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# EXPERIMENTAL INVESTIGATION REPORT ON STRENGTH BEHAVIOUR OF FLANGED BEAMS ON REPLACEMENT OF REINFORCEMENT WITH GLASS FIBER POLYMERS

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**Abstract:**
**Environmental degradation, increased service loads, reduced capacity due to aging, degradation owing to poor construction materials and workmanships and conditional need for seismic retrofitting have demanded the necessity for repair and rehabilitation of existing structures. Fibre reinforced polymers has been used successfully in many such applications for reasons like low weight, high strength and durability. Many previous research works on torsional strengthening were focused on solid rectangular RC beams with different strip layouts and different types of fibres. Various analytical models were developed to predict torsional behavior of strengthened rectangular beams and successfully used for validation of the experimental works. But literature on torsional strengthening of RC T- beam is limited.**
**In the present work experimental study was conducted in order to have a better understanding the behavior of torsional strengthening of solid RC flanged T-beams. An RC T-beam is analyzed and designed for torsion like an RC rectangular beam; the effect of concrete on flange is neglected by codes. In the present study effect of flange part in resisting torsion is studied by changing flange width of controlled beams. The other parameters studied are strengthening configurations and fiber orientations.The objective of present study is to evaluate the effectiveness of the use of epoxy-bonded GFRP fabrics as external transverse reinforced to reinforced concrete beams with flanged cross sections (T-beam) subjected to torsion. Torsional results from strengthened beams are compared with the experimental result of the control beams without FRP application. The study shows remarkable improvement in torsional behavior of all the GFRP strengthen beams.**

**Keywords: POLYMERS,GGWT,MoRT&H**

## I. INTRODUCTION

Modern civilization relies upon the continuing performance of its civil engineering infrastructure ranging from industrial buildings to power stations and bridges. For the satisfactory performance of the existing structural system, the need for maintenance and strengthening is inevitable. During its whole life span, nearly all engineering structures ranging from residential buildings, an industrial building to power stations and bridges faces degradation or deteriorations. The main causes for those deteriorations are environmental effects including corrosion of steel, gradual loss of strength with ageing, variation in temperature, freeze-thaw cycles, repeated high intensity loading, contact with chemicals and saline water and exposure to ultra-violet radiations. Addition to these environmental effects earthquakes is also a major cause of deterioration of any structure. This problem needs development of successful structural retrofit technologies. So it is very important to have a check upon the continuing performance of the civil engineering infrastructures.

## 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.

## II. LITERATURE

Externally bonded, FRP sheets are currently being studied and applied around the world for the repair and strengthening of structural concrete members. Strengthening with Fiber Reinforced Polymers (FRP) composite materials in the form of external reinforcement is of great interest to the civil engineering community. FRP composite materials are of great interest to the civil engineering community because of their superior properties such as high stiffness and strength as well as ease of installation when compared to other repair materials. Also, the non-corrosive and nonmagnetic nature of the materials along with its resistance to chemicals made FRP an excellent option for external reinforcement.

Research on FRP material for use in concrete structures began in Europe in the mid 1950's by Rubinsky and Rubinsky, 1954 and Wines, J. C. et al., 1966. The pioneering work of bonded FRP system can be credited to Meier (Meier 1987); this work led to the first on-site repair by bonded FRP in Switzerland (Meier and Kaiser 1991).Japan developed its first FRP applications for repair of concrete chimneys in the early 1980s (ACI 440 1996).By 1997 more than 1500 concrete structures worldwide had been strengthened with externally bonded FRP materials. Thereafter, many FRP materials with different types of fibres have been developed. FRP products can take the form of bars, cables, 2-D and 3-D grids, sheet materials and laminates.

## III. EXPERIMENTAL STUDY

To study the most influential strengthening variables on torsional behavior a total of eleven medium scale reinforced concrete beams of 1900 mm long were constructed for this work. T-shaped beams, which are sorted in three groups (T2, T3 and T4 ) and were tested under combined bending torsion. Three numbers of beams are without torsional reinforcement were the control specimens and eight specimens were strengthened using epoxy-bonded glass FRP fabrics as external transverserein-forcemeat

## CASTING OF SPECIMENS.

For conducting experiment, eleven reinforced concrete beam specimen of size as Shown in the fig (Length of main beam (L) = 1900mm, Breadth of main beam(bw) = 150mm, Depth of main beam(D) = 270mm, Length of cantilever parts = 400mm, Width of cantilever part= 200mm, Depth of cantilever part= 270mm, Distance of cantilever part from end of the beam= 350mm) and all having the same reinforcement detailing are cast. The mix proportion is 0.5: 1:1.67:3.3 for water, cement, fine aggregate and course aggregate is taken. The mixing is done by using concrete mixture. The beams were cured for 28 days.

