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Analysis of Beam Openings Strengthened by Carbon Fibre Reinforced Polymer (CFRP) Using ANSYS

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Abstract: ***In the construction of modern buildings, many pipes and ducts are necessary to accommodate essential services like water supply, sewage, air-conditioning, electricity, telephone, and computer network. Usually, these pipes and ducts are placed underneath the soffit of the beam. The depth of ducts or pipes may range from a couple of centimetres to as much as half a meter. The presence of the opening leads to reduction in stiffness, cracking, excessive deflection and reduction in the strength of the beam. By wrapping Carbon Fibre Reinforced Polymer (CFRP) sheets, retrofitting of concrete structures provide a more economical and technically superior alternative to the traditional techniques in many situations because it offers high strength, low weight, corrosion resistance, high fatigue resistance, easy and rapid installation and minimal change in structural geometry. In this paper, the behaviour of RCC beam with square opening in shear zone strengthened by CFRP sheets were studied. This paper is to investigate the three different CFRP techniques and which will more effective were analysed by ANSYS 15. In this, four beams were modelled, one beam with opening in shear zone is considered as control beam. The remaining three beams were strengthened by CFRP techniques that is inside the opening, around the opening and both inside and around the opening. For each loading case, deflection corresponding to different load values can be tabulated and compared. Also crack pattern is obtained for different CFRP techniques and will analysed. Among all these techniques, it can be concluded that the strengthening with CFRP both around and inside the opening was found more effective and improving the load carrying capacity about three times greater than control beam.***

Keywords: reinforced concrete beam, square opening, CFRP, strengthening schemes, shear zone

1. Introduction

Composite materials are made from two or more constituent materials with different physical and chemical properties that when combined produce a material with characteristics different from the individual components. Most commonly used composite material is Fibre Reinforced Polymer (FRP).FRP is a composite material made of a polymer matrix reinforced with fibers. The application of FRP as external reinforcement has received much attention from structural engineering. Its laminates have gained popularity as external reinforcement for the strengthening or rehabilitation of reinforced concrete structures. Externally bonded FRP laminates and fabrics can be used to increase the flexural strength of reinforced concrete beams.

Flexural strengthening of beams, however, is likely to be more problematic when they are cast monolithically with slabs. Bonding FRP reinforcement to the tension face of a concrete flexural member with fibers oriented along the length of the member will provide an increase in flexural strength. FRP composites applied to the reinforced concrete members provide efficiency, reliability and cost effectiveness in rehabilitation. Experimental based testing has been widely used as a means to analyze individual elements and the effects of concrete strength under loading. While this is a method that produces real life response, it is extremely time consuming and the use of materials can be quite costly. In the present study an attempt is made to investigate the analysis of CFRP strengthened openings with different loads.ANSYS 15 is used for the modeling and analysis of the square opening in shear zone.

2. Modeling

2.1 Geometric Model

Here, a linear analysis is considered throughout the study by assuming that there is a perfect bonding between reinforcement and the steel. In general, a finite-element solution may be broken into three stages that is pre-processing stage, solution stage and post processing stage. Firstly the element types are selected, as shown in Table 1.

Table 1: Element Type

Material Type	*Elements*
Concrete	Solid 65
Steel	Solid 186

Beam considered having an overall length of 2000 mm and Size of the beam is 240 × 300 mm. High-Yield Strength Deformed bars of top longitudinal reinforcement consists of two bars of 10mm diameter and the bottom longitudinal reinforcement consists of two bars of 20mm diameter and 8 mm diameter bars are used as stirrups at 250mm spacing. Dimension of beam model and reinforcement details as shown in Figure 1.

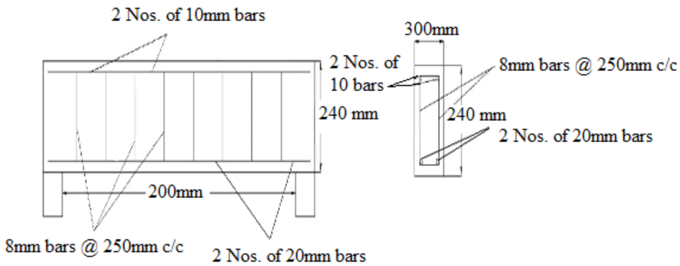

Figure 1: Dimension of beam model and reinforcement details

The geometric model of control beam as shown in Figure 2.

