

Comparison Experimental & Analytical Results of Lightweight Reinforced Concrete Beam Strengthened with GFRP Strips

Satish S. Kotwal¹, Ananda S. Patil², Mayur M. More³, Gautam S. Adure⁴

Assistant Professor, Department of Civil Engineering, Bharati Vidyapeeth's College of Engineering, Kolhapur,
Maharashtra, India¹

Assistant Professor, Department of Mathematics, Bharati Vidyapeeth's College of Engineering, Kolhapur,
Maharashtra, India²

Assistant Professor, Department of Civil Engineering, Bharati Vidyapeeth's College of Engineering, Kolhapur,
Maharashtra, India³

Assistant Professor, Department of Civil Engineering, Bharati Vidyapeeth's College of Engineering, Kolhapur,
Maharashtra, India⁴

ABSTRACT: This study includes performance of reinforced lightweight concrete beam strengthened with GFRP. Experimental results of reinforced lightweight concrete beams are compared with Finite Element Analysis of RC beam using ANSYS software. The finite element method is a numerical analysis technique for obtaining approximate solutions to a wide range of engineering problems. ANSYS is a general purpose finite element modelling package for numerically solving a wide variety of problems which include static/dynamic structural analysis (both linear and nonlinear), heat transfer and fluid problems, as well as acoustic and electro-magnetic problems. The Rectangular beams with tensile reinforcement and shear reinforcement have been analyzed using a finite element (FE) model in ANSYS. Here, a linear analysis is considered throughout the study by assuming that there is a perfect bonding between reinforcement and the steel. Comparison of load deflection curve at midspan & pattern of failure of beam. Load deflection curve was calculated by using FEA at same location as the Experimental test of beam.

KEYWORDS: Reinforced Lightweight Concrete Beam, GFRP, ANSYS, Finite Element

I. INTRODUCTION

When structural lightweight concrete with pumice is used in construction and maintenance of civil engineering structures, the resultant benefits of reduced overall costs, better heat and sound insulation and better resistance to fire can be realized. Despite of its inferior compressive strength and lower modulus elasticity, pumice concrete can be potentially used in many kinds of structural elements. The reduced self-weight of walls also leads to a remarkable reduction in the stress. Under these conditions, the size of the foundation can be reduced too and moving and mounting are made easier when precast elements are used.

Glass Fibre reinforced polymer (GFRP) composite materials have been successfully used in new construction and for the repair and rehabilitation of existing structures. Strengthening or stiffening of reinforced lightweight concrete and pre stressed concrete structures may be required as a result of an increase in load requirements, a change in use, natural or man-made degradation of the structure, or design or construction defects. Repair with externally bonded FRP reinforcement is attractive to owners, Engineers, and contractors because of the ease and speed of installation, the structural efficiency of the repair, the corrosion resistance of the materials, and the minimal effect that these materials

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have on structural dimensions aesthetics, and versatility. Although many tests have been conducted investigating strengthening reinforced concrete members with FRP composite materials, there are still many aspects of their use that remain to be investigated.

The main problem to FEM of reinforced concrete structures is the difficulty in characterizing material properties. Much effort has been spent in search of a realistic model to predict the behaviour of reinforced concrete structures. Due mainly to the complexity of the nonlinear nature of material.

II. LITERATURE REVIEW

Finite element analysis of reinforcement concrete structure is difficult in characterizing material properties. Effort have been taken in past for modelling to study behaviour of reinforced concrete structures[9]. Reinforced concrete structure strengthened with GFRP are difficult to analyse as different material properties are involved and nature of composite behaviour is difficult to understand [7].The finite elements model uses a discrete approach to model the reinforced concrete members and three dimensional layered elements used to model fiber polymers composites [8].Apart from number of finite element software's like ETAB SAP2000 ,STAAD pro the ANSYS software focuses on analysis of composite members [4]

