# RETROFITTING OF RC BEAM USING DIFFERENT ORIENTATION OF GFRP LAMINATES

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***Abstract*— The use of fibre reinforced polymer for structural strengthening and rehabilitation is becoming more popular and an excellent option for use as external reinforcing, because of their light weight, resistant to corrosion and high strength. The fibre reinforced polymer laminates are introduced to enhance the flexural capacity and ductility. The main aim of this study to investigate the flexural characteristic of RC beams using different orientation of GFRP laminates. This paper presents experimental results of retrofitting of the RC beams with GFRP laminates having two type of orientation i.e. 90/90 and 45/45 orientation laminates.**

***Index Terms*— GFRP, flexural capacity, retrofitting, 90/90 and 45/45 orientation.**

## I. INTRODUCTION

Reinforced concrete (RC) structure using externally bonded fibre reinforced polymer (FRP) components has become a very universal practice, extensively accepted by recent design codes. Glass fibre reinforced polymers sheets are being increasingly used in rehabilitation and retrofitting of concrete structures, since low cost comparison with other types of FRP fibres. Over past few years, external strengthening using FRP composites gained popularity over steel because of several reasons including high strength-to-weight ratio, corrosion resistance and fatigue resistance, a low weight of the fibre make it easy to handle without lifting equipment at site, negligible change of cross section, self weight and free height of a structure. Glass fibres also have temperature resistance.

FRP can be retrofitted for any RC structural member like slab, beam, masonry wall or column.

## II. GFRP

Fiberglass is a type of fiber-reinforced plastic where the reinforcement fiber is specifically glass fiber. The glass fibers are made of various types of glass depending upon the fiberglass use. These glasses all contain silica or silicate, with varying amounts of oxides of calcium, magnesium, and sometimes boron. To be used in fiberglass, glass fibers have to be made with very low levels of defects. Fiberglass is a strong lightweight material and is used for many products. Although it is not as strong and stiff as composites based on carbon fiber, it is less brittle, and its raw materials are much cheaper. Its bulk strength and weight are also better than many metals, and it can be more readily molded into complex shapes.

In this project, bi-directional woven mat fibre can be used. The glass fiber may be randomly arranged, flattened into a sheet (called a chopped strand mat), or woven into a fabric.

### A. *Advantages of gfrp:*

1. GFRP has a very high strength to weight ratio.
2. Light weights of 2 to 4 lbs. per square foot means faster installation, less structural framing, and lower shipping costs.
3. Resists salt water, chemicals, and the environment - unaffected by acid rain, salts, and most chemicals.
4. Virtually any shape or form can be molded.
5. Research shows no loss of laminate properties after 30 years so maintenance is low.

## III. EPOXY RESIN

The large family of epoxy resins represent some of the highest performance resins of those available at this time. Epoxies generally out-perform most other resin types in terms of mechanical properties and resistance to environmental degradation, which leads to their almost exclusive use in aircraft components. As a laminating resin their increased adhesive properties and resistance to water degradation make these resins ideal for use in retrofitting purpose.

## IV. HARDENER

Hardener is a curing agent for epoxy resin. Epoxy resins require a hardener to initiate curing. It is also called the catalyst, the substance that hardens the adhesive when mixed with resin. It is the specific selection and combination of the epoxy and hardener components that determine the final characteristics and suitability of the epoxy coating for a given environment.

### A. *Scope and objective:*

1. To understand the load carrying capacity of gfrp

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wrapped beam with two different orientations.

2. To reduce the deflection of already loaded beam.
3. To increase the load carrying capacity of beam.
4. To compare the flexural behaviour of gfrp wrapped beam and control beam.

## V. EXPERIMENTAL STUDY

The tests were carried out on standard beam of 700*150*150 mm for 28 days curing to determine the mechanical properties of concrete. Firstly two control beams can be casted, cured and tested for maximum load carrying capacity. The deflection can be taken by dial gauge and their corresponding flexural strength can be calculated. After the application of load, the beam can be wrapped four sides by GFRP laminates with epoxy resin and hardener. During wrapping of fiber fabrics, the resin and hardener were correctly proportioned and thoroughly mixed together and the excess vinyl ester and air were removed using a ribbed roller moving in the direction of the fiber. One beam can be wrapped with 90/90 orientation gfrp laminate figure1. and another with 45/45 orientation laminate figure2.. Then the two beams were tested for their flexural strength. Compare the load carrying capacity of the wrapped and unwrapped beam. The increased load carrying capacity of the beam is determined.

