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# Flexural Studies on Reinforced Concrete Beams with Glass Fiber Reinforced Polymer

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**Abstract :** Since the last decade, the demand for the strengthening and retrofitting materials has been increased throughout the world due to the damages or failure occurred in flexural members of various Civil Engineering structures[2]. To overcome such demands many strengthening and retrofitting materials with various and unique properties has been available in the market. There are many techniques adopted to apply those retrofitting and strengthening materials. Among those we have selected Glass Fiber Reinforced Polymer (GFRP) as a retrofitting material for strengthening purpose by External bonding the RC Beam. In this study initially three beams will be preloaded and then retrofitted with Glass Fiber Reinforced Polymer(GFRP). On the other hand, initially other three beams will be strengthened with the same material.All the six beams will be tested under loading and flexural strength of each beam will be studied.

## 1.0 Introduction

Reinforced concrete beam is one of the most abundantly used construction material not only in the developed world, but also in rural parts of the developing world[3,4]. Existing concrete beams may need strengthening to improve its serviceability for many occasions namely due to crack in concrete and improving load carrying capacity of the beams[5-7]. In such cases, the application of certain strengthening and retrofitting materials may be advantages over new constructions. The commonly adopted techniques for retrofitting and strengthening of RC structure are namely externally bonding, jacketing, wrapping technique, steel bolts, wire mesh orientation, etc. In this project Glass Fiber Reinforced Polymer (GFRP) has been used as the best suited material for retrofitting and strengthening work on the flexural members on the basis of techniques used, cost-effectiveness and easily available, etc.

## 2.0 Objectives

To analyze the flexural strength of the beams with GFRP. From the experimental results, Strength and Stiffness behavior of the beam to be studied.

## 3.0 Experimental Program

Six numbers of RCC beams of dimension 1100x100x150mm were casted. Initially three beams were preloaded and their ultimate load capacities were observed. All the surfaces of the six beams were smoothened using emery sheet. The cracks on the beams were grooved up to 6mm and they were filled with epoxy bedding mortar. After that, all the beams were completely dried, they were wrapped with GFRP sheets using epoxy resin as the adhesive material. All the six beams were tested under two point loading conditions as per IS: 516: 1959 and the obtained results were compared with each other in order to analyze the flexural strength of the retrofitted beams and the strengthened beams. Finally the conclusion were drawn depends on the experimental results.

## 4.0 Expreimental Investigation

### 4.1 Casting of Beams

Two sets of beams were casted for this experimental test program. In SET I three beams (CB1, CB2 and CB3), In SET II three beams (SB1, SB2 and SB3) were casted using same grade of concrete and reinforcement detailing. The dimensions of all the specimens were identical. The cross sectional dimensions of the both set of the beams were 150 mm by 100 mm and length was 1100 mm. In both SET I and SET II beams 4 no of 10 mm dia bars are provided as the main longitudinal reinforcement and 6 mm dia bars as stirrups at a spacing of 150 mm center to center.

### 4.2 Materials for Casting

#### 4.2.1 Cement

Ordinary Portland Concrete (OPC) – 53 Grade was used for the investigation. It was tested for its physical properties in accordance withIS: 269-1989[11].

#### 4.2.2 Fine Aggregate

The fine aggregate obtained from river bed, clear from all sorts of organic impurities was used in this experimental program. The fine aggregate was passing through 4.75 mm sieve and had a specific gravity of 2.68. The grading zone of fine aggregate was zone III as per IS: 383-1970

#### 4.2.3 Coarse Aggregate

The coarse aggregates used were of two grades, non-reactive and available in local quarry. One grade contained aggregates passing through 4.75 mm sieve and retained on 10 mm size sieve. Another grade contained aggregates passing through 10 mm sieve but retained on 20 mm sieve.

#### 4.2.4 Water

Ordinary tap water (Drinking water in our college) used for concrete mix in all mix. It satisfies all properties as per IS: 456-2000.

