International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 06 | June 2020 www.irjet.net p-ISSN: 2395-0072

FINITE ELEMENT ANALYSIS OF STRENGTHENING OF CONTROL RC BEAM WITH CFRP USING ABAQUS

Suresh Kumar Paul[1], Pukhraj Sahu[2]

[1]*M.TECH. (Structural Engineering) Student, Department of Civil Engineering, GEC Jagdalpur, 494001. Chhattisgarh, India*
[2]*Assistant Professor, Department of Civil Engineering, GEC Jagdalpur, 494001, Chhattisgarh, India*

---***---

Abstract - Concrete structures retrofitted with fibre reinforced plastic (FRP) applications have become widespread in the last decade due to the economic benefit from it. This paper presents a finite element analysis which is validat against laboratory tests of eight beams. All beams have the same rectangular cross-section geometry and all beams are loaded under four point bending, but different in the length of the carbon fibre reinforced plastic (CFRP) plate. The commercial numerical analysis tool ABAQUS has been used. Linear elastic isotropic and orthotropic models have been used for the CFRP and a perfect bond model has been use for the concrete–CFRP interface. The analysis results show good agreement with the experimental data regarding load–displacement response. There is no significant difference between the elastic isotropic and orthotropic models for the CFRP. The results showed that when the length of CFRP in flexural retrofitting increases, the load capacity of the beam increases as well.

***Key Words*: RETROFITTING, FINITE ELEMENT ANALYSIS, ABAQUS, CFRP.**

1. INTRODUCTION

Reinforced concrete structures possess many advantages such as durability, strength and low maintenance, and reinforced concrete construction has been very popular all over the world. Reinforced concrete structures have to face modification and improvement of their performance during their service life. Reinforced concrete structures are subjected to structural deterioration, which might be caused by design and construction defects, environmental effects, and extreme loadings such as earthquake, impact load etc.

In such cases, to improve the load carrying capacity of the RC structures there are two possible solutions, first solution is replacement and second solution is retrofitting (strengthening). The replacement of full structures have disadvantages such as high costs for material and labour, limited working space and impact on nearby structures. When possible, it is often better to repair or upgrade the structure by retrofitting. Retrofitting of the structures is a cost efficient and more practical method than the replacement.

There has been an increasing interest in the use of high strength composites for repair and rehabilitation of reinforced concrete components in recent decades. Fibre reinforced Polymers (FRPs) are being used increasingly as promising composite materials for the enhancing of reinforced concrete structures in civil constructions.

1.1 FRP MATERIAL

Fibre reinforced polymer (FRP) composites consist of high strength fibres embedded in a matrix of polymer resin as shown in figure 1.1, the fibres are usually glass, carbon, aramid, or basalt and polymer is usually an epoxy, vinyl ester, or polyester thermosetting plastic etc.

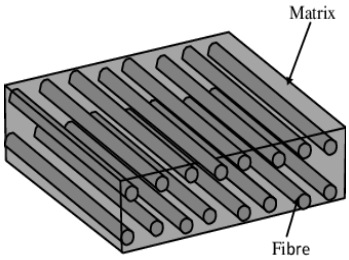


Figure 1.1: A schematic diagram showing a typical unidirectional FRP plate

These fibres are all linear elastic up to failure, with no significant yielding compared to steel. The primary functions of the matrix in a composite are to transfer stress between the fibres, to provide a barrier against the environment and to protect the surface of the fibres from mechanical abrasion.

The main characteristics of CFRP are follows:

a) High strength to weight ratio
b) Excellent corrosion resistance
c) Excellent fatigue resistance
d) Good durability, and
e) Cost effective fabrication.

In structural engineering, FRP can be used in different forms as listed below:

a) FRP strips and sheets for strengthening of structures
b) Reinforcing bars for reinforcing structures
c) Tendons for internal prestressing concrete
d) Tendons for external prestressing
e) Pultruded shapes.

2 MODELLING OF CFRP BONDED RC BEAMS

2.1 Experimental Technique

The finite element model has been implemented based on the parameters and conditions in the laboratory tests made by Yasmeen Taleb Obaidat, Susanne Heyden, Ola Dahlblom, Ghazi Abu-Farsakh and Yahia Abdel-Jawad.

