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Strengthening of RC Continuous Beam using FRP Sheet

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Abstract: Strengthening structures via external bonding of advanced fibre reinforced polymer (FRP) composite is becoming very popular worldwide during the past decade because it provides a more economical and technically superior alternative to the traditional techniques in many situations as it offers high strength, low weight, corrosion resistance, high fatigue resistance, easy and rapid installation and minimal change in structural geometry. Although many in-situ RC beams are continuous in construction, there has been very limited research work 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 fibre reinforced polymer (GFRP) sheets. Different scheme of strengthening have been employed. The program consists of fourteen continuous (two-span) beams with overall dimensions equal to (150×200×2300) mm. The beams are grouped into two series labeled S1 and S2 and each series have different percentage of steel reinforcement. One beam from each series (S1 and S2) was not strengthened and was considered as a control beam, whereas all other beams from both the series were strengthened in various patterns with externally bonded GFRP sheets. 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 flexural strength of RC beams can be significantly increased by gluing GFRP sheets to the tension face. In addition, the epoxy bonded sheets improved the cracking behavior of the beams by delaying the formation of visible cracks and reducing crack widths at higher load levels. The experimental results were validated by using finite element method.

Keywords: Continuous Beam, Flexural Strengthening,GFRP, Premature Failure, Deboning Failure.

I. INTRODUCTION

A structure is designed for a specific period and depending on the nature of the structure, its design life varies. For a domestic building, this design life could be as low as twenty-five years, whereas for a public building, it could be fifty years. Deterioration in concrete structures is a major challenge faced by the infrastructure and bridge industries worldwide. The deterioration can be mainly due to environmental effects, which includes corrosion of steel, gradual loss of strength with ageing, repeated high intensity loading, variation in temperature, freeze-thaw cycles, contact with chemicals and saline water and exposure 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.

Low weight: The FRP is much less dense and therefore lighter than the equivalent volume of steel. The lower weight of FRP makes installation and handling significantly easier than steel. These properties are particularly important when installation is done in cramped locations. Other works like works on soffits of bridges and building floor slabs are carried out from man-access platforms rather than from full scaffolding. The use of fibre composites does not significantly increase the weight of the structure or the dimensions of the member. And because of their light weight, the transport of FRP materials has minimal environmental impact.

II. REVIEW OF LITERATURE

This chapter provides a review of literature on strengthening of RC concrete beams. This review comprises of literature on strengthened beam under two types of support condition i.e. simply supported and continuously supported.

A. Simply Supported Beam

Grace et al. (1999) investigated the behaviour of RC beams strengthened with CFRP and GFRP sheets and laminates. They studied the influence of the number of layers, epoxy types, and strengthening pattern on the response of the beams. They found that all beams experienced brittle failure, with appreciable enhancement in strength, thus requiring a higher factor of safety in design. Experimental investigations, theoretical calculations and numerical simulations showed that strengthening the reinforced concrete beams with externally bonded CFRP sheets in the tension zone considerably increased the strength at bending, reduced deflections as well as cracks width (Ross et al., 1999; Sebastian, 2001; Smith & Teng, 2002; Yang et al., 2003; Aiello & Ombres, 2004). It also changed the behaviour of these beams under load and failure pattern. Most often the strengthened beams failed in a brittle way, mainly due to the loss of connection between the composite material and the concrete. The influence of the surface preparation of the concrete, adhesive type, and concrete strength on the overall bond strength is studied as well as characteristics of force transfer from the plate to concrete. They concluded that the surface preparation along with along with soundness of concrete could influence the ultimate bond strength. Thereafter, Study on de-bonding problems in concrete beams externally strengthened with FRP composites are carried out by many researchers.

