Linear Behaviour of FRP Strengthened Reinforced Concrete Beam

Dr. S. N. Tande
Professor & Head,
Department of Applied Mechanics,
Walchand College of Engineering, Sangli, Maharashtra, India.

Aboli K.Mane
Research Scholar, Department of Applied Mechanics,
Walchand College of Engineering, Sangli, Maharashtra, India.

Abstract - Fiber reinforced polymers (FRP) materials are now used for strengthening of existing structures. In the present paper results from elastic analysis of reinforced beams under transverse loading using an analysis software ABAQUS compaired to experimental results from paper. The results indicate good aggrement with load carrying capacity of FRP strengthened beam is more than control beam. Only the linear analysis of simple concrete beam, Reinforced concrete beam and the reinforced concrete beam by applying GFRP sheets at bottom face.

Keywords - Concrete, fiber reinforced polymer (FRP), retrofitting, ABAQUS

I. INTRODUCTION

Fiber reinforced polymer (FRP) is one of the best retrofitting material for strengthening due to a number of advantages, such excellent strength to self weight ratio, large fatigue resistance capacity etc. These FRP materials are less affected by corrosive environmental conditions known to provide longer life and required less maintenance The concrete may have become structurally inadequate for example, due to deterioration of materials, poor initial design and/or construction, lack of maintenance, upgrading of design loads or accident events such as earthquakes. In recent years, the development of FRP and strong epoxy glue has led to a technique which has great potential in the field of upgrading structures. Basically the technique involves gluing FRP plates to the surface of the concrete. The plates then act compositely with the concrete and help to carry the loads The external bonding of high strength fiber reinforced polymer to structural concrete members has widely gained popularity in rehabilitation works and newly builds structures. There are various types of fibers. Most generally carbon and steel FRP sheets are used for strengthening of structural members. These FRP sheets are applied on beam for increasing flexural and shear strength of beam.FRP sheets are attached at bottom face of beam to increase flexural strength of beam and for increasing the shear strength of beam FRP is attached on side face of beam. Many researchers have investigate the structural behaviour of FRP strengthened beam by using glass fibers and carbon fibers.Sandeep G.sawant (2013) mentioned different types of glass fibers. Experimental work has been done. Four point loading method is used for testing of beams. They casted the R.C.C beams and then applying FRP sheets on both side, bottom side and U shape on beam. And also they carried out cost analysis. Load Vs deflection curves are plotted for each beam.

II. EXPERIMENTAL PROGRAMME

Generally for testing of beams four point loading test is used . the deflection is recorded in middle third part of the beam where shear force is zero and bending moment is constant. We referred the experimental data given in paper "Strengthening of R.C.C. beam- using different glass fibers". Four point loading test was used. The experimental work consists of casting of four sets of reinforced concrete (RC) beams having grade M30,cross-sectional dimensions of 150mm x 200mm and 1000mm length. We provided 2-12mm Ø bottom reinforcement and 2-8mm Ø top with 6mm Ø vertical stirrups @ 160mm c/c. The strengthening of the beams using GFRP sheet is done with three different configurations namely both side wrap, bottom wrap & U wrap.

III. FINITE ELEMENT ANALYSIS

Finite element analysis has been performed to model the linear behaviour of beams. The finite element based software ABAQUS has been used for analysis. The analysis is done for the various conditions

1) Plain cement concrete beam
2) Reinforced concrete beam
3) Reinforced concrete beam externally bonded with FRP.

A.Material properties

a. Concrete

Under uniaxial tension the stress- strain response follows a linear elastic relationship until the value of the failure stress is reached. The failure stress corresponds to the onset of microcracking in the concrete material. The elastic parameters required to establish relationship between modulus of elasticity Ec and compressive strength of concrete.

$Ec = 5000\sqrt{fck}$ ....(1) [2]

M30 grade concrete is used for beams. Density of concrete is taken as $24kN/m^3$ and $25kN/m^3$ for plain cement concrete and reinforced concrete beams respectively.
Poisson's ratio is 0.19

b.Steel

The elastic modulus of steel is 210 GPa and poisson's ratio is 0.3

c. Glass fibers

The elastic modulus of glass fibers is72.5 GPa, tensile strength is 3400 MPa, density 2.57 g/cm^3

IV.MODELLING OF BEAMS

The linear analysis has been done for the above mentioned three conditions. The analysis has been carried out for the comparison and the study of effect of GFRP. The beams modelled in ABAQUS for the various conditions are shown in fig.1, fig.2, fig.3.The application of loading and boundary conditions are shown in fig.4