In this experimental work, eight RC beams are loaded with four point bending configuration with overall span of 1960 mm, and distance between loads of 520 mm. The distance between supports is 1560 mm. Beam have rectangular cross section of 150 mm width and 300 mm height. In this beam, tension reinforcement (2 ϕ12), compression reinforcement (2 ϕ 10) are tied together with 8 mm stirrups c/c 100 mm along the beam.

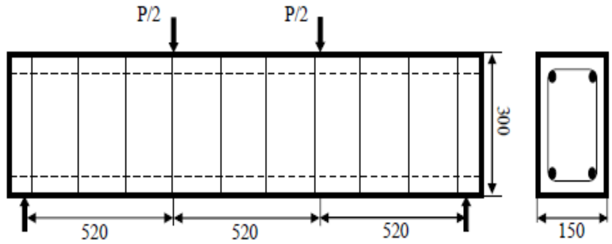
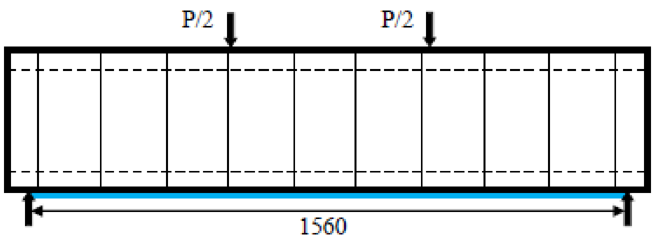
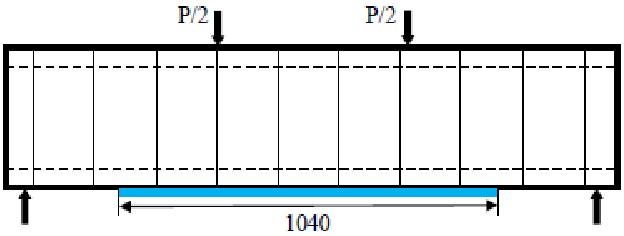


Figure 2.1: Geometry, reinforcement and load of the tested beams (Dimension in mm)

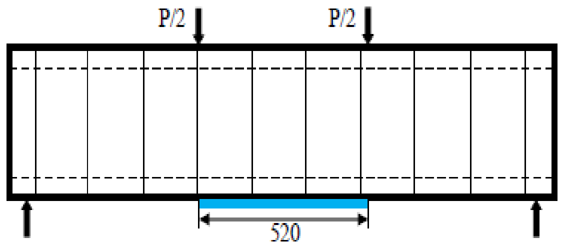
In this experimental work, two control beams are loaded to failure and other beams are loaded until cracks are appeared, then the soffit of beams are retrofitted with CFRP laminates 50 mm wide, 1.2 mm thick and three different lengths 1560 mm ,1040 mm, 520 mm as shown in figure. And retrofitted beams are retested and deflection and load are monitored.



(a) Retrofitted Beam RB1



(b) Retrofitted Beam RB2



(c) Retrofitted Beam RB3

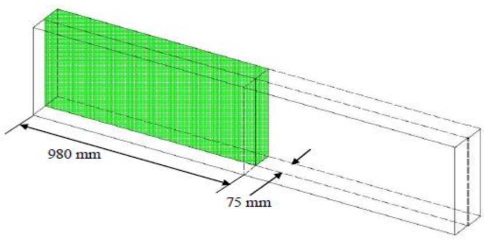
Figure 2.2: Length of CFRP laminates in test series RB1, RB2, RB3

2.2 Interface between concrete and CFRP

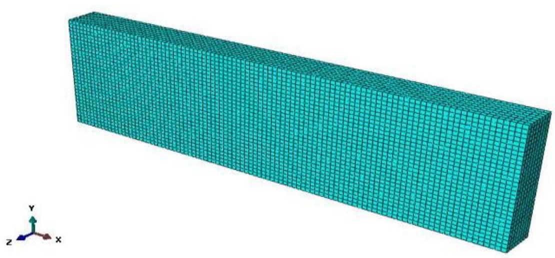
The model for the interface between FRP and concrete is of essential importance. In this analysis the interface between concrete and CFRP is assumed to be perfect bond.

2.3 Boundary Conditions & meshing

One quarter of the specimen was modelled by taking advantage of the double symmetry of the beam in three-dimensions and fine mesh used as shown in figure 3.3. The boundary conditions are shown in figure 3.4. A fine mesh is providing to obtain accurate result.