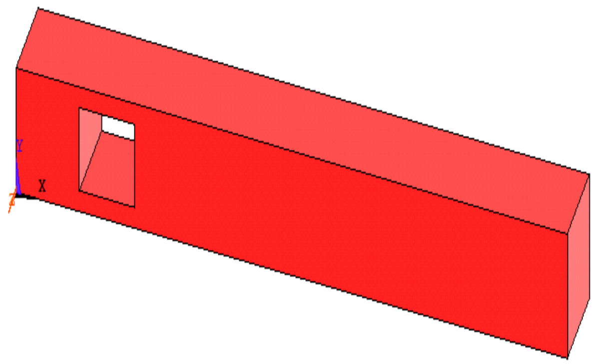

Figure 2: Beam with opening in shear zone

After creating the geometric model, the model is meshed under sweep meshing and element edge length is taken as 10mm.Meshing of model is shown in Figure 3.

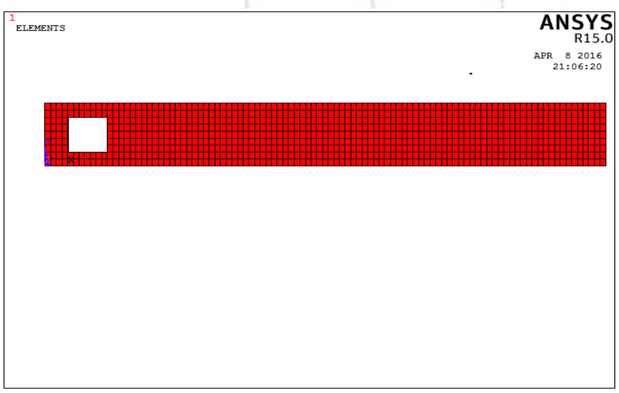

Figure 3: Control beam after meshing

2.2 Boundary Conditions

The two ends of the beam are held simply supported, as shown in Figure 4.

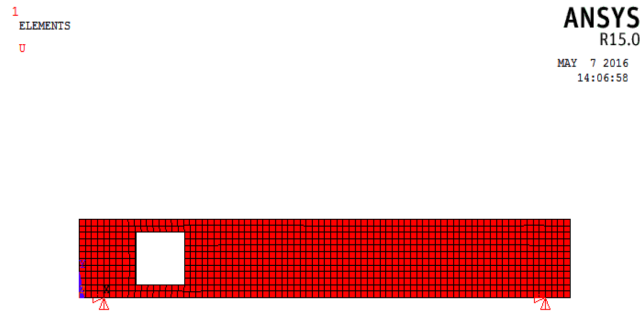

Figure 4: Beam after applying boundary conditions

2.3 Load assigning

Two point loadings of different load cases are assigned separately, as shown in Figure 5.

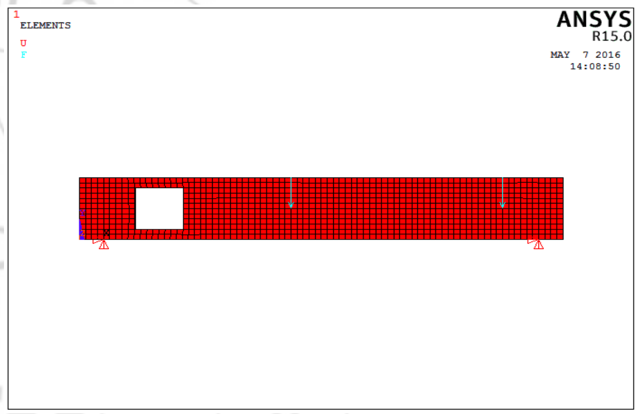

Figure 5: Beam after load application

Analysis Using ANSYS

3.1 Control Beam Analysis

Beam with shear zone opening without any wrapping scheme is considered. Figure(6-8) shows the deformed shape, load at ultimate failure and crack pattern of control beam.

