STRENGTHING AND COMPARATIVE STUDY OF RC BEAMS USING GFRP WITH VARIOUS LAYERS

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Abstract-- Reinforced Concrete structures are suffering from various deteriorations like corrosion, cracks large deflection. These deteriorations are caused by various factors such as ageing, corrosion of steel reinforcement, environmental effects and accidental impacts on the structure. There is a huge need for repair and strengthening of deteriorated, damaged structures. There are various types of techniques for repairing the existing columns and beams. In recent years, retrofitting of concrete beams by wrapping and bonding of Fibre-reinforced polymer (FRP) sheets around the beams have become increasingly popular. Fibre – Wrapping using Fibre – Reinforced Polymer (FRP) shells is one of the effective methods, significantly enhances the strength and ductility of concrete beams.

In the present work, the efficacy of GFRP for the flexural strengthening of the reinforced concrete beam is studied by laying various layers and it will compare with Glass Fibre Reinforced Polymers carrying out bending test on reinforced concrete beams. The work carries out the study of failure modes, flexural strengthening effect on ultimate load and load deflection behaviour as well as the deflection ductility study of RC beams bonded externally with GFRP, wrapped in layers, along the entire length of the beam in full wrapping and strip wrapping technique.

Keywords:GFRP, Flexural Strength, Strengthening, U-wrapping Technique.

I. INTRODUCTION

Reinforced Concrete structures are suffering from various deteriorations like corrosion, cracks, spelling and large deflection. These deteriorations are caused by various factors such as ageing, corrosion of steel reinforcement, environmental effects and accidental impacts on the structure. Generally, some of the structures need to be repaired because of some of the external or internal conditions. Therefore, for those reasons, the entire structure cannot be demolished and a new structure is built. For such reasons, there are various types of techniques for repairing the existing columns and beams. Such unserviceable structures require immediate attention, enquiry into the cause of distress and suitable remedial measures, so as to bring the structures back to their functional use again. This strengthening and enhancement of the performance of such deficient structural elements in a structure or a structure as a whole are referred to as retrofitting. Out of some techniques retrofitting is one of the techniques used for repairing the existing structures.

Structures deteriorate due to problems associated with reinforced concrete. Natural disasters like earthquakes have repeatedly demonstrated the susceptibility of existing structures to seismic effect and hence implements like retrofitting and rehabilitation of deteriorated structures are important in high seismic regions. Thus, retrofitting and strengthening of existing reinforced concrete structures has become one of the most important challenges in Civil engineering. It has often seen that retrofitting of the building is generally more economical as compared to demolition and reconstruction even in case of severe damage.

Externally bonded, FRP sheets are currently being studied and applied around the world for the repair and strengthening of structural concrete members. FRP composite materials are of great interest 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 noncorrosive and non-magnetic nature of the materials along with its resistance to chemicals makes FRP an excellent option for external reinforcement. The addition of externally bonded FRP sheets to improve the flexural and shear performance of RC beams has been actively pursued during recent years. Strengthening using FRP provides a substantial increase in post-cracking stiffness and ultimate load-carrying capacity of the members subjected to flexure and shear.

II. LITERATURE REVIEW

Tara Sen. et al. (2013)said that the development of fibre reinforced polymer (FRP) materials in various forms such as non-woven, that is loose fibres, woven, that is braided fibres, textile or fabric, that is strongly braided along with a backing material such as latex backing or natural rubber backing, etc. and configurations offer an alternative design approach for the strengthening of new existing structures. The applicability of jute textile FRP as a strengthening material was investigated through various experimental works of mechanical characterization of the FRP and strengthening effects provided by the bonding of jute textile FRP to beams over bonding of carbon textile FRP and glass textile FRP. The jute textile FRP exhibited a tensile strength of 189.479 N/mm2, which is 21% of the tensile strength of carbon FRP (923.056 N/mm2) and28% of the tensile strength of glass (E-glass) FRP (678.571 N/mm2). The jute textile FRP exhibited flexural strength of 208.705 N/mm2, which is 13% of the flexural strength of carbon FRP (1587.134 N/mm2) and 32% of the flexural strength of glass (E-glass) FRP (666.871 N/mm2). When jute fibre textile mats were subjected to heat treatment then it increased the flexural as well as the tensile strength of jute textile FRP. The specimens strengthened with one layer of fully wrapped carbon FRP, CF1, CF2, and glass FRP, GF1, GF2, the strengthening effect in the load-carrying capacity was improved by 150% and 125%, respectively. Increase in the ultimate load-carrying capacity of beams by about 25% with one layer of jute textile FRP strips, 50% with one layer of carbon FRP strips and 37.5%.

