STRENGTHENING OF PARTIALLY DAMAGED DEFICIENT RC BEAM WITH EXTERNALLY BONDED BFRP COMPOSITES USING FEA

Shaziya Ibrahim[1], Adila Abdulla Kunju[2]

[1]*Mtech Student, Computer Aided Structural Engineering, ICET, Mulavoor P.O, Muvattupuzha, Kerala, India*
[2]*Assistant Professor, Civil Department, ICET, Mulavoor P.O, Muvattupuzha, Kerala, India*

---***---

Abstract – *The failure of civil structure means loss of structural integrity due to loss of the load-carrying capacity. While experimental methods of investigation helps in evaluating the performance of these deficient structures under simulated loading conditions, use of numerical models helps in developing a good understanding of the behavior and to carry out parametric studies at lower costs. There are various methods for strengthening reinforced concrete beams against shear. External bonding of various composite members to RC beams is very popular and successful technique internationally nowadays. This study presents numerical results on strengthening of shear deficient RC beam by external bonding of Basalt Fiber Reinforced Polymer(BFRP) using ANSYS . BFRP straps were bonded along the shear deficient beams for strengthening against shear by using epoxy. The increase in strength and ductility where compared for different configurations in wrapping for BFRP composite. The results confirmed that all BFRP arrangements improved the strength and stiffness of the beam significantly.*

***Key Words*: Reinforced concrete beam, shear strengthening, BFRP, epoxy, Non-linear finite element analysis**

1. INTRODUCTION

A structure is designed for a specific period and depending on the nature of the structure, its design life varies. For a domestic building, this design life could be as low as twenty-five years, whereas for a public building, it could be fifty years. Deterioration in concrete structures is a major challenge faced by the infrastructure and bridge industries worldwide. The deterioration can be mainly due to environmental effects, which includes corrosion of steel, gradual loss of strength with ageing, repeated high intensity loading, variation in temperature, freeze-thaw cycles, contact with chemicals and saline water and exposure to ultra-violet radiations. As complete replacement or reconstruction of the structure will be cost effective, strengthening or retrofitting is an effective way to strengthen the same.

The use of FRP composites for structural strengthening was initiated in the late 1980s. FRP has some advantages over traditional steel plates, such as high strength to weight ratio, resistance to corrosion, flexibility and overall versatility. Basalt FRP (BFRP) is a promising material for the application to structure strengthening with its advantages of low cost, corrosion resistant and sound mechanical property.

Basalt fibre is a relative newcomer to fibre reinforced polymers and structural composites. It has a similar chemical composition as glass fibre but has better strength characteristics, and unlike most of the glass fibres, it is highly resistant to alkaline, acidic and salt attack, which is making it a good candidate for concrete, bridge and shoreline structures. Compared to carbon and aramid fibre, it has the features of wider application temperature range -269°C to +650°C, higher compression strength, and higher shear strength. The price of fibres made from basalt is higher than those made of E-glass, but less than S-glass, aramid or carbon fibre and as worldwide production increases, its cost of production should reduce further. Basalt fibres have high potential and are getting a lot of attention due to its high temperature and abrasion resistance. Compared to FRPs made from carbon, glass and aramid fibre, its use in the civil infrastructure market is very low.

Fig -1: Basalt Fiber Reinforced Polymer

2. NUMERICAL INVESTIGATION USING ANSYS WORKBENCH 16.1

2.1 Base Model

In this study, numerical investigations are carried out in a shear deficient RC beam. The numerical models are then used for studying the efficacy and effectiveness of various strengthening schemes developed using epoxy impregnated BFRP fabrics where the different orientations of the laminates were taken as parameters. Four different wrapping styles where adopted bottom wrapped, wrapped upto neutral axis, fully wrapped and diagonally wrapped.

The various configurations of wrapping and improvement in strength was compared.