Figure 1: 90/90 orientation gfrp laminates

Figure 2: 45/45 orientation gfrp laminates

## VI. EXPERIMENGTAL SETUP

The beams were tested in compression testing machine of capacity 1000 KN. Each member was positioned on the supports taking care to ensure that its centerline was exactly in line with the axis of the machine. The verticality of the specimens was checked using plumb bob and sprit level. Each beam was placed in the test setup on a clear span of 700 mm. The two external loads were positioned at a distance of 50 mm on either side of the centre line of the beam. Strain gauges were bonded at centre bottom of the beam. For Deflection of dial gauge was fixed at L/2 of the beam shown in figure3. The series of can be applied and the corresponding deflection can be taken for every 5KN.

Figure 3: Experimental setup

## VII. RESULT

The failure modes of all tested beams of 28days curing were show in figure. All the specimens were tested until failure to fully understand the influence of GFRP characteristics on their flexural behavior.

BEAM 1 BEFORE WRAPPING

| GRADE OF CONCRETE | ULTIMATE LOAD IN KN | DEFLECTION IN mm | FLEXURAL STRENGTH IN N/mm² |
|---|---|---|---|
| M30 | 0 | 0 | 0 |
| | 5 | 0.02 | 0.80 |
| | 10 | 0.06 | 1.60 |
| | 15 | 0.09 | 2.40 |
| | 20 | 0.17 | 3.20 |
| | 25 | 0.20 | 4.00 |
| | 30 | 0.31 | 4.80 |
| | 35 | 0.40 | 5.60 |
| | 40 | 0.52 | 6.40 |
| | 45 | 0.64 | 7.20 |
| | 50 | 0.78 | 8.00 |
| | 55 | 0.86 | 8.80 |
| | 60 | 0.94 | 9.60 |
| | 62.5 | 1.02 | 10.00 |

