

# **A Systemically Reconsideration of Torsional behaviour of Rectangular Reinforced Concrete Beams Bound with GFRP**

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**ABSTRACT:** Environmental degradation, improved service loads, reduced capability because of the aging, degradation owing to terrible construction materials and workmanships and the basic need for rehabilitation and repair of existing structures have been demanded by conditional need for seismic retrofitting. Fibre reinforced polymers has been utilized effectively in a lot of such uses for factors like lower weight, higher power and durability. In the experimental action up, performance and behaviour of concrete beams rectangular in shape is actually strengthened with externally bonded GFRP (glass fiber reinforced polymer) for research of torsion. Investigate was carried out on rectangular RC beams bonded with GFRP. This set was under test to determine to detect result of transferring transfer torque to main part of the beam utilizing cantilever situated at reverse arms. Every arm in the set up was situated under a few static load. This was damaging sort of testing need and all beams are actually meant to get produce fail results so far as torsion in considered. Out of 8 beams under test one beam is actually call as management beam and any other beams are actually strengthened using various kinds of configuration to confirm the impact of various configuration.

**KEYWORDS:** Concrete Beams, Wrapping, GFRP, reinforced concrete, T- beam, torsional strength

## **I. INTRODUCTION**

During its entire life span, almost all engineering structures ranging from residential buildings, an industrial structure to power stations as well as bridges faces degradation or perhaps deteriorations. The primary reasons for those deteriorations are actually environmental effects which includes corrosion of steel, gradual loss of strength with ageing, perturbation in heat, freeze-thaw cycles, repeated higher intensity loading, contact with chemical substances & saline water as well as coverage to ultra-violet radiations. Addition to these environmental effects earthquakes is also a key cause of deterioration of every structure. This particular problem needs development of effective structural retrofit technologies. Thus it's really important to have an inspection upon the continuing functionality of the civil engineering infrastructures. The structural retrofit issue has 2 choices, repair/retrofit or perhaps demolition/reconstruction. Demolition or perhaps reconstruction means total replacement of an existing framework might not be a cost-effective fix and it's apt to be an increasing economic burden if upgrading is a practical option. Therefore, repair and rehabilitation of bridges, structures, along with other civil engineering structures is quite often picked over reconstruction for the harm caused because of degradation, aging, absence of maintenance, and serious earthquakes and changes in the present style requirements.

Earlier, the retrofitting of reinforced concrete structures, like columns, beams and additional structural elements, was carried out by taking away and changing the low quality or even damaged concrete or/and metal reinforcements with new & more powerful materials. However, with the launch of new innovative composite materials like fiber reinforced polymer (FRP) composites, concrete users may now easily be and effectively strengthened making use of externally bonded FRP composites. Retrofitting of concrete buildings with wrapping FRP sheets present a more economical and technically better substitute for the conventional methods in many situations because it provides high strength, great weight, corrosion resistance, higher fatigue resistance, simple and quick installation and little change in structural geometry. Additionally, FRP manufacturing provides a distinctive opportunity for the improvement of shapes and types which would be difficult or even impossible with the traditional metal materials. Even though the fibers and resins employed in FRP methods are comparatively costly in contrast with traditional strengthening items, labor & equipment

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fees to install FRP methods are usually lower. FRP methods may also be used in regions with restricted access in which traditional methods would be impractical.

Many investigators has taken up concrete beams as well as columns retrofitted with carbon fiber reinforced polymer (CFRP) glass fiber reinforced polymer (GFRP) composites in order to study the enhancement of power plus ductility, durability, impact of confinement, planning of style guidelines and experimental investigations of the members. The outcomes received from various investigations regarding enhancement in fundamental parameters like strength/stiffness, ductility as well as durability of structural members retrofitted with externally bonded FRP composites, though very encouraging, still suffers from numerous limitations. This must have further research to be able to show up at knowing FRP composites as a likely full proof structural preservative. FRP fix is a very simple method to boost both the strength and style life of a framework. Due to its high power to weight ratio and resistance to corrosion, this particular repair approach is perfect for deteriorated concrete structure.