III. EXPERIMENTAL STUDY

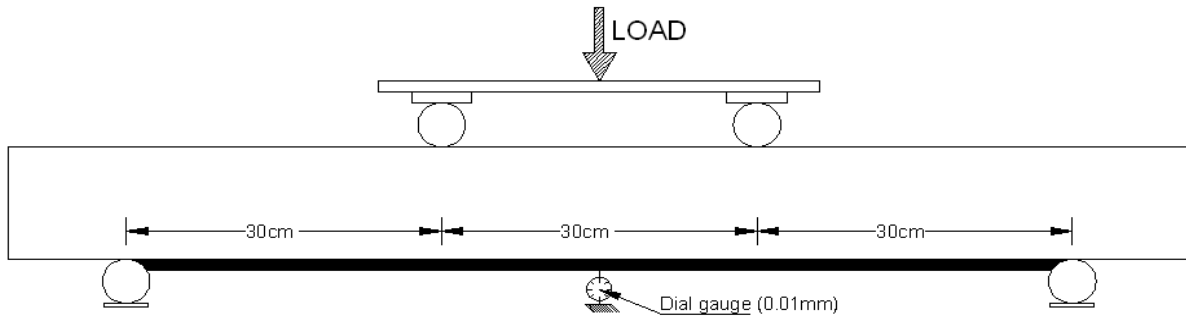
1. Details of Test: Mechanical properties such as compressive strength and flexural strength of M20 grade concrete are studied. Specimens for compressive strength are cube moulds, and for flexural strength reinforcement concrete beams are caste & strengthened by GFRP for full length & tested using CTM and UTM. Experimental work consists of mix design for M20 grade concrete by using natural pumice as coarse aggregate in concrete. Pumice aggregate size less than 20mm is used. Water absorption of pumice aggregate is more than 30% so, aggregates are pre-soaked. Locally available sand & 43-garde cement is used. Beams were cured for 28days in pure drinking water.

2. Details of Beam Specimen: The experimental work consisting of 3 rectangular under reinforced beams. All beams were having same size 100mmx150mmx1000mm. Reinforced with 2 no's of 8mm diameter bars were used for flexural reinforcement at bottom and 2 no's of 6mm at top of each beam, 6mm diameter bars used as stirrups spaced at 150 mm c/c for shear reinforcement. All beams casted with M20 grade concrete.

3. Preparation of Test Beam: Bottom surfaces of these beams were cleaned to assure a good bond between GFRP strip and concrete surface. Cracked and pre cracked were externally bonded with GFRP strip and epoxy at bottom face of beam as per the procedure laid down by the manufacture. Physical properties of E-Glass fiber are given in table 1.

Materials	Density (kg/m ³)	Elastic Modulus (N/mm ²)	Poison's ratio	fck28 (N/mm ²)	Fy (N/mm ²)	Element Used
Concrete	1790	24035	0.2	17.78	--	SOLID65
Reinforcing Steel	7850	210000	0.3	--	415	BEAM188
GFRP	2.7(gm/cm ³)	70000	0.15	--	415	SOLID45

4. Test Procedure: All beam specimens were instrumented and loaded simply supported as shown in fig 1. The load was applied through UTM (600 KN). All beams were tested under two point loading. They were statically tested to failure at equal 5KN increment of load. During loading the mid span deflection was measured by using dial gauge. Load & deflection readings were recorded for each stage. The results of all beam tests were summarised. Cracks formed on the surfaces were marked and identified, load and deflection characteristics.



WITH GFRP

Figure: -1 Two point load test with GFRP strip

IV. FINITE ELEMENT ANALYSIS

1. Reinforced Concrete: SOLID65 is used for the 3-D modelling of solids with or without reinforcing bars (rebar). The solid is capable of cracking in tension and crushing in compression. In concrete applications, for example, the solid capability of the element may be used to model the concrete while the rebar facility is available for modelling reinforcement behaviour. Other cases for which the element is also applicable would be reinforced composites (such as fibreglass), and geological materials (such as rock). The element is defined by eight nodes having three degrees of freedom at each node, translations in the nodal x, y, and z directions. Up to three different rebar specifications may be defined.