B. Objective And Scope of the Present Work

The objective of this work is to carry out the investigation of externally bonded RC continuous beams using FRP sheet. In the present work, behavior of RC continuous rectangular beams strengthened with externally bonded GFRP is experimentally studied. The beams are grouped into two series labeled S1 and S2. Each series have different longitudinal and transverse steel reinforcement ratios. All beams have the same geometrical dimensions. These beams are tested up to failure by applying two points loading to evaluate the enhancement of flexural strength due to strengthening. A finite element model has been developed to study the response of strengthened beams.

III. EXPERIMENTAL STUDY

The experimental study consists of casting of fourteen large scale continuous (two-span) rectangular reinforced concrete beams. All the beams weak in flexure are casted and tested to failure. The beams were grouped into two series labeled S1 and S2. Each series had different longitudinal and transverse steel reinforcement ratios which are mentioned in Table 3.6 and Table 3.7 for S1 and S2 respectively. Beams geometry as well as the loading and support arrangements are illustrated in Figure 3.6. All beams had the same geometrical dimensions: 150 mm wide × 200 mm deep × 2300 mm long. One beam from each series (S1 and S2) was not strengthened and was considered as a control beam, whereas all other beams from both the series were strengthened with externally bonded GFRP sheets. Experimental data on load, deflection and failure modes of each of the beams are obtained. The change in load carrying capacity and failure mode of the beams are investigated for different types of strengthening pattern.

A. Materials for Casting

Cement: Portland Slag Cement (PSC) (Brand: Konark) is used for the experiment. It is tested for its physical properties in accordance with Indian Standard specifications. It is having a specific gravity of 2.96.

(i) Specific gravity : 2.96
(ii) Normal Consistency : 32%
(iii)Setting Times : Initial : 105 minutes Final : 535 minutes.
(iv) Soundness : 2 mm expansion
(v) Fineness : 1 gm retained in 90 micron sieve

B. Detailing of Reinforcement

For the same series of continuous reinforced concrete beams, same arrangement for flexure and shear reinforcement is made.

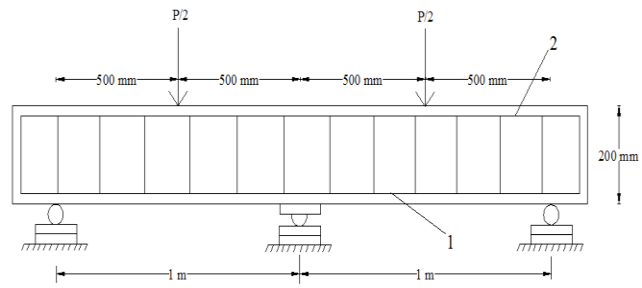

Fig1. Detailing of reinforcement 1, 2 – top and bottom steel reinforcement.

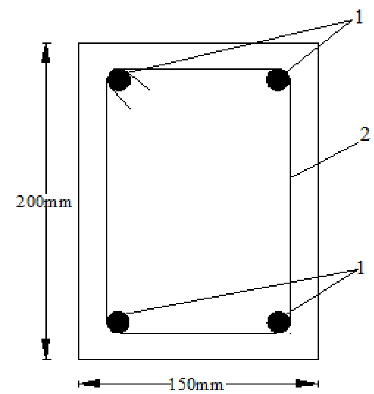

Fig2. Cross section: 1–Longitudinal rebars, 2–close stirrups.

C. Form Work

Fig3. Steel Frame Used For Casting of Beam.

IV. TEST RESULTS AND DISCUSSIONS

The beams were loaded with a concentrated load at the middle of each span and the obtained experimental results are presented and discussed subsequently in terms of the observed mode of failure and load-deflection curve. 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 and it is observed that the control beam had less load carrying capacity than the strengthened beam. Two sets of beams i.e. S1 and S2 were examined and one beam from each series was tested as un-strengthened control beam and rest beams were strengthened with various patterns of FRP sheets. The different failure modes of the beams were observed for both the series S1 and S2 as shown in Table 1 and Table 2.