In this study, numerical modelling of RC beams is carried out using ANSYS, a finite element software for mathematical modelling and analysis to simulate the behavior of the control as well as shear deficient beams, from linear through non-linear response and up to failure.The dimensions and material properties of the control beam is given in Table 1 and Table 2 respectively. The numerical study was done using the data from the experimental results reported in the study conducted by N.K Banjara [1]. Shear deficiency is induced by providing less number of shear reinforcement stirrups than required. 60% shear deficient beam with 750mm stirrup spacing where adopted. These sections were created using 3D shell elements while loading and support bearing plates were modelled with discrete rigid elements. The concrete was modelled using solid45 element which handles non-linear behaviour. It is defined by eight nodes having three translational degrees of freedom at each node. Steel reinforcements are modelled using two node spar element LINK8 with three translational degrees of freedom at each node. The modelled view of shear deficient RC beam is shown in Fig.2

Boundary conditions were assigned to the model in the bearing plates placed at the end of the specimen. One end were provided with roller supports and other end were pinned. The supports were provided at a distance of 75mm from both sides. Two point loading were applied at a distance of 600mm from the edges.

Table -1: Geometry of section

DESCRIPTION		DIMENSION
Beam	Length	1800mm
	Cross-section	150mm×200mm
Supporting plate	Length	150mm
	Cross-section	50mm×25mm
Loading plate	Length	150mm
	Cross-section	50mm×25mm

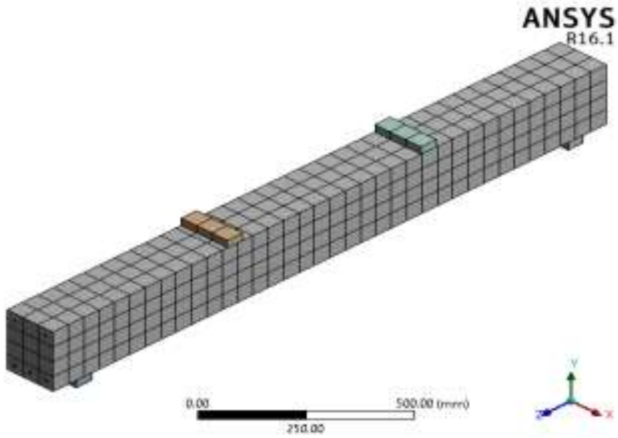

Fig -2: Modelled view of shear deficient RC beam.

Table -2: Material Properties of Concrete and Steel.

MATERIAL PROPERTY	VALUE
Concrete	
28 days compressive strength of concrete	44.7 N/mm^2
Modulus of elasticity	31500 N/mm^2
Poisson’s ratio	0.2
Reinforcing steel	
Modulus of elasticity	200,000 N/mm^2
Poisson’s ratio	0.3
Yield stress	500 N/mm^2

Epoxy impregnated BFRP fabric is used for shear strengthening. In this study, epoxy and fabric are modelled as a single element with different layers. Isotropic properties like modulus of elasticity and Poisson’s ratio are adopted for both epoxy as well as the fabric. The input data needed for strengthening materials included thickness of each layer, modulus of elasticity and Poisson’s ratio. The values of material properties for epoxy and fabric are presented in Table 3.In the finite element analysis fine mesh was adopted for accuracy. The modeled view of these sections were shown in the figures given below.

Table -3: Material properties of BFRP and epoxy

MATERIAL PROPERTY	BFRP	EPOXY
Tensile strength	2303 MPa	43 MPa
Modulus of elasticity	105 GPa	3800 MPa
Ultimate tension strain	1.84%	1.5%
Poisson's ratio	0.3	0.21
Thickness	0.121mm	1mm

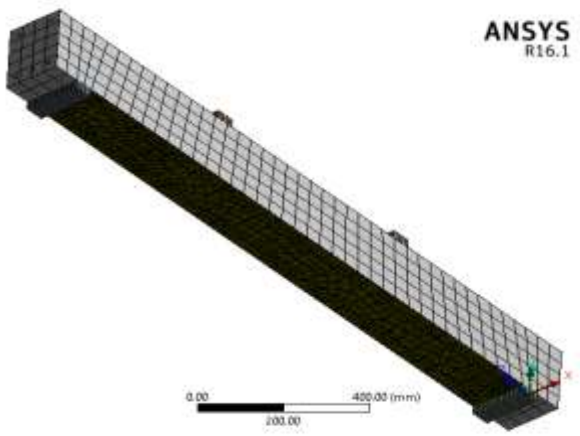

Fig -3: Modelled view of shear deficient beam with BFRP wrapped on bottom.

