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FRP SHEET USED TO STRENGTHEN OF RC CONTINUOUS BEAMS

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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 behaviour 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 debonding 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. 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 .The most popular techniques for strengthening of RC beams have involved the use of external epoxy-bonded steel plates. It has been found experimentally that flexural strength of a structural

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member can increase by using this technique. To eliminate these problems, steel plate was replaced by corrosion resistant and light-weight FRP Composite plates. FRPCs help to increase strength and ductility without excessive increase in stiffness. Further, such material could be designed to meet specific requirements by adjusting placement of fibres. So concrete members can now be easily and effectively strengthened using externally bonded FRP composites. By wrapping FRP sheets, retrofitting of concrete structures provide a more economical and technically superior alternative to the traditional techniques in many situations because it offers high strength, low weight, corrosion resistance, high fatigue resistance, easy and rapid installation and minimal change in structural geometry. FRP systems can also be used in areas with limited access where traditional techniques would be impractical. However, due to lack of the proper knowledge on structural behavior of concrete structures, the use of these materials for retrofitting the existing concrete structures cannot reach up to the expectation. Successful retrofitting of concrete structures with FRP needs a thorough knowledge on the subject and available user-friendly technologies/ unique guidelines .Beams are the critical structural members subjected to bending, torsion and shear in all type of structures. Similarly, columns are also used as various important elements subjected to axial load combined with/without bending and are used in all type of structures .Therefore, extensive research works are being carried out throughout world on retrofitting of concrete beams and columns with externally bonded FRP composites. Several investigators took up concrete beams and columns retrofitted with carbon fibre reinforced polymer (CFRP)/ glass fibre reinforced polymer (GFRP) composites in order to study the enhancement of strength and ductility, durability, effect of confinement, preparation of design guidelines and experimental investigations of these members.

II. MATERIALS USED

The following materials are used for preparing the test specimen:

Cement

Coarse aggregate

Fine aggregate

Water

- Reinforcing steel

2.1CEMENT

Portland Slag Cement (PSC) (Brand: Konark) is used for the experiment. It is tested forits physical properties in accordance with Indian Standard specifications. It is having a specific gravity of 2.9

(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

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2.2 FINE AGGREGATE

The fine aggregate passing through 4.75 mm sieve and having a specific gravity of 2.67are used . The grading zone of fine aggregate is zone III as per Indian Standard specifications.

2.3 COARSE AGGREGATE

The coarse aggregates of two grades are used one retained on 10 mm size sieve and another grade contained aggregates retained on 20 mm sieve.It is having a specific gravity of 2.72.

2.4 WATER

Ordinary tap water is used for concrete mixing in all the mix.

2.4 REINFORCING STEEL

Table No.1: Tensile Strength of the bars

Diameter of the reinforcement (mm)	Tensile strength (MPa)
8	523
10	429
12	578

III. MIX PROPORTIONS AND EXPERIMENTAL WORK

Table No.2 : Design Mix Proportions

Description	Cement	Sand (Fine aggregate)	Course aggregate	Water
Mix proportion (By weight)	1	1.67	3.33	0.55
Quantities of materials (Kg/m^3)	368.42	533.98	1231.147	191.58

TEST SPECIMAN

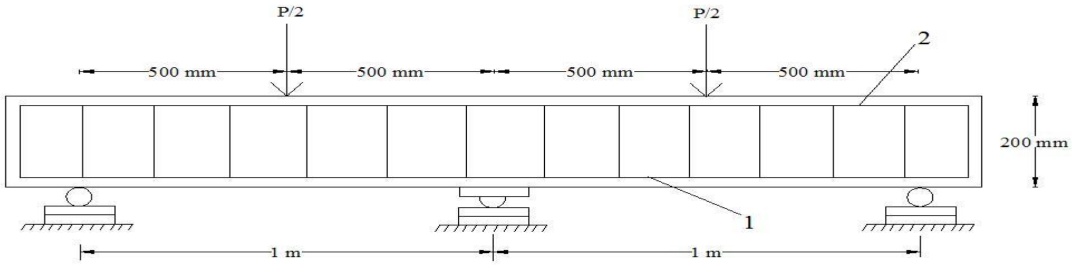

Figure.1: Detailing of reinforcement 1, 2 – top and bottom steel reinforcement

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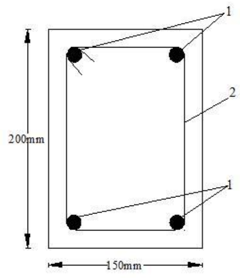

Figure.2: Cross section: 1 – Longitudinal rebars , 2 – close stirrups

3.1 MIXING OF CONCRETE

Mixing of concrete is done thoroughly with the help of machine mixer so that a uniform quality of concrete is obtained.

