Study The Behavior of Continuous RC Beams under Static Loading

Aman Prakash[1], Afzal Khan[2]
[1]Research Scholar, [2]Assistant Professor
[1, 2]Department of CE, MIT, Bhopal, India

Abstract - Strengthening structures through external bonding of advanced fibre reinforced polymer (FRP) composite is turning out to be exceptionally well known worldwide amid the previous decade on the grounds that it gives a more practical and in fact better option than the conventional procedures much of the time as it offers better strength, good fatigue resistance, low weight, corrosion resistance, easy and rapid installation along with minimal change in geometry of the structure. Although many in-situ RC beams are continuous in construction, there has been limited research in the area of FRP strengthening of continuous beams. In the present study, an experimental investigation is carried out to study the behavior of continuous RC beams under static loading. The beams are strengthened with externally bonded glass fiber reinforced polymer (GFRP) sheets and also with unbounded GFRP using steel bolt system. Different scheme of strengthening has been employed. The experiment consists of six continuous (two-span) beams with overall dimensions equal to (150×250×2300) mm. All the beams will have similar longitudinal and transverse steel reinforcement. One beam was not strengthened and was considered as a control beam, whereas all other beams were strengthened in various patterns with externally bonded GFRP sheets and unbounded GFRP with end anchorage using the steel bolt system. The present study examines the responses of RC continuous beams, in terms of failure modes, enhancement of load capacity and load deflection analysis. The results indicate that the shear strength of RC beams can be significantly increased by gluing GFRP sheets to the shear face. In addition, the unbounded sheets with end anchorage also improved the cracking behavior of the beams by delaying the formation of visible cracks and reducing crack widths at higher load levels.
Keywords: Continuous Beam; Strengthening; GFRP; Debonding Failure;

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I. INTRODUCTION

Concrete structures might, for a mixture of reasons, be found to perform unacceptably. This could show itself by poor execution under static loading, as cracking or excessive deflections, or there could be insufficient extreme quality or strength. A structure is designed for a specific period and depending on the nature of the structure, its design life varies. Decay in solid structures is a noteworthy test confronted by the foundation and scaffold commercial ventures around the world. The degradation could be mainly due to nature's effects, which includes gradual loss of strength with ageing, corrosion in steel, high intensity loading, freeze-thaw cycles, temperature variation, or exposure to chemicals or saline water and due to ultra-violet radiations. As complete replacement or reconstruction of the structure will be cost effective, strengthening or retrofitting is an effective way to strengthen the same.

Reinforced concrete structures regularly need to face adjustment and change of their execution amid their administration life. The primary contributing components are change in their utilization, new plan guidelines, weakening because of consumption in the steel brought about by introduction to a forceful situation and mischance occasions, for example, seismic tremors. In such circumstances there are two conceivable arrangements: substitution or retrofitting. Full structure substitution may have determinate disservices, for example, high expenses for material and work, a more grounded natural effect and drawback because of interference of the capacity of the structure, e.g. activity issues. At the point when conceivable, it is frequently better to repair or redesign the structure by retrofitting.

II. LITERATURE SURVEY

Maghsoudi et al., [2022] inspected the flexural conduct and moment redistribution of RHSC (Reinforced High-Strength Concrete) continuous beams reinforced with carbon fiber. They watched that by expanding the quantity of CFRP layers, a ultimate capacity expands, and in the mean time ductility, moment redistribution, and ultimate strain of CFRP sheet diminish. Test outcomes likewise demonstrated that by expanding the quantity of CFRP sheet layers, there was an adjustment in the failure mode from ductile break to IC debonding.

Grace et al. [2021] explored the conduct of strengthened RC beams with GFRP and CFRP sheets and covers or laminates. They considered the impact of the quantity of layers, epoxy sorts, and pattern of strengthening on response of the RC beams. They discovered that all the beams experienced brittle failure, with obvious upgrade in strength, and thus requiring a higher design factor of safety.

F. Ceroni [2020] explored the experimental program on RC beams remotely bonded with carbon Fiber Reinforced Plastic (FRP) overlays and Near Surface Mounted (NSM) bars under monotonic and cyclic burdens, the last ones described by a low number of cycles in the versatile and post-flexible extent. Comparisons on theoretical and experimental failure loads are examined in point of interest.