## MATERIALPROPERTIES

### Concrete

For conducting experiment, the proportions in the concrete mix are tabulated in Table 3.1 as per IS:456-2000. The water cement ratio is fixed at 0.55. The mixing is done by using concrete mixture. The beams are cured for 28 days. For each beam six 150x150x150 mm concrete cube specimens and six 150x300 mm cylinder specimens were made at the time of casting and were kept for curing, to determine the compressive strength of concrete at the age of 7 days & 28 days

**Table 3.1 Design Mix Proportions of Concrete**

| Description | Cement | Sand(Fine Aggregate) | Coarse Aggregate | Water |
|---|---|---|---|---|
| Mix Proportion (by weight) | 1 | 1.67 | 3.33 | 0.5 |

## Cement

Cement is a material, generally in powered form, which can be made into a paste usually by the addition of water and, when molded or poured, will set into a solid mass. Numerous organic compounds used for an adhering, or fastening materials, are called cements, but these are classified as adhesives, and the term cement alone means a construction material. The most widely used of the construction cements is Portland cement. It is bluish-gray powered obtained by finely grinding the clinker made by strongly heating an intimate mixture of calcareous and argillaceous minerals. Portland Slag Cement (PSC) Konark Brand was used for this investigation. It is having a specific gravity of2.96.

## Fine Aggregate

Fine aggregate is an accumulation of grains of mineral matter derived from disintegration of rocks. It is distinguished from gravel only by the size of the grains or particles, but is distinct from clays which contain organic material. Sand is used for making mortar and concrete and for polishing and sandblasting. Sands containing a little clay are used for making molds in foundries. Clear sands are employed for filtering water. Here, the fine aggregate/sand is passing through 4.75 mm sieve and having a specific gravity of 2.64. The grading zone of fine aggregate is zone III as per Indian Standard specifications IS: 383-1970.

## Coarse Aggregate

Coarse aggregates are the crushed stone is used for making concrete. The commercial stone is quarried, crushed, and graded. Much of the crushed stone used is granite, limestone, and trap rock. The coarse aggregates of two grades are used one retained on 10 mm size sieve and another grade contained aggregates retained on 20 mm size sieve. The maximum size of coarse aggregate was 20 mm and is having specific gravity of 2.88 grading confirming to IS: 383-1970

**Table 3.3 Tensile Strength of reinforcing steel bars**

| Sl. no. of sample | Diameter of bar (mm) | 0.2% Proof stress ($N/mm^2$) | Avg. Proof Stress ($N/mm^2$) |
|---|---|---|---|
| **1** | 20 | 475 | 470 |
| **2** | 10 | 530 | 529 |
| **3** | 8 | 520 | 523 |