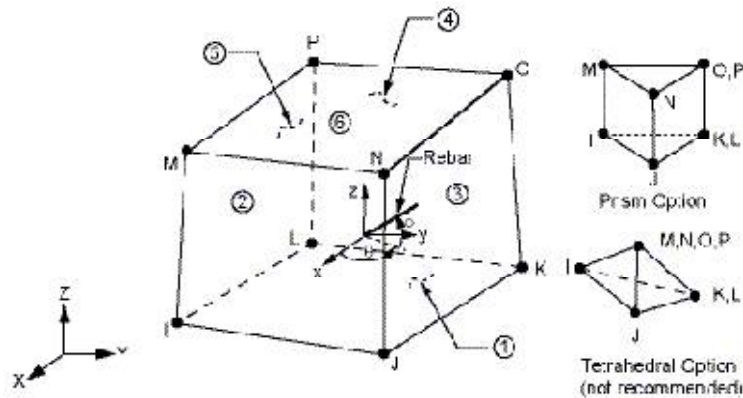


Figure: - 2 Solid65 element

2. Steel Reinforcement: To model concrete reinforcing, discrete modelling is used by assuming that bonding between steel and concrete is 100 percent. BEAM188 is used as reinforcing bars; it is a quadratic beam element in 3-D. BEAM188 has six degrees of freedom at each node. These include translations in the x, y, and z directions and rotations about the x, y, and z directions. This element is well-suited for linear, large rotation, and/or large strain nonlinear applications.

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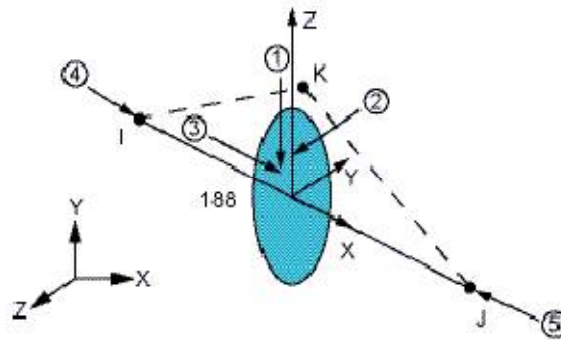


Figure: - 3 Beam188 element.

3 Geometry And Loading Conditions: Simply supported beam is considered having an overall length of 1000 mm with an effective length of 900 mm. Size of the beam is 100 x 150 mm. Beam subjected to two points loading at $1/3^{\text{rd}}$ span points from the support by equal loads. To get the accuracy of results mesh size considered as 10 mm as edge length as shown in figure 4.

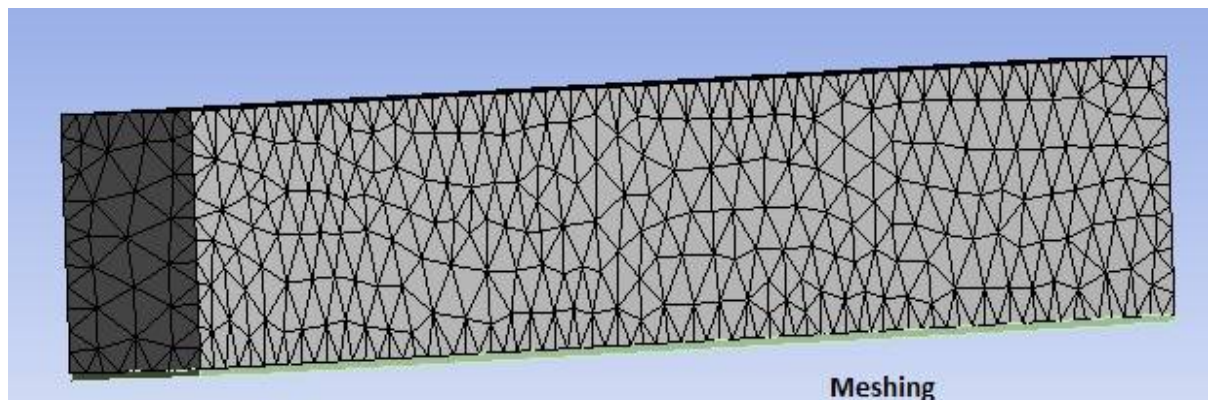


Figure: - 4 Beam model in ANSYS.

High-Yield Strength Deformed bars of 8 mm and 6 mm diameter are used for the longitudinal reinforcement and 6 mm diameter bars are used as stirrups. The tension reinforcement consists of 2 no's 8 mm diameter HYSD bars. Two bars of 6 mm of mild steel bars are also provided as hang up bars. The detailing of reinforcement of the beam is shown in figure 5.5 and figure 5.6 shows the beam model with FRP.