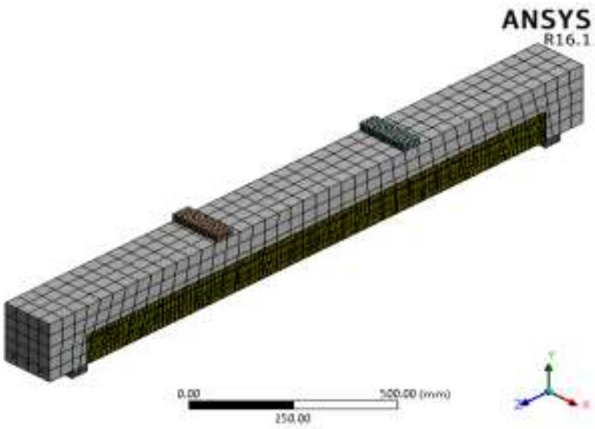

Fig -4: Modelled view of shear deficient beam with BFRP wrapped upto neutral axis

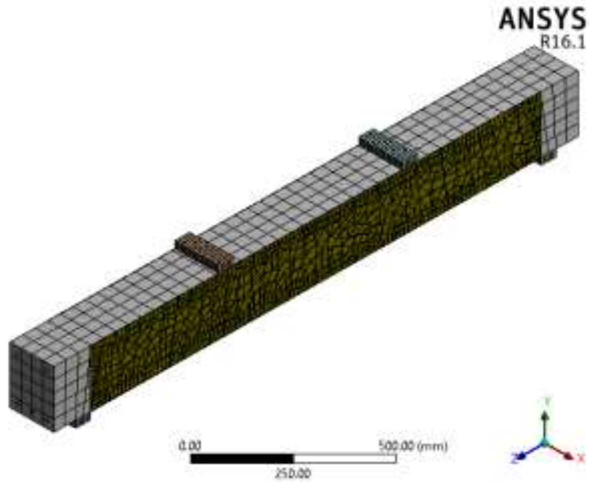

Fig -5: Modelled view of shear deficient beam with BFRP diagonally wrapped

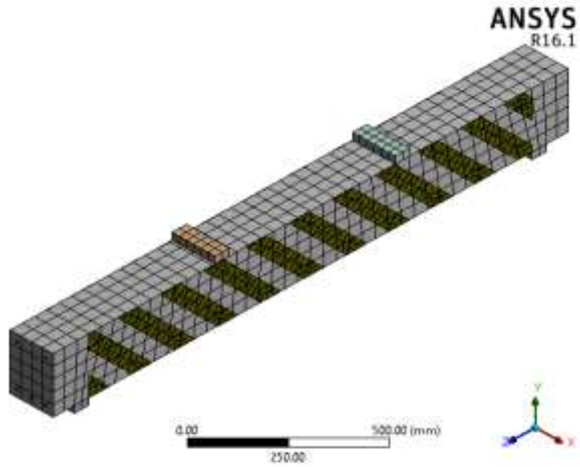

Fig -6: Modelled view of shear deficient beam with BFRP diagonally wrapped

3. RESULTS AND DISCUSSIONS

The load and corresponding displacements of shear deficient beam with different BFRP wrapping configurations were obtained. The load vs deflection graph for bottom wrapped, wrapped upto neutral axis, fully wrapped and diagonally wrapped BFRP is shown in Fig.7.