A.For the modelling of beams in ABAQUS elements used are as follows:

a. Concrete : for modelling of concrete in ABAQUS C3D8R 3D stress element is used. 8 node linear brick element reduced integration-(designation C3D8R): It is a8 node 3D brick element and it used for higher beam analysis it gives more accurate result. Displacements, rotations, temperatures, and the other degrees of freedom mentioned in the section are calculated only at the nodes of the element. At any other point in the element, the displacements are obtained by interpolating from the nodal displacements. Usually the interpolation order is determined by the number of nodes used in the element. Elements that have nodes only at their corners, such as the 8-node brick shown in Figure 18, use linear interpolation in each direction and are often called linear elements or first-order elements [4].

b.Steel: for modelling of steel reinforcing bars in ABAQUS T3D2 2 Node linear 3-D truss element is used. 3 node quadratic 3-D truss element Here in the modelling of reinforced cement concrete beam the main reinforcement (tension reinforcement), compression reinforcement and stirrups are modelled by T3D3 elements [4].

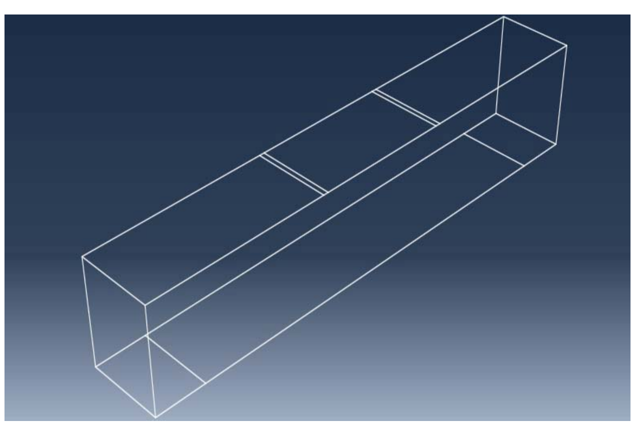

Fig.1 Plain cement concrete beam

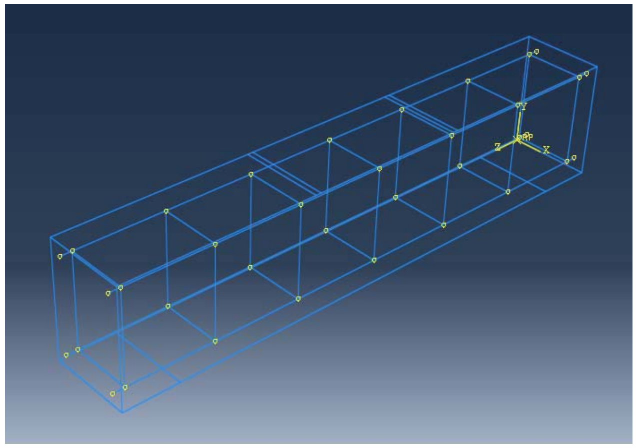

Fig.2 Reinforced concrete beam

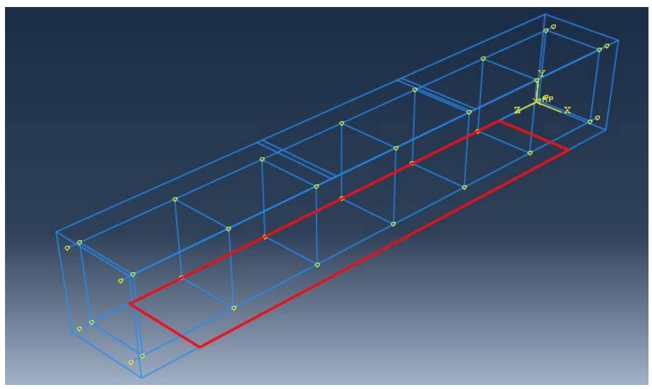

Fig.3 Reinforced concrete beam externally bonded with FRP

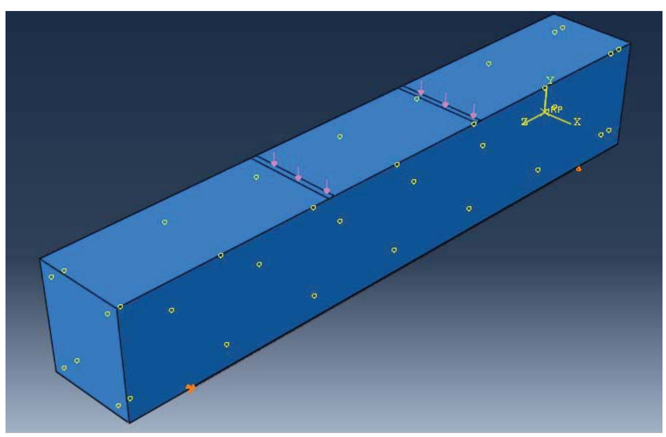

Fig.4 Load and boundary conditions

V. ANALYTICAL RESULTS

The analytical results of the beams for the various conditions are shown in Table.1, Table 2, Table 3