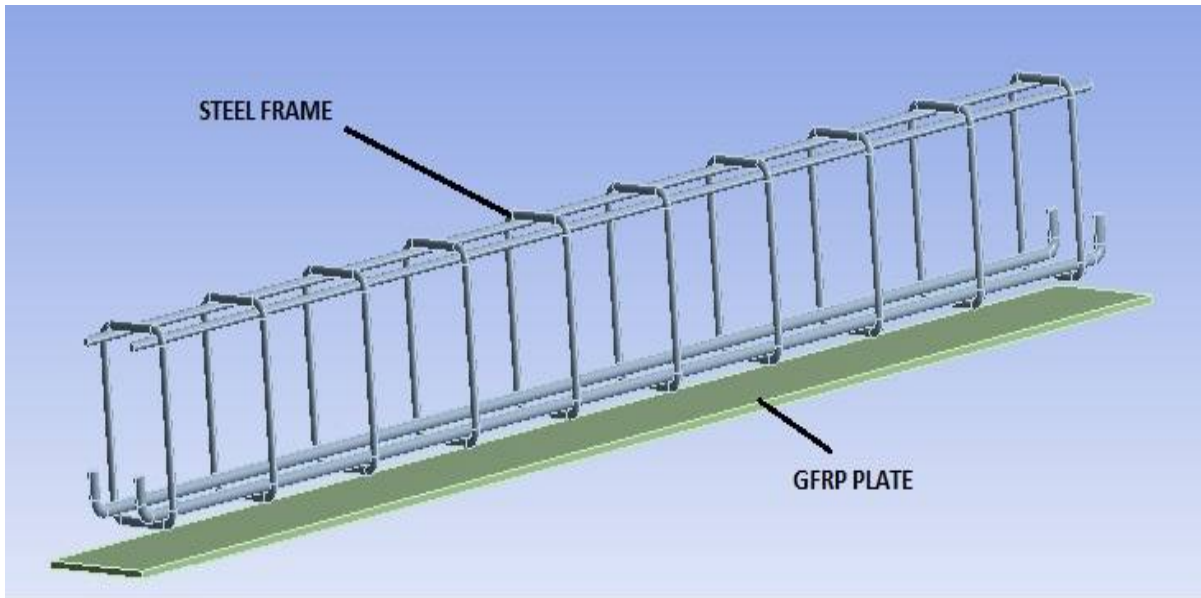


Figure: - 5 Reinforcement model in ANSYS.