## **II. RELATED WORK**

Most researchers have paid much attention to flexural and shear strengthening beams bonded with FRP by experimental and numerical studies [2-4], and the investigated achievements have made significant progress. However, few types of research were involved in the torsional behaviour of the beams strengthened with FRP. From the present century, Zhang et al. [5] and Ghobarah et al. [6] conducted preliminary and exploratory studies on the torsional strengthening behaviour of RC members bonded with FRP. The two experimental investigations showed the ductility and torsional strength of the strengthened RC rectangular specimens with FRP increased reasonably.

The researchers [7-9] did not only perform a torsional test on rectangular beams strengthened with carbon fiber-reinforced polymer (CFRP) and glass fiber-reinforced polymer GFRP but also proposed an analytical method for calculating ultimate torque of strengthened RC specimens. The experimental study proved that the ductility of all strengthened torsional specimens increased, but the level of increment based on the configuration of FRP. The authors suggested that compressive strength of confined concrete should be applied in the proposed model to calculate the ultimate torsional strength more accurately.

Hii and AlMahaidi [10-12] focused on the experimental and numerical studies of the box and solid cross section RC beams bonded with FRP; the testing results showed an increase in percentage of solid section beam was more than that of the box section beam. Chalioris [13, 14] conducted the experimental study on rectangular and T-beams strengthened with CFRP subjected to torsion; the testing investigation displayed that complete wrapping with continuous sheets was more efficient than the same volume of strips in the torsional strengthening rectangular members, and a limited increase in torsional strength appeared in the T-beams with U-wrap. Thus, the author suggested that rational anchor should be used in T-beams with U-wrap for improving the strengthening effectiveness. In practical projects, it is impossible to access the entire cross section of a beam by fully wrapping due to the presence of the surface of the floor slab or bridge deck [6, 15].

## **III. DESIGN METHODOLOGY**

At the time of bonding of fiber, the concrete surface is made rough using a coarse sand paper texture and then cleaned with an air blower to remove all dirt and debris. After that the epoxy resin is mixed in accordance with manufacturer's instructions. The mixing is carried out in a plastic container (100 parts by weight of Araldite LY 556 to 10 parts by weight of Hardener HY 951). After their uniform mixing, the fabrics are cut according to the size then the epoxy resin is applied to the concrete surface. Then the GFRP sheet is placed on top of an epoxy resin coating and the resin is squeezed through the roving of the fabric with the roller. Air bubbles entrapped at the epoxy/concrete or an epoxy / fabric interface are eliminated. During hardening of the epoxy, a constant uniform pressure is applied to 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 is carried out at room temperature. Concrete beams strengthened with glass fiber.