3.2 COMPACTION

Needle vibrator was used for proper Compaction and care is taken to avoid displacement of the reinforcement cage inside the form work. Then the surface of the concrete is leveled and smoothened by metal trowel and wooden float.

3.3 CURING OF CONCRETE

Curing is done to prevent the loss of water which is essential for the process of hydration and hence for hardening. Here curing is done by spraying water on the jute bags spread over the surface for a period of 28 days.

3.4 STRENGTHENING OF BEAMS

At the time of bonding of fiber, the concrete surface is made rough using a coarse sand paper texture and then cleaned with an air blower to remove all dirt and debris. The fabrics are cut according to the size and after that the epoxy resin is mixed in accordance with manufacturer's instructions. The mixing is carried out in a plastic container (100 parts by weight

of Araldite LY 556 to 10 parts by weight of Hardener HY 951). After the uniform mixing, the epoxy resin is applied to the concrete surface. Then the GFRP sheet is placed on top of epoxy resin coating and the resin is squeezed through the roving of the fabric with the roller. Air bubbles entrapped at the epoxy/concrete or epoxy/fabric interface are eliminated. This operation is carried out at room temperature. Concrete beams strengthened with glass fiber fabric are cured for at least 7 days at room temperature before testing.

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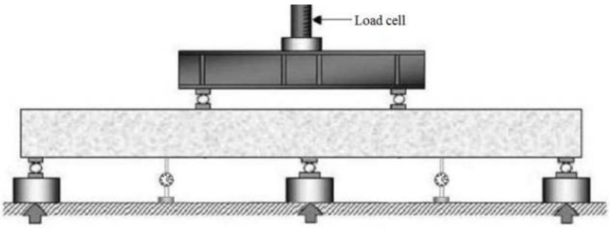
TESTING ARRANGEMENTS



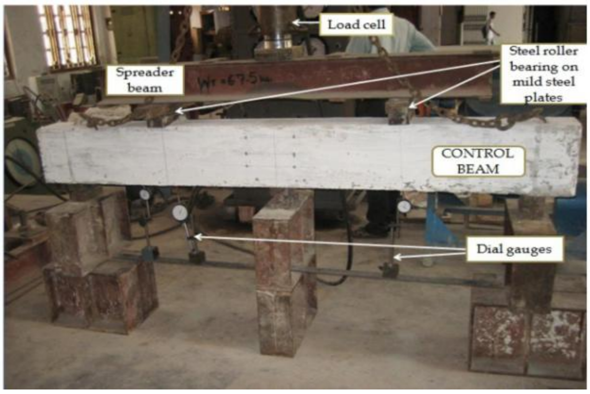


Figure.3: Experimental setup

INSTRON 1195

Figure .4 : Specimen failure after tensile test

TESTING OF BEAMS:

Experimental set up

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V. RESULTS & FAILURE MODE OF BEAMS

Table No.3 : Result of the specimens

Thickness of the specimen	Ultimate stress (MPa)	Ultimate load (N)	Young's Modulus (MPa)
2 Layers	172.79	6200	6829.9
4 Layers	209.09	9200	7788.5
6 Layers	236.23	12900	7207.4
8Layers	253.14	26200	7333.14