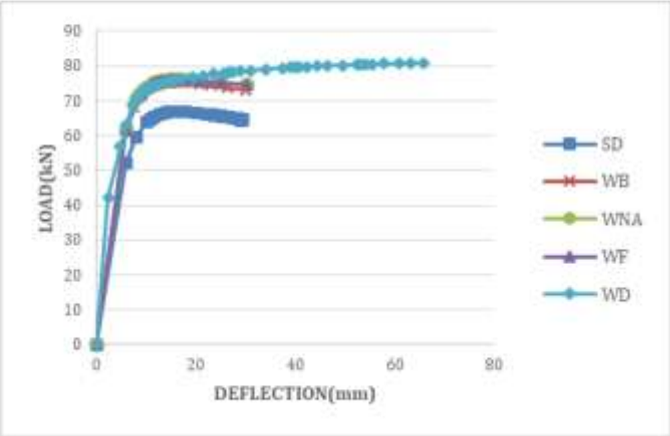

Fig -7: Load vs deflection graph for different wrapping configurations.

Figure 8 to Figure 11 shows the total deformation of all the models obtained from ansys. Figure 12 to Figure 15 shows the equivalent von mises stress of all the models from ansys.

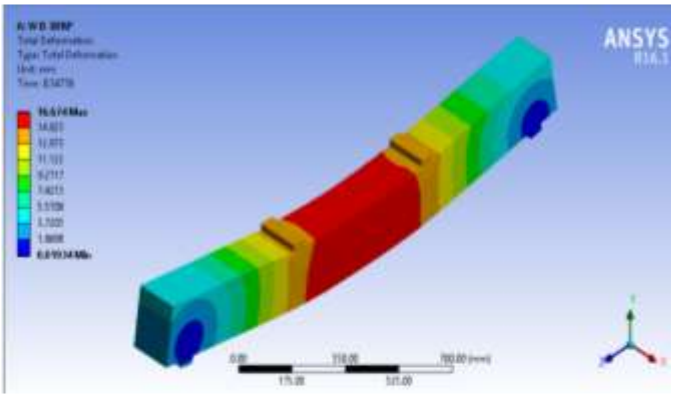

Fig -8: Total deformation for bottom wrapped shear deficient beam.

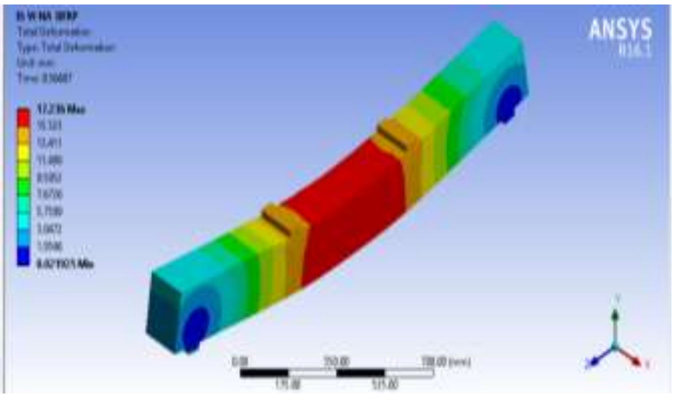

Fig -9: Total deformation for upto neutral axis wrapped shear deficient beam.

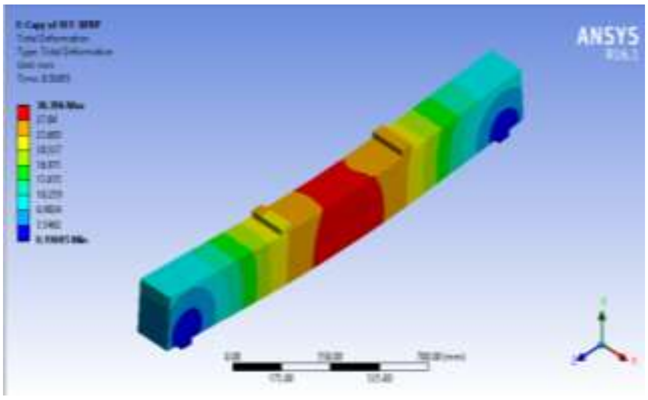

Fig -10: Total deformation for fully wrapped shear deficient beam.