Table.1 Results of PCC beam

Load in (kN)	Stress at top N/mm^2	Strain at top $X10^{-4}(mm^4)$	Stress at bottom N/mm^2	Strain at bottom $X10^{-4}(mm^4)$	Deflection in mm
0	0	0	0	0	0
10	3.214	1.025	2.545	0.878	0.08421
20	5.947	2.000	4.587	1.517	0.1684
30	7.989	2.7295	6.554	2.32	0.2526
40	11.000	3.642	9.40	3.5	0.3368
50	13.50	4.74	12.34	4.231	0.4210

Table.2 Results of RCC beam

Load in (kN)	Stress at top N/mm^2	Strain at top $X10^{-4}(mm^4)$	Stress at bottom N/mm^2	Strain at bottom $X10^{-4}(mm^4)$	Deflection in mm
0	0	0	0	0	0
10	2.31	0.8780	2.200	0.8775	0.07334
20	3.98	1.517	4.100	1.517	0.1467
30	6.102	2.32	6.125	2.319	0.22
40	7.500	3.102	8.35	3.300	0.2934
50	11.024	3.865	10.24	3.865	0.366

Table.3Results of RCC beam attached with FRP

Load in (kN)	Stress at top N/mm^2	Strain at top $X10^{-4}(mm^4)$	Stress at bottom N/mm^2	Strain at bottom $X10^{-4}(mm^4)$	Deflection in mm
0	0	0	0	0	0
10	1.465	0.775	1.454	0.7714	0.0213
20	3.012	1.407	3.168	1.407	0.0356
30	4.425	2.012	4.785	2.10	0.0498
40	6.785	2.828	6.674	2.828	0.0615
50	7.895	3.123	8.012	3.30	0.0703

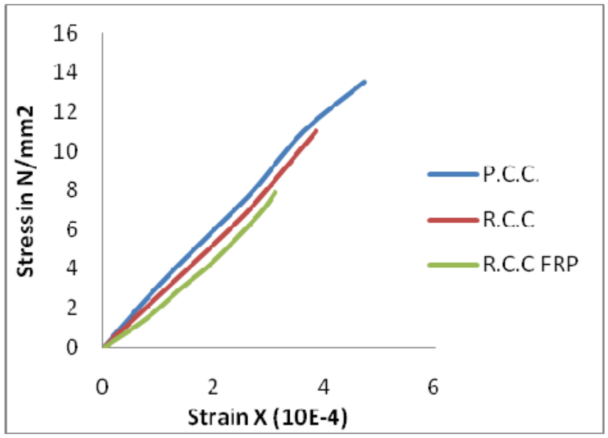

Fig.5 Stress-strain (top) curve for all the cases

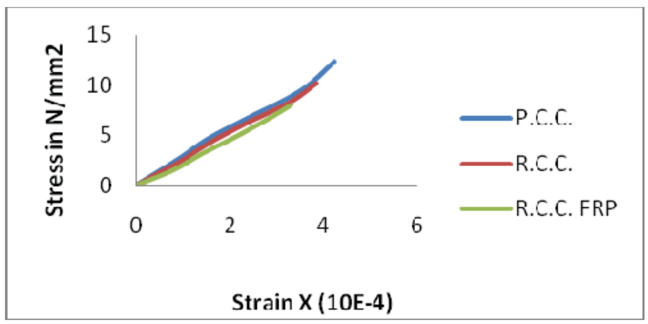

Fig.6 Stress-strain (bottom) curve for all the cases

VI. ANALYTICAL AND EXPERIMENTAL COMPARISON

The analytical and experimental comparisons have been done in the load-deflection case. The comparison includes the load- deflection of RCC and RCC beam with FRP.Fig.7shows the load- deflection curve of RCC beam and fig.8 shows the load- deflection of RCC beam with FRP. For both the cases the experimental results and analytical results are coinciding for the linear case