Obaidat et al. [2019] concentrated on the Retrofitting {a component or accessory} of reinforced concrete beams composite laminates while the main variables considered were steel reinforcement, the length and position of CFRP. The trial tests were performed to research the conduct of beams composed in such a route, to the point that either shear or flexural failure will occur. The beams were loaded in four-point bending until there was cracks. The beams were then emptied and retrofitted with CFRP. At last the bars were loaded until failure.

Kim [2018] carried on test investigations of 14 strengthened RC beams retrofitted with new hybrid FRP(fiber reinforced polymer) framework comprising carbon FRP (CFRP) and glass FRP (GFRP). The target of this study was to inspect impact of hybrid FRPs on structural conduct of retrofitted RC beams and to research if different groupings of CFRP and GFRP sheets of the hybrid FRPs have impacts on strengths of reinforced RC beams.

Grace et al. [2017] explored the test execution of CFRP strips utilized for flexural reinforcing as a part of the negative moment area of a full-scale reinforced concrete beam. They considered two classes of beams (I and II) for flexural fortifying. Class I beams were intended to fail in shear whereas Class II beams were intended to come up short in flexure. A total of five full scale beams of each class were tried. It was observed that beams of Class I failed due to diagonal cracking along with local debonding at the top.

III. PROBLEM IDENTIFICATION

- The beams have same longitudinal and transverse steel reinforcement ratios.
- All beams have the same geometrical dimensions.
- The beams were strong in flexure and shear reinforcement was not strong.
- All the beams had same longitudinal and transverse steel reinforcement ratios and were casted and tested to failure.

IV. RESEARCH OBJECTIVES

- The objective of the present work is to study the behavior of continuous beams strengthened with bonded and unbounded GFRP sheets under static loading condition.
- In the present work, behavior of RC continuous rectangular beams strengthened

with externally bonded or unbounded GFRP is experimentally studied.

- These beams are tested up to failure by applying two points loading to evaluate the enhancement of its strength due to strengthening.

V. METHODOLOGY

The experimental part comprises of casting six two-span continuous rectangular reinforced concrete beams. All the beams had same longitudinal and transverse steel reinforcement ratios and were cast and tested to failure. The beams were strong in flexure and shear reinforcement was not strong. Beams geometry as well as the loading and support arrangements are illustrated in the figure below. All beams had the same geometrical dimensions: 150 mm wide × 250 mm deep × 2300 mm long.

One of the six beams was not strengthened by GFRP and was considered as a control or reference beam, whereas other five beams were strengthened with unbonded or externally bonded GFRP sheets. Experimental data on load, deflection and failure modes of each of the six beams were obtained. The change in the load carrying capacity and the failure modes of the beams are investigated for different types of strengthening pattern.

A proportion of 1: 1.7: 3.2 is taken for cement, fine aggregate and courses aggregate for casting of beams. The mixing of these materials is done by using concrete mixture. The beams are cured for 28 days. Six concrete cube specimens of dimensions 150mm cube were made at the time of casting of every beam and were kept for curing. The uni-axial compressive tests on the concrete produced were performed and the average compressive strength (f_{ck}) of the beams after 28 days for each beam was recorded.

Portland Slag Cement (PSC) is used for the experiment. It is tested for It's physical properties in accordance with Indian Standard specifications.

Tests were conducted on Cement and the results are as below:

(i) Normal Consistency: 33%
(ii) Setting Times: Initial Setting Time: 85 minutes
Final Setting Time: 485 minutes
(iii) 28-day Compressive Strength: 47.33 MPa
(iv) Fineness: 4 gm retained in 90-micron sieve

The fine aggregate passing through 4.75 mm sieve is used. The grading zone of fine aggregate is zone III as per Indian Standard specifications. Ordinary tap water is used for concrete mixing in all the mix. Two grades of coarse aggregates are used one retained on 10 mm size sieve and the other grade contained aggregates retained on 20 mm sieve. Both the grades of coarse aggregates had different weight age.

