN and a maximum deflection of 3.78 mm.

5. SPECIFIC CONCLUSION

Based on the results of the above pilot study, it can be generally concluded that the FRP wrapping techniques adopted for rehabilitated reinforced concrete beams are much better than external jacketing. External jacketing involves a change in the size of the structure (improvement of the size of the structure), which looks very strange from an aesthetic point of view.

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