#### 4.2.5 Reinforcing Steel

Reinforcement bars of 10 mm dia bars are used as main reinforcement. And 6 mm dia bars are used as stirrups. Reinforcement details of the beam were shown in fig 4.1

#### 4.2.6 Form Work

Fresh concrete, being plastic requires some kind of form work to mould it to the required shape and also to hold it till it sets. The form work has, therefore, got to be suitably designed. It should be strong enough to take the dead load and live load, during construction and also it must be rigid enough so mat any bulging, twisting or sagging due to the load if minimized, Wooden beams, mild steel sheets, wood, and several other materials can also be used. Formwork should be capable of supporting safely all vertical and lateral loads that might be applied to it until such loads can be supported by the ground, the concrete structure, or other construction with adequate strength and stability. Dead loads on formwork consist of the weight of the forms and the weight of and pressuresfrom freshly placed concrete. Live loads include weights of workers, equipment, material storage, and runways, and accelerating and braking forces from buggies and other placement equipment. Impact from concrete placement also should be considered in formwork design. Horizontal or slightly inclined forms often are supported on vertical or inclined support members, called shores, which must be left in place until the concrete placed in the forms has gained sufficient strength to be self-supporting. The shores may be removed temporarily to permit the forms to be stripped for reuse elsewhere, if the concrete has sufficient strength to support dead loads, but the concrete should then be restored immediately. The form work used for casting of all the specimen consists of mould prepared with two Channel sections of iron bolted by iron plates at the ends. The form work was thoroughly cleaned and all the corners and junctions were properly sealed by plaster of Paris to avoid leakage of concrete through small openings. Shuttering oil was then applied to the inner face of the form work. The reinforcement cage was then placed in position inside the form work carefully keeping in view a clear cover of 20 mm from all sides.

### 4.3 Mixing of Concrete

Mixing of concrete should be done thoroughly to ensure that concrete of uniform quantity is obtained. Hand mixing is done in small works, while machine mixing is done for all big and important works. Although a machine generally does the mixing, hand mixing sometimes may be necessary. A clean surface is needed for this purpose, such as a clean, even, paved surface or a wood platform having tight joints to prevent paste loss. The surface and level the platform, spread cement over the sand, and then spread the coarse aggregate over the cement. Use either a hoe or a square-pointed D-handled shovel to mix the materials. Turn the dry materials at least three times until the color of the mixture is uniform. Add water slowly while you turn the mixture again at least three times, or until you obtain the proper consistency. Usually 10% extra cement is added in case of hand mixing to account for inadequacy in mixing.

### 4.4 Compaction

All specimens were compacted by using needle vibrator for good compaction of concrete. Sufficient care was taken to avoid displacement of the reinforcement cage inside the form work. Finally the surface of the concrete was leveled and finished and smoothened by metal trowel and wooden float. Fig 4.2. shows the casted beam, when after removal from the mould.

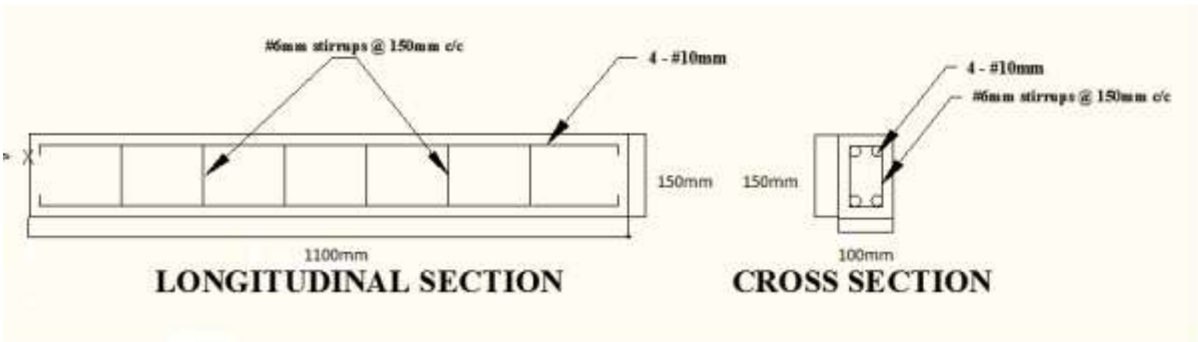


**Fig 4.1 Details of Reinforcement**

**Fig 4.2. Casting of Beams**

### 4.5 Curing of Concrete

The concrete is cured to prevent or replenish the loss of water which is essential for the process of hydration and hence for hardening. Also curing prevents the exposure of concrete to a hot atmosphere and to drying winds which may lead to quick drying out of moisture in the concrete and thereby subject it to contraction stresses at a stage when the concrete would not be strong enough to resists them. Concrete is usually cured by water although scaling compounds are also used. It makes the concrete stronger, more durable, more impermeable and more resistant to abrasion and to frost. Curing is done by spraying water or by spending wet heissian cloth over the surface. Usually, curing starts as soon as the concrete is sufficiently hard. Normally 14 or more days of curing for ordinary concrete is the requirement. However, the rate of hardening of concrete is very much reduced with the reduction of ambient temperature.

