Study of RC beams with flexural opening strengthened with FRP fabrics

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Abstract - *In order to provide the passage of utility pipes and service ducts openings are provided through the beams. Due to the presence of web opening in the rc beams resulted in many problems including reduction in beam stiffness, excessive cracking and deflection and reduction in beam capacity .In this project the behavior of R.C.C. beam with rectangular opening strengthened by CFRP, AFRP,GFRP,BFRP,BORON FRP are studied. This project presents the most effective and fastest method of strengthening beams with opening. In this analytical study total eight beams are model, one beam without opening (i.e. solid beam), and one beam with rectangular shear opening and last one with rectangular flexural opening. These three considered as a control beams for comparison. The remaining five beams will strengthened by CFRP, AFRP, GFRP, BFRP, BORON FRP. These beams will analyzed using ANSYS17. From the analytical study resuls it is concluded that the maximum load carrying capacity of the R.C.C. beam with flexure opening strengthened with GFRP, CFRP, AFRP, GFRP, BFRP, and BORON FRP increases from 38% to 62%.among these tested materials BORON FRP shows high increase in strength.*

***Key Words*: Reinforced concrete beams, Beams with rectangular opening, CFRP, AFRP, GFRP, BFRP, BORON FRP, Ultimate load carrying capacity.**

1. INTRODUCTION

In high-rise buildings we can often see set of pipes traveling vertically and horizontally. These are service ducts, their purpose is to provide essential services such as conduits, power supply, water and drainage pipes, ventilation system, air- conditioning and network system access or even for inspection purposes in beam structures. Sometimes the duct openings are used for aesthetical purpose also. Beam depth is one of the factors to decide the floor to floor height and overall height of the building. Engineers face very difficult to maintain the maximum load carrying capacity of beam without increasing the depth of beam. If these ducts travel below the depth of beam overall height of building will increase, results in increase of total height of building, dead load of building, cost of foundation will increase and results the building uneconomical.

Saadatmanesh et.al (1992) [1] conducted experimental study to find out the behaviour of rc beams strengthened with GFRP plates. GFRP plates are bonded on the tension face by epoxy bonding. Results shows that the crack widths are reduced at higher load levels.

Abdalla et al. (2003) [2] finds out design against cracking by wrapping openings in beam with cfrp sheets inside and around the opening.

Mohammad et.al (2006) [3studid the behaviour of rc beam with web opening in ansys. The numerical method of analysis developed was capable of providing useful information about the behaviour of rc beams with web openings.

Lee et al. (2010) [4] investigated the R.C T- section deep beams strengthened externally with CFRP sheets and concluded that all shear compression failure due to partial elimination of CFRP sheets and U- wrapped anchorage CFRP sheets increased the load carrying capacity of the beam.

Pimanmas (2010) [5] investigated the rc beams with openings strengthened with externally installed FRP rods and resulted that placing of FRP rods partially was not effective but placing FRP rods in full length diagonally would be more effective in preventing the cracks.

Ammas et.al (2011) [6] conducted study on rc beams with openings strengthened with cfrp laminates and found that using FRP offer high advantages such as simplicity of installation, lower construction time and improved durability.

This project presents the most economical, effective and fastest method of strengthening beams with opening. This investigation will helps the practicing engineers to provide an opening in the beams without reducing its load carrying capacity

2. MODELING AND ANALYSIS PROCESS BY ANSYS

Table -1: Beam Details

Length	2400mm
Length(c/c)	2000mm
Depth	250mm
Width	100
Top bar	10 mm Ø 2 no’s
Bottom bar	10 mm Ø 4 no’s
Stirrups	8 mm Ø @150 mm c/c

Opening size	200 x100 mm
Steel grade main bar	Fe 400 N/mm2
Steel grade Stirrups	Fe 240 N/mm2
Concrete grade	M49

2.1 Element Types

SOLID65 is used for the 3-D modeling of concrete. Compressive strength of concrete was 49 MPa and tensile strength was Assumed 9% of concrete compressive strength. Poisson's ratio of 0.2 was used.
LINK180 is defined by two nodes which has used for the modeling of reinforcing bar. Yield strength of longitudinal reinforcements and stirrups were 400 Mpa. Poisson's ratio of 0.3 was used.
Shell 91 is used. It is be used for layered applications of a structural shell for modelling thick sandwich structures.