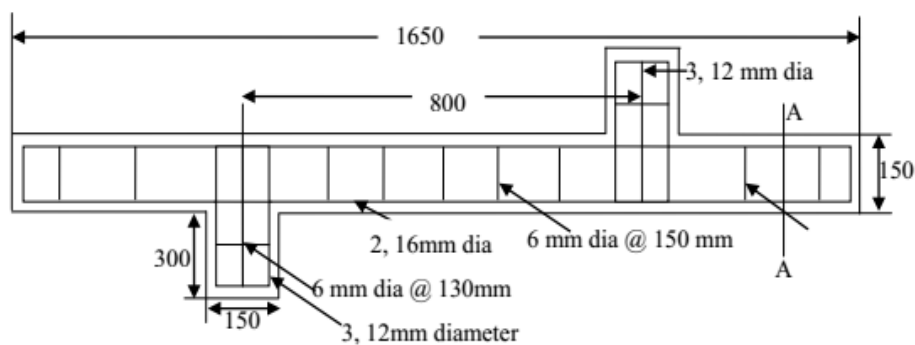


Fig. 1 Application of epoxy and hardener on the beam



Fig. 2 Roller used for the removal of air bubble

Total nine numbers of reinforced concrete rectangular beams were cast for the experimental study. All the nine beams weak in torsion are cast, out of which one is taken as controlled beam and other eight beams are strengthened using glass fiber reinforced polymer (GFRP). The eight beams were strengthened with GFRP in four different series. In SERIES-1 two beams were continuously fully wrapped, one with unidirectional GFRP and other with bidirectional GFRP. In SERIES-2 two beams were wrapped with 10cm GFRP strips, one with unidirectional GFRP and other with bidirectional GFRP. In SERIES-3 two beams were wrapped with 5cm GFRP strips, one with unidirectional GFRP and other with bidirectional GFRP. In SERIES-4 two beams were wrapped with 5cm GFRP strips, one with unidirectional GFRP and other with bidirectional GFRP making 450 with the axis of the beam.



Top view of Torsional Beam

Fig: 3 Reinforcement Detailing of Beam

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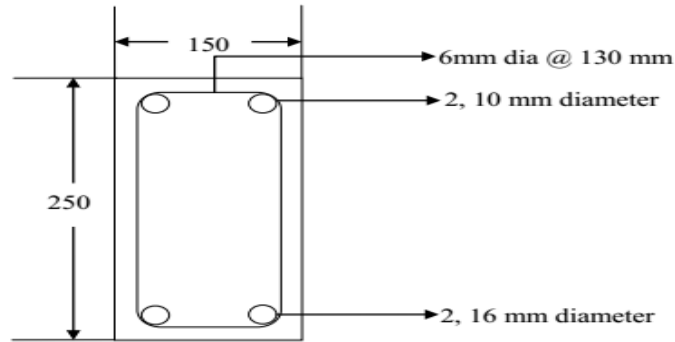


Fig: 4 Reinforcement Detailing of Beam at Sec-A-A

For conducting experiment, nine reinforced concrete Torsion beam specimen of size as Shown in the fig (Length of main beam (L) = 1.65m, Effective length ( $l_{eff}$ ) = 1.6m. Breadth of main beam (B) = 0.15m, Depth of main beam (D) = 0.25m, Length of cantilever part (l) = 0.3m, Width of cantilever part = 0.15m, Depth of cantilever part = 0.25m, Distance of cantilever part from end of the beam = 0.35m) and all having the same reinforcement detailing are cast. The mix proportion is 0.5: 1:1.8:3.6 for water, cement, fine aggregate and coarse aggregate is taken. The mixing is done by using concrete mixture. The beams were cured for 28 days. For each beam three cubes, two cylinders and two prisms were casted to determine the compressive strength of concrete for 28 days.

Table 1: The characteristics of the specimens

Specimen	Configurations	No of Layers	Concrete cube compressive strength ( N/mm <sup>2</sup> )	Flexural Strength Of Concrete Prism (N/mm <sup>2</sup> )	Split Tensile Strength of Concrete Cylinder (N/mm <sup>2</sup> )
Beam No 1	Control beam	None	27.11	6	2.96
Beam No 2	Uni-GFRP Continuous fully wrap	2	31	5.83	2.68
Beam No 3	Bi-GFRP Continuous fully wrap	2	29.34	6.3	3.15
Beam No 4	10cm Uni-GFRP strips wrap	2	30.25	5.65	3.34
Beam No 5	10cm Bi-GFRP strips wrap	2	28.53	6	2.76
Beam No 6	5cm Uni-GFRP strips wrap	2	25.78	5.7	2.87
Beam No 7	5cm Bi-GFRP strips wrap	2	27.36	5.87	2.4
Beam No 8	5cm Uni-GFRP strips wrap(450)	2	30	6.1	2.76
Beam No 9	5cm Bi-GFRP strips wrap(450)	2	31.5	6.54	3.32



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**Form Work**



Fig.5 Reinforcement Cage



Fig. 6 Steel Frame Used For Casting of Beams

**A. Mixing Of Concrete**

Mixing of concrete is done thoroughly with the help of machine mixer so that a uniform quality of concrete was obtained.

