Study on Retrofitting of Concrete Beam Structure using Carbon Fibre Reinforced Polymer (CFRP)

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Abstract— Recent earthquakes have demonstrated that most of the reinforced concrete structures were severely damaged during earthquakes and they need major repair works. Beam-column structures, being the lateral and vertical load resisting members in reinforced concrete structures are particularly vulnerable to failures during earthquakes. The existing reinforced concrete beam column structures, which are not designed as per code IS 13920:1993 must be strengthened since they do not meet the ductility requirements. The Finite Element Method (FEM) has become a staple for predicting and simulating the physical behaviour of complex engineering systems. The commercial finite element analysis (FEA) programs have gained common acceptance among engineers in industry and researchers. The details of the finite element analysis of beam-column joints retrofitted with carbon fiber reinforced polymer sheets (CFRP) carried out using the package ANSYS are presented here. Four exterior reinforced concrete beam-column structures were modelled using ANSYS package. The first beam is the control specimen. This had reinforcement as per code IS 456:2000. Other beams are retrofitted with one layer, two layers and three layers of Carbon Fibre Reinforced Polymer (CFRP) respectively. During analysis both ends of beam are simply supported and concentrated load is applied at the midpoint, but in case of column, bottom end is fixed and other end is free. An axial load is applied at the top of the column. This performance is compared with the concrete beam-column structure which do not layered with Carbone Fibre reinforced Polymer (CFRP) sheet.

Key words: FEM, FEA, CFRP

I. Introduction

Strengthening of existing Reinforced concrete structures (RCC) is now a major part of the construction activity all over the world. The RCC structures constructed across the world are often found to exhibit distress and suffer damage, even before service life is over, due to several causes such as earthquakes, corrosion, overloading, change of codal provisions, improper design, faulty construction, explosions and fire. Different methods suggested for repairing/upgrading of RC buildings, the use of externally bonded Fibre reinforced polymers (FRPs) has increased significantly, especially in recent years. The inherent advantages of FRPs pose them as a more reliable candidate for seismic retrofitting of RC buildings in comparison to the traditional methods such as external bracing or steel jacketing. These include high tensile strength, low specific weight, high resistance to corrosion, and ease of application. The efficiency of FRP retrofitting in strengthening/repairing of structural beam-column joints has been confirmed in many studies worldwide. Researchers have also investigated the related problems such as FRP-concrete interface interaction and creep behaviour in FRP strengthened structural members.

Some of the structures are damaged by environmental effects which include corrosion of steel, variations in temperature, freeze–thaw cycles and exposure to ultra-violet radiation. There are always cases of construction-related and design-related deficiencies that need correction. Many structures, on the other hand, need strengthening because the allowable loads have increased, or new codes have made the structures Sub-standard. This case applies mostly for seismic regions, where new standards are more comprehensive than the old ones.

In recent years FRP materials with wide range of fibre types of Glass, Aramid, Hybrid or Carbon provide designers with an adaptable and cost effective construction material with a large range of modulus and strength characteristics. Comparing with traditional rehabilitation techniques, the FRP composites have high specific strength/stiffness, flexibility in design and replacement as well as robustness in unfriendly environments. With FRP composites it is possible and also necessary to achieve the best strengthening results by optimising the constitute materials and architecture. Become essential in order to utilise the superiority of FRP composites in application of rehabilitation. FRP can be produce with higher strength and higher modulus of elasticity than steel, hence improving the flexural strength, shear strength, and deflection of structural member. In this research, analysis of the reinforced cement concrete beam retrofitted with one, two and three layer of carbon fiber reinforced polymer(CFRP) respectively by using ANSYS software.

II. Modelling

A. *Description of material properties*

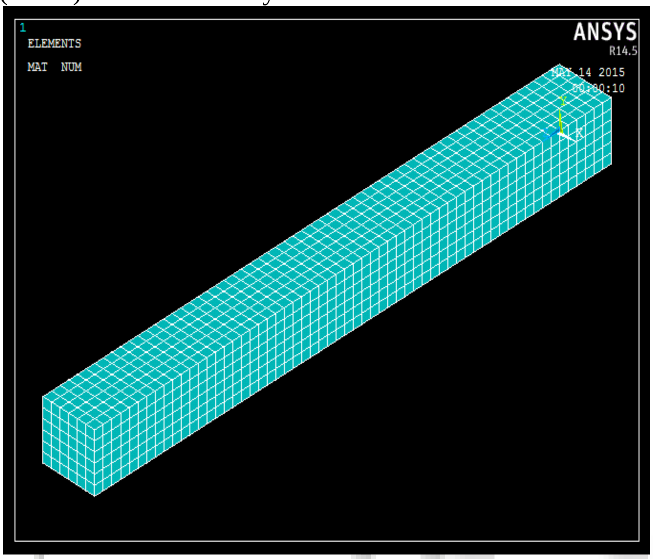
The properties of material specimen model are given below TABLE 1.

