

Experimental Study on Behavior of Externally Bonded Beam Using FRP Composites

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Abstract—Fiber-Reinforced Polymer (FRP) application is a very effective way to repair and strengthen structures that have become structurally weak over their life span. FRP repair systems provide an economically viable alternative to traditional repair systems and materials. In this study experimental investigation on the flexural behavior of RC beams strengthened using Fiber Reinforced Polymer (FRP) sheets are carried out. Reinforced concrete beams externally bonded with FRP sheets were tested to failure using a symmetrical mid point static loading system. RC Rectangle-beams were casted for this experimental test. All of them were weak in flexure and were having same reinforcement detailing. One beam was used as a control beam and other beams were strengthened using different configurations of Fiber Reinforced Polymer (FRP) sheets. Experimental data on load, deflection and failure modes of each of the beams were obtained. The effect of different amount and configuration of FRP on ultimate load carrying capacity and failure mode of the beams were investigated. The experimental results show that externally bonded FRP can increase the flexural capacity of the beam significantly. A series of comparative studies on deflection between the present experimental data and results from finite element method and IS code method were made. Future area of research is being outlined.

Keywords — Deflection, Strengthening, Warping, GFRP sheets

I. INTRODUCTION

In this analytical study of flexural performance of retrofitted or strengthening of beam by Fiber Reinforced Polymer (FRP) are done. Now a day investigator prefer numerical and analytical study to minimize error which can't reduce in experimental study, hence numerical study is more reliable than experimental study and analytical study less time consuming than experimental still having good agreement with experimental study.

.Almost all the software available in market are work based on Finite Element Method (FEM) such as ANSYS, ATENA 3D and ABAQUS. Analytical study carried out by different author using FEM based software they found ultimate capacity of beam increased noticeably. Analytical investigation of Reinforced Concrete (RC) beam with FRP were carried out by number of investigator they all studied on different aspect, some of those worked on single layer or double layer of FRP, some of those worked on different pattern and thickness of FRP and then compared stress, strain and deflection with control specimen.

Fiber has High Strength to Weight Ratio also known as Specific Strength Strength of a material is the force per unit area at failure, divided by its density. Any material that is strong and light has a favorable Strength/weight ratio. Materials such as Aluminium, titanium, magnesium, Carbon and glass fiber, high strength steel alloys all have good strength to weight ratios

Fiber's Tensile strength or ultimate strength, is the maximum stress that a material can withstand while being stretched or pulled before necking, or failing. Necking is when the sample cross-section starts to significantly contract. If you take a strip of plastic bag, it will stretch and at one point will start getting narrow.

A. LITERATURE REVIEW.

Rania salih (2020) In this study, the cyclic behavior of RC beam with openings strengthened using Carbon Fiber-Reinforced Polymers was experimentally investigated. Seven rectangular RC beams were cast and strengthened through external bonding of carbon fiber-reinforced polymer CFRP sheets around the beam web opening with different orientations to evaluate the maximum resistance, secant stiffness, strength degradation, ductility, energy dissipation capacity and behavior of the specimens' failure mode under cyclic load. One solid beam without an opening (i.e., control specimen) and six beams constructed with circular web openings typically located in the middle of the beam and adjacent to the supports were used in the experiments

DuicJ (2018) The execution of concrete beams reinforced with Basalt Fiber Composite Rebar. Full-scale tests on eight extensive scale concrete beam specimens reinforced with either BFRP rebars or steel rebars were embraced. The test information was broken down to assess the execution of BFRP rebar reinforced concrete beams in shear and flexure. It was discovered that at a low support proportion, BFRP rebar reinforced beams displayed more flexural and shear breaking than partner steel rebar reinforced concrete beams.

C.Spyrakos(2014) carried out experimental and analytical investigation of the effectiveness of FRP strengthening sheets on RC beams to increase their flexural strength and stiffness. Author conducted four point bending tests on four full scale reinforced concrete beams strengthened with externally bonded FRP. Author investigated the strength, deflection and failure mode strengthened beams .

Form the results by the application of CFRP increased beam strength and stiffness. They were observed that

different resin and anchorage system significantly influenced the resulting strength and stiffness of the specimen.

Kaushal Parikh(2012) carried out experimental and analytical investigation on preloaded retrofitted beam with GFRP for enhancement in flexural strength. They took seventeen beam for experimental study, out of that two were control beams and fifteen were preloaded at 0%, 40% and 90% of control beam. Author used new arrangement of FRP for strengthening the beam in which they were apply full length of single layer, they reduced length and width in second and third layer. Author also carried out analytical investigation using ATENA 3D software which are based on finite element method. Author concluded from the analytical and experimental results, new arrangement so effective that was shift the flexural crack away from the flexural region and also come out from the debonding failure. They observed load vs. deflection not more than 5% varied in experimental and analytical results, failure mode are also remarkable compared.

II. MATERIALS

MATERIAL TESTING

A.Coarse Aggregate

Coarse aggregate is an ingredient that gives concrete more strength and stability. Particulates larger than 4.75 mm in size are referred to be coarse aggregates. Uniform coarse aggregate with a length of 12.5 mm and compliance with IS 383-1970 were employed in this analysis. The properties of coarse aggregate are

TABLE 1
PROPERTIES OF COARSE AGGREGATE

S.No	Material	Coarse Aggregate Value
1	Specific gravity	2.72
2	Water Absorption	0.3%
3.	Bulk density	1760 kg/m ³

B.Fine Aggregate

Fine aggregate/ sand is an accumulation of grains of mineral matter derived from the disintegration of rocks. The optimal quality of fine aggregate to be used in concrete is mostly decided by its impact on water requirements.

