Finite Element Analysis of Different Types of FRP on Beam-Column Joint

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***Abstract*— In any type of building the most crucial element is the beam-column joint. In this study, the beam-column joint analysis is done using ANSYS. The design is first carried out in ETABS and using the design data it is analysed in ANSYS. The equivalent stresses and the total deformation generated in the beam-column joint is calculated. Due to the bad effects of environmental changes, pollution, carbonation, corrosion occurring in a structural element due to which the building is likely to collapse. The failure in the beam-column joint can occur due to these reasons and also due to lack of proper reinforcement in the joint region. While experiencing seismic activity with inadequate reinforcement the beam-column joint will fail. This project aims in introducing FRP in the beam column joints which are likely to fail by retrofitting it. The failure can be identified by observing cracks or carrying out NDT tests to find out the region of cracks and the amount of reinforcement corroded. In this study different types of FRP is introduced to the beam-column joint in ANSYS. It is7analysedfand then the equivalent stresses and total deformations generated5are compared with each other whichever will be more effective to be used in the field of construction.**

Keywords—Finite Element Analysis, ANSYS, FRP

I. INTRODUCTION

In a framed structure, the load transfer mechanism takes place in the manner of loads from the slabs gets distributed to the beams, then the loads from beams get distributed to the columns and then the loads from columns to the footings which eventually transfers the loads to the ground surface. The junction of beam and column behaves as a crucial part during the action of seismic forces and it tends to fail if the detailing is not proper. The failure of a beam-column joint will result in the collapse of the structure. The joint of beam-column in a structure can be said as the weakest part of a structure. These joints are the important zones for transfer of forces and moments effectively between the subsequent connecting elements of beam and columns. The performance of a framed structure mostly depends upon the integrity of the joints for which the beam-column joints joint is a crucial part. The behaviour of the beam-column joint of a framed structure is being studied in this project. Upon the application of Fiber Reinforced Polymer (FRP) laminate in the beam-column joint, the behaviour is also studied. It is studied by doing Finite Element Analysis in ANSYS 14.5. The stresses and deformations are obtained as results from the analysis. The building is being designed using Etabs 2016.

Types of Fiber Reinforced Polymer used in this study:

- Carbon Fiber Reinforced Polymer.
- Glass Fiber Reinforced Polymer.
- Basalt Fiber Reinforced Polymer.
- Aramid Fiber Reinforced Polymer

II. ANALYSIS

A. Analysis in ETABS

For the analysis of the structure using ETABS 2016, a frame structure is taken into consideration. The frame structure has the dimension of 15m*19m having a storey height of 3.5m at first floor and 3.2m for the subsequent 4 floors. A depth of 1.5m is assumed for the foundation below the ground level.

Material properties used:
Grade of Concrete= M30
Grade of Steel= Fe415
Details of the dimension of the structural elements used:
Main beam, B1= 300*500mm
Secondary beam, B2= 300*400mm
Plinth beam, B3= 300*400mm
Column, C1= 300*500mm
Column, C2= 400*400mm
Column, C3= 400*500mm
Slab thickness= 125mm
Storey height= 3.5m (First floor)
= 3.2m (Other floors)

The beam-column joint to be analyzed is the connection between B29 and C2. The beam is in the first floor.

Loads:
At all floors masonry load due to main beam= 11.96 kN/m
At all floors masonry load due to Secondary beam=12.42kN/m
At ground floor masonry load due to main beam= 13.34 kN/m
At ground floor masonry load due to Secondary beam= 13.8 kN/m
Shell loads applied as:
At the roof Live load= 1.5kN/m²
At the other floors Live load= 3kN/m² [18]

Taking the moments and axial forces from ETABS, calculating the reinforcements manually the following results are obtained:

Reinforcement for Beam:
Main bar diameter= 16mm
Number of bars=2
Anchor bar diameter= 10mm

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Number of bars= 2
Provide 2 legged 8mm diameter stirrups with spacing of 260mm c/c.
Reinforcement for Column:
Number of bars= 5
Diameter of Bars= 20mm