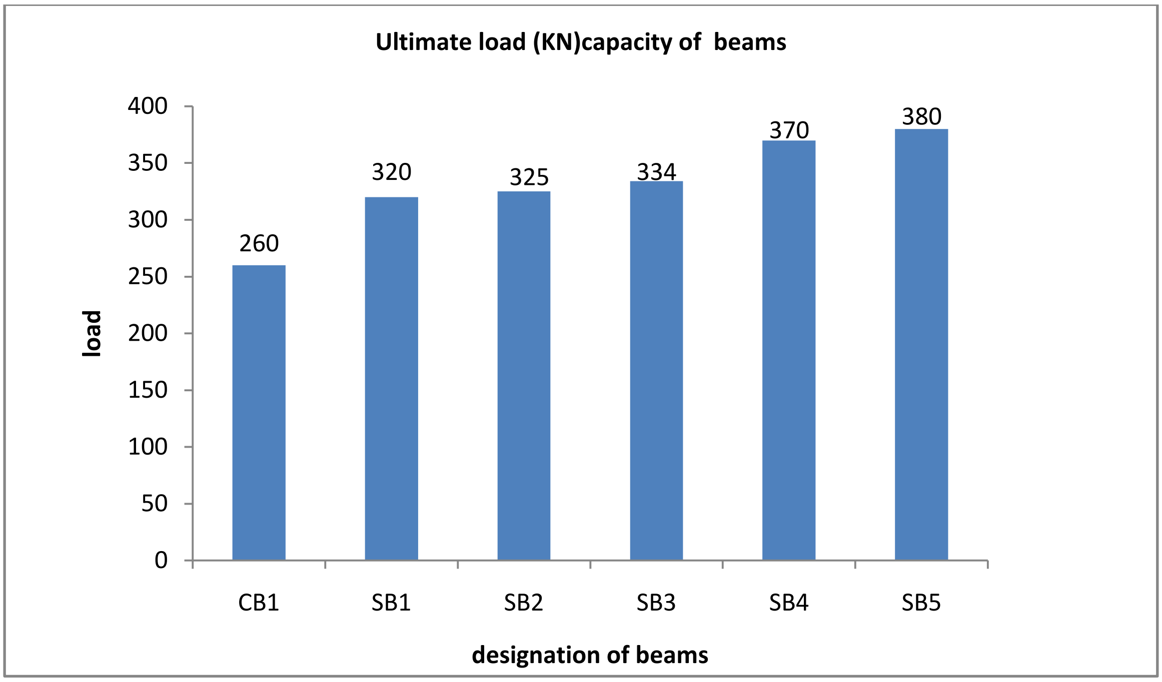

Figure.5: Ultimate Load Capacity of beams

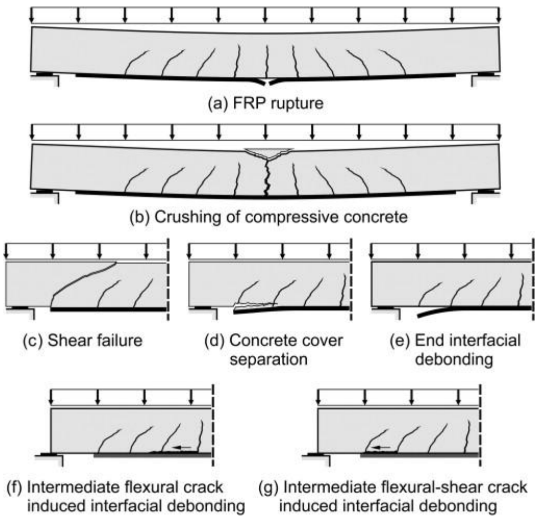

Figure 6: Failure of the beam by tensile rupture

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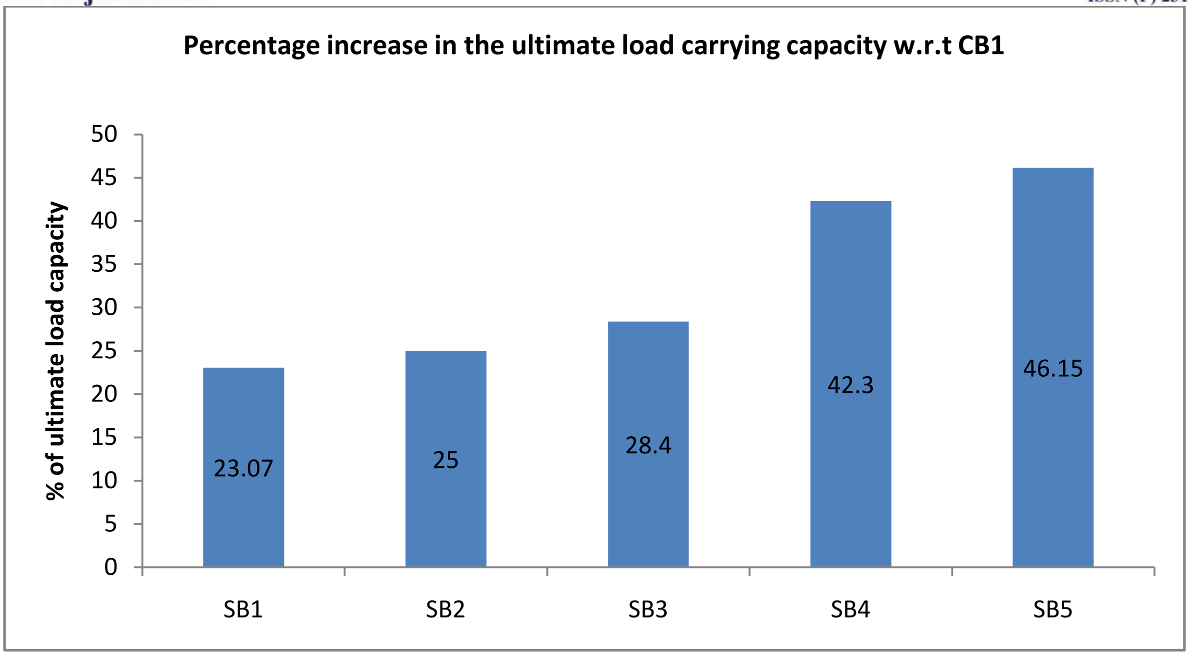