TABLE 2
PROPERTIES OF FINE AGGREGATE

S.No	Property	Fine Aggregate Value
1	Specific gravity	2.65
2	Fineness test	2.74
3.	Bulk density	1640 kg/m ³

C.Ordinary Portland cement

Ordinary Portland Cement (OPC) 53 grade was mainly used for preparing the specimens. The important properties of cement are given below.

TABLE3
TEST ON CEMENT

S.No	Test Performed	Result
1	Fineness test	2%
2	Consistency test	33%
3	Specific gravity of cement	3.15
4	Initial setting time	39min
5	Final setting time	10hrs
6	Soundness Test(Le-Chatlier)	2mm expansion

III. EXPERIMENTAL WORK

Mix design was done according to IS 10262:2009 and IS456:2000.

The mix proportion adopted here is 1: 1.4: 3.3

A. Experimental Results of Compression Strength

The test was carried out as per IS 15658: 2006. The 150 x 150 x 150mm cube of concrete mixture was cast to test under compressive testing machine. The specimen after demolding were stored in curing tank and on removal of specimen from water the compressive test was conducted at 7 days and the results are represented in tables given below. Compressive strength is defined as the ratio of load to contact area and unit is N/mm². After 28 days the compressive strength of control mix is 23 N/mm²

Mix	Cube	Compressive strength (N/mm ²) for 7 days	Average Compressive strength (N/mm ²) for 7 days
M 20	1	23.1	23.
	2	22.8	
	3	23.1	

B. Casting Of Specimen

For conducting experiment, seven reinforced concrete beam specimen of size length= 1 m, width= 0.15 m, depth= 0.2m, and all having the same reinforcement detailing are casted. the proportion of 0.5: 1: 1.46: 3.3 for water, cement, fine aggregate and coarse aggregate is taken. the mixing is done by using concrete mixture. the beams are cured for 28 days. for each beam three cubes are casted to determine the compressive strength of concrete for 28 days.

C.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. After that the epoxy resin is mixed in accordance with manufacturer's instructions. The mixing is carried out in a plastic container.

After their uniform mixing, the fabrics are cut according to the size. Then the epoxy resin is applied to the concrete surface and 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.

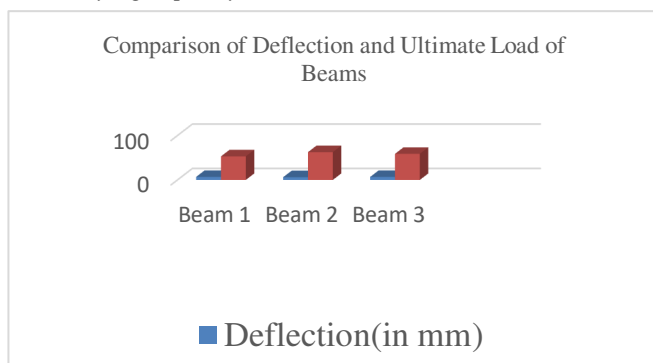
IV. TESTING OF BEAMS

The beams are tested in the loading frame of the "Structural Engineering" Laboratory of Government College of Engineering, Tirunelveli. The testing procedure for all the specimens is same. First the beams are cured for a period of 28 days. The mid-point single loading arrangement is used for testing of beams.

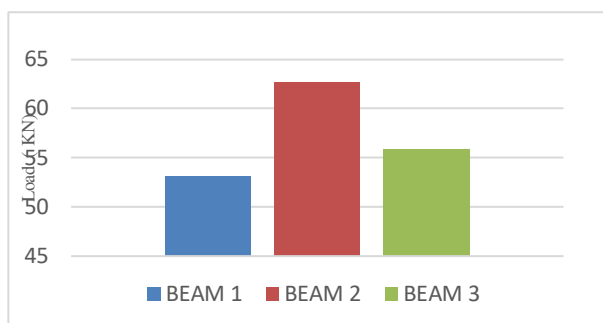
All the beams are tested one by one. Two beams with FRP wrapped and one without FRP which is taken as the control beam. All of them are tested in the above arrangement. The gradual increase in load and the corresponding deformation reading are taken throughout the test. The dial gauge reading shows the deformation. The load at which the first visible crack is developed is recorded as cracking load. Then the load is applied till the ultimate failure of the beam.

V. RESULTS

The experimental results of all the beams with different types of layering of GFRP are interpreted. Their behavior throughout the test is described using recorded data on deflection behavior and the ultimate load carrying capacity.



The ultimate load of all the beams and their corresponding deflection are compared and plotted below



The load carrying capacity of the control beams and the strengthened beam are plotted below. It is observed that beam 2 is having the max load carrying capacity.

VI. CONCLUSION

The present experimental study is done on the flexural behavior of Reinforced Concrete beams strengthened by GFRP sheets. Three Reinforced Concrete (RC) beams weak in flexure having same reinforcement detailing are casted and tested. From the test results and calculated strength values, the following conclusions are drawn:

- The ultimate load carrying capacity of all the strengthened beams were enhanced as compared to the Control Beam 1.
- Initial flexural cracks appear for higher loads in case of strengthened beams.
- The load carrying capacity of the strengthened Beam 2 was found to be maximum of all the beams. It shows increased up to 17.89 % more than the control beam 1.

Beam 2 which is the U-wrapping showed minimum deflection values on same loads as compared to other strengthened beams and the control beam

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