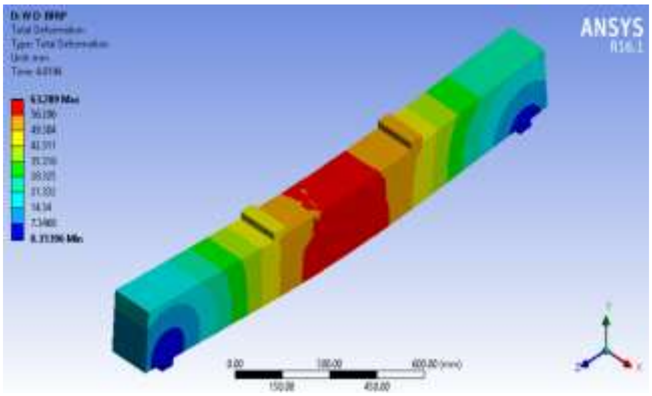

Fig -11: Total deformation for diagonally wrapped shear deficient beam.

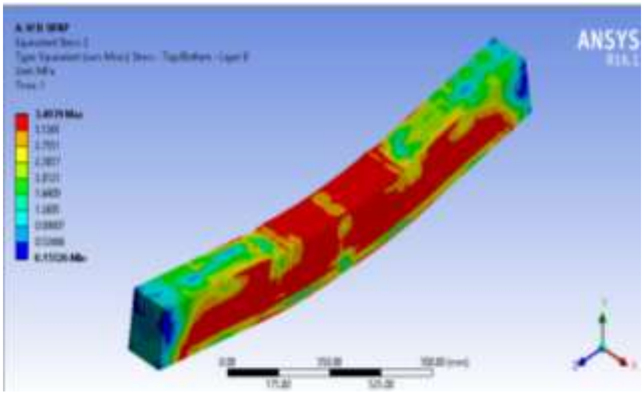

Fig -12: Equivalent von mises stress for bottom wrapped shear deficient beam

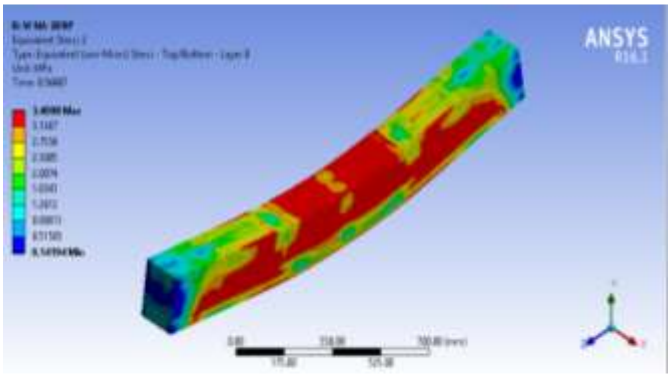

Fig -13: Equivalent von mises stress for fully wrapped shear deficient beam

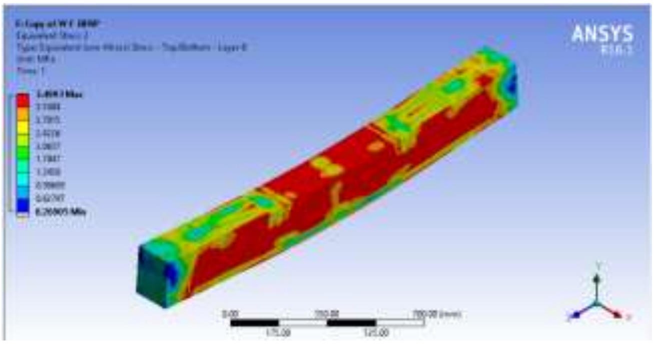

Fig -14: Equivalent von mises stress for fully wrapped shear deficient beam

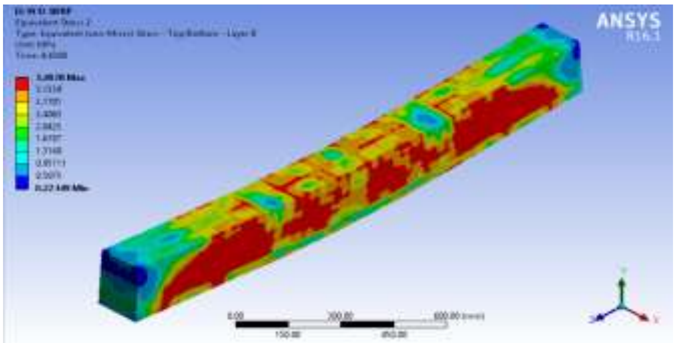

Fig -15: Equivalent von mises stress for diagonally wrapped shear deficient beam

Table representing maximum load and deflections for BFRP bottom wrapped, wrapped upto neutral axis, fully wrapped and diagonally wrapped is illustrated below.

Table -4 Maximum load and deflections for different wrapping configurations

TYPE OF WRAPPING	BOTTOM	UPTO NA	FULLY	DIAGONAL
ULTIMATE LOAD (kN)	75.357	75.968	92.039	80.854
DEFORMATION(mm)	16.674	17.236	30.396	63.289

4. CONCLUSIONS

In this paper, strengthening of shear deficient beam using BFRP fabric under different wrapping configurations where studied. Based on the numerical studies, the conclusions can be summarized as follows:

- All the BFRP strengthened beams showed improvement in both strength and ductility compared to shear deficient beam.
- At any given load level, the deflections are increased significantly thereby increasing the stiffness for the strengthened beams.
- Fully and diagonally wrapped strengthened beams showed more improvement in strength. But fully wrapped BFRP showed more increase in strength than than other configurations. They showed about 37.7% increase in strength.
- The diagonally wrapped BFRP strengthened beam showed more increase in ductility than other wrapping configurations due to the variation in stiffness. They showed about 298.5% increase in ductility.

ACKNOWLEDGEMENT

