ANALYSIS OF CFRP STRENGTHENED REINFORCED CONCRETE STRUCTURAL MEMBERS USING ANSYS

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ABSTRACT. Civil engineering is the field of exploring the limits of building structures and for discovering technologies to make the buildings go higher, last longer and consist of lighter materials. A combination of exposure to aggressive effects, poorly constructed structural details, negligence of the durability issues, construction errors and underestimation of the importance of maintenance can lead to a severe damage of reinforced concrete structural components. For the suspended structures because of corrosion and extreme loading, the steel cable loses its strength. Hence, CFRP cables can be used as a replacement for steel cables. Carbon fibres are preferred as reinforcing polymers because of its irrefutable properties such as high modulus of elasticity as compared to steel, high tensile strength, low density, high chemical inertness. Also, CFRP sheets are durable and light in weight. The structure which loses its load-bearing capabilities can be retrofitted with carbon fibre reinforced polymer sheets. With the rise in temperature strength of structural components decrease rapidly. This can be strengthened using CFRP sheets. Application of CFRP sheets to the Reinforced concrete structural members reduces deflection, crack width and stress in steel reinforcement. The purpose of this study is to analyze, examine behavior property of RC structural members using finite element analysis. The finite element analysis was carried out using ANSYS software. A beam model was developed using elements such as SOLID 65 for concrete and SOLID 45 for CFRP and analyzed accordingly. The parameters such as load deflections, maximum and minimum stresses, total deformations were studied from the analysis.

Keywords: Durable, Reinforcement, Retrofitted, Elasticity, Stresses, Corrosion.

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INTRODUCTION

Concrete is a composite material which consists of a binding medium along with a combination of coarse and fine aggregates. Civil engineers face a lot of challenges nowadays corresponding to the maintenance of reinforced concrete structures. There is a need to protect these assets using various effective techniques. Concrete structures are subjected to wide range of damages such as accidental damage, environmental factors, exposure to corrosive elements, inadequate design and construction or need for structural upgradation so as to meet new seismic design requirements because of new design standards. A combination of exposure to aggressive effects, poorly constructed structural details, negligence of the durability issues, construction errors and underestimation of the importance of maintenance can lead to a severe damage of reinforced concrete which is used for the construction of these structures. Physical damage to the structure arises from the internal and external restraints against structural movement. These factors, coupled with the quality of construction built into the structure, mean that the time to initial deterioration may vary widely. Fire damage to concrete structures reduces the significant strength of structural components due to rise in temperatures. To improve these circumstances various techniques such as column jacketing, retrofitting, strengthening using additional steel members are used.

LITERATURE REVIEW

[1] studied the behaviour of steel-concrete composite girders strengthened with CFRP sheets under static loading. A total of three large-scale composite girders made of steel beam and 75-mm thick by 910-mm wide concrete slab were prepared and tested. One, three and five layers of CFRP composites were tested having uniform thickness. The ultimate load-carrying capacities of the girders significantly increased by 44, 51, and 76% for one, three, and five-layer retrofitting systems respectively. The accuracy for utilizing the CFRP sheet decreased with the increased number of CFRP layers. Stress in the CFRP laminate for the one-layer system was 75% of its ultimate strength while in the five-layer system, it dropped to 42%. This states that a balanced design should be considered to effectively utilize the strength of CFRP laminates.

[2] performed finite element analysis of three beams retrofitted with carbon fibre reinforced polymer, glass fibre reinforced polymer and Kevlar fibre reinforced polymer. It was concluded that the strength of the RC beam increases when wrapped with FRP composites. The RC beam retrofitted with carbon fibre reinforced polymer (CFRP) showed reduction in deflection by 73% as compared to RC beam. It was also observed that the RC beam wrapped with glass fibre reinforced polymer (GFRP) showed reduction in deflection by 65% and when wrapped with Kevlar fibre reinforced polymer (KFRP), the deflection of the beam is depreciated by 60% as compared to the RC beam specimen.