(a) Quarter of the beam was modelled



(b) Finite element mesh of quarter of beam

Figure 2.3: Geometry and element used in FEM analysis

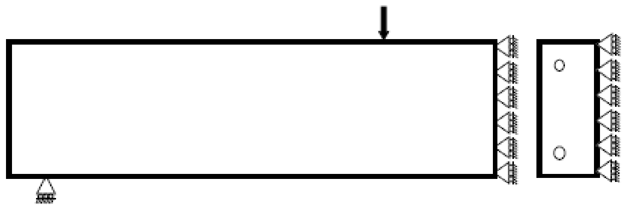


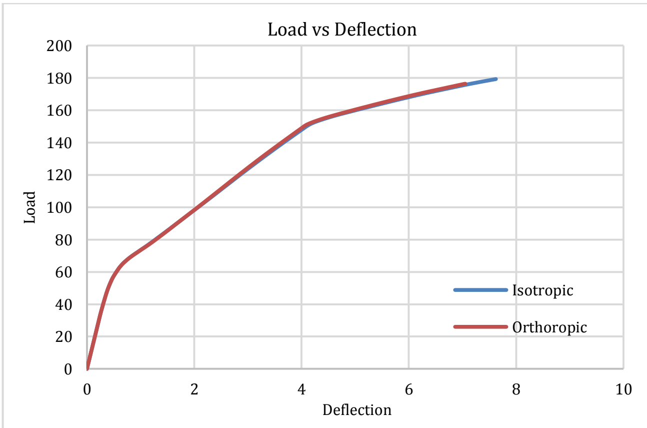
Figure 2.4: Boundary condition used in numerical analysis

2.4 Numerical Analysis:

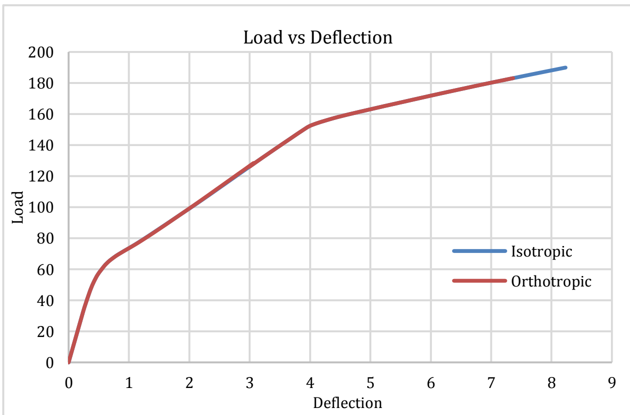
In this project, C3D8R element is use for concrete, T3D2 element is use for reinforcement and S4R element is use for CFRP. To show the effect of CFRP on the RC beam, CFRP plate is apply on control beam.

3. RESULT & DISCUSSION

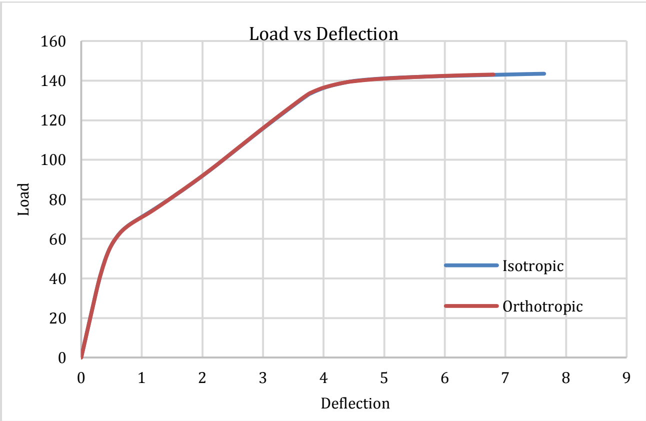
The load vs deflection curve for strengthen with CFRP to soffit of the control beam are shown in figure



(a)RB1



(b)RB2



(c)RB3

Figure 3.1: Load vs Deflection curve for strengthen by CFRP on control beam

From the load vs deflection graph of RB1, the ultimate load taken by RB1 beam is 189.85 KN in isotropic model and 183.03 KN in orthotropic model. It is clear that the isotropic model takes more load about 3.5% as compared to orthotropic model. The RB1 with isotropic model is compared with control model is found that the strength was increased about 41.88%.

From the load vs deflection graph of RB2, the ultimate load taken by RB2 beam is 179.31 KN in isotropic model and 176.43 KN in orthotropic model. It is clear that the isotropic model takes more load about 1.63% as compared to orthotropic model. The RB2 with isotropic model is compared with control model is found that the strength was increased about 34%.