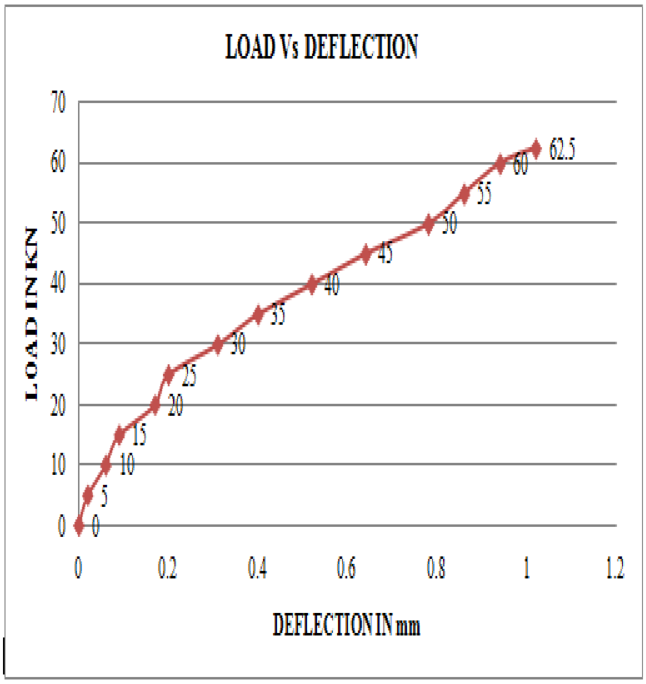


Figure4. Load vs Deflection of beam 1

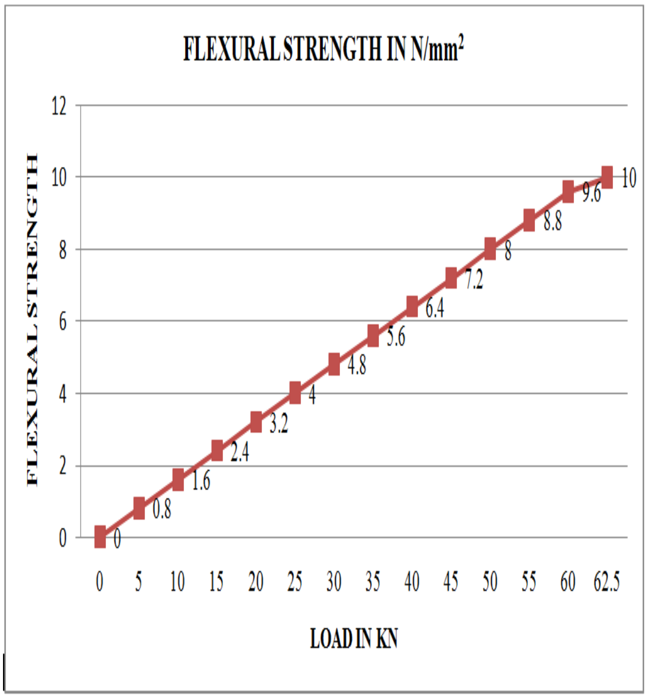


Figure5. Load vs Flexural strength of beam 1

BEAM 2 BEFORE WRAPPING

| GRADE OF CONCRETE | ULTIMATE LOAD IN KN | DEFLECTION IN mm | FLEXURAL STRENGTH IN N/mm² |
|---|---|---|---|
| M30 | 0 | 0 | 0 |
| | 5 | 0 | 0.80 |
| | 10 | 0.04 | 1.60 |
| | 15 | 0.17 | 2.40 |
| | 20 | 0.54 | 3.20 |
| | 25 | 0.59 | 4.00 |
| | 30 | 0.64 | 4.80 |
| | 35 | 0.71 | 5.60 |
| | 40 | 0.79 | 6.40 |
| | 45 | 0.88 | 7.20 |
| | 50 | 0.95 | 8.00 |
| | 55 | 1.04 | 8.80 |
| | 60 | 1.14 | 9.60 |
| | 65 | 1.23 | 10.40 |
| | 70 | 1.26 | 11.20 |
| | 74.5 | 1.42 | 11.92 |