I wish to thank the Management, Principal and Head of Civil Engineering Department of Ilahia College of Engineering and Technology, affiliated by Kerala Technological University for their support. This paper is based on the work carried out by me (Shaziya Ibrahim), as part of my PG course, under the guidance of Mrs. Adila Abdulla Kunju (Assistant Professor, Ilahia College of Engineering and Technology, Muvattupuzha, Kerala). I express my gratitude towards her for her valuable guidance.

REFERENCES

[1] A.K. Panigrahi, K.C. Biswal, M.R. Barik, "Strengthening of shear deficient RC T -beams with externally bonded GFRP sheets", Constr. Build. Mater. 57 (2014) 81–91.

[2] Muhammad Ikramul Kabir, Mahbube Subhani, Rijun Shrestha, Bijan Samali, "Experimental and theoretical analysis of severely damaged concrete beams strengthened with CFRP" ,Construction and Building Materials 178 (2018) 161–174.

[3] Chen W, Pham TM, Sichembe H, Chen L, Hao H, "Experimental study of flexural behaviour of RC beams strengthened by longitudinal and U-shaped basalt FRP sheet", Composites Part B (2017).

[4] Deyuan Zhou, Zhen Lei, Jibing Wang, "In-plane behavior of seismically damaged masonry walls repaired with external BFRP", Composite Structures 102 (2013) 9–19.

[5]] N. Aravind , Amiya K. Samanta , Joseph V. Thanikal , Dilip Kr. Singha Roy, "An experimental study on the effectiveness of externally bonded corrugated GFRP laminates for flexural cracks of RC beams", Construction and Building Materials 136 (2017) 348–360.

[6] N.K. Banjara, K. Ramanjaneyulu , "Experimental and numerical investigations on the performance evaluation of shear deficient and GFRP strengthened reinforced concrete beams", Construction and Building Materials 137 (2017) 520–534.

[7] Ozgur Anil, "Improving shear capacity of RC T-beams using CFRP composites subjected to cyclic load" Cement & Concrete Composites 28 (2006)

[8]] Zidani, B., Belakhdar, K., Tounsi, A., Bedia, E.A.A., "Finite Element Analysis of Initially Damaged Beams Repaired with FRP Plates", Composite Structures (2015).