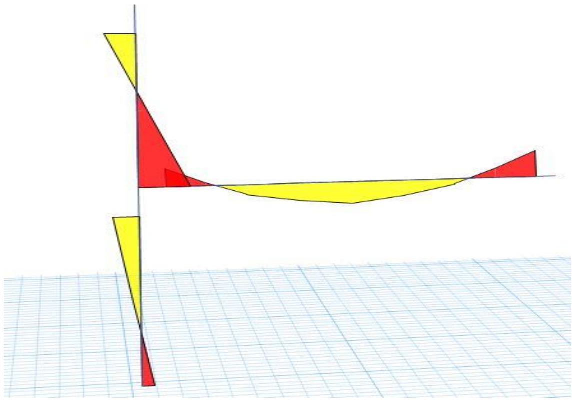

Fig.1: Combined Bending Moment diagram of the beam B29 and column C2 at first floor and second floor

B. Analysis in ANSYS

In this study, 5 different models are created in ANYS. They are: Beam-Column joint with reinforcement. Beam-Column joint with reinforcement and Carbon FRP. Beam-Column joint with reinforcement and Glass FRP (S2 Glass). Beam-Column joint with reinforcement and Basalt FRP. Beam-Column joint with reinforcement and Aramid FRP (Kevlar 49).

For the modelling part the length of the column considered is= 3.35m. (half of the centre to centre distance between the column heights has been assumed). And the length of the beam is= 3.7m

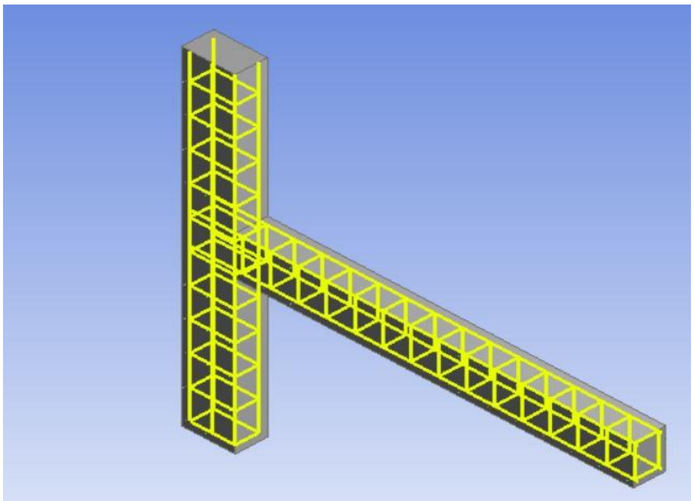

Fig. 2: Beam-Column joint with reinforcement modelled in ANSYS

The modelling of the 4 different types of FRP is also done in the same way with a thickness of 9.9mm of FRP applied in all the types. It is considered that the FRP has an uniform thickness of 1.1mm and 9 layers have been applied.

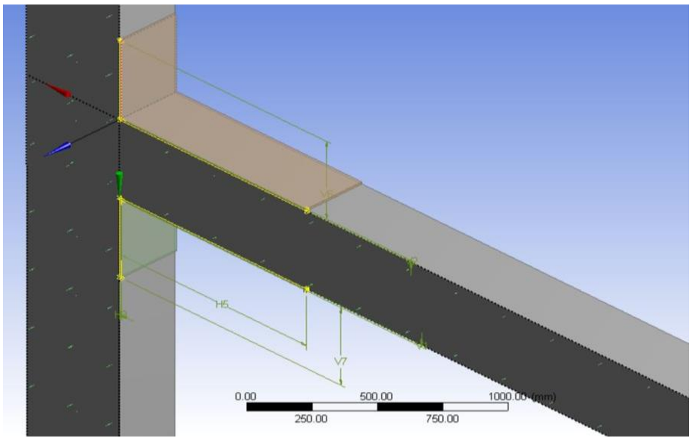

Fig. 3: Application of FRP in the beam-column joint

In the fig. 2 it can be seen that the FRP has been applied to the beam column joint in the area where the stress concentration is more which is considered as 400mm in below and top from the face of the column vertically and 1000mm in below and top horizontally. The length of the application of FRP is same throughout all other FRP.

