# Experimental Study on Strengthening Of RC Beam by Using GFRP

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*Abstract*— Strengthening structures through external bond of advanced fibre reinforced polymer (FRP) fused is becoming very popular worldwide during the past decade because it provides a more economical and technically greater alternative to the traditional techniques in many situations as it offers high potency, low weight, corrosion resistance, high weariness resistance, easy and hasty installation and smallest change in structural geometry. Although many in-situ RC beams are uninterrupted in construction, there has been very limited research work in the area of FRP strengthening of uninterrupted beams. In the present study an experimental investigation is approved out to study the behavior of uninterrupted RC beams under static loading. The beams are strengthened on the exterior bonded glass fiber reinforced polymer (GFRP) sheets. Different scheme of strengthening have been employed. The program consists of four continuous (two-span) beams with overall dimensions equal to (150×250×1700) mm. Among this the first beam is tested conservatively whereas all other beams were strengthening in same pattern with diversity of externally bonded GFRP sheets. The present study examines the response of RC continuous beams, in terms of collapse modes, enhancement of load capacity and load deflection analysis. The results indicate that the flexible strength of RC beams can be significantly increased by gluing GFRP sheets to the flexible face. In addition, the epoxy bonded sheets enhanced the cracking behavior of the beams by delaying the construction of visible cracks and reducing crack widths at higher load levels.

***Key words:*** RC concrete; Glass fiber reinforced polymer; Epoxy resin; Loading Frame

## I. Introduction

A structure is designed for a precise period and depending on the environment of the structure, its design life varies. For a domestic building, this design life could be as low as twenty-five years, whereas for a public building, it could be fifty years. Worsening in concrete structures is a major challenge faced by the infrastructure and bridge industries worldwide. The worsening can be mainly due to environmental effects, which includes corrosion of steel, steady loss of strength with ageing, continual high intensity loading, disparity in temperature, freeze-thaw cycles, contact with chemicals and saline water and revelation to ultra-violet radiations. As complete alternate or reconstruction of the structure will be cost effective, strengthening or retrofitting is an effective way to make stronger the same. The most popular techniques for strengthening of RC beams have involved the use of exterior epoxy-bonded steel plates. It has been found experimentally that flexible strength of a structural member can increase by using this technique. Although steel bonding performance is simple, cost-effective and efficient, it suffers from a serious problem of worsening of bond at the steel and concrete inter phase due to corrosion of steel. Other common strengthening performance involves construction of steel jackets which is moderately valuable from strength, stiffness and ductility contemplation. However, it increases overall cross-sectional dimensions, leading to increase in self-weight of structures and is labor exhaustive. To eliminate these problems, steel plate was replaced by corrosion resistant and light-weight FRP complex plates. FRPCs help to increase strength and ductility without excessive increase in rigidity. Further, such material could be designed to meet specific supplies by adjusting placement of fibres. So concrete members can not be easily and effectively strengthened using externally bonded FRP composites. By packaging FRP sheets, growth of concrete structures provide a more inexpensive and technically greater alternative to the traditional performance in many situations because it offers high strength, low weight, corrosion resistance, high weariness resistance, easy and rapid installation and nominal change in structural geometry. Thus FRP sheet is stick to the conventional beam by using epoxy resin.

## II. Properties

### A. Epoxy Resin

The primary reason for epoxy's reputation is its outstanding mechanical strength. Welding is often the only alternative. Epoxy is nearly always cheaper and quicker than welding. Epoxy also has outstanding resistance to chemicals. After setting, there is no agonize of a chemical reaction that will weaken the seal. It also resists heat. That resistance makes it superlative for electronics and electrical systems and other industrial applications. Those who use epoxy are aware of the outstanding mechanical strength and low curative contraction. They also know the epoxy resins are well-balanced industrial materials and appropriate to a broad range of applications. Engineers are faced with concern about heat rakishness, electrical insulation, adhering dissimilar substrate, light weighting, sound dampening, vibration, and reduction corrosion. The outlook has to be considered, as well as, assembling costs. Epoxy is an epoxy resin formulation that meets all of those concerns. Its thermal and electrical properties, strength, and strength are what epoxy is noted for. Those properties along with the resistance to immersion and hostile chemical vapor are the reason epoxy frequently is chosen by engineers.