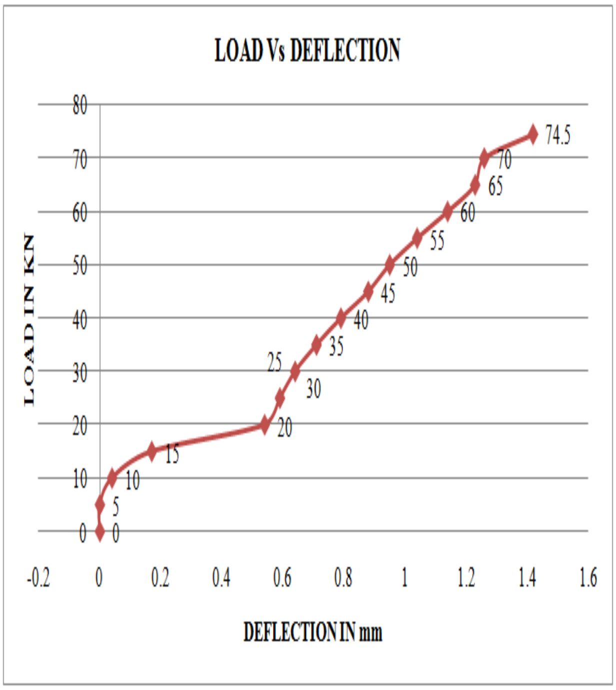


Figure 6. Load vs Deflection of Beam 2

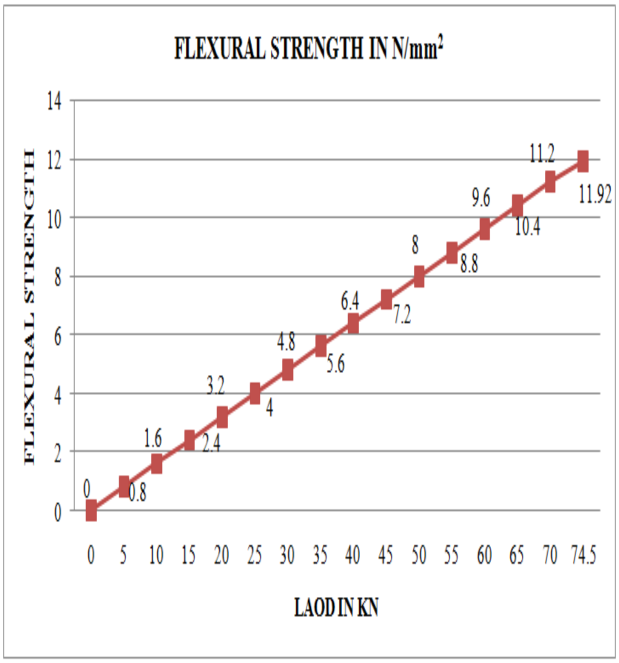


Figure 7. Load vs Flexural strength of beam 2

BEAM 1 AFTER WRAPPING WITH GFRP 45/45 ORIENTATION LAMINATE

| GRADE OF CONCRETE | ULTIMATE LOAD IN KN | DEFLECTION IN mm | FLEXURAL STRENGTH IN N/mm² |
|---|---|---|---|
| M30 | 0 | 0 | 0 |
| | 10 | 0.08 | 1.60 |
| | 20 | 0.22 | 3.20 |
| | 30 | 0.36 | 4.80 |
| | 40 | 0.50 | 6.40 |
| | 50 | 0.63 | 8.00 |
| | 60 | 0.76 | 9.60 |
| | 70 | 0.91 | 11.20 |
| | 80 | 1.03 | 12.80 |
| | 90 | 1.20 | 14.40 |
| | 100 | 1.34 | 16.00 |
| | 110 | 1.51 | 17.60 |
| | 120 | 1.76 | 19.20 |
| | 130 | 2.09 | 20.80 |
| | 140 | 2.59 | 22.40 |
| | 150 | 3.58 | 24.00 |
| | 160 | 4.86 | 25.60 |
| | 160.3 | 6.10 | 25.65 |

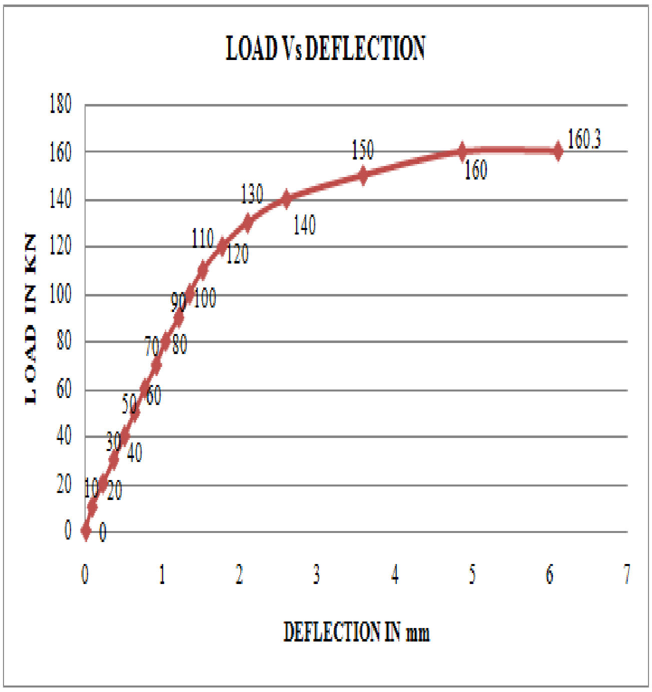


Figure 8. Load vs Deflection of beam 1 after wrapped with 45/45 gfrp

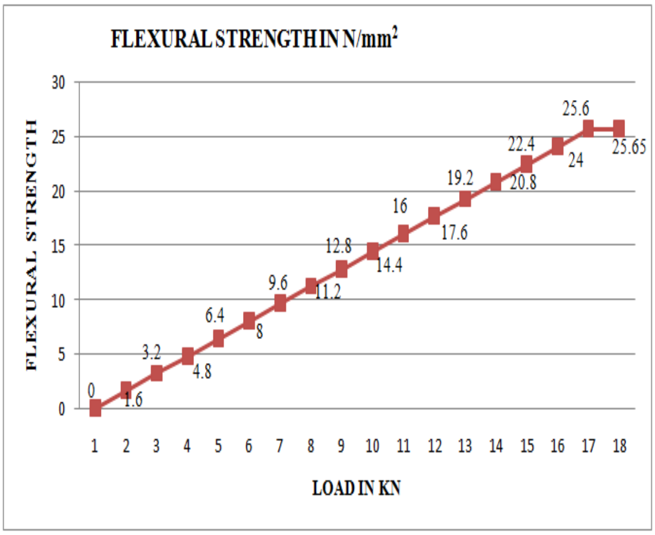


Figure 9. Load vs Flexural strength of beam 1 after wrapped with 45/45 gfrp

BEAM 2 AFTER WRAPPING WITH GFRP 90/90 ORIENTATION LAMINATE

| GRADE OF CONCRETE | ULTIMATE LOAD IN KN | DEFLECTION IN mm | FLEXURAL STRENGTH IN N/mm² |
|---|---|---|---|
| M30 | 0 | 0 | 0 |
| | 10 | 1.13 | 1.60 |
| | 20 | 1.32 | 3.20 |
| | 30 | 1.55 | 4.80 |
| | 40 | 1.65 | 6.40 |
| | 50 | 1.81 | 8.00 |
| | 60 | 1.98 | 9.60 |
| | 70 | 2.13 | 11.20 |
| | 80 | 2.30 | 12.80 |
| | 90 | 2.47 | 14.40 |
| | 100 | 2.66 | 16.00 |
| | 110 | 2.86 | 17.60 |
| | 120 | 3.09 | 19.20 |
| | 130 | 3.36 | 20.80 |
| | 140 | 3.74 | 22.40 |
| | 150 | 4.16 | 24.00 |
| | 160 | 4.67 | 25.60 |
| | 170 | 5.62 | 27.20 |
| | 178.6 | 7.18 | 28.58 |