[3] conducted numerical analysis on fifty-seven reinforced concrete beams, one of them was without any opening, nine of these beams were control beams four beams were with opening. In order to keep reinforcing bars in their right positions and to obtain internal strains in them, the discrete technique using the 3D spar Link8 element was followed. It was observed that the strengthening of beams at the openings increased its strength considerably which was lowered because of openings. Also, this element is capable of plastic deformation.

PRESENT STUDY

Analysis of CFRP strengthened reinforced concrete structural members using ANSYS [4]

Reinforced concrete structural components get damaged due to environmental factors, physical damages, insufficient design etc. CFRP composites are preferred in this situation since it possesses unique properties such as high strength, good damping capacity, lightweight and easy to fabricate and also high corrosion-resistant. Its operational cost is low and can be applied conveniently. A quantity whose actual solution cannot be found in other cases can be analyzed using finite element analysis for esteemed results. Finite element analysis is a numerical method for analysing complicated structural issues.

ANSYS is a finite element analysis tool for structural analysis, containing linear, non-linear and dynamic studies. This computer simulation product caters finite elements to model performance and supports material models and equation solvers for a wide range of mechanical design problems. It is a general purpose software used to simulate collaboration of all disciplines of physics, structural, vibration, fluid dynamics, heat transferred electromagnetic for engineers. ANSYS meshing is a general purpose, intelligent programmed, high performance product. It generates the most suitable mesh for accurate, efficient multi-physics solutions. The concrete beam model used in present study is shown in Fig.1.

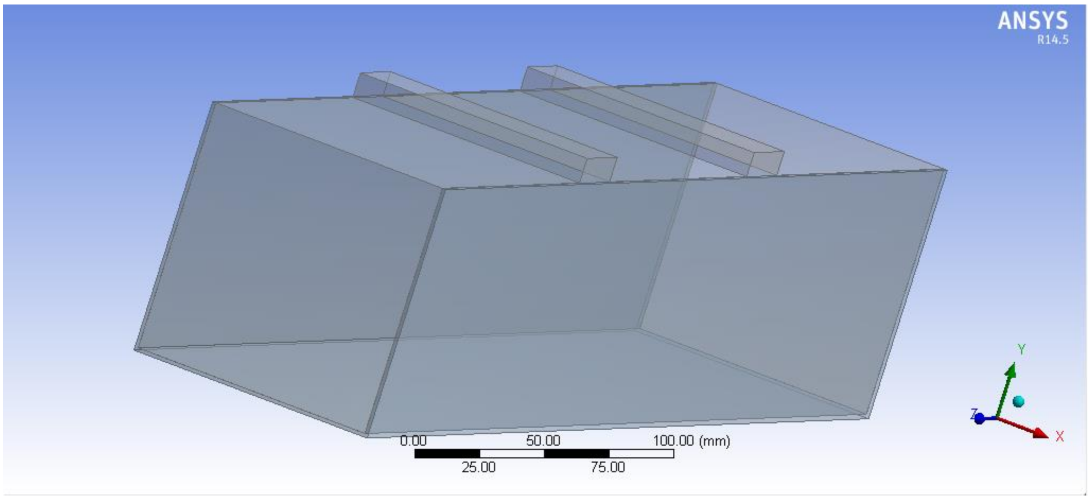

Figure 1 Concrete beam model used in the present study

Analysis of Simply supported beam

The finite element analysis is conducted on concrete beams to check deflection. Plain concrete beams and concrete beams retrofitted with carbon fibre reinforced polymer are analyzed with three support conditions to satisfy deflection and stress parameters. Total six beams are analysed in ANSYS, three beams are retrofitted with CFRP and three are plain concrete beams. To create a model, from sketching rectangle tool is used. The section is drawn and thickness of about is given to obtain the 3D model. Figure 2 shows the model of concrete beam wrapped with CPRF. A concrete beam model strengthened with CFRP is developed in Ansys using solid 65 elements for concrete and solid 45 elements for FRP. No separation property is used in Ansys for accurate CFRP bonding. Concrete beams of length