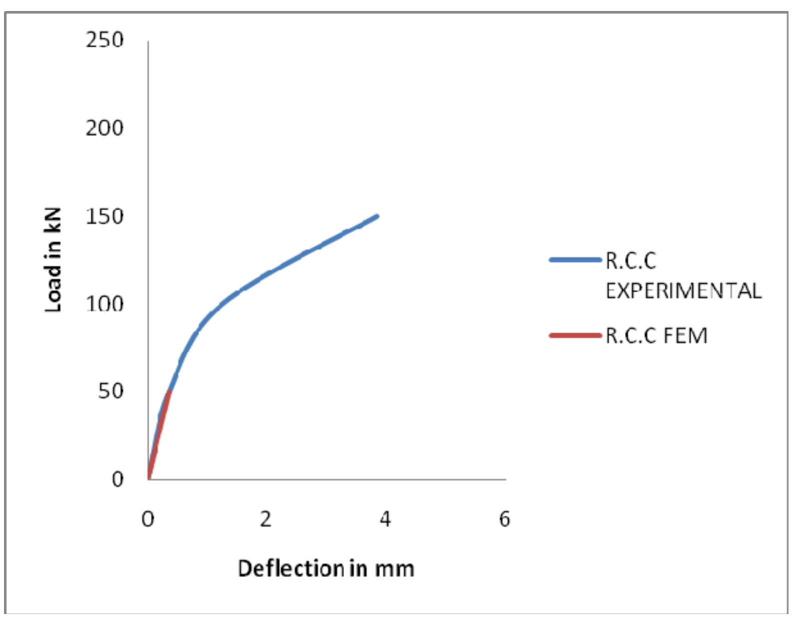

Fig.7 Load-deflection curve for RCC beam

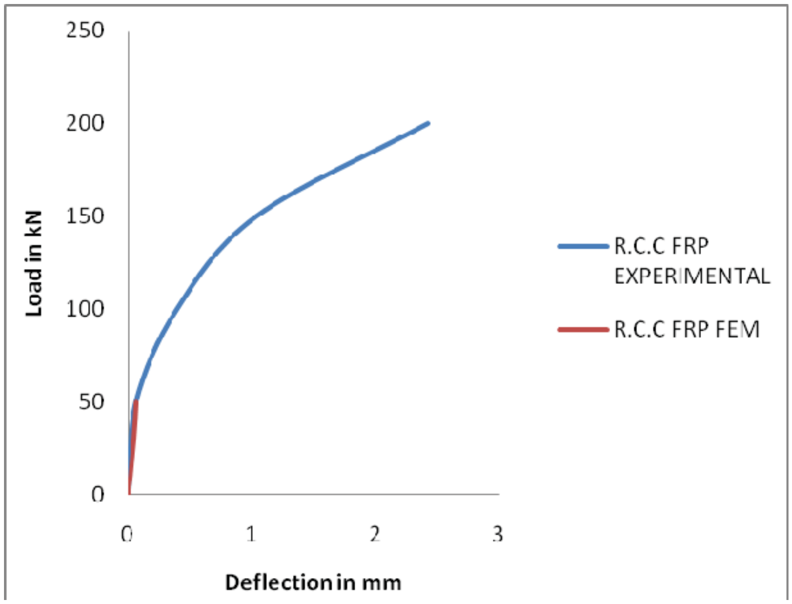

Fig.8 Load-deflection curve for RCC FRP beam

VII. CONCLUSIONS

Rehabilitation by GFRP has proven itself to be a better feasible option than other methods. So the future prospects for the utilization of GFRP in Civil engineering infrastructure are good. Researchers around the world are now looking at the new and innovative ways of utilization of the same. The behaviour of concrete beams strengthened with GFRP unidirectional composite laminates have been studied. GFRP casted beams behave better than the RCC beam. Deflections in the beams retrofitted with GFRP are less than RCC beam .For the same load the RCC beam with FRP has the less stresses and strains. In the comparison cases both experimental and analytical results are coinciding. Therefore the FEA software ABAQUS can use effectively for the beam analysis.

REFERENCES

[1] Abacus Inc., ABAQUS 6.9.3 User's Manual, SIMULIA, USA

[2] IS 456: 2000 Indian standard. "Plain and reinforced standard, 2000), New Delhi.

[3] Z.J. Yanga,, J.F. Chenb, D. Proverbsc, *Finite element modelling of concrete cover separation failure in FRP plated RC beams,* Construction and Building Materials 17 (2003) 3–13.

[4] Sandeep G. Sawant, A. B. Sawant, M. B. Kumthekar,"Strengthening of R.C.C. Beam- Using Different Glass Fiber", International Journal of Inventive Engineering and Sciences (IJIES) ISSN: 2319–9598, Volume-1, Issue-2

[5] www.glass-fiber.net

[6] www.reasins.com

[7] www.retrofitting.com