N. F. Grace et al. (1999)said that the strengthening of beams using GFRP plates they concluded that bonding GFRP plates to the concrete reduced the crack size at all load levels. It was also indicated that using GFRP plates reduced the ductility of the Beams the strengthening of beams using GFRP plates; they concluded that bonding GFRP plates to the concrete reduced the crack size at all load levels. It was also indicated that using GFRP plates reduced the ductility of the beams. The use of FRP laminates in strengthening concrete beams reduces deflections and increases load-carrying capacity in the beams. Cracks that do occur are smaller and more evenly distributed. Furthermore, the use of FRP vertical layers can help to further reduce deflections and to further increase the ultimate load-carrying capacity. The presence of vertical layers also prevents a rupture in the flexural (horizontal) strengthening fibres. The ultimate load-carrying capacity of beams can be doubled by using a proper combination of horizontal and vertical fibres coupled with the proper epoxy. Extending the vertical layers over the entire span of the beam reduces the diagonal cracks so that the longitudinal fibres are fully used and the load-carrying capacity of the beams is significantly increased. The use of CFRP plates on the bottom and sides of the beam improves the response in comparison with using CFRP plates only at the bottom of the beam. All the FRP strengthened beams exhibited brittle behaviour requiring a higher factor of safety in design. The strengthening should ideally minimize the amount of material added to the structure to avoid increasing the dead load or decreasing the clearance requirements. Along with that, strengthening should minimize disruption to the structure and its usage. Bonding steel plates might be considered as a very convenient method for strengthening indoor beams.

Mehmet Mustafa Onal et al. (2014) said that the Strength increasing of the beams strengthened with CFRP was 84% and the displacement reduction was found to be 39.5%. Strength increasing of the beams strengthened with GFRP was 45%, and the displacement reduction was found to be 53.6%. In reinforced concrete beams strengthened with CFRP, there occurred a failure reduction by 29% as compared to control beams but energy consumption was increased by 14.5%. In reinforced concrete beams specimens strengthened with GFRP, there occurred a failure reduction by 25% as compared to control beams specimens but energy consumption was Increased 18%. With increasing loading, the strengthened beams collapsed as a shear fracture. In the samples, strength increased to some degree, but no increase was observed in terms of ductility and energy consumption. An apparent increase was observed in the bending strength. In the CFRP and GFRP reinforced beams, compared to controls, 38% and 42%, respectively, strength increase was observed. GFRP beams were observed to break apart, like layers, easier than the CFRP beams. In all beams, failure-flexural stress occurred in the centre as expected.] Most cracking was observed in the flexural region in the control beams, crack size was observed as 0.25mm in the secondary shear regions. On the other hand, in the same region, the crack size was 0.54mm in CFRP beams and 0.33mm in GFRP beams. Cracking values recorded at the centre and bottom of beams, where the maximum flexural and tensile stress were observed, were 0.68mm in the control beams, and 0.71mm and 0.14mm in the CFRP and GFRP beams, respectively. Displacement value of the control beams was observed as 45mmand 21mm and 29mm in the CFRP and GFRP beams, respectively.