All the beams had same longitudinal and transverse steel reinforcement ratios and were casted and tested to failure. The beams were reinforced with two 12 mm diameter at the bottom, two 10 mm diameter bars as top reinforcement throughout the length to strengthen the beam in flexure.

Stirrups of 8 mm diameter high-yield Strength Deformed (HYSD) bars were provided throughout the beam at 150 mm center-to-center distance to make the beam weak in shear. And, finally 6 mm bars are used as hanger bars for lifting of the beam.

Figure 1: Steel Reinforcement for the beam

Machine mixer is used for mixing concrete thoroughly to produce uniform quality of concrete.

Needle vibrator was used for proper Compaction and proper care was taken so as to prevent the displacement of the internal steel reinforcement cage. And then with the help of a wooden float and metal trowel, the concrete surface was leveled.

The loss of water due to evaporation can be prevented by curing which is important for the cement hydration

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and hardening of concrete. Here curing is done by pouring water on the jute bags spread over the concrete surface for 28 days.

VI. RESULTS AND ANALYSIS

The deflections at the mid-spans were recorded at various loads for control as well as the strengthened beams and the load-deflection curves of the strengthened beams were contrasted with the control beams and the conclusions were drawn for each beam.

Load-displacement curve for SB 1 vs CB

To strengthen SB1, single layer of glass FRP was applied at the surfaces to prevent shear failure and it was observed that the deflection values were less than that of the control beam for the same load value. At lower load value, debonding of FRP without concrete cover occurred andSB1 finally failed in shear. At the load of 110 KN initial cracks appeared. Later on increasing the load values, the cracks propagated further and the beam failed with an ultimate load of 288KN.

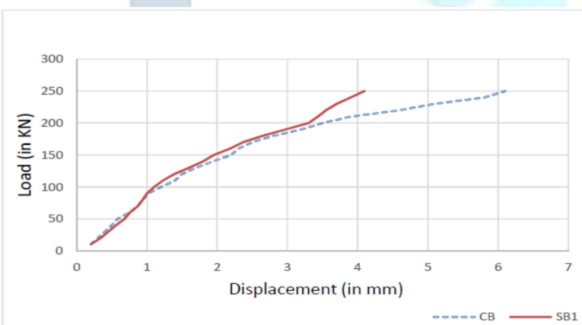

Figure 2: Load-Displacement Curve for SB 1 Vs CB

Load-displacement curve for SB 2 vs CB

SB2 was strengthened with two layers of glass FRP applied at the surfaces similar to SB1 to prevent shear failure. And from Fig 4.2, it is clear that the deflection values of SB2 are less than that of the control beam for the same load value. At the load of 130 KN initial hairline cracks appeared. Later on increasing the load values, the cracks propagated further and the beam failed with an ultimate load of 310 KN.

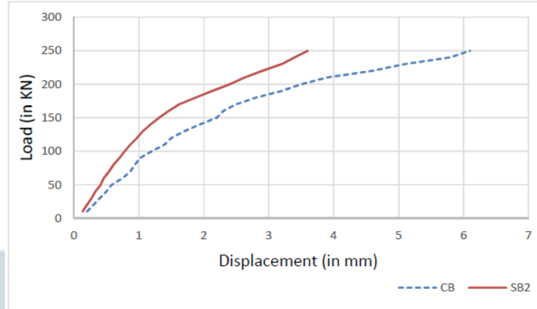

Figure 3: Load-Displacement Curve for SB 2 Vs CB

Load-displacement curve for SB 3 vs CB

Similarly, SB3 was strengthened with four layers of glass FRP. And, from the graphs in Fig 5.3 it is clear that the deflection values are much less compared to the control beam for the same load value. Moreover, the beam failed due to debonding of glass FRP sheets from the concrete cover and flexural cracks were found at the central support due to negative bending moment (hogging) at the central support. The ultimate load of SB3 was found out to be as high as 340 KN.