2.2 Loading and Boundary Condition

To ensure that the model behave the same way as the experimental beam boundary conditions supports were modeled to create simply supports. The force P was applied on all nodes through the entire center line of two points in top fibre of the beam at equal distance from the mid span.

2.3 Meshing

In this research a convergence study was carried out to determine an appropriate mesh density. Various mesh sizes were examined in ANSYS. It was observed that the obtained ultimate load for mesh size 25 mm is nearest to the ultimate load of experimental beam [2]. For this reason, the mesh size equal to 20 mm was chosen for this study

3. RESULTS AND DISCUSSION

3.1 General

The beams were modelled in Ansys workbench 17 and the obtained results are presented and discussed subsequently in terms of the observed mode of failure and load-deflection curve. All the beams are tested for their ultimate strength.

Here a total of 8 beams were modelled and analyzed. i.e. 3 control beams and 5 beam with flexure zone opening strengthened using GFRP, CFRP, BFRP, AFRP AND BORON FRP sheets. .

3.2 Observation of Control Beams

Here 3 controls beams are modelled in ANSYS 17.first beam is a solid beam, second one has shear opening and the third one has flexure opening. All beams are analyzed based on ultimate load, principle stress,

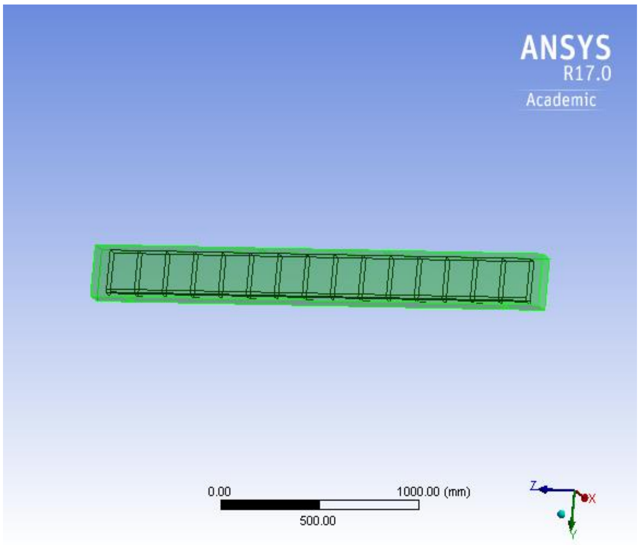

Fig -1: model of control beam with no opening

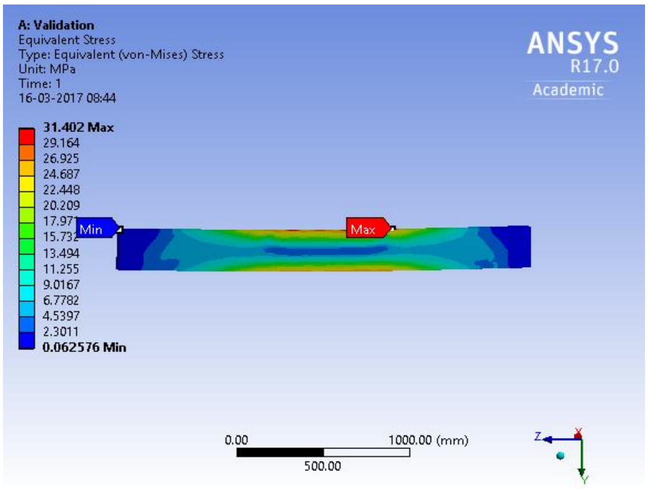

Fig -2: equivalent stress of control beam with no opening

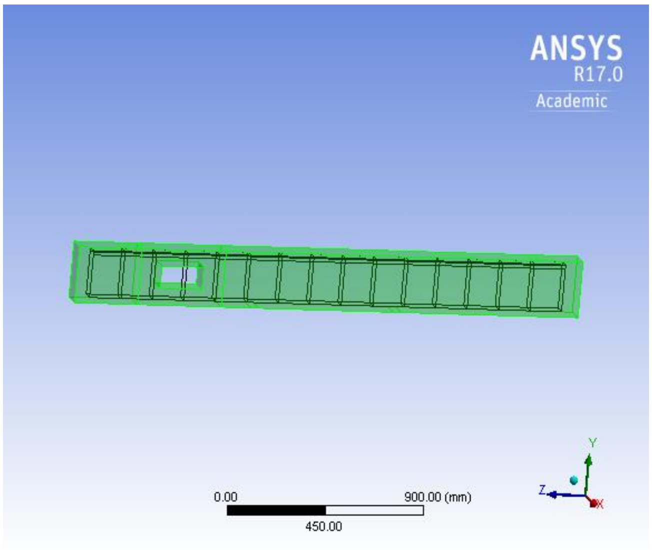

Fig -3: model of control beam with no opening

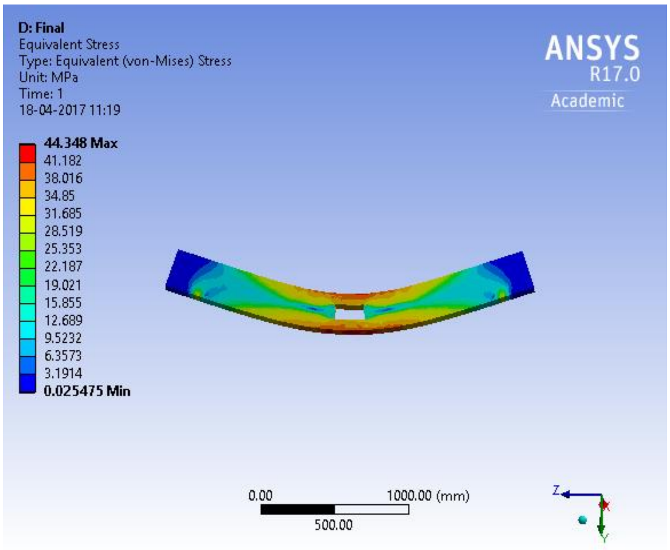

Fig -6: equivalent stress of control beam with no opening

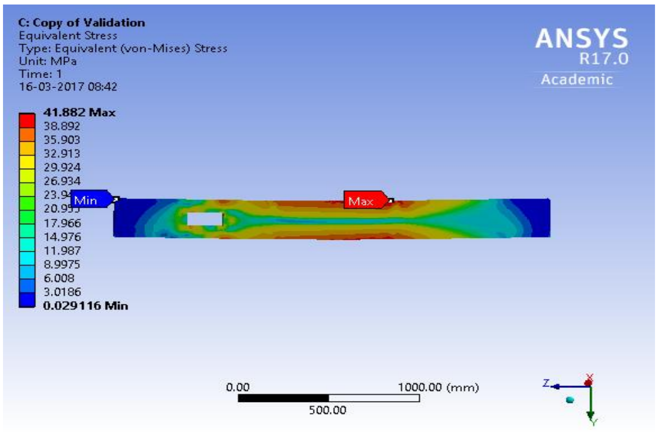

Fig -4: equivalent stress of control beam with no opening

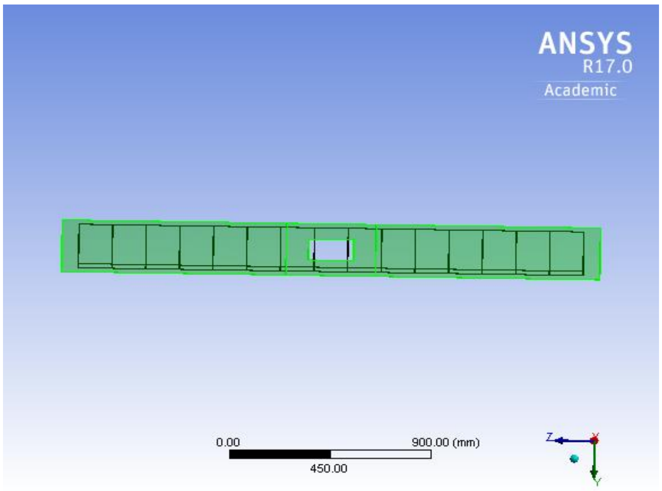

Fig -5: model of control beam with no opening

The following are findings that are plotted on the basis of the analysis of beam strengthened

- The numerical results presented in figure, it is clear that the presence of an opening not only reduced the load carrying capacity of the beam but also reduce the stiffness of the beam.
- Stress is more concentrated at the corners of opening
- The percentage of decrease in load carrying capacity for the beam with shear opening and flexure opening is 38% and 62% respectively