P. Polu Raju at el (2011) said that Retrofitting is the modification of existing structures to make them more resistant to external force quantities. Advances in the field of plastics and composites have resulted in the development of high-strength, fibre reinforced plastics (FRP) that offer great potential for lightweight, cost-effective retrofitting of concrete structures, including bridges. Flexural retrofitting also increases the shear strength of concrete and could be shown in terms of the equivalent percentage of mild steel. The beam Weak-In-shear exhibited greater cracking load compared to all the other specimens.

III. EXPERIMENTAL INVESTIGATION

The testing of the ingredient materials of concrete such as cement, fine aggregates and coarse aggregates are carried out and results are presented below.

A. *Cement*

Ordinary Portland Cement (OPC) – 53 Gradewas used for the investigation. It was tested for physical properties in accordance with Indian Standard specifications.

- Initial Setting Time - 32 min
- Final Setting Time - 500 min
- Fineness – 3 %

B. *Fine Aggregates*

The locally available good quality sand is used as fine aggregate and the following tests have been performed on fine aggregate.

- Specific Gravity – 2.63
- Water Absorption – 0.27 %
- Fineness Modulus – 2.8

C. *Coarse Aggregate*

The coarse aggregates used were locally available crushed granite stone. The tests conducted on coarse aggregate are

- Specific Gravity – 2.8
- Water Absorption – 0.31 %
- Fineness Modulus – 7.0

D. *Reinforcement*

Steel used in beams is high yield strength deformed (HYSD) bars, yield strength of 415 N/mm^2. For each beam 2 no. of 8 mm diameter longitudinal reinforcement is adopted in bottom as well as 2 no. of 8 mm diameter longitudinal reinforcement is adopted in top for anchorage and 6mm diameter steel is used as stirrups at 125mm c/c reinforcement. The steel bars used are free from dust, rust or any organic matter.

E. *Concrete Epoxy*

Concrete Epoxy is one of the best suitable epoxies for concrete or cement surfaces. It is having the high tendency to bond with the surface and it is selected for the bonding procedure for the beams. It is available in the nearby hardware store or other paint stores. There are two parts in this concrete epoxy they are Part-A and Part-B. They are to be mixed in equal proportion in the ratio of 1:1.

F. *Mix Proportion*

By taking the standard arbitrary proportions of concrete ingredient's which is also called as Nominal Mix. The nominal mix M-20 is used for the preparation of concrete for six beams.

Cement	Fine Aggregate	Coarse Aggregate	Water
21 kg	31.1 kg	62 kg	9.45 litres

IV. RESULTS

Days of Curing	Flexure		
	No Layer Wrap	Single Layer Wrap	Double Layer Wrap
7	212.608 × 10^3 kN/m^2	280.80 × 10^3 kN/m^2	311.248× 10^3 kN/m^2
14	264.992 ×10^3 kN/m^2	343.784 ×10^3 kN/m^2	378.928 ×10^3 kN/m^2
28	311.248 ×10^3 kN/m^2	390.824 ×10^3 kN/m^2	427.716 ×10^3 kN/m^2

V. CONCLUSION

In this experimental investigation the reinforced concrete beams strengthened by GFRP sheets are studied. The enhancement of ultimate load carrying capacity and failure modes of RC beams with various layers of GFRP by showing the effectiveness of GFRP and flexural strength, deflection as well as in cost reduction by conducting a bending test. By performing the test following conclusions are drawn.

1. Reinforced concrete beams which are wrapped with glass fibre reinforced polymer have high strength in terms of flexure.
2. Beams wrapped with double layer of GFRP have high strength in terms flexure.
3. More the layers of wrapping are done higher the flexural strength of beams.
4. By using the epoxy durability of the beam towards other conditions is possible.
5. Due to the resisting property of glass fibre to fire and water it sustains in most of the worst conditions.

VI. SCOPE FOR FUTURE WORK

It promises a great scope for future studies. Following areas are considered for future research:

- Strengthening of beam with different type of fibre reinforced polymer sheet like woven roving, Unidirectional mat and Carbon fibre reinforced polymer.
- Variation of beam dimension.
- Variation of thickness and for different grades of concrete.
- Strengthening of beam weak in shear and torsional strength.

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