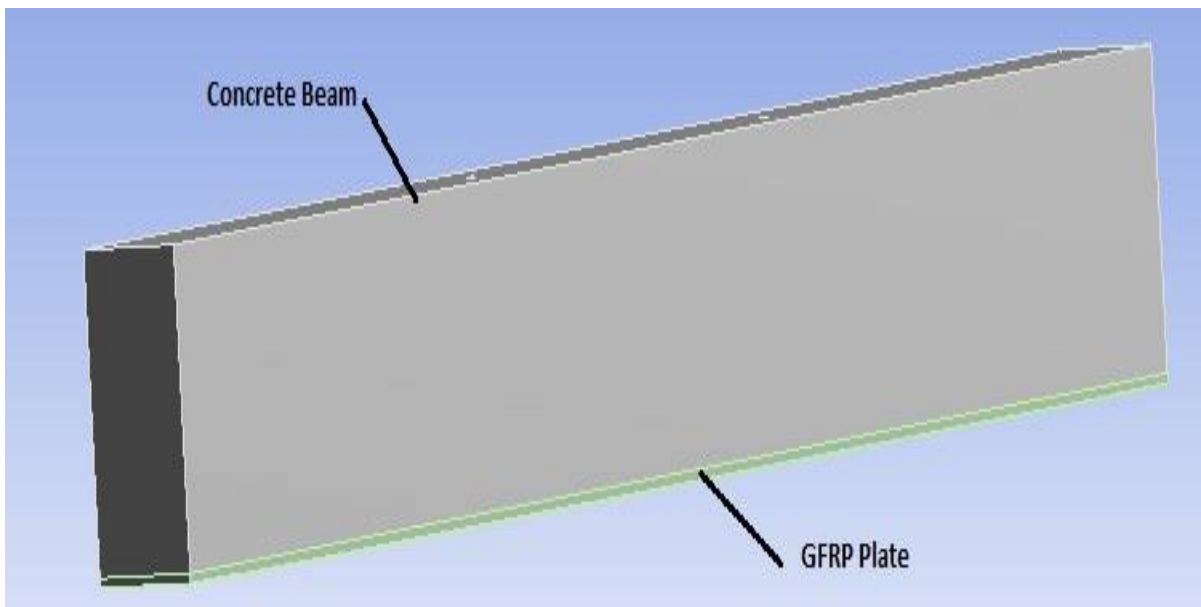
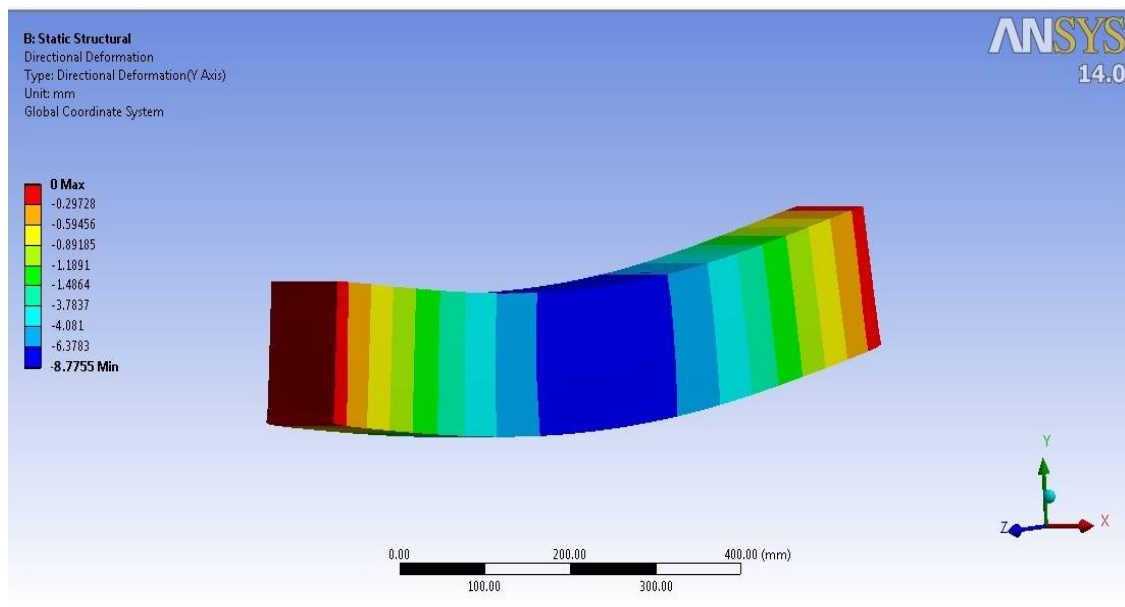
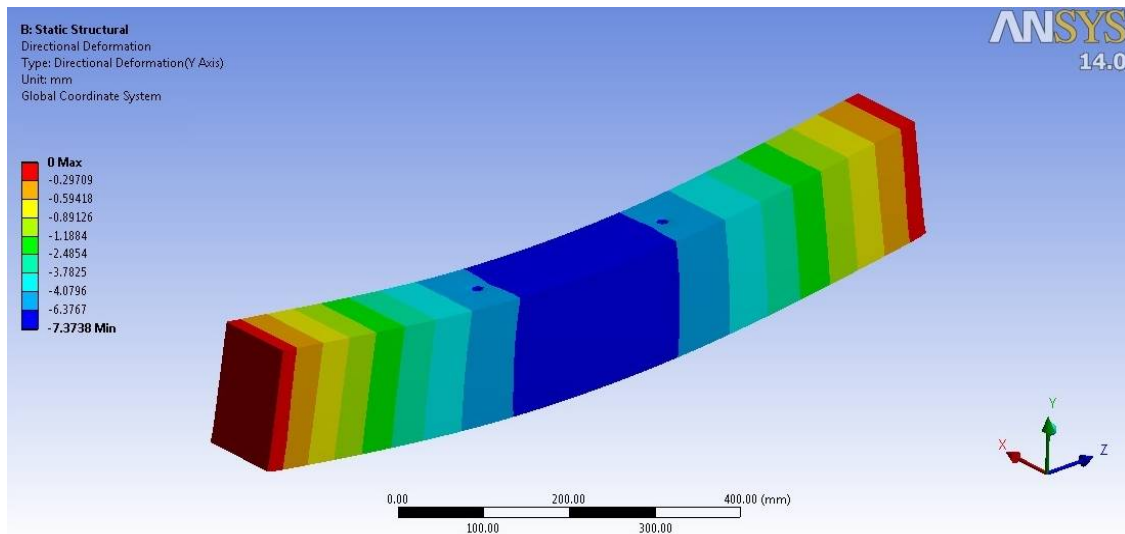