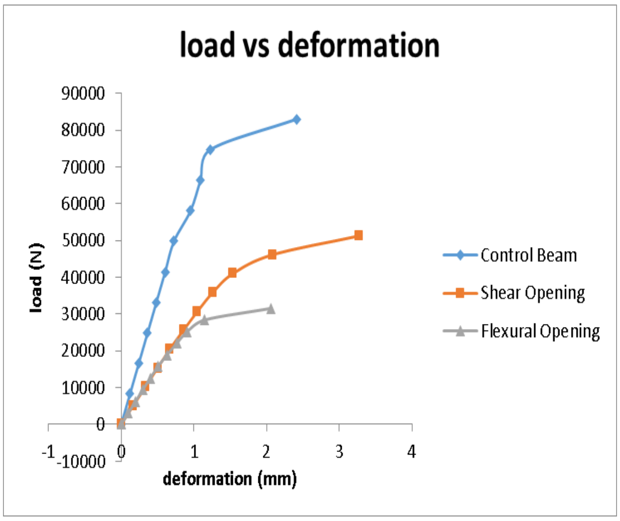

Chart -1: load vs deformation (control beam)

- So beam with most load reduction is flexure opening. This beam is used for further strengthening.

3.3 Observation of Beam Strengthened With FRP Fabrics

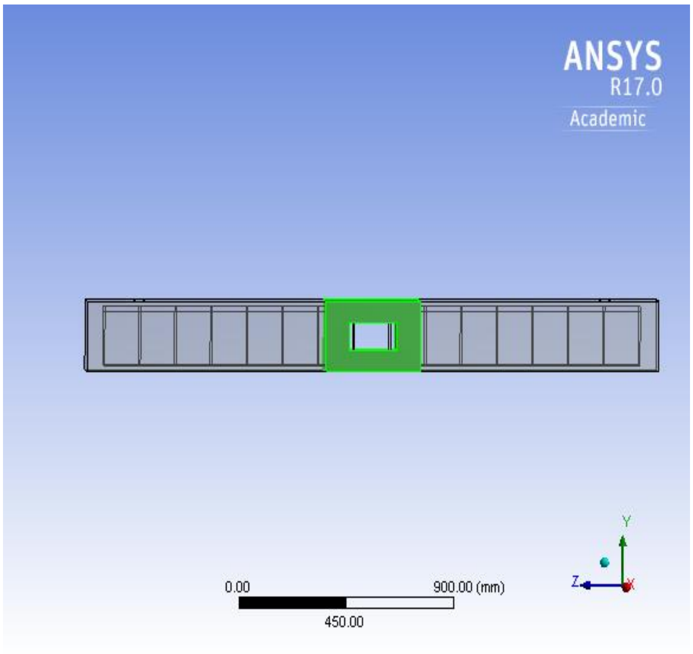

Fig -7: model of control beam with no opening

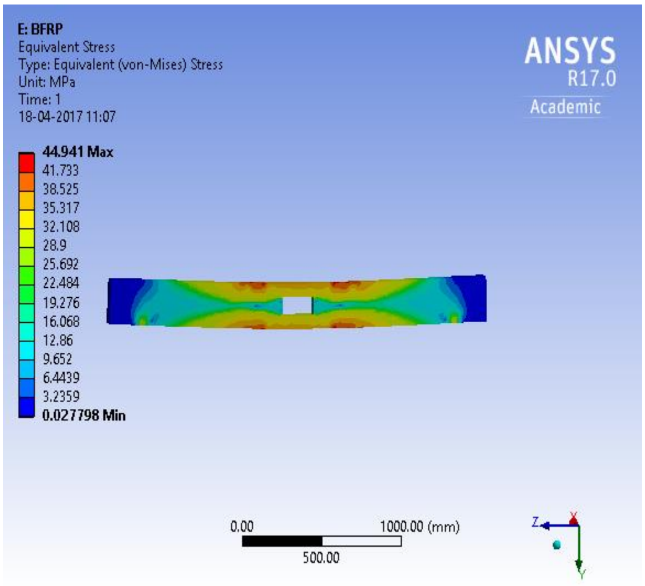

Fig -8: equivalent stress of control beam with no opening

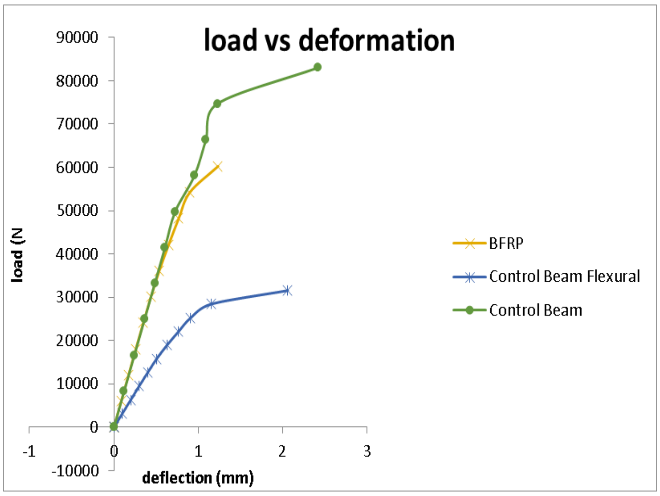

Chart -2: load vs deformation (BFRP wrapped)

- The numerical results presented in figure, it is clear that the wrapping with BFRP at opening not only increase the load carrying capacity of the beam but also increase the stiffness of the beam.