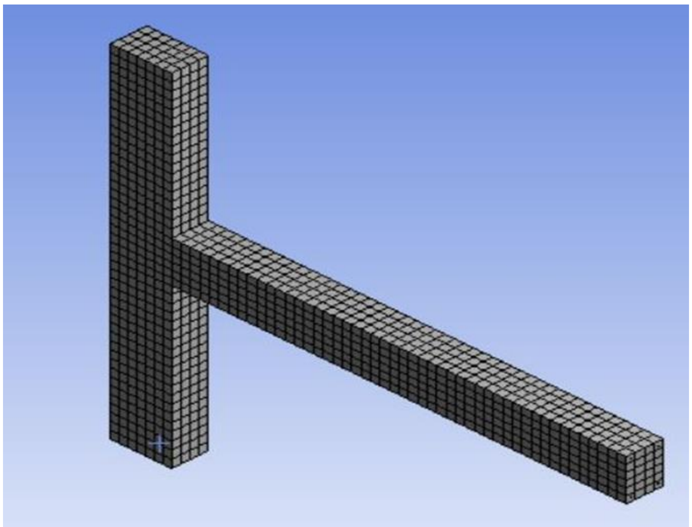

Fig.4: Meshed model of the Beam-Column joint

Fine mesh property is being used and the size of the mesh is selected as default.

Fixed support conditions are applied at the free ends of the beam and column.

The load applied on the beam is applied as pressure load. The pressure loads applied are as follows:

Pressure acting as slab load= 0.0321Mpa

Pressure acting as wall load= 0.046 Mpa

The same wall load and slab load is applied through all the 5types of analysis performed: without FRP, with CFRP, with GFRP, with BFRP and with AFRP.

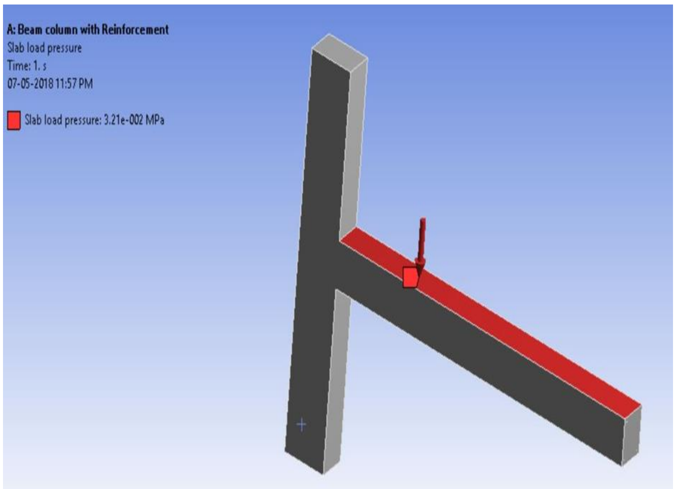

Fig 5: Slab load is applied in the form of Ramped Pressure on the beam

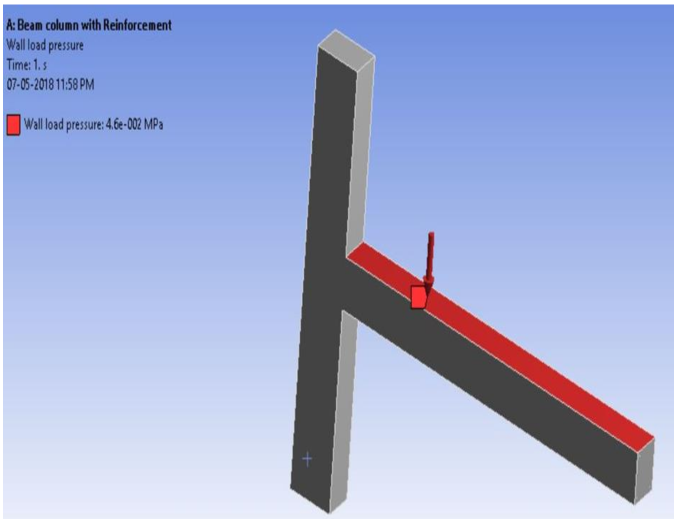

Fig. 6: Wall load is applied in the form of Ramped Pressure on the beam

SOLID 65 element is used for concrete structural rectangular or block. It is assigned to define the property of concrete. LINK 180 is used to define the property of reinforcement. SOLID 64 element is used to define the FRP layer on concrete.

