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A Study on RCC Beams wrapped with GFRP for torsional Behavior

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***Abstract*: Fiber Reinforced Polymer (FRP) is widely used as an external reinforcement in structural systems to meet flexure and shear strength requirements. However, the strengthening of members subjected to torsion has only recently been investigated. Torsion failure is an unfavorable brittle type of failure that should be avoided, particularly in earthquake-prone areas. The behavior and performance of rectangular reinforced concrete beams reinforced with externally bonded Glass Fibre Reinforced Polymer (GFRP) fabrics subjected to combined flexure and torsion are investigated experimentally in this work.**

RC Rectangular beams that were externally connected with GFRP fabrics and were rectangular in shape were tested until they failed using a system that transferred torque to the central portion of the beam through two opposing cantilevers known as moment arms. During the experiment, an equal static loading is applied to each arm. For the study, a total of nine RC beams were cast and evaluated. Every beam was intended to fail in torsion. Eight beams were strengthened utilizing various configurations and GFRP fabric types, with one beam serving as a control beam. The investigation is limited to GFRP fabrics that have been continually wrapped.

Experimental information was gathered on the ultimate and initial cracking loads, twist angle, and failure modes of each of the beams. Investigated were the effects of various GFRP kinds and configurations on the first crack load, ultimate load carrying capability, and failure mode of the beams. Using ANSYS software, the experimental data were finite element analysis confirmed and found to be in good agreement with analytical values. According to the experimental findings, externally bonded GFRP can greatly boost the beam's torsional capability. The full-wrap of GFRP textiles appears to be the most efficient arrangement, according to the results. Additionally, GFRP applied in 45 degree with the beam's axis provides greater strength than GFRP applied in 90 degree with the beam's axis.

***Index Terms*: RCC Beams, GFRP, Torsion, Fiber Reinforced Polymer**

I. Introduction (Heading 1)

Nearly all engineering structures, including houses, factories, power plants, and bridges, experience degradation or deterioration throughout the course of their whole lives. Environmental factors, such as corrosion of steel, gradual loss of strength with age, temperature variation, freeze-thaw cycles, repeated high intensity loading, contact with chemicals and saline water, and exposure to ultraviolet radiation are the main causes of these deteriorations. A significant factor in the degeneration of any construction, in addition to these environmental factors, is earthquakes. The creation of effective structural retrofit technology is required to solve this issue. Therefore, it is crucial to keep an eye on how well the civil engineering infrastructures are performing.

There are two solutions for the structural retrofit issue: repair/retrofit or demolition/reconstruction. If upgrading is a practical alternative, total replacement of an old facility may not be a cost-effective choice and may instead become a growing financial burden. Due to the damage caused by degradation, ageing, lack of maintenance, strong earthquakes, and changes in the current design standards, repair and rehabilitation of bridges, buildings, and other civil engineering structures are frequently chosen over reconstruction.

Previously, the retrofitting of reinforced concrete structures, such as columns, beams and other structural elements, was done by removing and replacing the low quality or damaged concrete or/and steel reinforcements with new and stronger material. However, with the introduction of new advanced composite materials such as fiber reinforced polymer (FRP) composites, concrete members can now be easily and effectively strengthened using externally bonded FRP composites

Retrofitting of concrete structures with wrapping FRP sheets provide a more economical and technically superior alternative to the traditional techniques in many situations because it offers high strength, low weight, corrosion resistance, high fatigue resistance, easy and rapid installation and minimal change in structural geometry. In addition, FRP manufacturing offers a unique opportunity for the development of shapes and forms that would be difficult or impossible with the conventional steel materials. Although the fibers and resins used in FRP systems are relatively expensive compared with traditional strengthening materials, labour and equipment costs to install FRP systems are often lower. FRP systems can also be used in areas with limited access where traditional techniques would be impractical.

Several investigators took up concrete beams and columns retrofitted with carbon fiber reinforced polymer (CFRP) glass fiber reinforced polymer (GFRP) composites in order to study the enhancement of strength and ductility, durability, effect of confinement, preparation of design guidelines and experimental investigations of these members. The results obtained from different investigations regarding enhancement in basic parameters like strength/stiffness, ductility and durability of structural members retrofitted with externally bonded FRP composites, though quite encouraging, still suffers from many

limitations. This needs further study in order to arrive at recognizing FRP composites as a potential full proof structural additive. FRP repair is a simple way to increase both the strength and design life of a structure. Because of its high strength to weight ratio and resistance to corrosion, this repair method is ideal for deteriorated concrete structure.