- Stress is shifted from the corners of opening
- The percentage of increase in load carrying capacity is 34% compared to solid control beam
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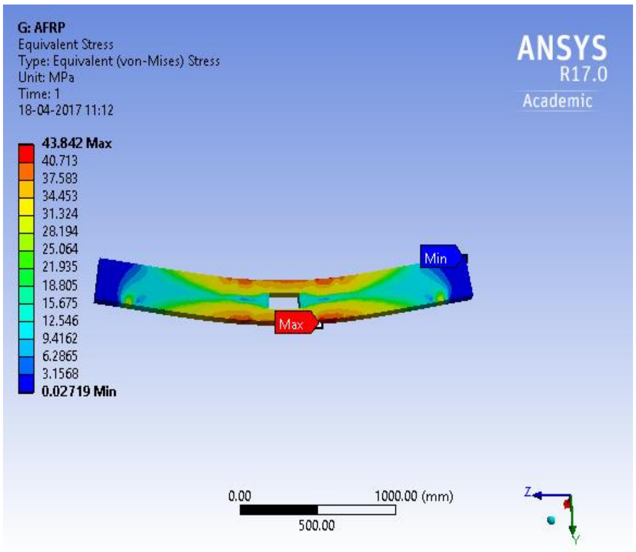

Fig -9: equivalent stress of control beam with no opening

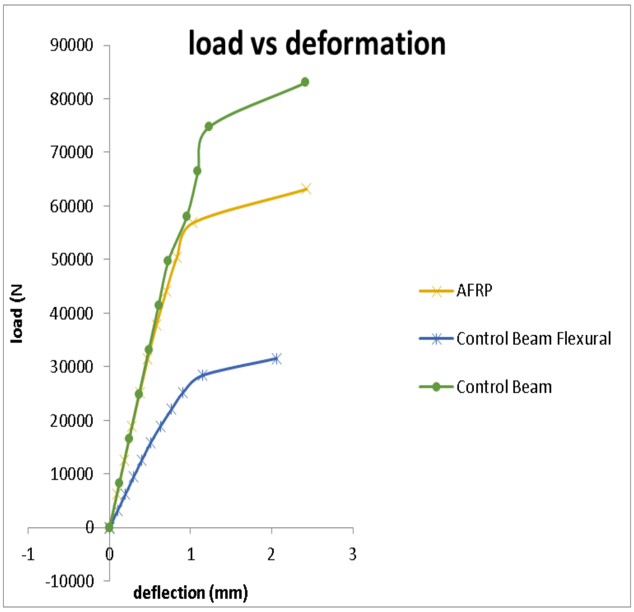

Chart -3: load vs deformation (AFRP wrapped)

- The numerical results presented in figure, it is clear that the wrapping with BFRP at opening not only increase the load carrying capacity of the beam but also increase the stiffness of the beam.
- Stress is shifted from the corners of opening
- The percentage of increase in load carrying capacity is 38% compared to solid control beam