Material	Element	Modulus of Elasticity (KN/m2)	Poisson's Ratio
Concrete	Solid 65	22360670	0.15
Steel	Link180	2×10^8	0.30
CFRP	Solid 65	5×10^8	0.183

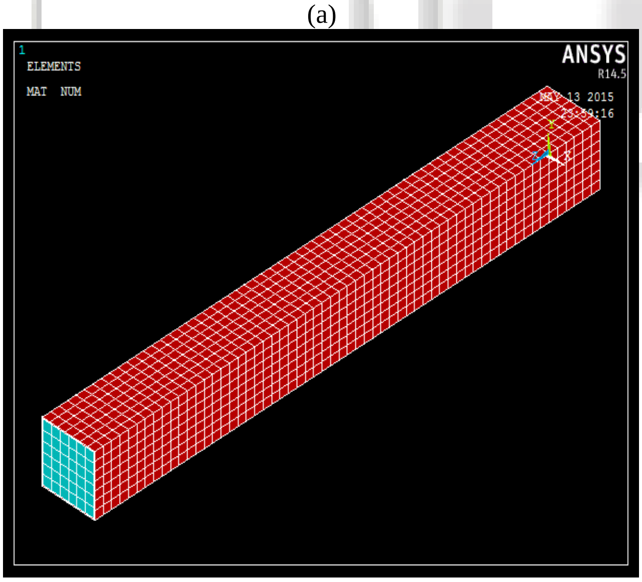
The Reinforced concrete (RC) beam considered for analysis consists of a simply supported portion. The Reinforced beam had a cross section of 150 mm X 150 mm with an overall length of 1500 mm. The control specimen were designated as B1 (Beam) had reinforced as per code IS 456-2000. The concrete grade is M20 adopted in this case.

The Beam Retrofitted with externally bonded Carbon Fibre Reinforced Polymer (CFRP) sheet was designated as B2, B3 and B4 which had reinforced as per code IS 456-2000. The thickness of Carbon fibre Reinforced polymer (CFRP) sheet is 1 mm. The Reinforced beam was

Reinforced with 4 number of 12 mm diameter Fe 415 rod s each in tension and compression zone.
B1 = Reinforced concrete beam Section
B2 = Reinforced concrete beam section Retrofitted with Carbon Fibre Reinforced Polymer (CFRP) sheet on one layer
B3 = Reinforced concrete beam section Retrofitted with Carbon Fibre Reinforced Polymer
(CFRP) sheet on two layer
B4 = Reinforced concrete beam section Retrofitted with Carbon Fibre Reinforced Polymer
(CFRP) sheet on three layer



(a)



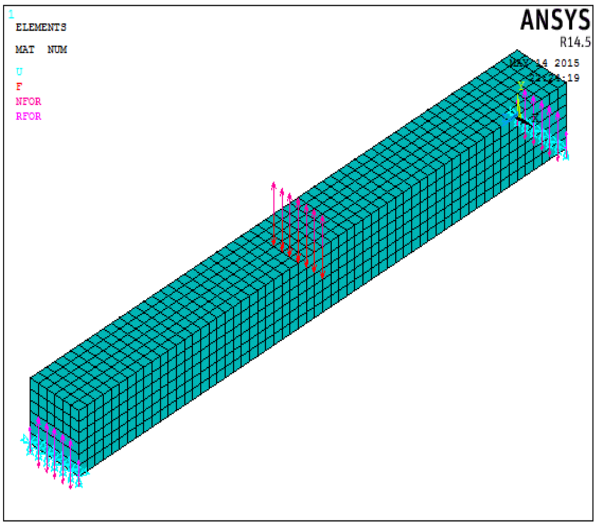
(b)