1.2. TORSIONAL STRENGHTENING OF BEAMS

Early efforts for understanding the response of plain concrete subjected to pure torsion revealed that the material fails in tension rather than shear. Structural members curved in plan, members of a space frame, eccentrically loaded beams, curved box girders in bridges, spandrel beams in buildings, and spiral stair-cases are typical examples of the structural elements subjected to torsional moments and torsion cannot be neglected while designing such members. Structural members subjected to torsion are of different shapes such as T-shape, inverted L–shape, double T-shapes and box sections. These different configurations make the understanding of torsion in RC members a complex task.

In addition, torsion is usually associated with bending moments and shearing forces, and the interaction among these forces is important. Thus, the behaviour of concrete elements in torsion is primarily governed by the tensile response of the material, particularly its tensile cracking characteristics. Spandrel beams, located at the perimeter of buildings, carry loads from slabs, joists, and beams from one side of the member only. This loading mechanism generates torsional forces that are transferred from the spandrel beams to the columns. Reinforced concrete (RC) beams have been found to be deficient in torsional capacity and in need of strengthening. These deficiencies occur for several reasons, such as insufficient stirrups resulting from construction errors or inadequate design, reduction

in the effective steel area due to corrosion, or increased demand due to a change in occupancy.

Similar to the flexure and shear strengthening, the FRP fabric is bonded to the tension surface of the RC members for torsion strengthening. In the case of torsion, all sides of the member are subjected to diagonal tension and therefore the FRP sheets should be applied to all the faces of the member cross section. However, it is not always possible to provide external reinforcement for all the surfaces of the member cross section. In cases of inaccessible sides of the cross section, additional means of strengthening has to be provided to establish the adequate mechanism required to resist the torsion. The effectiveness of various wrapping configurations indicated that the fully wrapped beams performed better than using FRP in strips.

1.3. ADVANTAGES AND DISADVANTAGES OF FRP

1.3.1. Advantages

There have been several important advances in materials and techniques for structural rehabilitation, including a new class of structural materials such as fiber-reinforced polymers (FRP). One such technique for strengthening involves adding external reinforcement in the form of sheets made of FRP. Advanced materials offer the designer a new combination of properties not available from other materials and effective rehabilitation systems. Strengthening structural elements using FRP enables the designer to selectively increase their ductility, flexure, and shear capacity in response to the increasing seismic and service load demands. For columns, wrapping with FRP can significantly improve the strength and ductility.

A potent advantage of using FRP as an alternate external confinement to steel is the high strength to weight ratio comparisons. In order to achieve an equivalent confinement, FRP plates are up to 20% less dense than steel plates and are at least twice as strong, if not more. Manufacture of modern composites is, then, possible in reduced sections and allows composite plates to be shaped on-site. The lower density allows easier placement of confinement in application. Design of external confinement to a structure should be made with conservative adjustments to the primary structures dead weight load. Changes of the stiffness of members should be considered when redesigning the structure. The improved behaviour of FRP wrapped members reduces the strains of internal steel reinforcement thereby delaying attainment of yielding. Much like internal steel confinement in longitudinal and lateral axes, external confinement exerts a similar pressure on the concrete as well as to the internal steel. Furthermore, FRP have high corrosive resistance equating to material longevity whilst within aggressive environments. Such durability makes for potential savings in long-term maintenance costs.

1.3.2. Disadvantages

With the above advantages FRP does also have some disadvantages as follows: The main disadvantage of externally strengthening structures with fiber composite materials is the risk of fire, vandalism or accidental damage, unless the strengthening is protected. As FRP materials are lightweight they tend to poses aerodynamic instability. Retrofitting using fiber composites are more costly than traditional techniques. Experience of the long-term durability of fiber composites is not yet available. This may be a disadvantage for structures for which a very long design life is required but can be overcome by appropriate monitoring. This technique need highly trained specialists. More over there is lack of standards and design guides.