### 4.6 Strengthening of Beams

Before bonding the composite fabric onto the concrete surface, the required region of concrete surface was made rough using a coarse sand paper texture and cleaned with an air blower to remove all dirt and debris. Once the surface was prepared to the required standard, the epoxy resin was mixed in accordance with manufacturer's instructions. Mixing was carried out in a plastic container (Araldite LY 556 – 100 parts by weight and Hardener HY 951 – 8 parts by weight) and was continued until the mixture was in uniform colour. When this was completed and the fabrics had been cut to size, the epoxy resin was applied to the concrete surface. The composite fabric was then placed on top of epoxy resin coating and the resin was squeezed through the roving of the fabric with the roller. Air bubbles entrapped at the epoxy/concrete or epoxy/fabric interface were to be eliminated. Then the second layer of the epoxy resin was applied and GFRP sheet was then placed on top of epoxy resin coating and the resin was squeezed through the roving of the fabric with the roller and the above process was repeated. During hardening of the epoxy, a constant uniform pressure was applied on the composite fabric surface in order to extrude the excess epoxy resin and to ensure good contact between the epoxy, the concrete and the fabric. This operation was carried out at room temperature. Before testing, 24 hours curing were done for GFRP strengthened concrete beams.

## 5.0 Experimental Setup

All the specimens were tested in Universal Testing Machine having 100T capacity. The testing procedure for the entire specimen was same. After the curing period of 28 days was over, the beam washed and its surface was cleaned for clear visibility of cracks. The most commonly used load arrangement for testing of beams will consist of two-point loading as IS: 516:1959. This has the advantage of a substantial region ofnearly uniform moment coupled with very small shears, enabling the bending capacity of the central portion to be assessed. If the shear capacity of the member is to be assessed, the load will normally be concentrated at a suitable shorter distance from a support. Two-point loading can be conveniently provided by the arrangement shown in Fig 5.1. The load is transmitted through a load cell and spherical setting on to a spreader beam.This beam bears on rollers seated on steel plates bedded on the test member withmortar, high-strength plaster or some similar material. The test member is supported on roller bearing acting on similar spreader plates. The loading frame must be capable of carrying the expected test loads without significant distortion. Ease of access to the middle third for crack observations, deflection readings and possibly strain measurements is an important consideration, as is safety when failure occurs. The specimen was placed over the two steel rollers bearing leaving 50 mm from the ends of the beam. The remaining 1000 mm was divided into three equal parts of 500 mm as shown in the figure.

**Fig 5.1 Experimental setup**

Two point loading arrangement was done as shown in the Fig 5.2. Loading was done by hydraulic jack of capacity 100 KN. Three number of dial gauges were used for recording the deflection of the beams.To measure delection, a dial gauge is placed under the center of the beam.

**Fig 5.2 Loading pattern**

**6.0procedure**

The member was checked dimensionally before testing, and all information were carefully recorded by detailed visual inspection. After setting and reading all gauges, the load was increased incrementally up to the calculated working load, with loads and deflections recorded at each stage. Loads will then normally be increased again in similar increments up to failure, with deflection gauges replaced by a suitably mounted scale as failure approaches. This is necessary to avoid damage to gauges, and although accuracy is reduced, the deflections at this stage will usually be large and easily measured from a distance. Similarly, cracking and manual strain observations must be suspended as failure approaches unless special safety precautions are taken. If it is essential that precise deflection readings are taken up to collapse. Cracking and failure mode was checked visually, and a load/deflection plot was prepared.

## 7.0 Result and Discussions

### 7.1 Strength of RC Beams

Strength, also known as modulus of rupture, bend strength, or fracture strength, a mechanical parameter for beam, is defined as the beam's ability to resist deformation under load. The transverse bending test is most frequently employed, in which a rod specimen having either a circular or rectangular cross-section is bent until fracture using a three point flexural test technique. The flexural strength represents the highest stress experienced within the beam at its moment of rupture. It is measured in terms of stress, here given the symbol $\sigma$

### 7.2 Stiffness

Stiffness is the rigidity of an object to the extent which it resists deformation in response to an applied force.The stiffness, *k,* of a body is a measure of the resistance offered by an elastic body to deformation. For an elastic body with a single degree of freedom (for example, stretching or compression of a rod), the stiffness is defined as

$$k = \frac{F}{\delta}$$

where

$F$ is the force applied on the body

$\delta$ is the displacement produced by the force along the same degree of freedom (for instance, the change in length of a stretched spring)

### 7.3 Result From Control Beams

Three sets of beams were tested for their ultimate strengths. The beams CB1, CB2, and CB3 were taken as the control beams. When compared to that of the fully strengthened beams it was observed that the beams CB1, CB2, and CB3 had a less load carrying capacity. The second set of beams are one which is externally bonded with GFRP throughout the span and third set of beams are those which were already loaded and repaired with GFRP Deflection behavior and the ultimate load carrying capacity of the beams were noted.