From the load vs deflection graph of RB3, the ultimate load taken by RB3 beam is 143.504 KN in isotropic model and 143.10 KN in orthotropic model. It is clear that the isotropic model takes more loads about 0.28 % as compared to orthotropic model. The RB3 with isotropic model is compared with control model is found that the strength was increased about 7.24%.

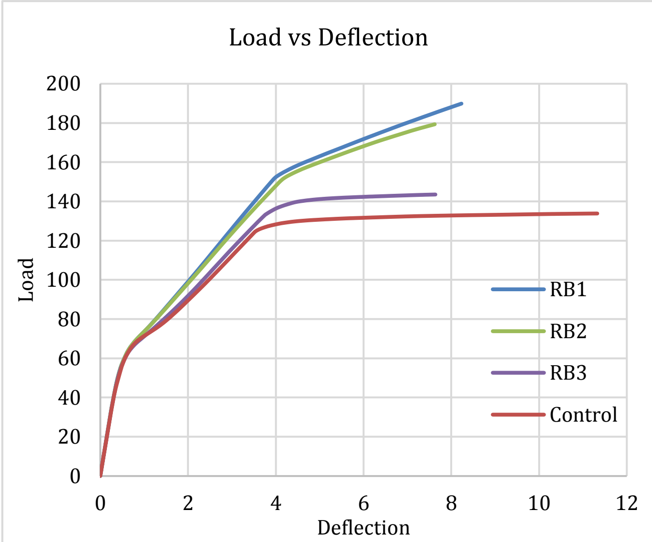


Figure 3.2: Comparison of load vs deflection of strengthen beam and control beam

6. CONCLUSIONS

A finite element model was developed to analyse strengthen of control beam with CFRP plate. The finite element results show good agreement with the experimental results. Elastic, orthotropic and isotropic behaviours have been used to represent the CFRP behaviour. The following conclusions can be drawn from this study:

1. The behaviour of the retrofitting of control beam is significantly influenced by the length of CFRP. The load carrying capacity increases 41.88%, 34%, 7.24% with the length 1560 mm, 1040 mm, and 520 mm of the CFRP respectively
2. Application of CFRP to uncracked beam provides greater strength as compared to cracked beam.
3. The stiffness of the CFRP-retrofitted beams is increased compared to that of the control beams.

7. FUTURE SCOPE FOR STUDY

1. In this project interface between concrete and CFRP plate is assumed as perfect bonding, for future work cohesive zone modelling is also used.

2. Many environmental factors such as seasonal temperature variation, degradation of material properties, creep etc. involved during the life span of a retrofitted structure that needs more attention. The durability of CFRP reinforced beams under these environmental conditions should be investigated.

3. Models based on extended finite element method (XFEM) may be developed to represent the cracks in the concrete.

REFERENCES

1. Obaidat Y. "Retrofitting of reinforced concrete beams using composite laminates", Jordan University of Science and Technology; 2007.

2. ABAQUS 6.14 Documentation.

3. ABAQUS 6.14-1 software.

4. Piggott M. "Load bearing fibre composites". 2nd ed. Boston/Dordrecht/ London: Kluwer Academic Publishers; 2002.

5. Balamurali krishnan R., and Jeyasehar C. A. (2009), "Flexural behaviour of RC beams strengthened with Carbon Fiber Reinforced Polymer (CFRP) fabrics". The Open Civil Engineering Journal, 3, 102-109.

6. Hibbitt, Karlsson, and Sorensen, Inc. ABAQUS Theory manual, User manual and Example Manual, Version 6.7. Providence, RI; 2000.

7. Ever J. Barbero "Finite element analysis of composite materials".

8. Khalifa A, Gold WJ, Nanni A and Aziz A. (1998), "Contribution of externally bonded FRP to shear capacity of RC flexural members". Journal of Composites for Construction, 2, 195–201.

9. Chen J. F., and Teng J. G. (2003), "Shear capacity of Fiber-Reinforced Polymer-strengthened Reinforced Concrete Beams: Fiber Reinforced Polymer Rupture". Journal of Structural Engineering, Vol. 129.

10. Kachlakev D, Mccurry DD. "Behavior of full-scale reinforced concrete beams retrofitted for shear and flexural with FRP laminates". Compos J 2000.

11. Esfahani M, Kianoush M, Tajari A. "Flexural behaviour of reinforced concrete beams strengthened by CFRP sheets", 2007.