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Experimental Study on Structural Strengthening of Beams using Woven Glass Fibre Reinforced Polymer Composites

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***Abstract*—- Experimental investigations on the flexural behavior of RC beams strengthened using woven glass fibre reinforced polymer (GFRP) sheets are carried out. The dimensions of the beam specimens are 120 mm x 240 mm x 2400 mm. Externally reinforced concrete beams with bonded GFRP sheets were tested to failure using a symmetrical two point concentrated static loading system. Total of six beams were casted for this experimental test program. Three beams were used as controlled beam and other three beams were strengthened using woven glass fibre reinforced polymer (GFRP) sheets in one layer, two layer and three layer. Experimental data on load, deflection and ultimate load of each of the beams were obtained. The load vs deflection curves were compared between control specimens and GFRP wrapped specimens**.

Keywords- Strengthening of beams, woven glass fibre polymer composites

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

To eliminate these problems, steel plate was replaced by corrosion resistant and light-weight Fibre Reinforced Polymer (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 fibre. 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.

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.

A. Scope and Objective

The primary objective of this study is to examine the application of GFRP fabric wrap to strengthen concrete beams and the associated failure modes. More particularly, the effects of the number of GFRP layers on the strength and ductility of beams are investigated. To study the ultimate load carrying capacity, deflection of normal beam and beams strengthened with GFRP fabric wrap. A comparison shall also be done with the ultimate load carrying capacity and deflection of normal beam and beams strengthened with GFRP wraps.

II. METHODOLOGY

A. Cement

Portland Pozzolana Cement (PPC)-53 grade was used for the investigation. It was tested for its physical properties in accordance with Indian Standard specifications.

B. Aggregate

Locally available fine and coarse aggregates are used in the investigation. and coarse aggregate sieved to the required quantity of volume to the maximum nominal size of 20 mm. Care is taken to arrive the size of coarse aggregate ranging from 4.75 mm to the maximum nominal size of 20 mm.

C. Water

Potable water available in Concrete and highway laboratory of department of civil engineering is used for mixing the concrete and curing the specimens.

D. *Rebar*

HYSD bars of 10 mm and 8 mm φ were used as main reinforcement. 6 mm φ mild steel bars were used for shear reinforcement.

E. Resin

Polymer resin is used for wrapping the specimens with GFRP.

F. Accelerator

It is used along with catalyst to harden the resin from liquid states to solid states.

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G. Catalyst

Catalyst increases the rate of a chemical reaction of two or more reactants and helps in rapid hardening of the mix

H. Preparation of Mould

Fresh concrete, being plastic requires some kind of form work to mould it to the required shape and also to hold it till it sets. The form work has, therefore, got to be suitably designed. It should be strong enough to take the dead load and live load, during construction and also it must be rigid enough to withstand any bulging, twisting or sagging due to the load.

The form work used for casting of all specimen consists of mould prepared with 3.5mm thick iron plate at the sides and 5 mm thick plate at the bottom. These plates are bolted together using angle section of dimension 40 mm by 40 mm by 6 mm in order to gain more stiffness.

I. Casting of Specimens

Six specimens are prepared for this experiment using cement, fine aggregate and coarse aggregate for which the designs mix proportion is arrived. To investigate the ultimate load carrying capacity of beam, specimens are prepared and designated as follows.

CB– Control Beam specimens.
BS I – Beam specimen with one layer of GFRP wrapping.
BSII– Beam specimen with two layer of GFRP wrapping.
BSIII – Beam specimen with three layer of GFRP wrapping.

Preliminary tests are carried as per IS standard on the material used for concrete like specific gravity, fineness, consistency, and initial setting time for cement. For fine and coarse aggregates tests such as sieve analysis, specific gravity, impact value, crushing value and abrasion value (Los Angeles) are conducted as per standards and results are tabulated.

The ingredients of concrete such as cement, fine aggregate, coarse aggregate of maximum nominal size of 20mm are weighed accurately using the platform weighing machine. The ingredients are mixed manually and adequate amount of water is added to the constituents of concrete. The mixing is done till to get uniform mix of concrete is obtained.

J. Wrapping of Beam Specimens

The beam specimens are cleaned properly using sand paper and brush to remove dust and other impurities and obtain a smooth surface for application of the GFRP composites. The mix is applied on the beam using brush and GFRP is placed on top of it. A layer of mix is applied to the top of GFRP to finish the wrapping of one layer. The same process is repeated for wrapping the second and third layers of GFRP.

The ingredients for GFRP composite materials are Resin, Pigment, Accelerator and Catalyst along with woven glass fibre. The mix is prepared by pouring half kg of resin in a mug, pigment of 20 gm is pour into the mixed and it is stirred well. 1% of accelerator is added to the mixed and 1% of catalyst is also added. The mixture is stirred well before use.

III. EXPERIMENTAL SETUP AND TESTING

The self-straining load frame and the Hydraulic loading jack along with Load cell are arranged in such a way to apply the concentrated force over the specimen. Two-point loading is conveniently provided by the arrangement. The load is transmitted through a load cell and spherical seating on to a spreader beam. The test member is supported on adjustable steel plates.