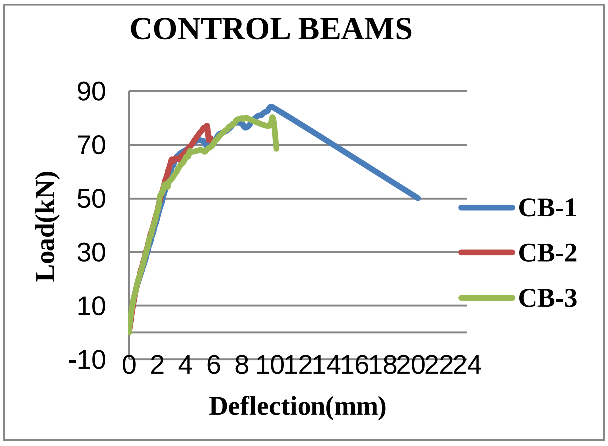


**Fig 7.1 Result from control beams**

### 7.4 Results from Control Strengthen Beams

The beams CB1, CB2, and CB3 were taken as the control beams. After the ultimate load of the control beams were noted those beams were repaired with GFRP and named as CSB1, CSB2 and CSB3.

### 7.5 Results From Strengthened Beams

Beams strengthened with GFRP sheets is named as SB1, SB2 and SB3. Those beams were tested for ultimate load capacity under suitable conditions. The comparison of those strengthened beams were shown in Fig 7.3.

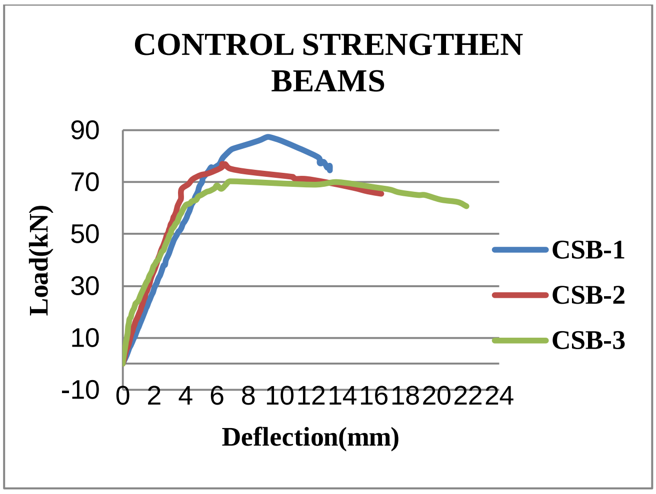


**Fig 7.2 Result from repaired beams**

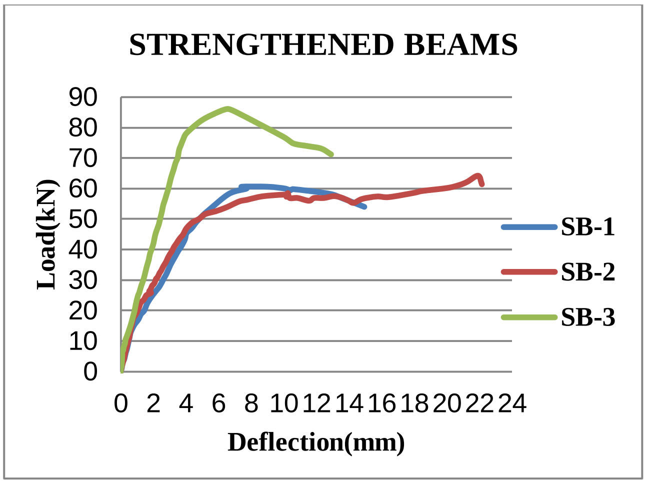


**Fig 7.3 Result from strengthened beams**

### 8.0 Result Discussion

From the graph illustrated in Fig 8.1, gives the repaired beams and strengthend beams were withstand the load carrying capacity was 90% and 106% of the control beams respectively.