Fig. 1: Meshing of Reinforced concrete section (a) Without CFRP (b) With CFRP

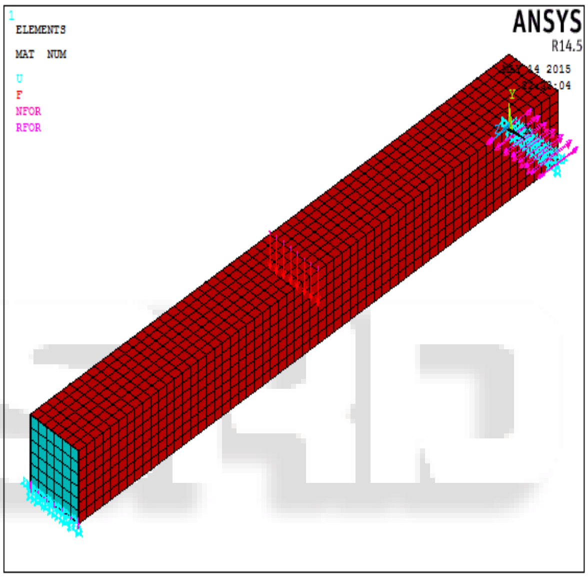
B. *Load and Boundary Condition*

Displacement boundary conditions are needed to constrain the model to get a unique solution. To achieve this, the translations at the nodes (UX, UY and UZ) are given constant values of 0.

The load of 10 kN applied downward at the mid-section of flexural simply supported Reinforced concrete beam.



(a)



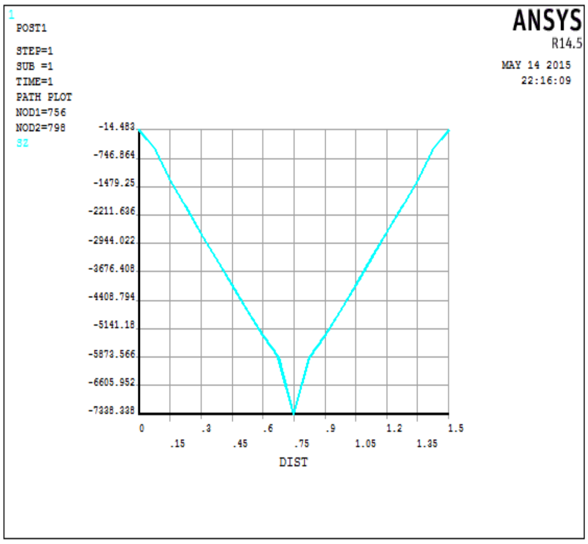
(b)

Fig. 2: Load and boundary condition in Beam section (a) without CFRP (b) With CFRP

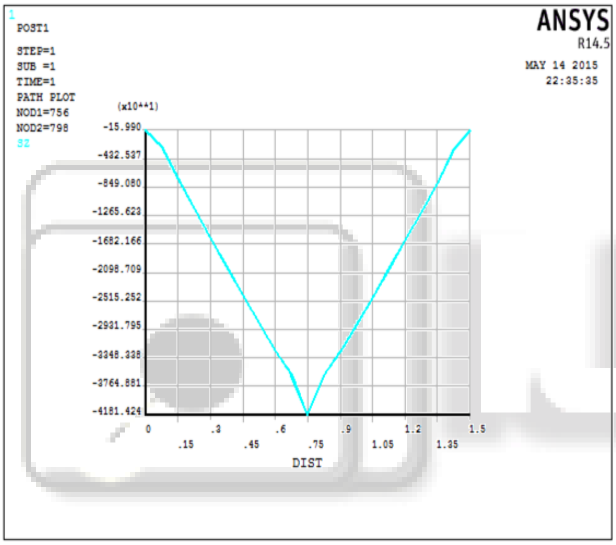
III. RESULT AND DISCUSSION

The beams were loaded with a concentrated load at the middle of each span and the obtained experimental results are presented and discussed subsequently in terms of the observed Stress and Deflection. the results from the Finite Element Method (FEM) study of the controlled specimen are compared with the results from the Reinforced Concrete beam and Retrofitted Reinforced Concrete beam with Carbon fibre Reinforced Polymer (CFRP).

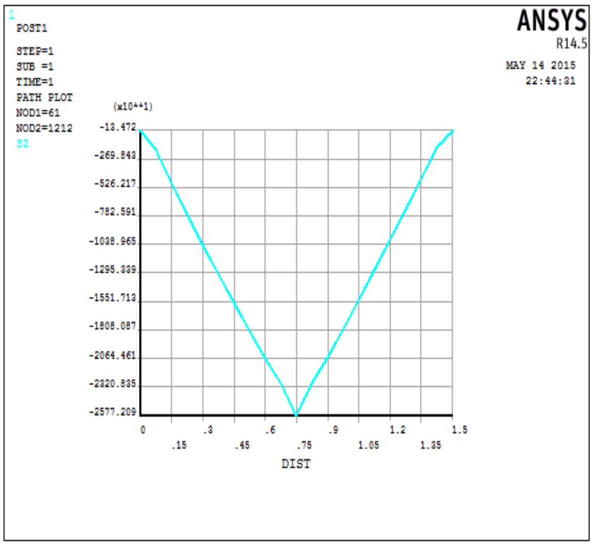
A. Stress Variation on Top Layer of RC Beam