500mm, depth 100mm & width 100mm are analyzed. The CFRP of 1.4mm is modelled by creating new plane tangential to 3 adjacent faces of the beam. The mesh of 10mm coarse size is used. Appropriate support condition is given. The 2360N load is applied to check deflection. The equivalent stresses were also found out. Figures 3 and 4 shows deflections and equivalent stresses for simply supported normal beam, while Fig. 5 and Fig. 6 represents deflections and equivalent stresses for CPRF wrapped beams with simple supports.

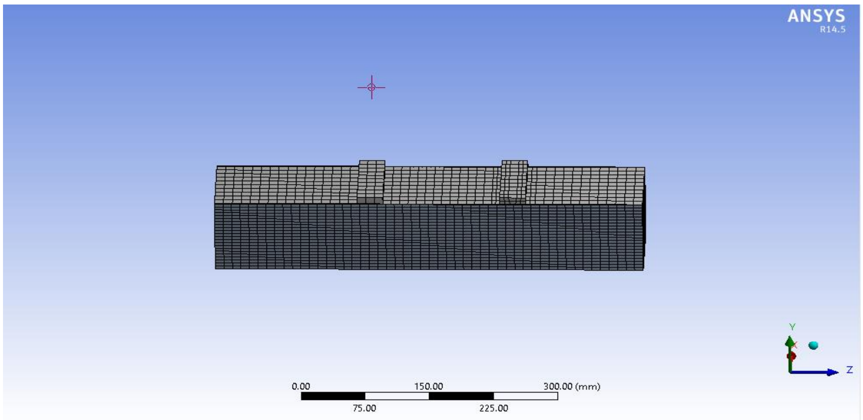

Figure 2 Concrete beam wrapped with CFRP

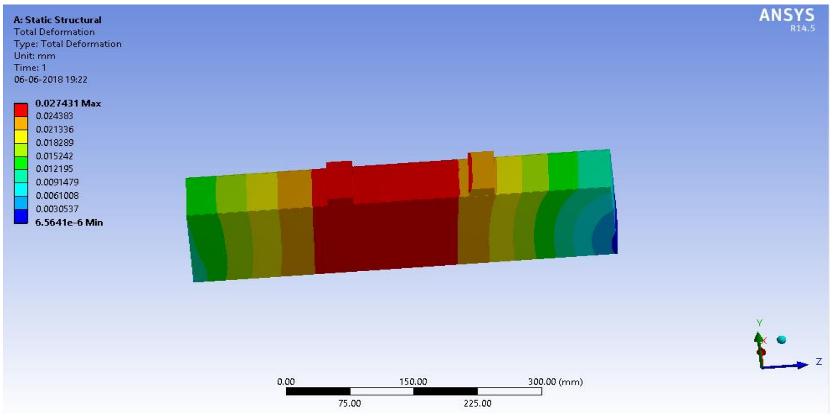

Figure 3 Deflections for the simply supported concrete beam

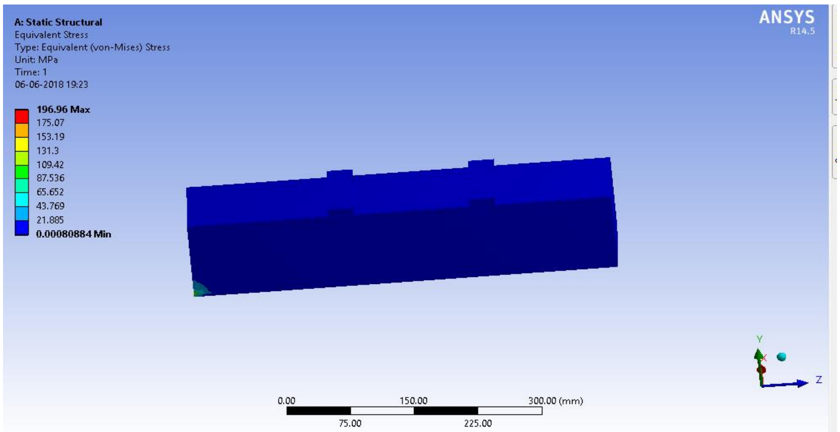

Figure 4 Equivalent Stress for the simply supported concrete beam

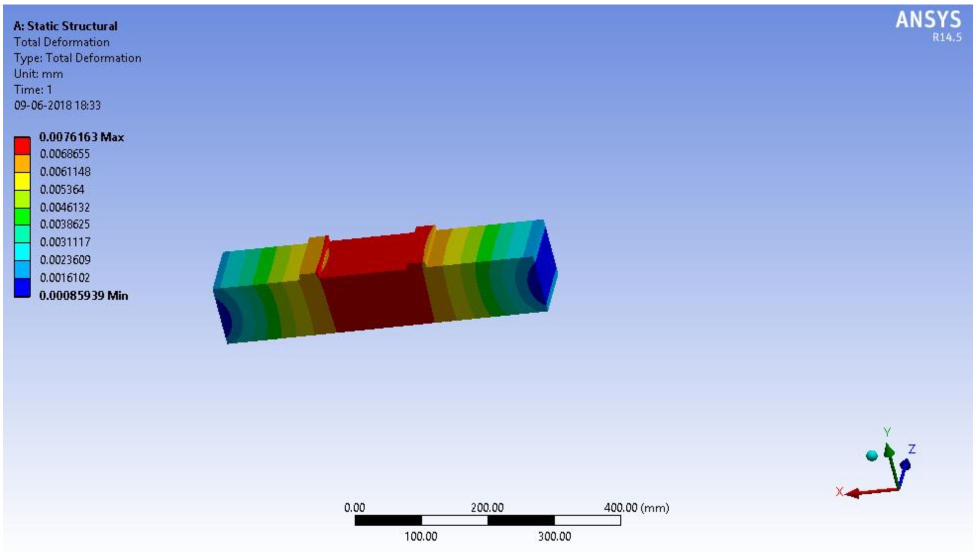