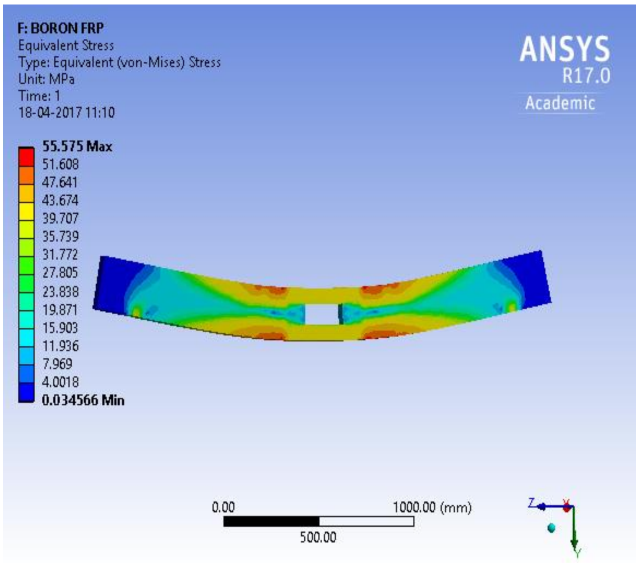

Fig -10: equivalent stress of control beam with no opening

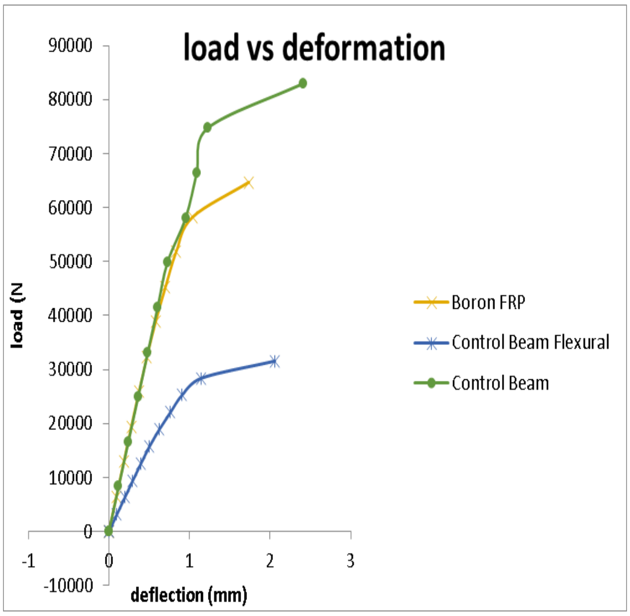

Chart -4: load vs deformation (BORON FRP wrapped)

- The numerical results presented in figure, it is clear that the wrapping with BFRP at opening not only increase the load carrying capacity of the beam but also increase the stiffness of the beam.
- Stress is shifted from the corners of opening
- The percentage of increase in load carrying capacity is 40% compared to solid control beam