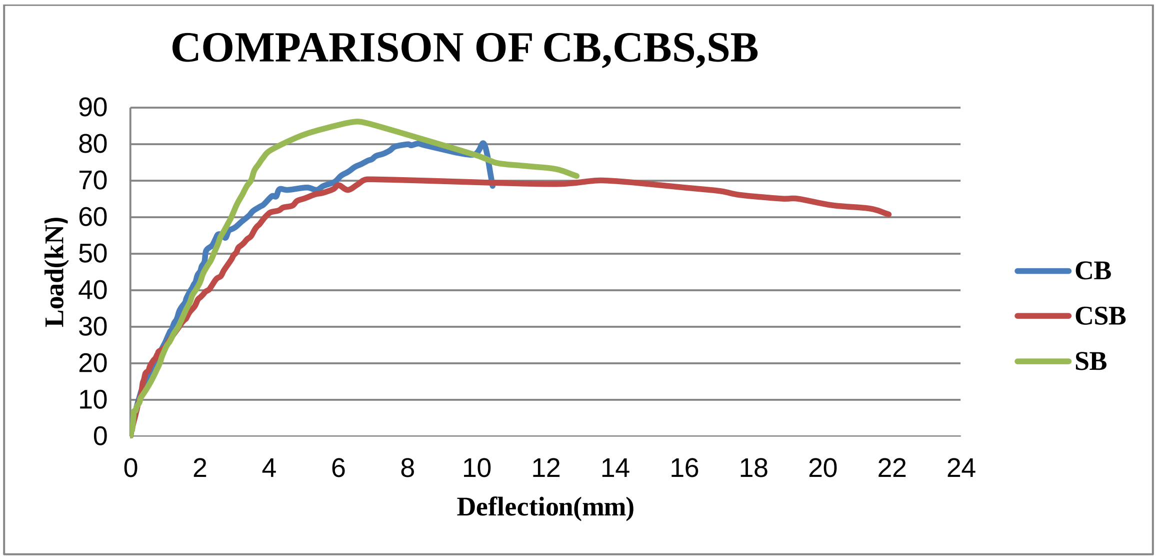


**Fig 8.1Comparisons of results**

**Table 8.1 Strength of Beams**

| S.No | Type of Beam | Ultimate Load (N) | Deflecton (mm) | Stiffness (N/mm) | Average Stiffness (N/mm) | Relative Stiffness Index (%) |
|---|---|---|---|---|---|---|
| 1. | CB1 | $84.1X10^3$ | 10.17 | $8.27X10^3$ | $8.74X10^3$ | 1 |
| 2. | CB2 | $76.6X10^3$ | 9.20 | $8.33X10^3$ | | |
| 3. | CB3 | $80.1X10^3$ | 8.33 | $9.62X10^3$ | | |
| 4. | CSB1 | $85.9X10^3$ | 8.65 | $9.93\ X10^3$ | $10.64\ X10^3$ | 21.74 |
| 5. | CSB2 | $76.9X10^3$ | 6.54 | $11.75\ X10^3$ | | |
| 6. | CSB3 | $70.3X10^3$ | 6.86 | $10.25\ X10^3$ | | |
| 7. | SB1 | $60.6X10^3$ | 5.39 | $11.24X10^3$ | $12.14\ X10^3$ | 38.90 |
| 8. | SB2 | $64.2X10^3$ | 5.34 | $12.02X10^3$ | | |
| 9. | SB3 | $86.1X10^3$ | 6.54 | $13.17X10^3$ | | |

From the Table 8.1, the relative stiffness index of Control Strengthen Beams and the Strengthend Beams was 21.74% and 38.90% when compared to Control Beams.

## 9.0 Conclusion

In this experimental investigation the flexural behavior of reinforced concrete beams strengthened by GFRP are studied. In two sets of reinforced concrete beams SET 1, three beams weak in flexure and results were noted. These beams were repaired with GFRP and then they were loaded and the results were observed. In SET 2, the load carrying capacity of the beams were noted for threebeams which were strengthened with GFRP. From these results, the following conclusions were drafted.

1. By strengthening the beam at soffit, initial flexural cracks appear at a higher load. The ultimate load carrying capacity of the repaired beam is 10% less than the control beam.
2. The strengthened beam's ultimate oad carrying capacity is 6% more than the control beams and 16% more than the repaired beams.
3. 3.Compared to Control Beams, the Relative Stiffness Index of the Control Strengthen Beams and the Strengthened Beams was 21.74% and 38.90% respectively.

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