Table1. Experimental Result of the Tested Beams for Series S1

Designation of Beams	Failure Mode	P_u (KN)	$\lambda = \frac{Pu(\text{strengthened beam})}{Pu(\text{Control beam})}$
CB1	Flexural failure	260	1
SB1	Debonding failure without concrete cover	320	1.23
SB2	Tensile rupture	325	1.25
SB3	Debonding failure without concrete cover	334	1.28
SB4	Tensile rupture	370	1.42
SB5	Tensile rupture	380	1.46
SB6	Debonding failure without concrete cover	415	1.59
SB7	Debonding failure	332	1.27
SB8	Debonding failure without concrete cover	345	1.32
SB9	Debonding failure	421	1.61

Table2. Experimental Result of the Tested Beams for Series S2

Designation of Beams	Failure Mode	P_u (KN)	$\lambda = \frac{Pu(\text{strengthened beam})}{Pu(\text{Control beam})}$
CB2	Flexural failure	200	1
TB1	Debonding failure	224	1.12
TB2	Tensile rupture	298	1.49
TB3	Debonding of FRP	326	1.68

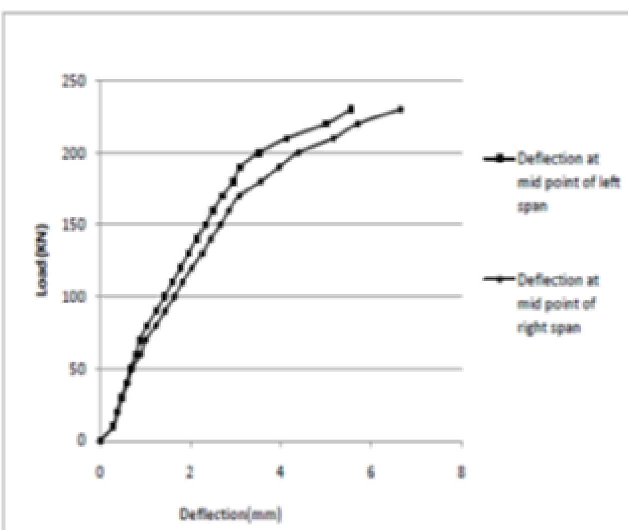

Fig4. Load versus Deflection Curve for CB1.

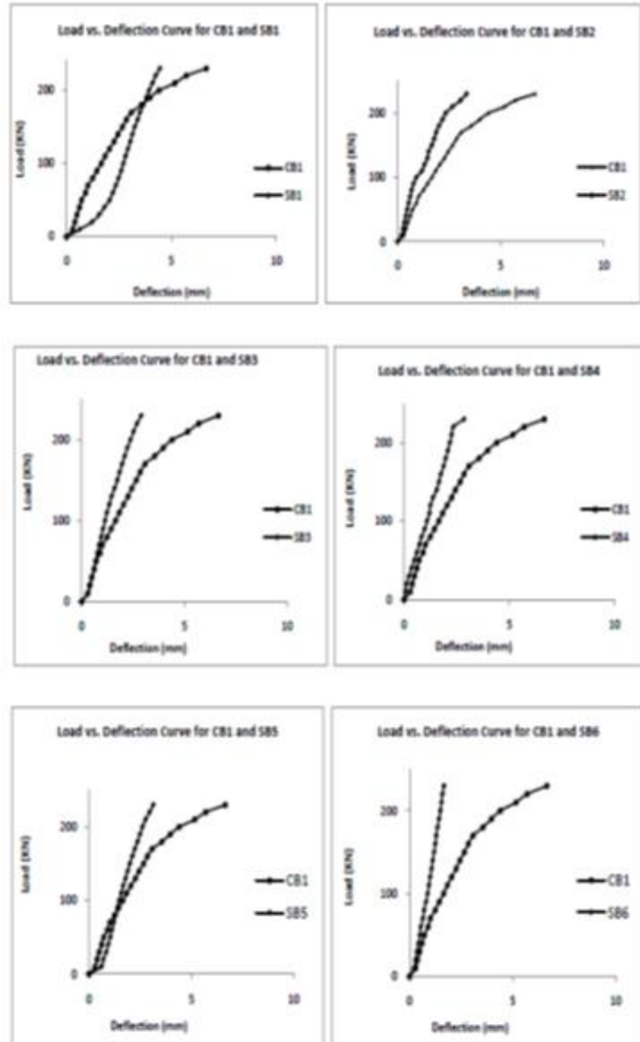

Fig5. Load versus Deflection multiple Curves for CB1.

