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Shear Strengthening of RC Beams using Externally Bonded GFRP

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Abstract:
The rehabilitation of existing reinforced concrete (RC) bridges and building becomes necessary due to ageing, corrosion of steel reinforcement, defects in construction, demand in the increased service loads, and damage in case of seismic events and improvement in the design guidelines. The Fiber-reinforced polymers (FRP) have emerged as promising material for rehabilitation of existing reinforced concrete structures. The rehabilitation of structures can be in the form of strengthening, repairing or retrofitting for seismic deficiencies. Shear failure of RC beams is identified as the most disastrous failure mode as it does not give any advance warning before failure. The shear strengthening of RC T-beams using externally bonded (EB) FRP composites has become a popular structural strengthening technique, due to the well-known advantages of FRP composites such as their high strength-to weight ratio and excellent corrosion resistance. This study assimilates the experimental works of glass fiber reinforced polymer (GFRP) retrofitted RC beams under symmetrical four-point static loading system.

Keywords: Glass fiber, carbon fiber, epoxy.

I. INTRODUCTION

Flexural failure and shear failure are the two primary modes of failure in reinforced concrete (RC) beams. Flexural failure of a beam is ductile in nature, i.e., it occurs gradually with large deflections and cracking, which provide a warning of incipient failure. Conversely, shear failure is brittle in nature and does not allow substantial redistribution of loads; thus, shear failure occurs without any prior warning and is often catastrophic. Poorly designed beams may fail in shear before reaching the flexural strengths. Hence, RC beams must have sufficient shear strength, higher than flexural strength, in order to ensure a ductile failure mode Shear failure of RC structures may be due to many factors, e.g., insufficient shear reinforcement, reduction of steel area due to corrosion and spalling of concrete caused by aggressive environmental conditions, increased service load due to change in usage of the structure, and any detailing, design, and/or construction error. Thus, strengthening and rehabilitation of RC structures may be needed to increase the ultimate load carrying capacity of shear-deficient beams. Structures that are deficient in shear can be strengthened or repaired by using various methods, e.g., external prestressing, shortcreting, polymer impregnation, steel plate bonding. Among these retrofit solutions, the use of externally bonded fiber reinforced polymer sheet/straps/fabrics (FRP) is becoming more popular used and widely recognized by modern design codes and guideline FRP shear retrofit of RC structures presents numerous advantages compared to other more traditional techniques, e.g., light weight and ease of installation, high strength to weight ratio, high stiffness to weight ratio, and corrosion resistance. However, the accurate prediction of the shear strength of FRP-retrofitted beams is a complex task. Shear retrofit of RC beams with externally bonded FRP is being widely recognized as an efficient retrofit technique. In recent years, many experimental studies have been carried out and several models have been implemented in modern design codes and guidelines. However, modelling of RC structures retrofitted in shear using FRP is a complicated task and represents an active research field, owing to the difficulty in interpreting the various factors simultaneously contributing to multiple resisting mechanisms. The interaction between these resistance mechanisms are very complex and still need to be predicted more accurately. Hence, reliable proposed models and formulations are needed to allow engineers to model FRP strengthened RC structures and to predict their structural response and performance under different strengthening configurations.

II. ADVANTAGES OF FRP

FRP composites have many benefits to their selection and use. The selection of the materials depends on the performance and intended use of the product. The composites designer can tailor the performance of the end product with proper selection of materials. It is important for the end-user to understand the application environment, load performance and durability requirements of the product and convey this information to the composites industry professional. A summary of composite material benefits include:

- Light weight
- High strength-to-weight ratio
- Directional strength
- Corrosion resistance
- Weather resistance
- Dimensional stability
- Low thermal conductivity
- Low coefficient of thermal expansion
- Low maintenance
- Long term durability
- Small to large part geometry possible

III. DISADVANTAGES OF FRP

- Reduces the overall factor of safety and is unlikely to lead to collapse.
- Risk of fire, or accidental damage.
- Low impact resistance, flammability, aging and loss of strength over time.
- Degradation, heat deflection, tensile strength, flexural strength, toxic components

IV. MIX DESIGN OF CONCRETE FOR FOUNDATION OF THE STRUCTURE

MATERIAL TESTING

- Specific Gravity Of Cement=3.1
- Specific Gravity Of Fine Aggregate=2.61
- Specific Gravity Of Coarse Aggregate=2.81
- Grading Of Fine Aggregate= (Zone-III)

MIX DESIGN

1. GRADE DESIGNATION = M30
2. CEMENT =RAMCO CEMENT
3. TARGET MEAN STRENGTH =38.25 N/MM^2 (IS 10262 2009)
4. W/C RATIO =0.44 (IS 456 ,TABLE 5)
5. WATER CONTENT =197 KG (IS 10262, TABLE NO 2)
6. CEMENT CONTENT=W/C=0.44
   C=197/0.44
   C=447 KG
7. VOLUME OF COARSE AGGREGATES = 0.64
8. VOLUME OF FINE AGGREGATES =0.36