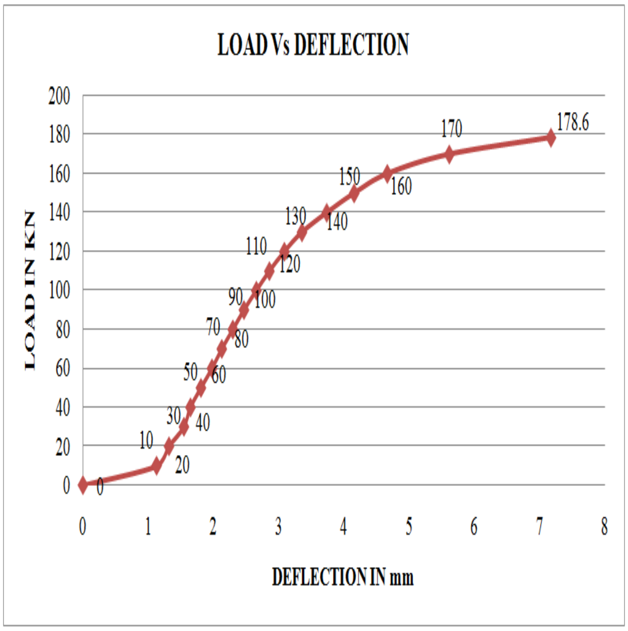


Figure 10. Load vs Deflection of beam 2 after wrapped with 90/90 gfrp

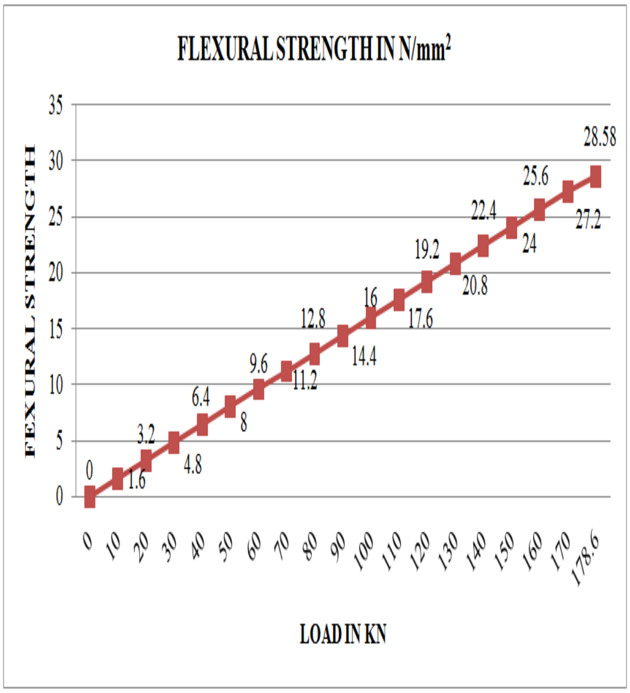


Figure 10. Load vs Flexural strength of beam 2 after wrapped with 90/90 gfrp

A. *Failure mode :*

1. For beam 1 without wrapping the failure occurred at the load of 62.5KN with corresponding flexural strength 10 N/mm².
2. For beam 2 without wrapping the failure occurred at the load of 74.5KN with corresponding flexural strength 11.9N/mm².
3. For beam 1 with wrapping of 45/45 orientation of GFRP laminates the failure occurred at the load of 160.3KN with corresponding flexural strength 25.65N/mm².
4. For beam 1 without wrapping the failure occurred at the load of 178.6KN with corresponding flexural strength 28.58 N/mm².
5. In addition there was no rupture of fiber was observed in top and bottom.

## VIII. CONCLUSION

In this study, it is suggested that the retrofitting of the beams using GFRP laminates is a quite effective technique in increasing the load carrying of the beam.

By comparing the above results, the glass fibre laminate wrapped with 90/90 orientation gives increased load carrying capacity.

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