Figure 5 Deflections for the CFRP wrapped simply supported concrete beam

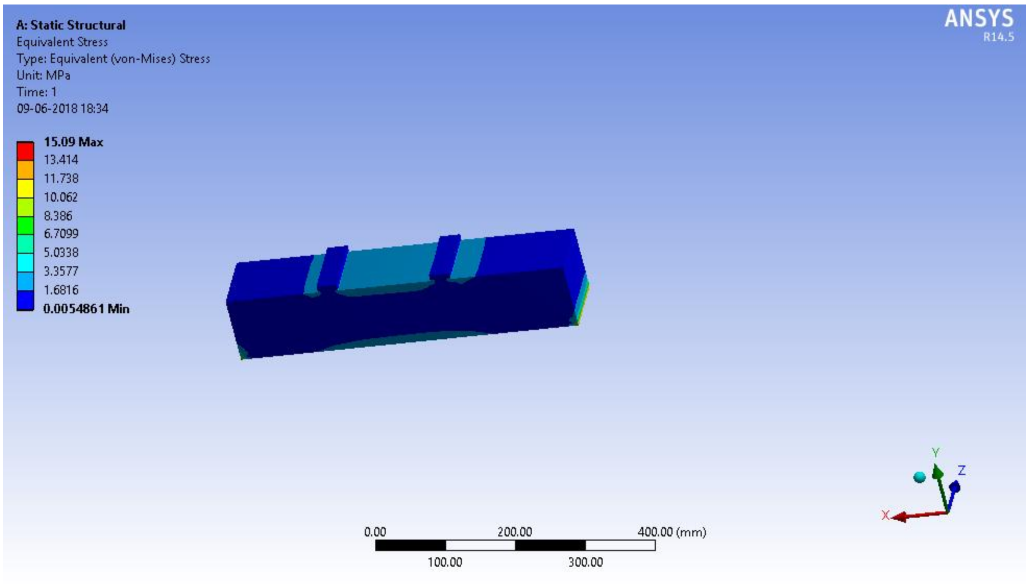

Figure 6 Equivalent stresses for the CFRP wrapped simply supported concrete beam

Total deformation is the vector sum of all directional displacements of the system. Equivalent stresses predict yielding of materials under multiaxial loading conditions. From the above analysis for the simply supported support condition, it was studied that beams wrapped with CFRP show lower deflections and equivalent stresses as compared to plain concrete beams.

Fixed end support condition for beam

The analysis of beam with fixed supports for normal concrete beam and CPRF retrofitted concrete beam is presented in Fig. 7 to Fig. 10. It can be observed that there is considerable reduction in deflections and stresses for retrofitted concrete beams for both the end conditions as compared to normal beam.