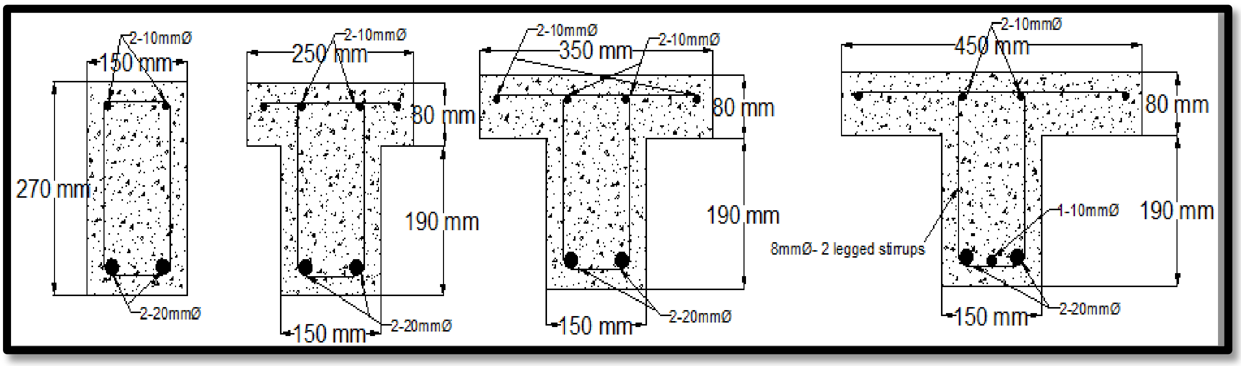


**Figure 3-1. Detailing of Reinforcement**

**STRENGTHENING OFBEAMS**

**Fig. 3.5 Application of epoxy and hardener on the beam**

**Fig 3.6 Roller used for the removal of air bubble**

**Form Work**

Fresh concrete being plastic in nature requires good form work to mold it to the required shape and size. So the form work should be rigid and strong to hold the weight of wet concrete without bulging anywhere. The joints of the form work are sealed to avoid leakage of cement slurry. Mobil oil was then applied to the inner faces of form work.

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**Figure 3-7. Steel Frame Used For Casting of RC T-Beam**

## EXPERIMENTAL SETUP

The beams were tested in the loading frame of "Structural Engineering" Laboratory of National Institute of Technology, Rourkela. The testing procedure for the all the specimen is same. First the beams are cured for a period of 28 days then its surface is cleaned with the help of sand paper for clear visibility of cracks. The two-point loading arrangement was used for testing of beams.