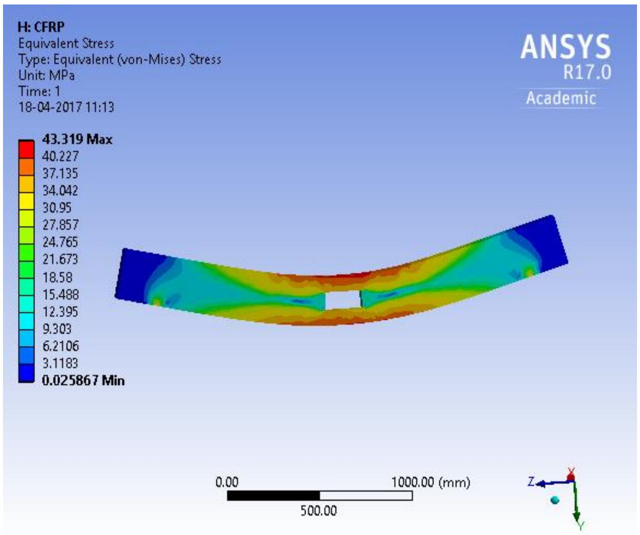

Fig -11: equivalent stress of control beam with no opening

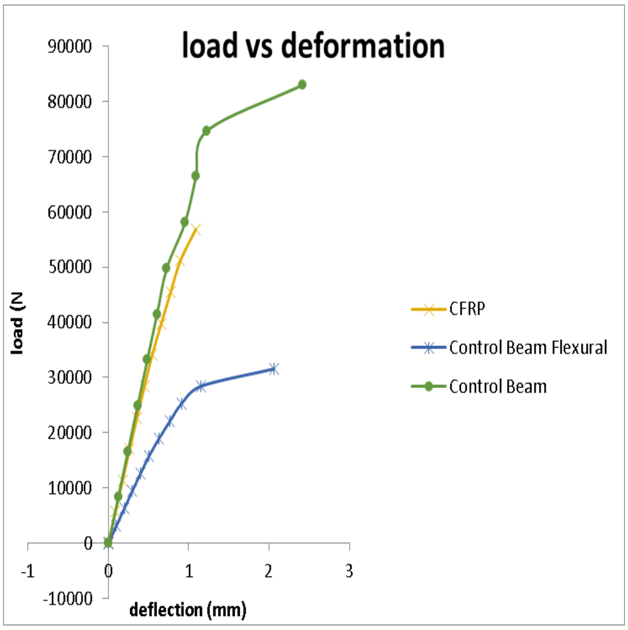

Chart -5: load vs deformation (CFRP wrapped)

- The numerical results presented in figure, it is clear that the wrapping with BFRP at opening not only increase the load carrying capacity of the beam but also increase the stiffness of the beam.
- Stress is shifted from the corners of opening
- The percentage of increase in load carrying capacity is 32% compared to solid control beam

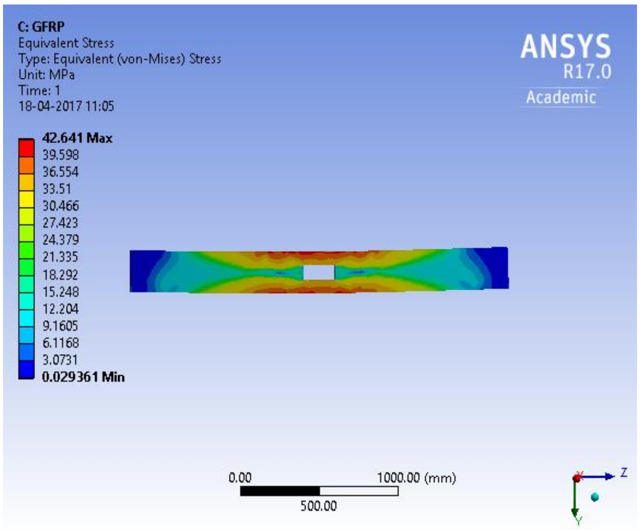

Fig -12: equivalent stress of control beam with no opening

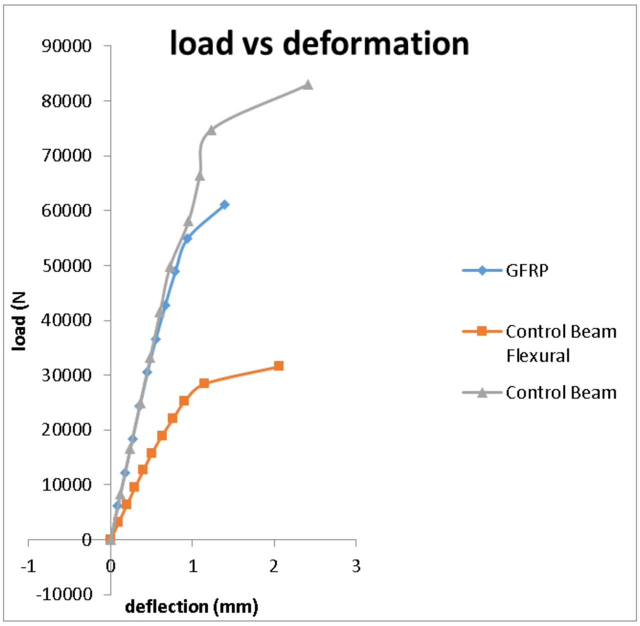

Chart -6: load vs deformation (GFRP wrapped)

- The numerical results presented in figure, it is clear that the wrapping with BFRP at opening not only increase the load carrying capacity of the beam but also increase the stiffness of the beam.
- Stress is shifted from the corners of opening
- The percentage of increase in load carrying capacity is 36% compared to solid control beam

4. CONCLUSIONS

1. By an inclusion of rectangular post opening in the beam the load carrying capacity of the beam decreases by 38% and 62% for shear and flexure opening respectively as compared to solid beam.
2. GFRP, CFRP, BFRP, AFRP AND BORON FRP can increase the strength of beam from the overall study, it can be concluded that the strengthening with BORON FRP around and inside the opening is more efficient and is considered as best strengthening scheme.
3. By wrapping with fiber sheets stress concentration is shifted from the corners of opening
4. These improving method will helps the structural engineers to increase the load carrying capacity of beam with opening without increasing depth of beam.

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