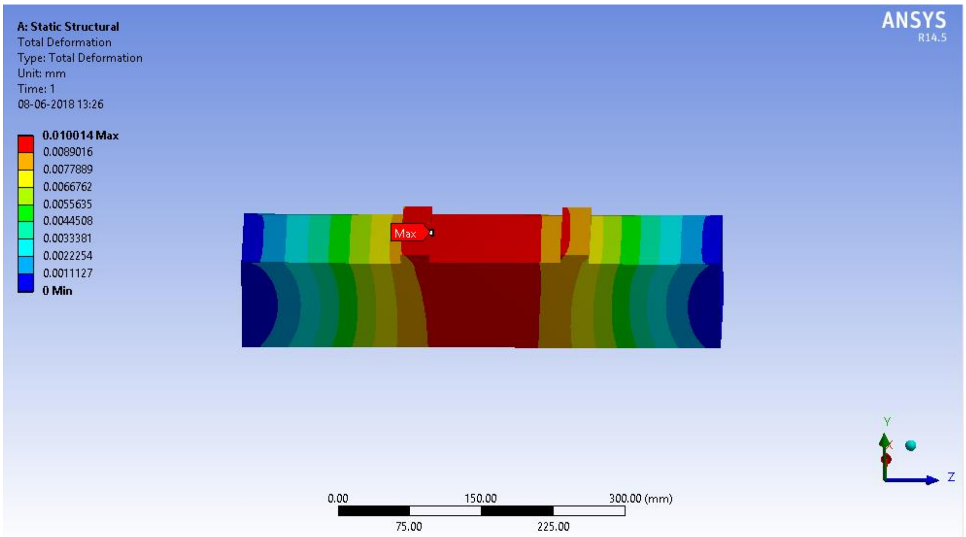

Figure 7 Deflections for the normal concrete beam with fixed supports

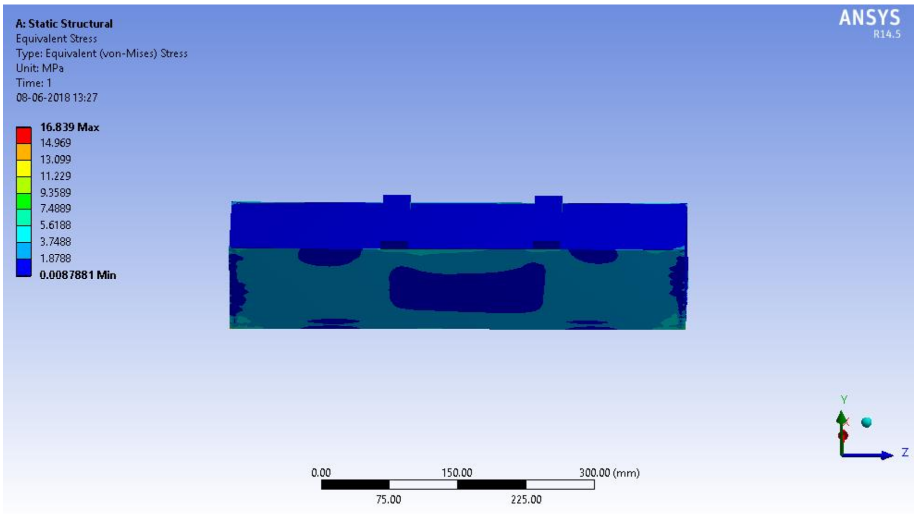

Figure 8 Equivalent stresses for the normal concrete beam with fixed supports

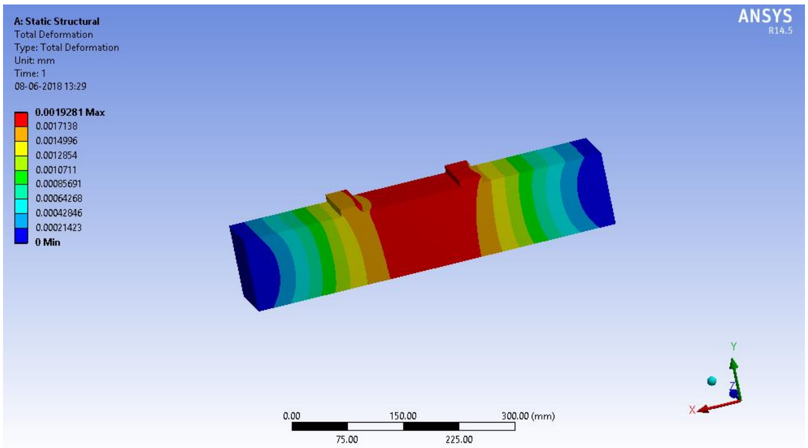

Figure 9 Deflections for the CFRP wrapped fixed concrete beam

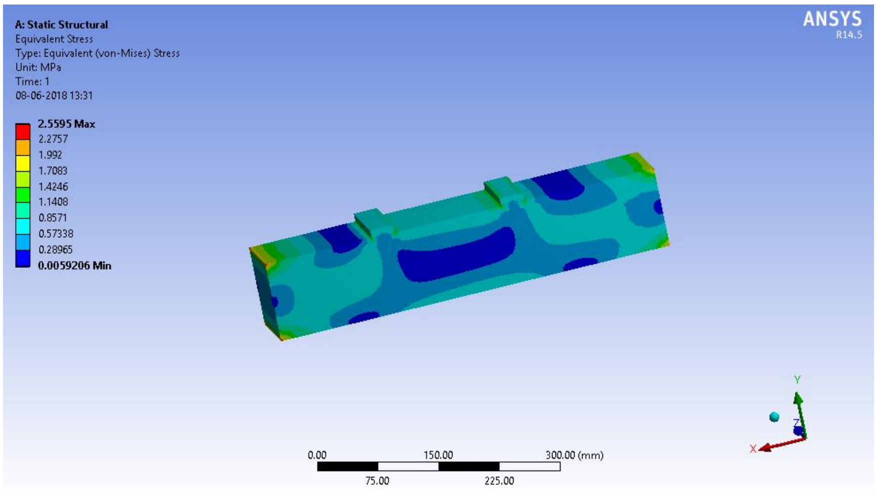

Figure 10 Equivalent stresses for the CFRP wrapped fixed concrete beam

Table 1 Comparison of deflections and equivalent stresses for normal and retrofitted beams

	Deflections (mm)		Equivalents stresses (N/mm^2)	
	Simply support	Fixed support	Simply support	Fixed support
Normal concrete beam	0.02743	0.010014	196.96	16.839
CFRP wrapped concrete beam	0.0076163	0.001928	15.09	2.5595

Analysis of cantilever support condition for concrete beam

For comparison purpose, analysis of normal concrete beam and CPRF retrofitted concrete beam with cantilever end condition is performed. The results presented in Fig. 11 to Fig. 14.