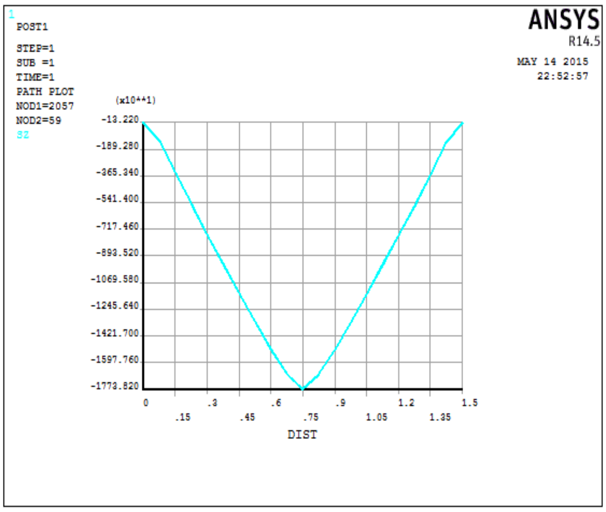
(a)



(b)



(c)



(d)

Fig. 4: Stress variation on top layer of Beam (a) Without CFRP (b) With one layer CFRP (c) With two layers CFRP (d) with three layers CFRP

It is observed from the Fig.4(a), Fig4(b), Fig.4(c) and Fig.4(d) and analysis is carried out the stress is increase in Retrofitted with CFRP Beam as compare to the without CFRP Beam.

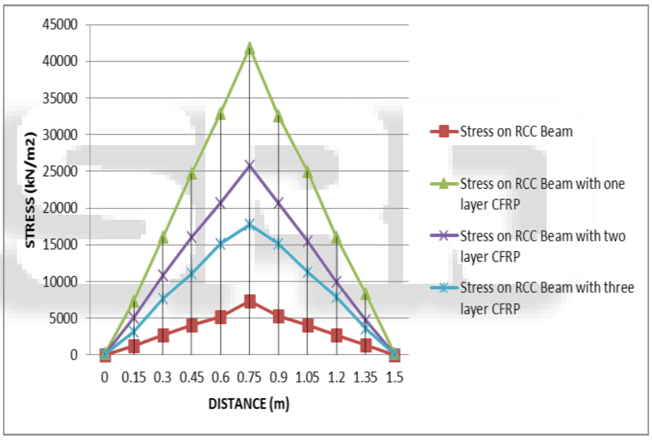
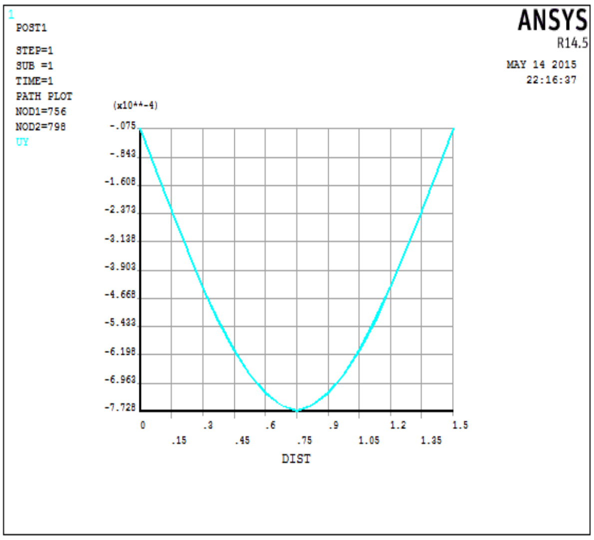
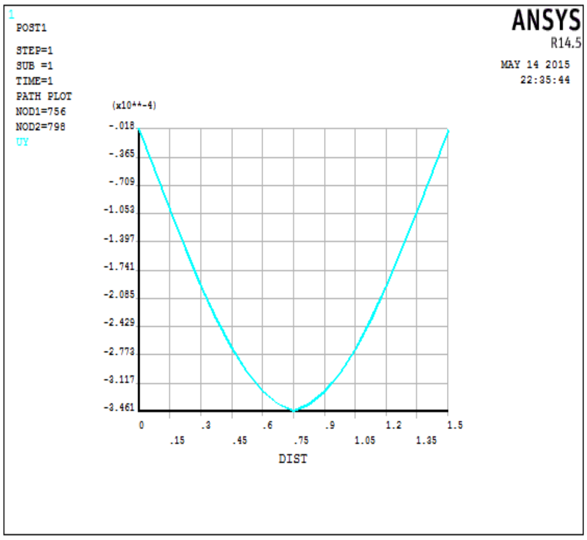