Properties of different types of FRP used:

NAME	YOUNG'S MODULUS	POISSON'S RATIO
CARBON [15,3]	76.35GPa	0.26
GLASS (S_2 GLASS) [8]	86.9 GPa	0.22
BASALT [16]	89 GPa	0.2
ARAMID (KEVLAR 49)[17]	151.7 GPa	0.35

III. RESULTS

A. *Equivalent stress:*

The results obtained from the equivalent stress can be summarized as:

- The equivalent stress for concrete without FRP is 1.2047 MPa
- The equivalent stress for concrete with CFRP is 0.61384 MPa
- The equivalent stress for concrete with GFRP is 0.61263 MPa
- The equivalent stress for concrete with BFRP is 0.6124 MPa
- The equivalent stress for concrete with AFRP is 0.60545 Mpa

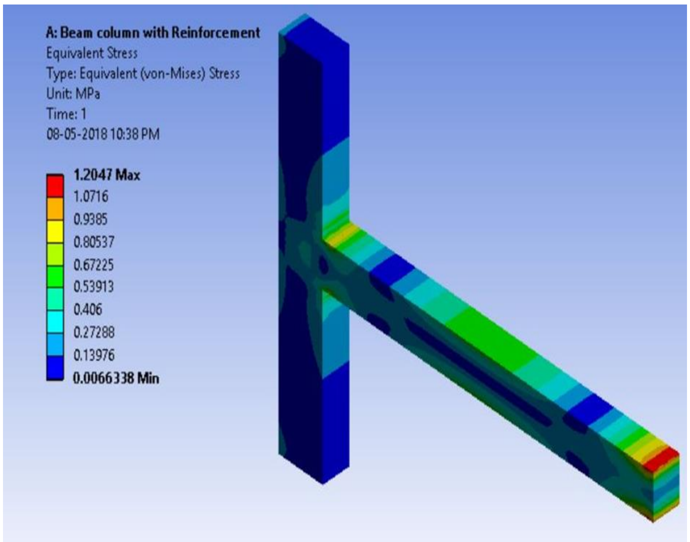

Fig 7: Equivalent stress in concrete without FRP

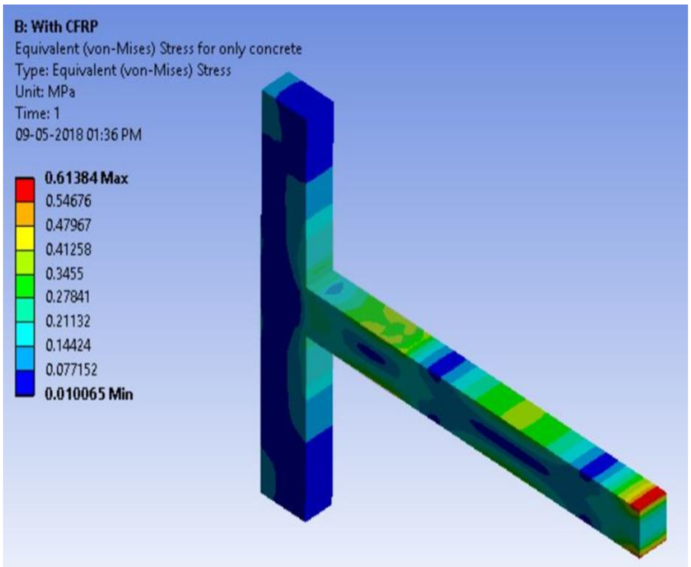

Fig 8: Equivalent stress in concrete with CFRP

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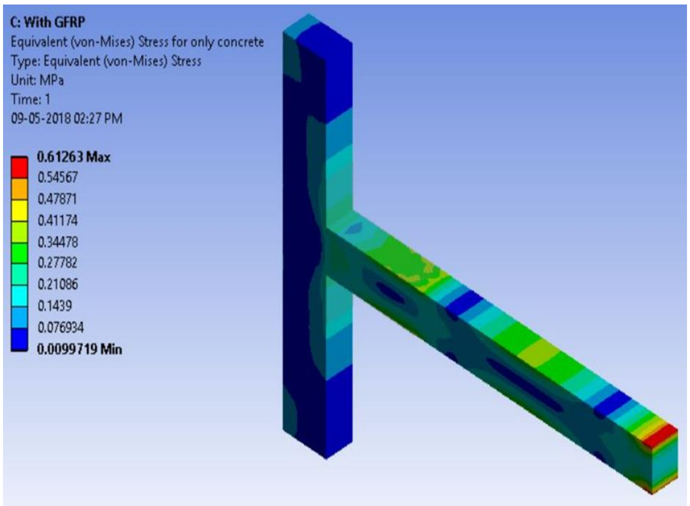