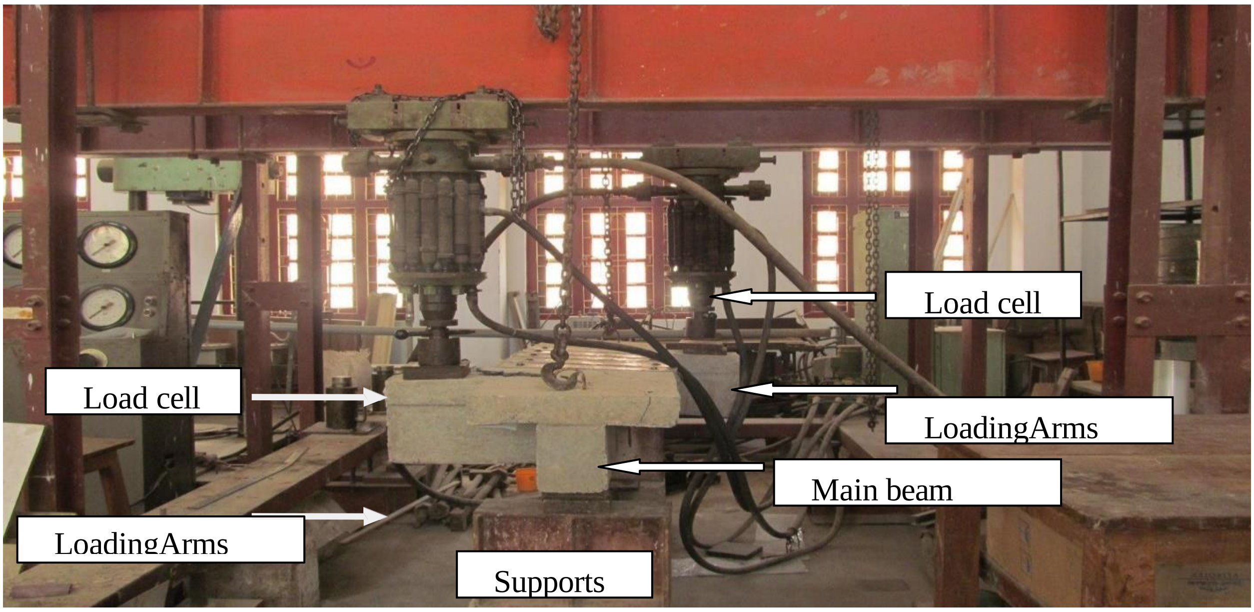


**Fig no.3.8 Loading Setup**

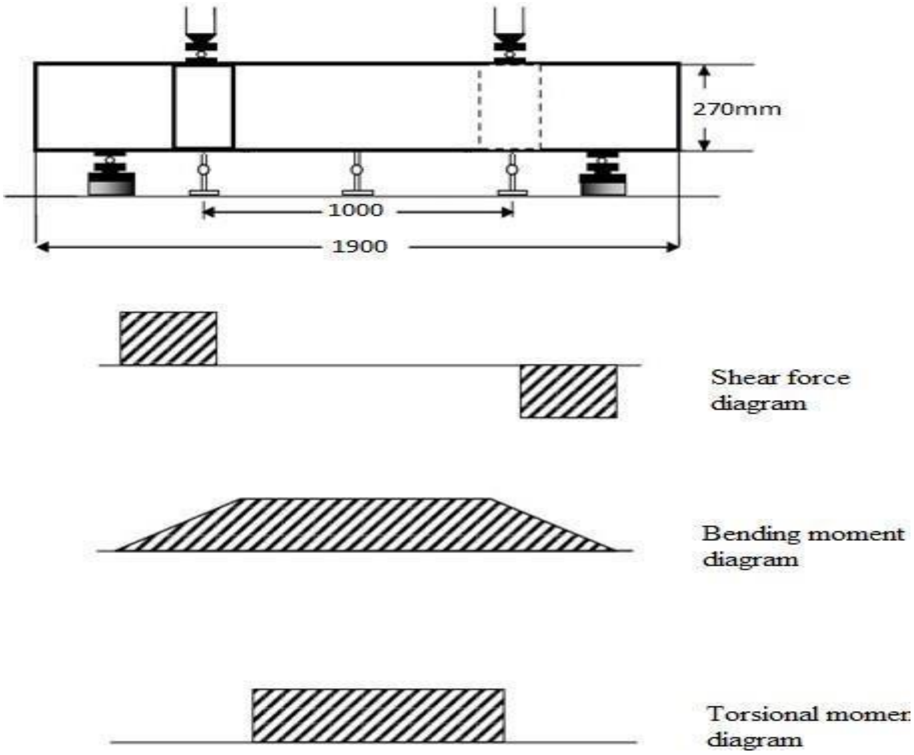


**Fig. 3.9 Shear force and bending moment diagram for two point loading**

## III. ANALYTICAL ANALYSIS

Various analytical models have been proposed for evaluating ultimate torque of FRP Strengthened Reinforced concrete beams. Earlier the FIB model introduced in 2001 was the only available analytical method to evaluate the FRP contribution in the ultimate torsional capacity of the RC beams

**Table 5.1 Comparison of Analytical and Experimental Results**

| Beam Name | | tf (mm) | n | θ | B | fc 2 N/mm | Tf,cal kN m | Tfexp= Tult* - Tcont* kNm | |
|---|---|---|---|---|---|---|---|---|---|
| Series- A | T3SU | 2.26 | 5 | 65º | 90º | 28.62 | 28.61 | 27 | 1.05 |
| | T3SF | 2.51 | 5 | 50º | 90º | 28.69 | 109.61 | 114 | 0.96 |
| | T3S45 | 2.46 | 4 | 55º | 45º | 28.69 | 99.69 | 94 | 1.060 |
| Series- B | T4SU | 2.43 | 5 | 55º | 90º | 30.89 | 51.3 | 56 | 0.91 |
| | T4SF | 2.53 | 5 | 45º | 90º | 30.77 | 149.98 | 163 | 0.97 |
| | T4S45 | 2.28 | 4 | 42º | 45º | 29.83 | 133.17 | 145 | 0.91 |

## V.CONCLUSIONS

i. Experimental results shows that the effect of flange width on torsional capacity of GFRP strengthened RC T-beams aresignificant.

ii. Torsional strength increases with increase in flange area irrespective of beam strengthening with GFRP following different configurationsschemes.

iii. With 250 mm wide flange width increase in strength was 13%, with 350mm wide flange was 29% and for 450mm wide flange was found to be 69%. This is due to increase in area enclosed inside the critical shear path.

iv. The cracking and ultimate torque of all strengthen beams were greater than those of the control beams.

v. The increase in magnitude depends on the FRP strengtheningconfigurations.

vi. The maximum increase in torque was obtained for 900fully wrappedconfigurations. Increase of 133.33% to 116.67% in first cracking and 155.55% to 107.23% in ultimate torsion were recorded for series B beams and series C beams respectively.

vii. Beams U wrapped with 900 oriented GFRP stripes showed lowest torsional resisting capacity. Since shear flow stresses take a close path during torsional loading ,torsion would not be well resisted in case of U-jacketingstrengthening.

viii. For U wrapped beams increase of 22.22% to 33.33% in first cracking and 23.27% to 36.84% in ultimate torsion were recorded for series B beams and series C beams respectively

ix. Beams strengthen with U jacketing in web and top of flange and anchored with bolts exhibited increase of 11.11% to 55% in first cracking and 28.33% to 61.84% in ultimate torsion were recorded for series B beams and series C beamsrespectively.

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