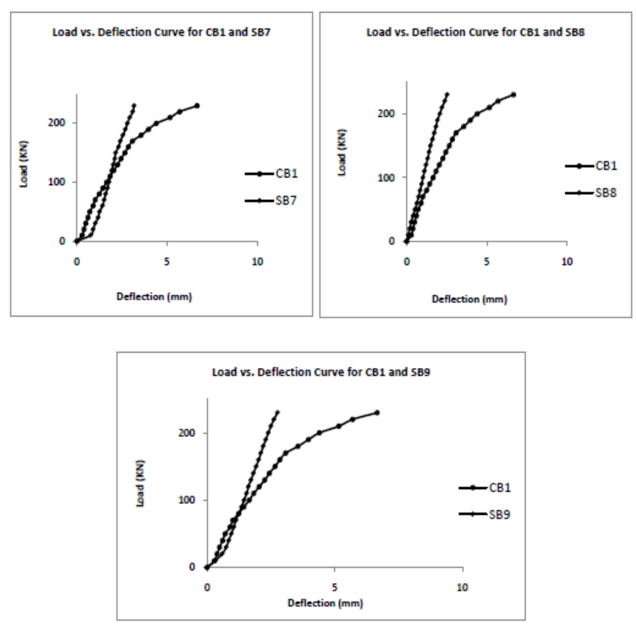

Fig6. Load versus Deflection Curve for Set S1 strengthened beams with CB1.

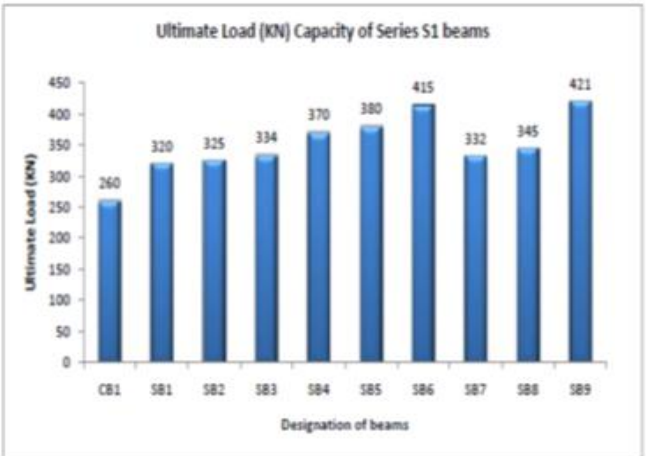

Fig7. Ultimate Load Capacity of Series S1 beams.

V. FINITE ELEMENT ANALYSIS

Finite element method (FEM) is a numerical method for solving a differential or integral equation. It has been applied to a number of physical problems, where the governing differential equations are available. The method essentially consists of assuming the piecewise continuous function for the solution and obtaining the parameters of the functions in a manner that reduces the error in the solution. The displacement field v(x) assumed for the beam element should be such that it takes on the values of deflection and the slope at either end as given by the nodal values v_i, θ_i, v_j, θ_j.

The v(x) can be given by,

$$v(x) = c_0 + c_1 x + c_2 x^2 + c_3 x^3 \quad (1)$$

In solving the differential equations through integration, there will be constants of integration that must be evaluated by using the boundary and continuity conditions. The variables whose values are to be determined are approximated by piecewise continuous polynomials. The coefficients of these polynomials are obtained by minimizing the total potential energy of the system. In FEM, usually, these coefficients are expressed in terms of unknown values of primary variables.