Fig. 5: Effect of Stress on RCC Beam

B. Deformation of RC Beam



(a)



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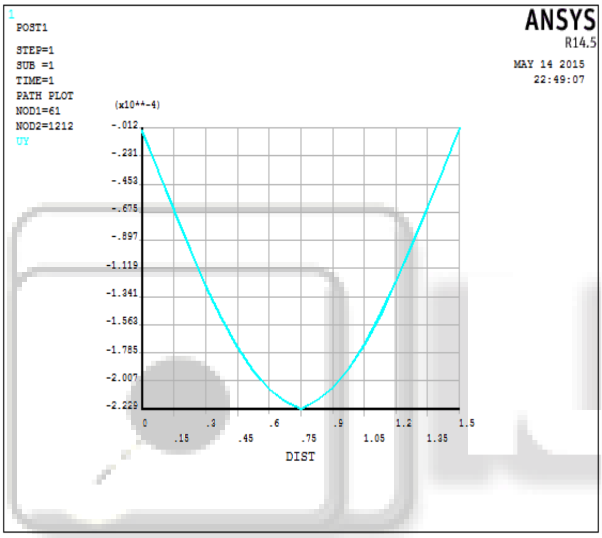

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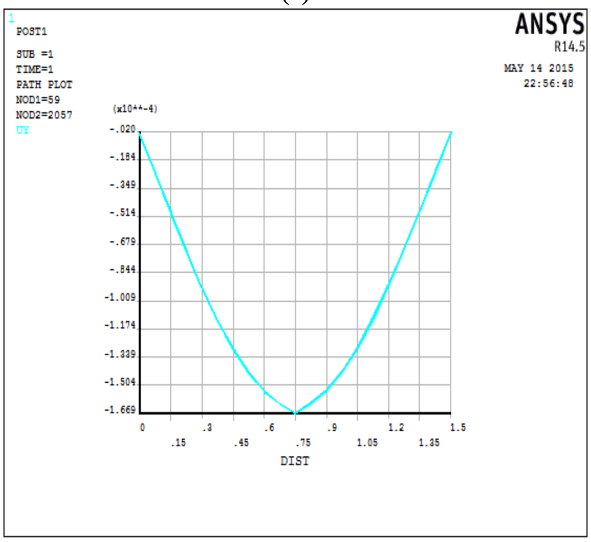

(d)

Fig. 6: Deformation effect on Beam (a) without CFRP (b) with one layer CFRP (c) with two layers CFRP (d) with three layers CFRP

It is observed from Fig. 6(a), Fig. 6(b), Fig. 6(c), Fig. 6(d) that deflection is reduces, when using CFRP.

Deflection is continuous reduce, when the number of layer CFRP is increase.

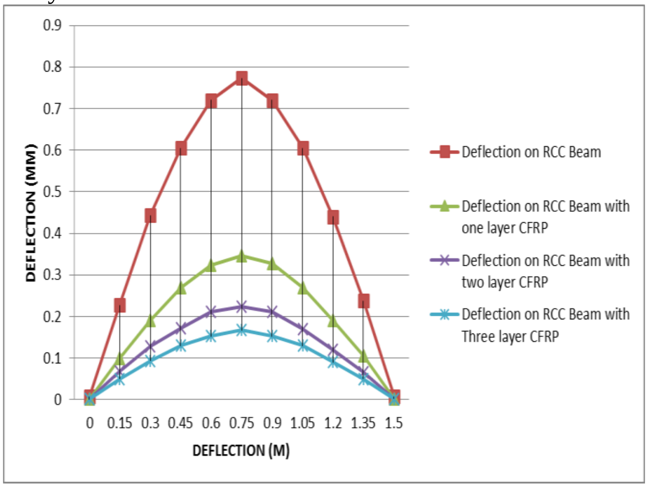

Fig. 7: Effect of Deformation on RCC Beam

IV. CONCLUSION

In the present study an attempt has been made to study the effect of CFRP layers in beam and column structure. ANSYS is used for the analysis purpose.

On the basis of the study, following conclusion may be drawn.

- The flexural strength and load carrying capacity of the beams can be improved by Retrofitting with CFRP.
- Retrofitting of concrete beam using Carbon Fibre sheet gives more load carrying capacity than without CFRP concrete beam.
- Deflection of Retrofitting Beam with CFRP is reduces as compare to without CFRP beam.
- The stress of Retrofitting with CFRP is increases as compare to without CFRP beam.

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