Figure: - 6 Beam model with FRP in ANSYS.

V. ANSYS ANALYSIS OF BEAM

Flexural Strength Analysis Of Reinforced Lightweight Concrete Beam Strengthened With GFRP Strip



VI. COMPARISON WITH ANSYS

Table: - 2 Comparison between EXPT, ANSYS

Load (KN)	Avg. Deflection (mm) EXPT	Load (KN)	Avg. Deflection (mm) ANSYS
0	0	0	0
5	0.07	5	0.0353
10	0.15	10	0.0631
15	0.28	15	0.1567
20	0.32	20	0.2678
25	0.48	25	0.4752
30	0.55	30	0.7653
35	0.68	35	0.9867
40	0.98	40	1.2237
45	1.25	45	1.5456
50	1.76	50	2.2376
55	2.38	55	2.9888
60	3.28	60	3.9023
65	4.3	65	4.7534
70	5.45	70	5.7645
75	6.54	75	6.9855
80	7.99	80	8.1968
84	9	84	9.2222

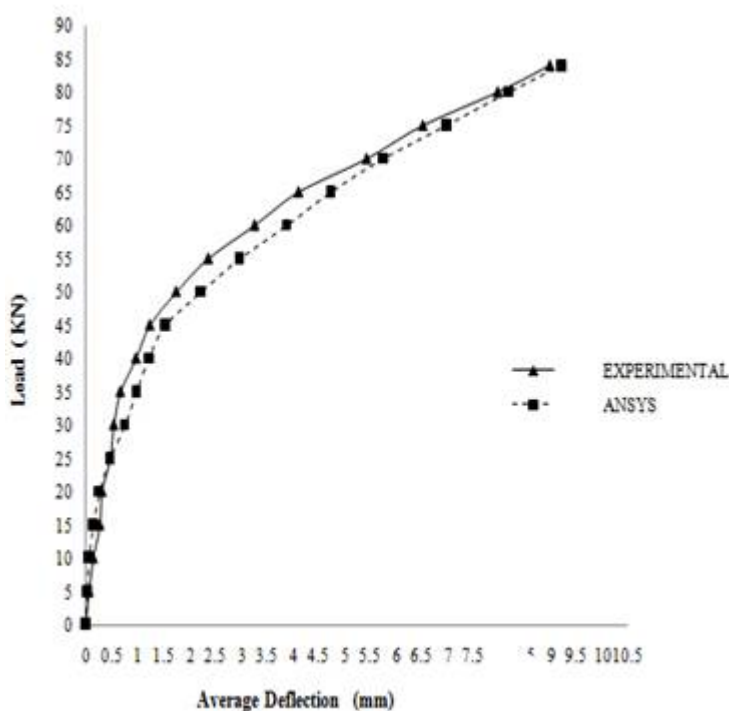


Figure:- 7 Load Vs Avg. Deflection curve

VII. CONCLUSIONS

Analysis carried out by Finite Element Method using ANSYS, The results are compared with experimental values

1. Deflection obtained using ANSYS are in good agreement for lower and higher range of load values when compared with experimental results. Experimental deflection compared with ANSYS deflection shows an error of 3.5%.
2. A number of failure modes have been observed in the study of RC beams strengthened by GFRPs. These include shear failure, shear failure due to GFRP rupture and crushing of concrete at the top and failure in flexure.
3. Beam strengthened with GFRP strip exhibited relatively good ductile behaviour. All beam exhibited ductile failure modes.
4. Strengthening and retrofitting of reinforced concrete beams by GFRP strips is effective technique.

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