The specimen was placed over the two steel supports, leaving 2000 mm from the ends of the beam. The remaining 2000 mm was divided into three equal parts of 667 mm. Two point loading arrangement was done as shown in the Figure 6.2. Loading was done by hydraulic jack of capacity 40Tonne. Two linear variable differential transformer (LVDT) were used for recording the deflection of the beams. One LVDT was placed just below the center of the beam and the remaining one was placed just below the point loads to measure deflections. The LVDT position are designated as follows

Y1 – LVDT placed at mid span.
Y2 – LVDT placed at point load.

IV. RESULTS AND DISCUSSIONS

A. Load vs Deflection Graph

The analysis of beam specimens are made and corresponding Deflection are obtained for the corresponding loads applied. The deflections where noted at mid span, Y1 and one-third span Y2 for corresponding loads. Load vs Deflection graph is plotted as shown in figure 1 and 2.

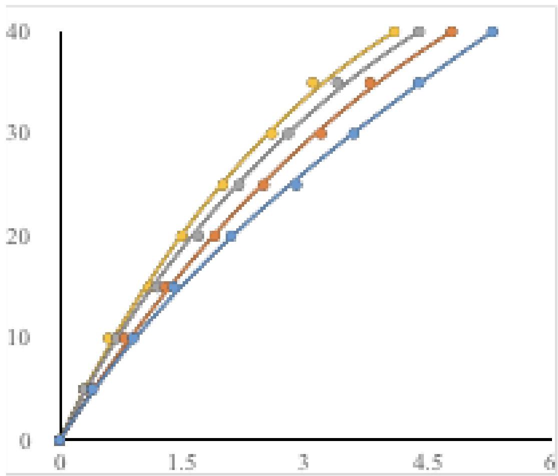

Fig. 1. Load vs Deflection Graph, Y1

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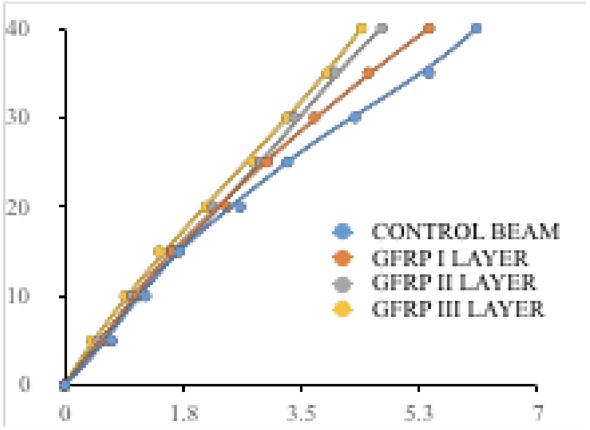

Fig. 2. Load vs Deflection graph, Y2

From the fig 1 and 2 of load vs Deflection and the table from appendix, it is observed that the deflection of beams increases with the increase in load. It was also noted that, as the number of GFRP layer increases, the deflection decreases for a corresponding load.

B. Results of Ultimate Load

After the elastic range all the specimens are subjected to failure and hence the ultimate loads are determined. Visible crakes first appeared at the center one-third surface of the beam and then propagated from the bottom of the beam towards the top, hence conforming flexural failure.

Type	Ultimate Load, Pu (kN)
CB	76
BS I	99
BS II	122
BS III	147

TABLE 1. TEST RESULTS OF ULTIMATE LOAD (PU) FOR BEAM SPECIMENS

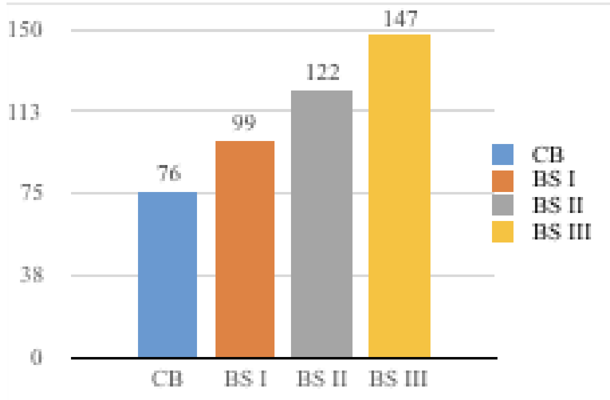

Fig. 3. Ultimate load on different specimens

The ultimate loads for the specimens are tabulated in table 1 and a plot is made between ultimate load on different specimens as shown in fig 3. It is observed that the ultimate load increases with increase in the number of layers of GFRP wrapping.

V. CONCLUSIONS

The following conclusions are drawn from the test results.

It is concluded that an increment of 23.23% of ultimate load (Pu) is observed in BS I when compared with CB.

It is concluded that an increment of 35.24% and 18.85% of ultimate load (Pu) is observed in BS II when compared with CB and BS I respectively.

It is concluded that an increment of 48.29%,32.65% and 17.06% of ultimate

Load (Pu) is observed in BS III when compared CB,BS I, BS II respectively.

The deflection of Reinforced Concrete Beams increases with increase in load within the elastic range.

Hence from Experimental Study on Structural Strengthening of Beams using Glass Fibre Reinforced Polymer Composites conclude the strength of the beams can be increased by wrapping with Glass Fibre Reinforced Polymer Composites.

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