### B. E-Glass Fiber

| Environmental Properties | |
|---|---|
| | Resistance Factors 1=Poor 5=Excellent |
| Flammability | 5 |
| Fresh Water | 5 |
| Organic Solvents | 5 |
| Oxidation at 500C | 5 |

 

| | |
|---|---|
| Sea Water | 5 |
| Strong Acid | 5 |
| Strong Alkalis | 4 |
| UV | 5 |
| Wear | 5 |
| Weak Acid | 5 |
| Weak Alkalis | 5 |

Table 1:

## III. EXPERIMENTAL STUDY

The experimental study consists of casting of four large scale continuous (two-span) rectangular reinforced concrete beams. All the beams weak in flexure are casted and tested to failure. All beams had the same geometrical dimensions: 150 mm wide × 250 mm deep × 1700 mm long. All beams were strengthened with externally bonded GFRP sheets. Experimental data on load, deflection and failure method of each of the beams are acquired. The change in load moving capability and failure mode of the beams are investigated for different types of strengthening pattern.

### *A. Detailing of Reinforcement*

For the same series of uninterupted reinforced concrete beams, same arrangement for flexure and shear reinforcement is made Units.

### *B. Casting of Specimen*

For conducting experiment, the quantity of **1: 1.67: 3.33** is taken for cement, fine aggregate and course aggregate. The mixing is done by using concrete mixture. The beams are cured for 28 days. Compressive tests on shaped concrete (150 × 150 × 150 mm concrete cube) were performed and the average concrete compressive strength (fcu) after 28 days for each beam.

Fig. 3.1:

### *C. Testing of Beams*

All the four beams are tested one by one. All of them are tested in the above arrangement. The gradual increase in load and the deformation in the dial gauge reading are taken throughout the test. The load at which the first noticeable crack is developed is recorded as furious load. Then the load is functional till the ultimate failure of the beam. The deviation at midpoint of each span is taken for all beams with and without GFRP and are documentation with reverence to increase of load.

Fig. 3.2:

## IV. TEST RESULTS AND DISCUSSION

The beams were loaded with a determined load at the middle of each span and the obtained experimental results are presented and discussed subsequently in terms of the experimental mode of failure and load-deflection curve. The crack patterns and the mode of failure of each beam are also described in this chapter. All the beams are tested for their ultimate strengths and it is observed that the conventional beam had less load carrying capacity than the strengthened beam. Two sets of beams i.e. conventional and strengthened were examined and were strengthened with various patterns of FRP sheets. The different failure modes of the beams were observed for both conventional and strengthened.

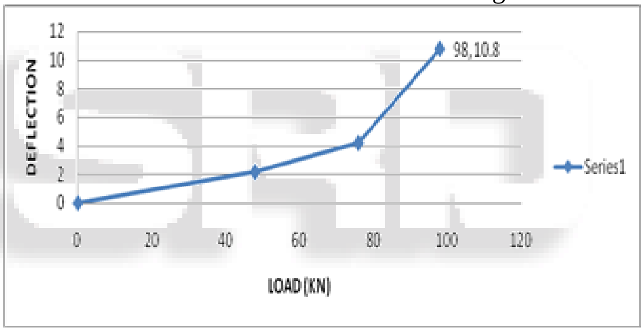


Fig. 4.1: Load versus Deflection Curve for CB1

Beam 1 was taken as the control beam (CB1) which is weak in flexure and no intensification was done to this beam. Two point static loading was applied on the beam and at the each augmentation of the load, deviation at midpoint of each span were taken with the help of dial gauges. Using this load and deflection data, load vs. deflection curve was plotted. At the load of 70 KN primary hairline cracks appeared. Later with the increase in loading values the crack proliferate further. The Beam CB1 failed completely in flexure at the load of 100 KN.