VI. CONCLUSION

The present experimental study is carried out on the flexural behavior of reinforced concrete rectangular beams strengthened by GFRP sheets. Fourteen reinforced concrete (RC) beams weak in flexure having different set of reinforcement detailing are casted and tested. The beams were grouped into two series labeled S1 and S2. Each series had different longitudinal and transverse steel reinforcement ratios. From the test results and calculated strength values, the following conclusions are drawn:

- The ultimate load carrying capacity of all the strengthen beams is higher when compared to the control beam.
- The initial cracks in the strengthened beams are formed at higher load compared to control beam.
- From series S1, beam SB9 which was strengthened by U-wrap and was anchored by using steel plate and bolt system, showed the highest ultimate load value of 415 KN. The percentage increase of the load capacity of SB9 was 61.92 %.
- The load carrying capacity of beam SB6, which was strengthened by two layers of U-wrap of length 88 cm in positive moment zone and two layers of U-wrap of length 44 cm over first two layers, was 415 KN which was nearer to the load capacity of beam SB9. The percentage increase of load carrying capacity was 59.61 % ,from which it can be concluded that applying FRP in the flexure zone is quite effective method to enhance the load carrying capacity.
- TB3 beam from Series S2, which was strengthened by two layers of U-wrap in positive moment zone and two layers of U-wrap in flexure zone above first two layers, was having maximum ultimate load value of 326 KN, than the other strengthened beams of same category. The percentage increase of this beam was 63 % which was highest among all strengthened beams.
- Using of steel bolt and plate system is an effective method of anchoring the FRP sheet to prevent the debonding failure.
- Strengthening of continuous beam by providing U-wrap of FRP sheet is a new and effective way of enhancing the capacity of load carrying.
- Flexural failure at the intermediate support section can be prevented by application of GFRP sheets.
- In lower range of load values the deflection obtained using Finite Element models are in good agreement with the experimental results. For higher load values there is a deviation with the experimental results because linear FEM has been adopted.

VII. REFERENCES

[1] ACI Committee 440, “Starte-of-the-art report on reinforcement for concrete structures”, Report ACI 440R-96, USA: American Concrete Institute, 1996.

[2]Aiello MA,Valente L,and Rizzo A,“Moment redistribution in continuous reinforced concrete beams strengthened with carbon fiber-reinforced polymer laminates”, Mechanics of Composite Materials, vol. 43, pp. 453-466, 2007.

[3] Aiello MA, and Ombres L, “Cracking and deformability analysis of reinforced concrete beams strengthened with externally bonded carbon fiber reinforced polymer sheet”, ASCE Journal of Materials in Civil Engineering, vol. 16, No. 5, pp.292-399,2004.

[4] Akbarzadeh H, and Maghsoudi AA, “Experimental and analytical investigation of reinforced high strength concrete continuous beams strengthened with fiber fiber reinforced plasticreinforced polymer”, Materials and Design, vol. 31, pp. 1130-1147, 2010.

[5] Arduini M, and Nanni A, “Behaviour of pre-cracked R. C. beams strengthened with carbon FRP sheets”, ASCE Journal of Composites for Construction, vol. 1, No. 2, pp. 63-70, 1997.

[6] Ashour AF, El-Refaie SA, and Garrity SW, “Flexural strengthening of RC continuous beams using CFRP laminates”, Cement and Concrete Composites, vol. 26, pp. 765-775, 2003.

[7] Bank LC, and Arora D, "Analysis of RC beams strengthened with mechanically fastened FRP (MF-FRP) strips", Composite Structures, vol. 79, pp. 180–191, 2006.
[8] Bousselham A and Chaallal O, "Behavior of reinforced concrete T-beams strengthened in shear with carbon fiber reinforced polymer - an experimental study", ACI Structural.

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