**B. Compaction**

Compaction is done with the help of needle vibrator in all the specimens. And care is taken to avoid displacement of the reinforcement cage inside the form work. Then the surface of the concrete is levelled and smoothed by metal trowel and wooden float

**C. Curing Of Concrete**

Curing is done to prevent the loss of water which is essential for the process of hydration and hence for hardening. It also 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 resist them. Here curing is to be done by spraying water on the jute bags spread over the surface for a period of 7 days.

**D. Fabrication of GFRP plate**

There are two basic processes for moulding: hand lay-up and spray-up. The hand lay-up process is the oldest and simplest fabrication method. The process is most common in FRP marine construction. In hand lay-up process, liquid

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resin is placed along with FRP against finished surface. Chemical reaction of the resin hardens the material to a strong light weight product. The resin serves as the matrix for glass fibre as concrete acts for the steel reinforcing rods. The following constituent materials were used for fabricating plates:

1. Glass Fibre
2. Epoxy as resin
3. Hardener as diamine (catalyst)
4. Polyvinyl alcohol as a releasing agent

A plastic sheet was kept on the plywood platform and a thin film of polyvinyl alcohol was applied as a releasing agent by the use of spray gun. Laminating starts with the application of a gel coat (epoxy and hardener) deposited in the mould by brush, whose main purpose was to provide a smooth external surface and to protect fibres from direct exposure from the environment. Steel roller was applied to remove the air bubbles.

Layers of reinforcement were applied and gel coat was applied by brush. Process of hand lay-up is the continuation of the above process before gel coat is hardened. Again a plastic sheet was applied by applying polyvinyl alcohol inside the sheet as releasing agent. Then a heavy flat metal rigid platform was kept top of the plate for compressing purpose. The plates were left for minimum 48 hours before transported and cut to exact shape for testing. Plates were casted using two different glass fibres Uni-GFRP and Bi-GFRP of 2 layers which are loosely spaced and are tested.



Fig.7 Uni-GFRP & Bi-GFRP Specimens for testing



Fig.8 Failure of Uni-GFRP & Bi-GFRP Specimens after tensile test

Table.2 Size of the specimens for tensile test

No. of layers	Length (cm)	Width (cm)	Thickness (cm)
2(Uni-GFRP)	15	2.3	0.15
2(Bi-GFRP)	15	2.3	0.3

**IV. RESULTS AND DISCUSSIONS**

All the experimental results of beams with different types of configurations and orientation of GFRP, their behavior throughout the test is described using recorded data on torsional behavior and the ultimate load carrying capacity. 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. Beam No-1 is taken as the control beam. It is observed that the control beam had less load carrying capacity and high deflection values compared to that of the externally strengthened Beams using GFRP sheets. All the eight beams except the control beam are strengthened with GFRP sheets in different patterns. In series -1, two nos of beams are completely wrapped, one with unidirectional and another one with Bidirectional GFRP sheets. Series -2 consists of two beams were wrapped with sheet having thickness of 10cm GFRP sheets, again same unidirectional and bidirectional way. In series-3 two beams were wrapped with smaller thickness GFRP sheets, having thickness of 5cm. and in series -4 beams were wrapped at an angle of 45 degrees having thickness of 5cm GFRP sheet