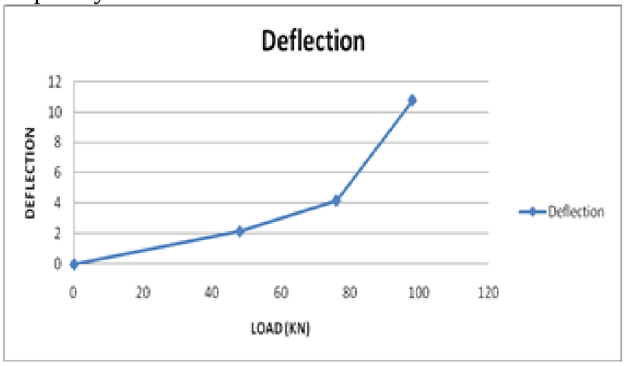


Fig. 4.2: Load versus Deflection Curve for SB1

Beam-2, SB1 is strengthened be appropriate GFRP at the soffit from support to support and at the top stuck between two load points. At the midpoint of each span, deviation values were taken and load versus deflection curve was plotted. The deflection values are less than that of the control beam for the same load value. At the load of 75 KN primary hairline cracks appeared. Later with the increase in loading values the crack propagated further. At lower load, debonding of FRP without concrete cover occurred and SB1 finally failed in concrete crushing with an ultimate load of 104 KN.

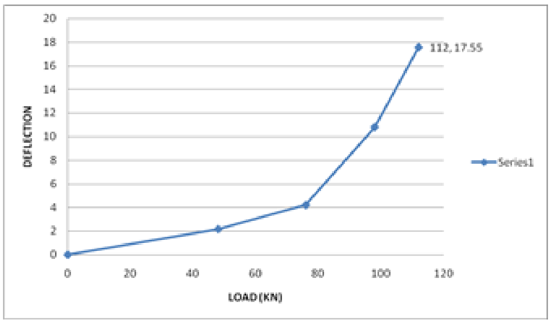


Fig. 4.3: Load versus Deflection Curve for SB2

Beam-3, SB2 is strengthened with GFRP of 20 microns from support to support distance and at the top of the beam between the two load points. The deflection values are less than that of the control beam for the same load value. No initial hairline cracks were visible due to the covering of GFRP. Later with the increase in loading values the crack propagated further under the GFRP. Tensile rupture took place at lower load and as the load increased, debonding of the FRP occurred with concrete cover and finally the beam failed in flexure and the failure load was 122 KN.

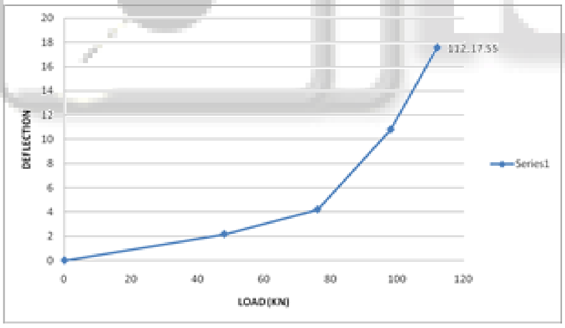


Fig. 4.4: Load versus Deflection Curve for SB3

Beam-4, SB3 is strengthened with GFRP from support to support distance, of two layers between the two load points. The beam failed in debonding of FRP without concrete cover. The cracking load was 75 KN and the failure load was 112 KN.

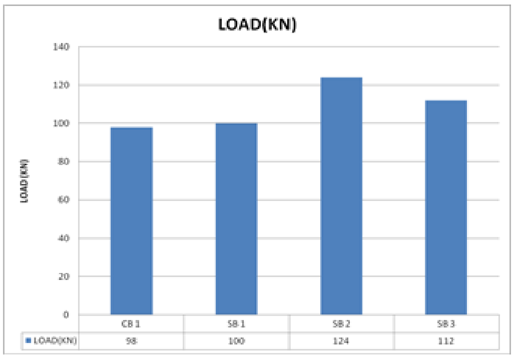


Fig. 4.5: Load comparison of various strengthened beams

## V. CONCLUSION

The present experimental study is carried out on the flexural behavior of reinforced concrete rectangular beams strengthened by GFRP sheets. Four reinforced concrete (RC) beams weak in flexure having same set of reinforcement detailing are casted and tested. Each beam had different longitudinal and transverse steel reinforcement ratios. From the test results and calculated strength values, the following conclusions are drawn:

1) The ultimate load carrying capacity of all the strengthen beams is higher when compared to the conventional beam.
2) The initial cracks in the strengthened beams are formed at higher load compared to conventional beam.
3) From the study the beam that was strengthened by GFRP of 20 micron showed the highest ultimate load value of 122 KN. The percentage increase of the load capacity of strengthened beam was 61.92 %.
4) From which it can be concluded that applying GFRP in the flexure zone is quite effective method to enhance the load carrying capacity.
5) Flexural failure at the intermediate support section can be prevented by application of GFRP sheet.

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