EXPERIMENTAL RESULTS

the experimental results of all 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 beams were fully wrapped, one with unidirectional GFRP and other with bidirectional GFRP. In series-2 two beams were wrapped with 10cm wide GFRP sheets, one with unidirectional GFRP and other with bidirectional GFRP. In series-3 two beams were wrapped with 5cm GFRP sheets, one with unidirectional GFRP and other with bidirectional GFRP. In series-4 two beams were wrapped with 5cm GFRP sheets, one with unidirectional GFRP and other with bidirectional GFRP making 450 with the main beam.

ULTIMATE LOAD CARRYING CAPACITY

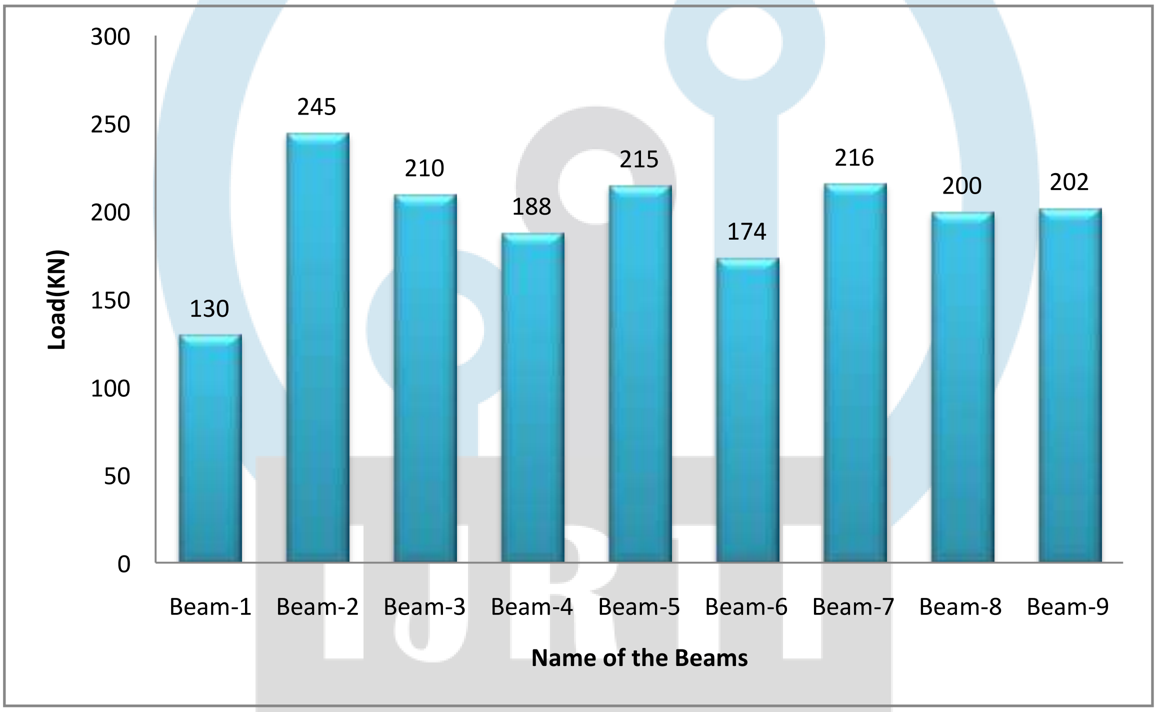

Fig. Ultimate Load carrying capacity

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

Increase in load carrying capacity

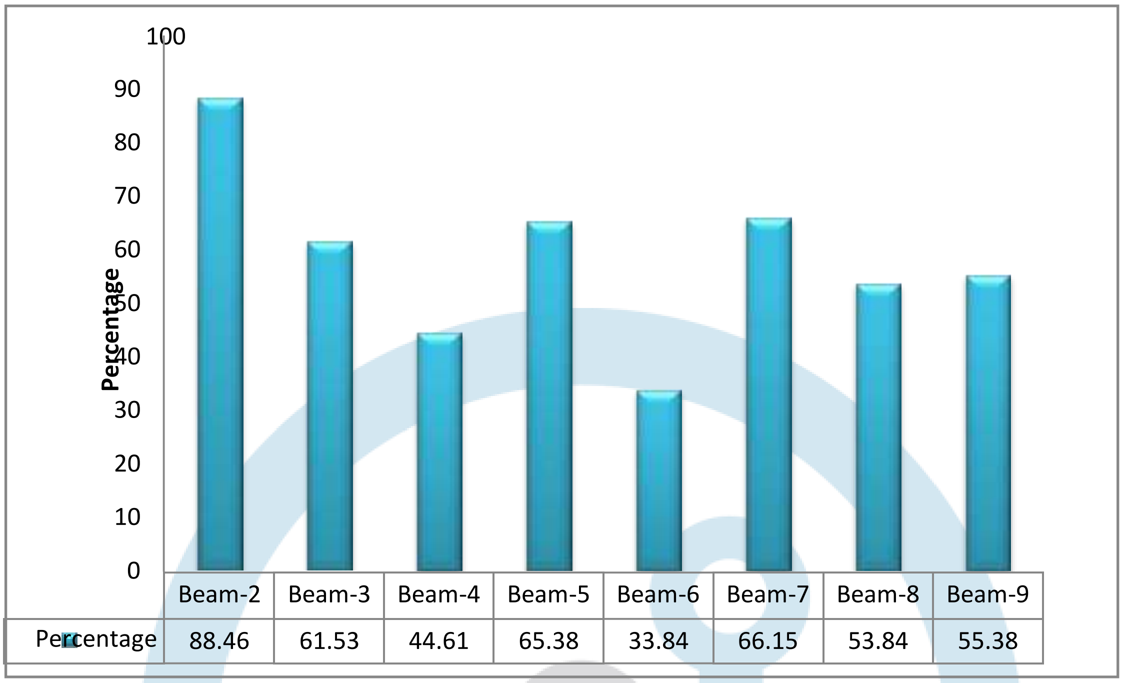

Fig. Percentage increase in the Ultimate Carrying capacity w.r.t Control Beam 1 The above figure shows the amount of increase in the Torsional strength for eachstrengthened beam with respect to the Control Beam.

CONCLUSIONS

The current experiment looks at the torsional behavior of rectangular RC beams reinforced with uni-directional and bi-directional GFRP textiles. Nine rectangular RC beams that are cast and tested until they break are engineered to fail in torsion and have the same reinforcement details. Dial gauges and a strain gauge are used during testing to measure deflections and strain. Following conclusions are drawn from the test results and calculated strength values:

1. The ultimate load carrying capacity of all the strengthen beams were enhanced as compared to the Control Beam1.
2. Torsional reinforced concrete beams strengthened with GFRP sheets exhibited significant increase in their cracking and ultimate strength as well as ultimate twist deformations.
3. Initial cracks appear for higher loads in case of strengthened beams.
4. The load carrying capacity of the strengthened Beam 2 fully wrapped with unidirectional fibre was found to be maximum of all the beams. The increase in load carrying capacity is 88.46% compared to control beam1.