Fig. 9: Equivalent stress in concrete with GFRP

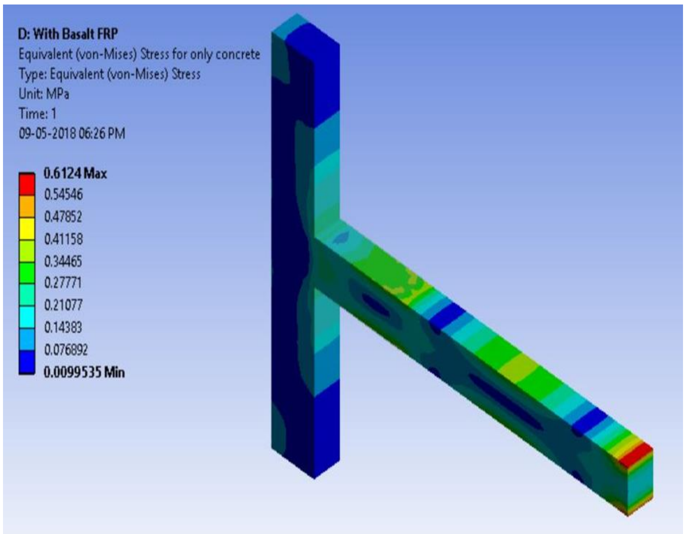

Fig. 10: Equivalent stress in concrete with BFRP

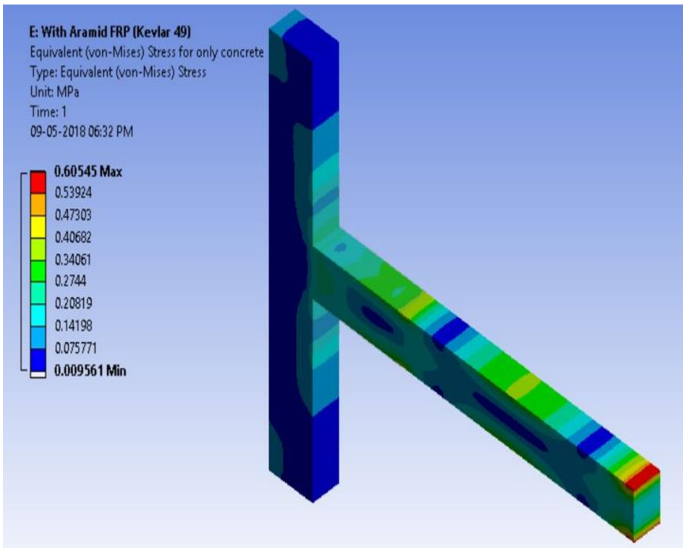

Fig. 11: Equivalent stress in concrete with AFRP

B. Total Deformation:

The results obtained after analyzing for total deformation are as follows:

- The total deformation on concrete without FRP is 0.11372 mm
- The total deformation on concrete with CFRP is 0.44181 mm
- The total deformation on concrete with GFRP is 0.38282 mm
- The total deformation on concrete with BFRP is 0.37043 mm
- The total deformation on concrete with AFRP is 0.22815 mm