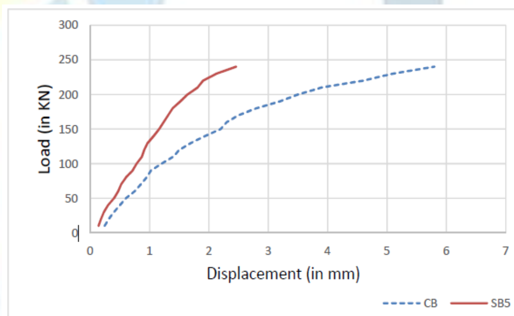

Figure 4: Load-Displacement Curve for SB 3 VS CB

Load-displacement curve for SB 4 vs CB

The technique of strengthening the beams with unbonded glass FRP was used. End anchorage was provided using steel bolts and plates. In SB4, one layer of glass FRP was U-wrapped just under the loading points. The ultimate failure of the beam was in shear at 270 KN. And it was observed that the displacement values were nearer to that of the control beam.

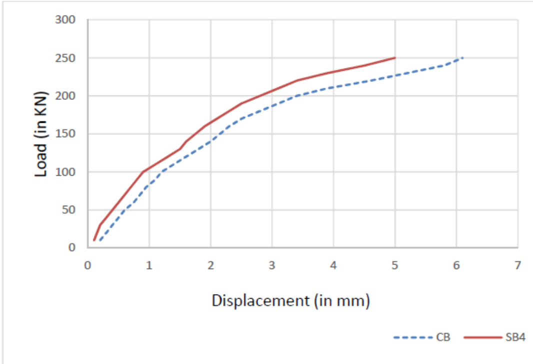

Figure 5: Load-Displacement Curve for SB 4 VS CB

Load-displacement curve for SB 5 vs CB

SB5 was also strengthened with unbounded glass FRP provided with end anchorages using steel bolts and plates. In SB5, one layer of glass FRP each was U-wrapped from loading point to central support and expectedly, the beam showed much resistance to shear failure. Interestingly, the beam developed cracks due to shear from the right mid-span to the end support and also cracks were found at the central support. The ultimate failure occurred at 318 KN.

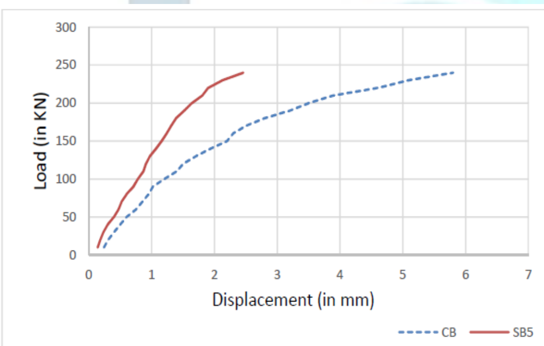

Figure 6: Load-Displacement Curve for SB 5 VS CB

Thus, the load carrying-capacity of all the strengthened beams are discussed here, and it is found that beam SB3 has the maximum load capacity of 340 KN and maximum percentage increase of load carrying capacity, i.e., 41.67%. Moreover, the ultimate shear capacities of all the strengthened beams are higher than that of the control beam.

VII. CONCLUSIONS

The present experimental study is carried out on the behavior of reinforced concrete rectangular beams strengthened by GFRP sheets. Six reinforced concrete (RC) beams weak in shear are casted and tested. All the beams had same longitudinal and transverse steel reinforcement ratios. The conclusions drawn from the experimental results are as follows:

1. The strengthened beams had higher load-carrying capacity as compared to the control beam.

2. The initial cracks in the strengthened beams appeared at higher loads compared to the control beam.

3. The test results show that on strengthening the beams using FRP technique, the shear capacity can be increased.

4. Strengthened beam SB3, which was strengthened by four layers of FRP showed the highest ultimate load value of 340 KN and the percentage increase in the load capacity of

SB3 was 41.67 %.

5. On increasing the number of layers of glass FRP, the load carrying capacity of the beams also increases.

6. Unbounded FRP system with end anchorage using steel bolts and plates is a very new, time and cost-effective technique.

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

- Experimental study of continuous beams with opening
- Non-linear analysis of RC continuous beam
- FEM modeling of unanchored U-wrap
- FEM modeling of anchored U-wrap

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