5. Both fully wrapped beams Beam 2 and Beam 3 had partially collapsed without achieving the ultimate load. The failure occurred in the unstrenghtened part of the specimens.
6. Beam 8 and Beam 9 were giving the best results in terms of load carrying capacity and angle of twist respectively. And both are having same wrapping pattern of GFRP which is bonded in the torsion part at an angle 450 with the main beam.
7. Less cracks appeared on the beams strengthened with bidirectional fabrics compare to unidirectional fabrics. This may be due to availability of fibre on diagonal compression side causing less stress in concrete face in bidirectional fabrics.
8. Test result reveals that strengthening using bidirectional GFRP sheets had not enhanced the ultimate strength but had increased the ductility of the beam.
9. The angle of twist obtained using ANSYS matches the experimental results for lower range of load value for the beam which are wrapped with GFRP in 900 angles with main beam. For higher loads there is a deviation with experimental results for these beams.
10. The experimental results obtained for beams wrapped with GFRP at an angle 450 with axis of the beam are in good agreement with ANSYS results.

SCOPE OF THE FUTURE WORK

This present experimental work can give great scope for future studies. Following areas can be considered for future research:

1. Experimental investigation of the behavior of a flanged RC section covered with FRP when subjected to mixed loads
2. Effect of different types of FRP like CFRP (carbon fibre reinforced polymer) or hybrid FRP strengthening on torsional behavior of RC beams.
3. Development of an analytical model to predict full behavior up to collapse for RC beams strengthens in torsion under combined loading.
4. Creating a non-linear finite element model to analyze various configurations of fibres oriented differently in strengthened rectangular RC beams.

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