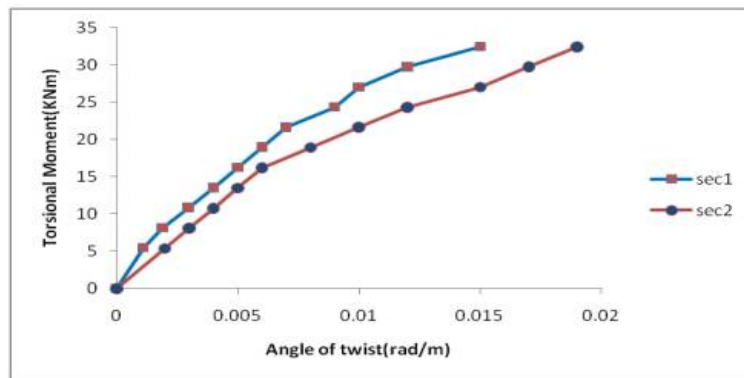


Fig. 9 Torsional Moment vs. Angle of Twist Curve for Control Beam-1

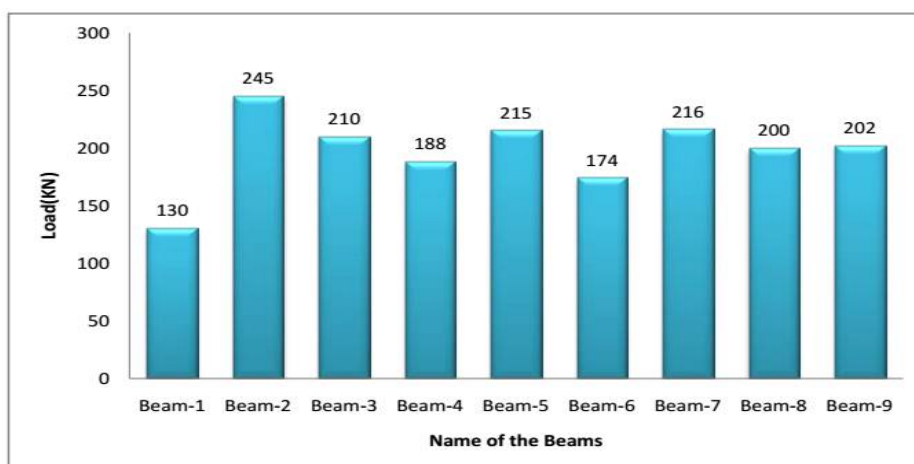


Fig. 10 Ultimate Load carrying capacity

In Fig.10 shows the load carrying capacity of the control beams and the strengthen beam are plotted below. It was observed that Beam 2 is having the max load carrying capacity.

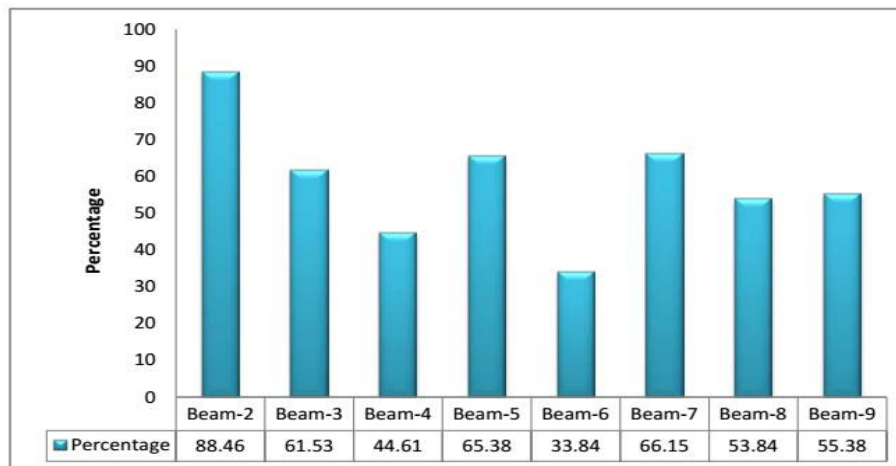


Fig. 11 Percentage increase in the Ultimate Carrying capacity w.r.t Control Beam 1

The above figure shows the amount of increase in the Torsional strength for each strengthened beam with respect to the Control Beam.

## V. CONCLUSIONS

The present experimental study is made on the torsional behavior of rectangular RC beams strengthened by uni-directional and bi-directional GFRP fabrics. Nine rectangular RC beams having same reinforcement detailing and designed to fail in torsion and are cast and tested till collapse. During testing deflections and strain measurements are observed with the help of dial gauges and strain gauge. Following conclusions are drawn from the test results and calculated strength values:

1. The enhancement in load carrying capacity is observed in other beams as compared to control beam.
2. Torsion of reinforced concrete beams strengthened with GFRP sheets exhibited significant increase in their cracking and ultimate strength as well as ultimate twist deformations.
3. Appearances of cracks were observed for higher loads in case of strengthened beams.

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