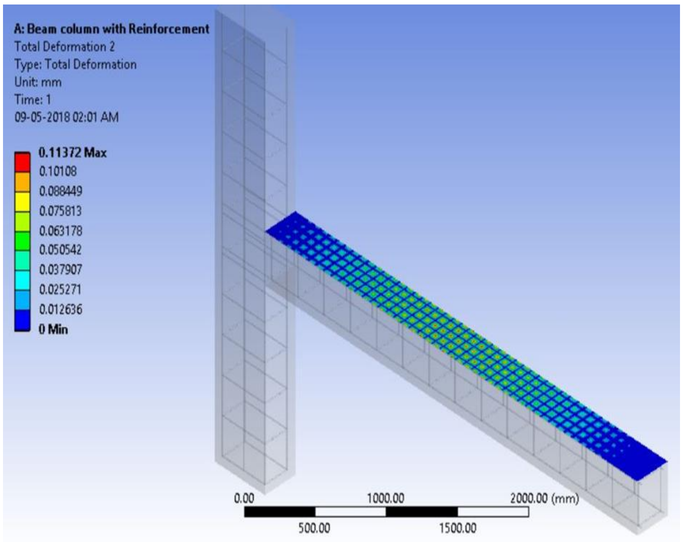

Fig. 12: Total deformation in the beam-column joint with reinforcement

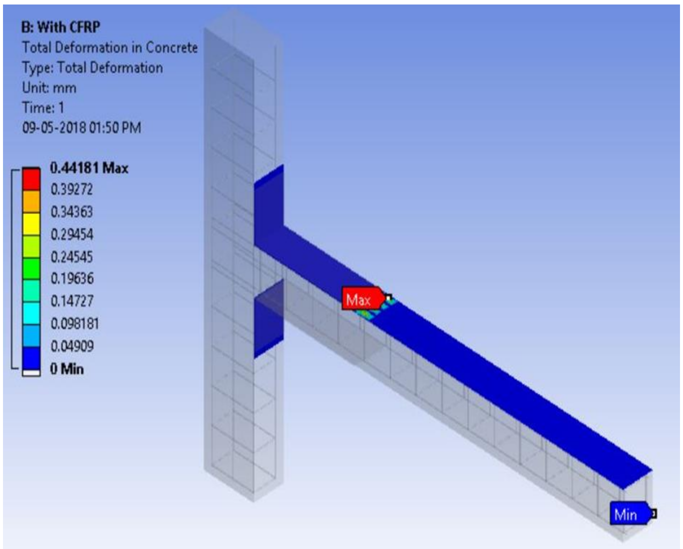

Fig. 13: Total deformation in the beam-column joint with CFRP

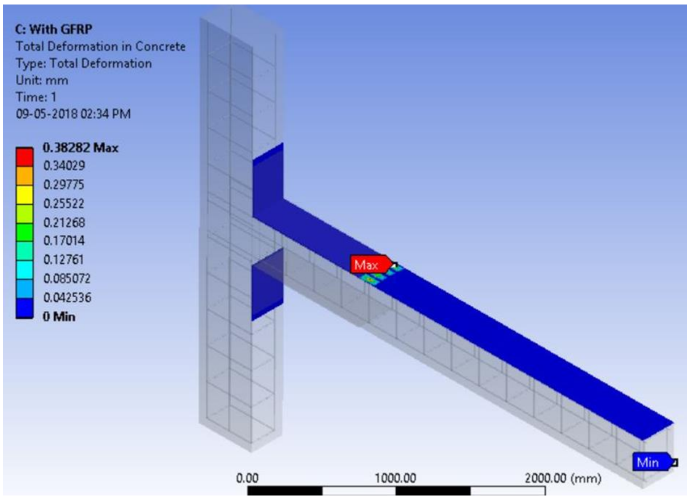

Fig. 14: Total deformation in the beam-column joint with GFRP

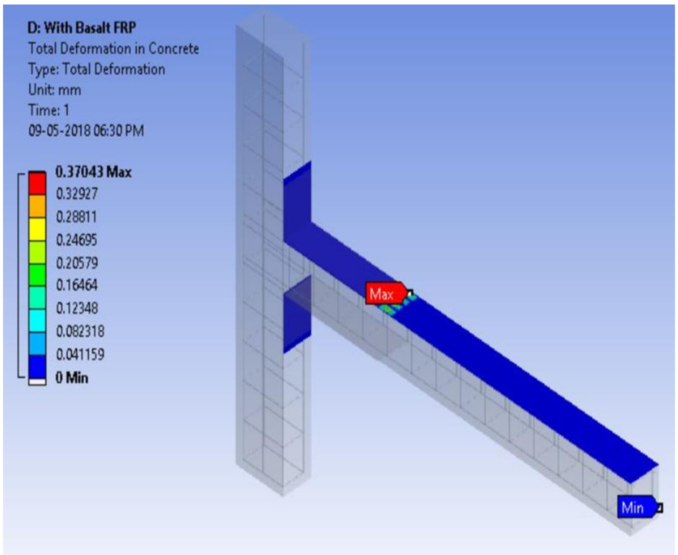

Fig. 15: Total deformation in the beam-column joint with BFRP

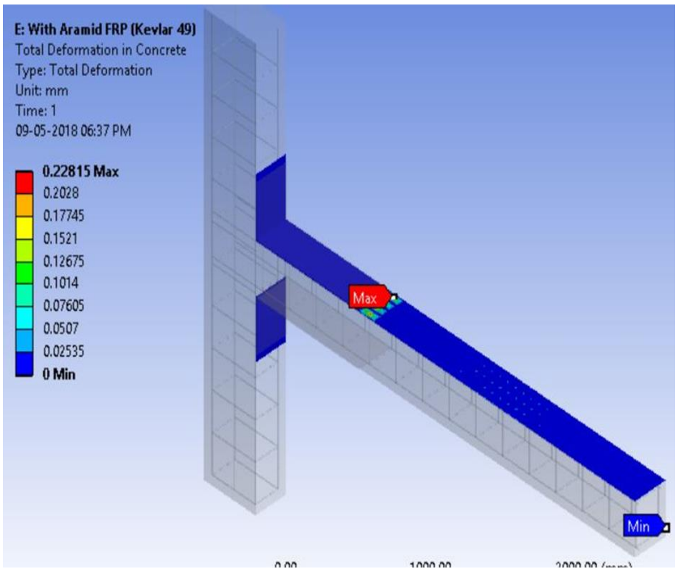

Fig. 16: Total deformation in the beam-column joint with AFRP

IV. CONCLUSIONS

A comparison between the results obtained are shown below:

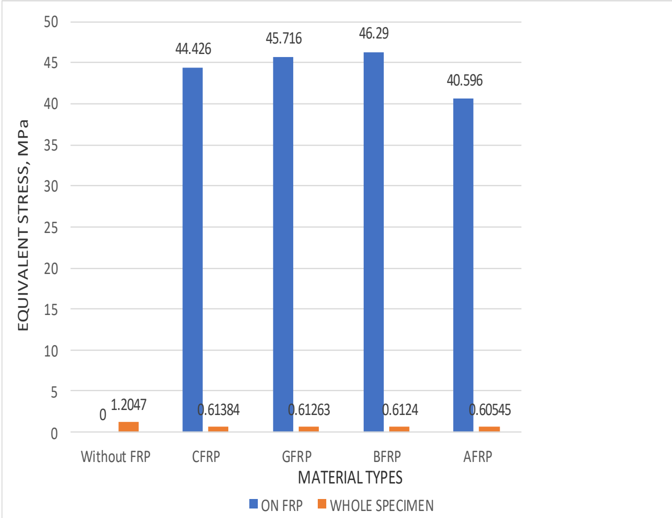

Fig 17: Comparison of equivalent stress obtained for different material types

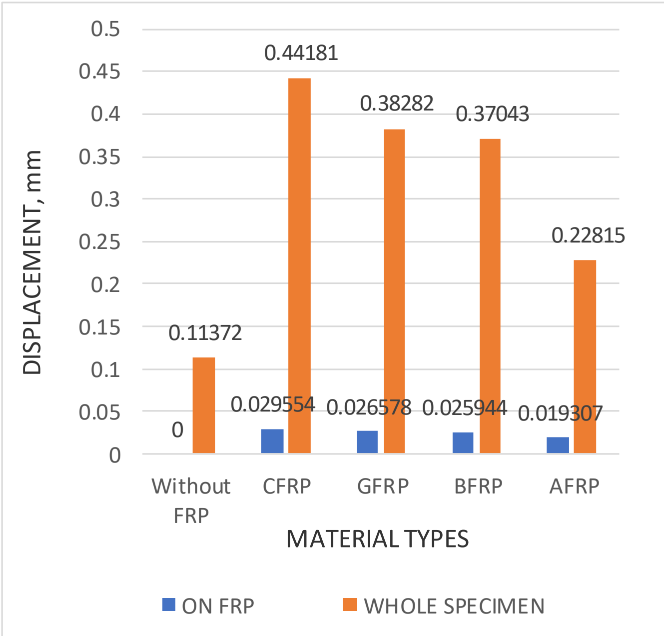

Fig 18: Comparison of total deformation obtained for different material types

From the results, it can be concluded that upon using the different types of FRPs the equivalent stresses in the concrete got reduced. The reduction is basically due to the fact that the FRP is acting like an external reinforcement to the beam-column joint and the stresses generated is taken by the FRPs. Different types of FRPs have different modulus of elasticity and different Poisson's ratio. Therefore, the variation is observed. The maximum equivalent stress is generated at the junction of the FRP and the beam of the beam-column joint because of the fact that the load applied on the beam is counteracted by the FRP and at the end point of the FRP the stresses are concentrated.

While observing at the total deformation, it can be concluded that the total deformation is lower when there is no use of FRP due to the fact that when FRP is used in the structure, the total load applied on the structure is taken up by the FRP used which results in maximum deformation in the FRP used specimen. Therefore, FRP helps to take up the load applied on concrete and reinforcement and it counteracts it. So, at the junction of beam-column joint it can be observed that the maximum deformation is occurring at the junction of the FRP and the beam of the beam-column joint.

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