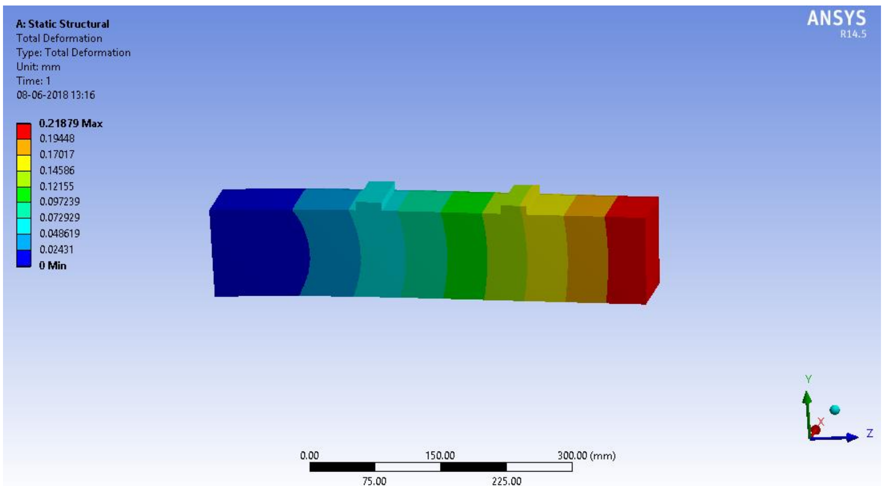

Figure 11 Deflections for the normal concrete beam with cantilever end condition

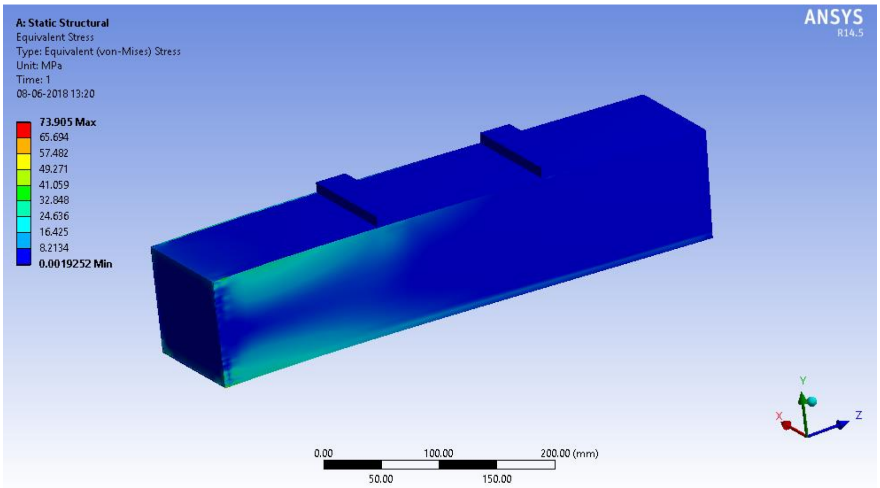

Figure 12 Equivalent stresses for the normal concrete beam with cantilever end condition