MIX CALCULATION PER UNIT VOLUME OF CONCRETE

a) Volume of concrete = 1 m^3

b) Volume of cement =mass of cement/ specific gravity of cement X 1/1000 =447/3.1 X 1/1000 =0.14 m^3

c) Volume of water = mass of water/ specific gravity of water X 1/1000 =197/1 X 1/1000 =0.197 m^3

d) Volume of aggregates = (a -(b+c)) = (1-(0.15+0.19))=0.66 m^3

e) Mass of coarse aggregates = d X volume of coarse aggregates X specific gravity of coarse aggregates X 1000 = 0.66 X 0.64 X 2.81 X 1000 =1186 kg

f) Mass of fine aggregates = d X volume of fine aggregates X specific gravity of fine aggregates X 1000 = 0.66 X 0.36 X 2.61 X 1000 =620 kg

g) Cement , fine aggregates and coarse aggregates ratio =447/447 :620/447:1106/447 =1:1.38:2.65

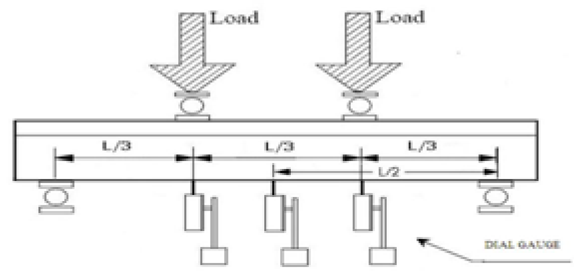
COMPRESSIVE STRENGTH TEST

Compressive strength after 7 days =25.10 n/mm^2

Compressive strength after 28 days =39.21 n/mm^2

V. EXPERIMENTAL SET-UP AND TESTING

The beam specimens were tested in the Universal Testing Machine (UTM-1000kN) in the Structural Engg. Lab at CUTM, BHUBANESWAR. All the beams were tested under two point loading to measure the deflection at the specified point for each increment of the load. The load at which the first visible crack has been developed is recorded as cracking load. Then the load has been applied till the ultimate failure of the beam occurs. Three dial gauges were fixed at L/3, L/2, 2L/3 from the left support in order to record the deflection at these silent points with the load increment, where L is the distance between c/c of the two supports and the data were entered into the tables and corresponding load-deflection curves were done.

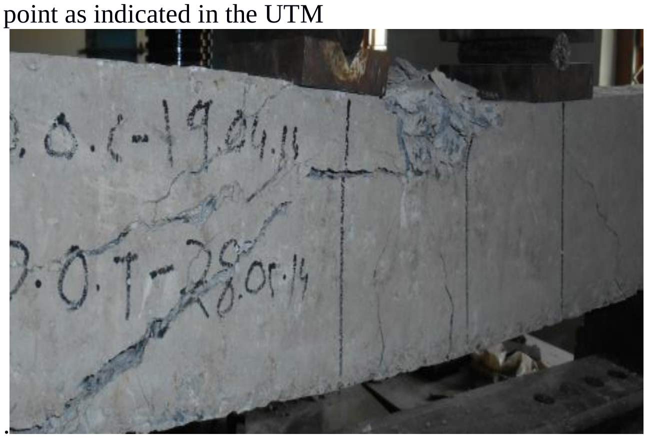


(a) Schematic diagram of test set up

Figure.1. Complete test set up in UTM

B_{01}-control beam without GFRP

At 110KN the first shear crack appeared accompanied by cracking sounds near the 2L/3 point. Then the second shear crack appeared near the L/3 point. With gradual increase in load the width of the crack became widening which is more significant at L/3. Thereafter, the flexural cracks were developed at the bottom of the beam near the mid-span. Then the load decreased and the beam failed at 98.4KN with crushing of concrete at the top near the mid-span and widening of diagonal cracks .The beam carried an ultimate load 123.40KN along with maximum deflection 6.9mm. The shear failure was observed. The load-deflection curves at the three salient points (L/3, L/2 and 2L/3) and the lad-deflection curve at the central loading point as indicated in the UTM



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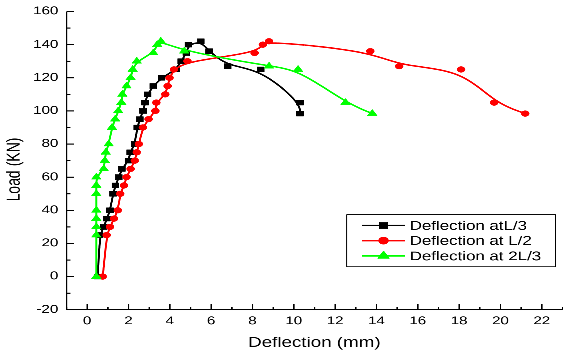

Figure.2. Loadvs. Deflection curves for B_{01}

VI.CONCLUSION

The present experimental study is done on the shear behavior of the reinforcement concrete beams retrofitted by GFRP sheets. The reinforced concrete (RC) beams were designed as weak in shear having same reinforcement detailing were retrofitted and tested under two points loading. From the calculated strength values, the following conclusions are drawn:

1. The ultimate load carrying capacity of all the retrofitted beams is higher when compared to the control Beam expect $B_{s1.}$
2. Initial shear cracks appear at higher loads in case of retrofitted beams.
3. In case of set 1 i.e 12mm dia.bar at bottom ,all the U-jacketed beams have more load capacity than side face FRP bonded beam .
4. The four layer U-jacketed FRP layer has less strength than three layered FRP sheets.
5. As diameter of the bottom longitudinal reinforcement increases, there is slightly difference of strength than the previous case i. e for 12mm longitudinal bar

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