Figure 7: Percentage increase in the Ultimate Load Carrying capacity of strengthened beams of S1 w.r.t CB1

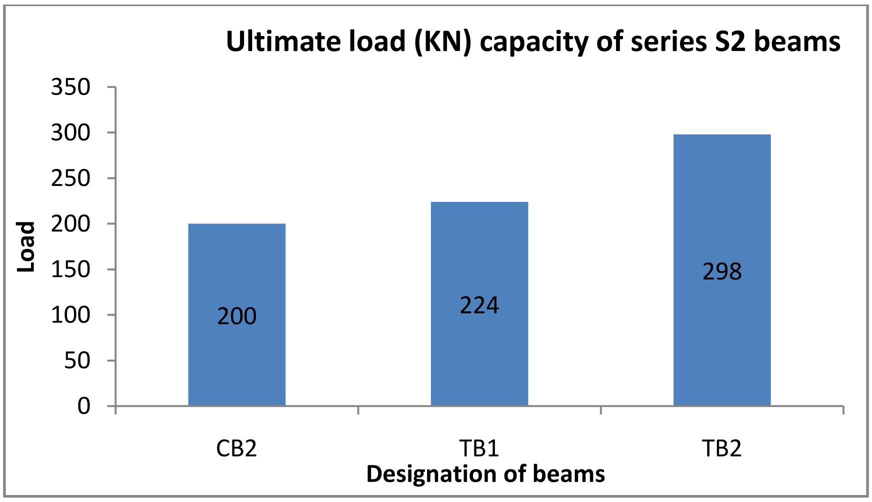

Figure 8: Ultimate Load (KN) capacity of series of S2 beams

FINITE ELEMENT ANALYSIS:

$[K]\{U\} = \{F\}$

U :global nodal displacement vector Figure 9: Continuous beam

F : global nodal force vector

$$\{f\} = [k]\{u\}$$

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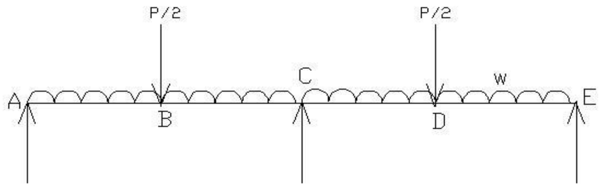

Figure 10: Finite element model

VI. CONCLUSIONS

The present experimental study is carried out on the flexural behavior of reinforced concrete rectangular beams strengthened by GFRP sheets. nine 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:

1. The ultimate load carrying capacity of all the strengthen beams is higher when compared to the control beam.
2. The initial cracks in the strengthened beams are formed at higher load compared to control beam.
3. From series S1, beam SB5 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 SB5 was 61.92 %.
4. The load carrying capacity of beam SB3, 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 SB6. 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.
5. 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.
6. Using of steel bolt and plate system is an effective method of anchoring the FRP sheet to prevent the debonding failure.
7. Strengthening of continuous beam by providing U-wrap of FRP sheet is a new and effective way of enhancing the capacity of load carrying.
8. Flexural failure at the intermediate support section can be prevented by application of GFRP sheets.

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9. 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.

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