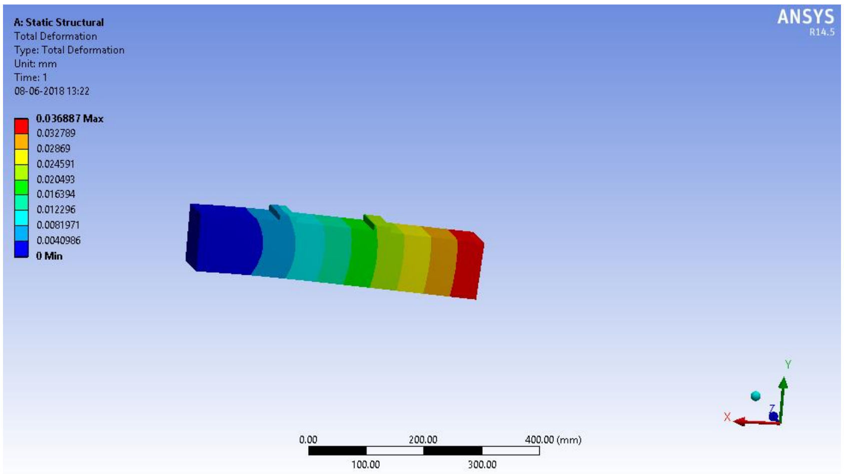

Figure 13 Deflections for the CFRP wrapped cantilever concrete beam

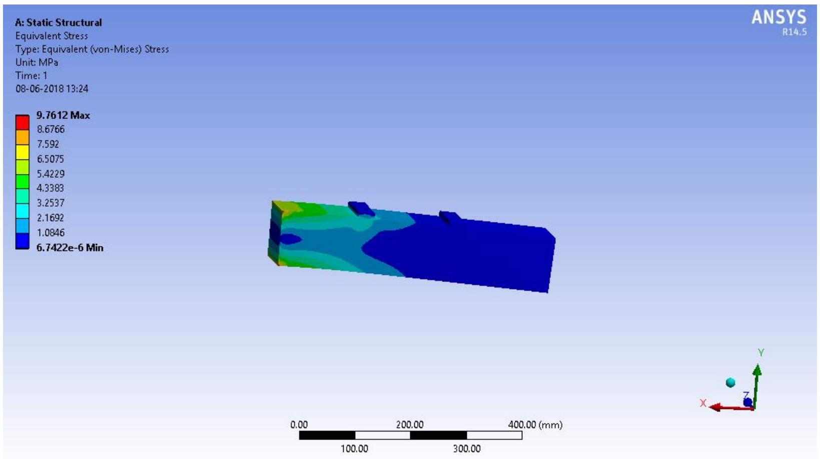

Figure 14 Equivalent stresses for the CFRP retrofitted cantilever concrete beam

As seen above from Fig. 3 to Fig 14, for the fixed end support condition of the concrete beam, the deflections and equivalent stresses are lower for CFRP wrapped beams as compared to normal concrete beams. Therefore, it can be concluded that irrespective of all the support conditions that the concrete beams retrofitted with CFRP stand efficiently against deformation and stresses. Also, CFRP wrapped beam has an ultimate load-bearing capacity.

CONCLUDING REMARKS

The finite element analysis of the concrete beam wrapped with CFRP is performed in this study to obtain deflections and its efficiency. The analysis is done using ANSYS software. The concrete beam is modelled and analysed for deflection and equivalent stresses.
This study concludes that:

- CFRP can be used well efficiently to strengthen the weakened reinforced concrete beams.
- The RC beam retrofitted with carbon fibre reinforced polymer (CFRP) shows reduction in deflection by 73% as compared to RC beam.
- A balanced design should be considered to effectively utilize the strength of CFRP laminates.
- From the finite element analysis using ANSYS, it is confirmed that the concrete beams retrofitted with CFRP stand efficiently against deformation. Also, CFRP wrapped beam has an ultimate load-bearing capacity.

REFERENCES

1. TAVAKKOLIZADEH M, SAADATMANESH H. Strengthening of steel-concrete composite girders using carbon fiber reinforced polymers sheets. Journal of Structural Engineering, 2003.

2. HASSAN N Z, SHERIFF A G, ZAMARAWY A H. Finite element analysis of reinforced concrete beams with opening strengthened using FRP. Ain Shams Engineering Journal, Vol 8, pp 531–537, 2017.

3. PARANDAMAN P, JAYARAMAN M. Finite element analysis of reinforced concrete beam retrofitted with different fiber composites. Middle-East Journal of Scientific Research, Vol 22, No. 7, pp 948-953, 2014.

4. ANSYS ® Workbench ™ 2.0 Framework, Version 14.5.0.