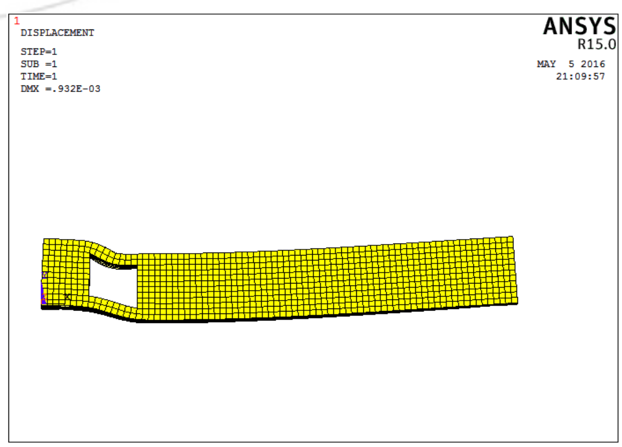

Figure 6: Deformed shape of control beam

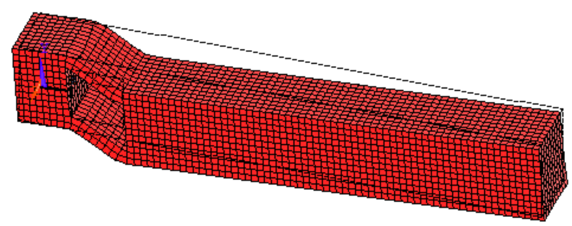

Figure 7: Control beam under failure

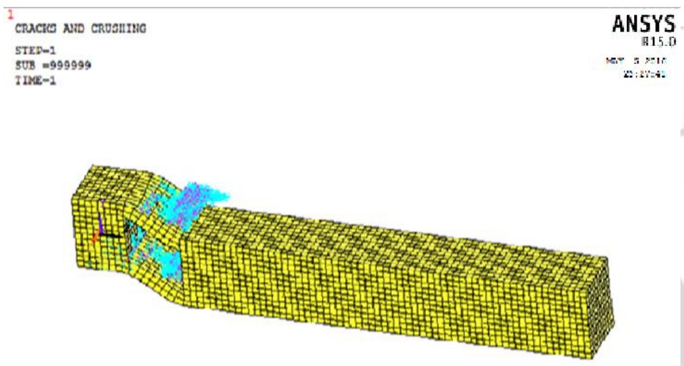

Figure 8: Crack pattern of control beam

3.2 Analysis of Beams with Different CFRP Schemes

Beams with opening in shear zone wrapped with CFRP by using different schemes, such as wrapping inside the opening, outside the opening and both inside and around the opening are analysed. The corresponding crack pattern is obtained as shown in Figure(9 – 11).

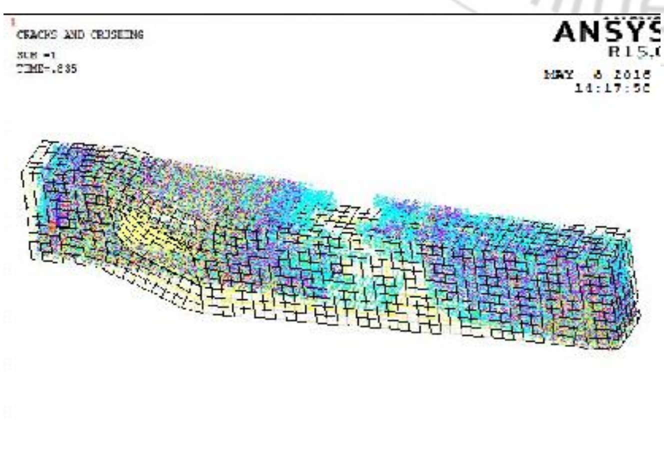

Figure 9: Crack pattern of CFRP wrapped inside the opening

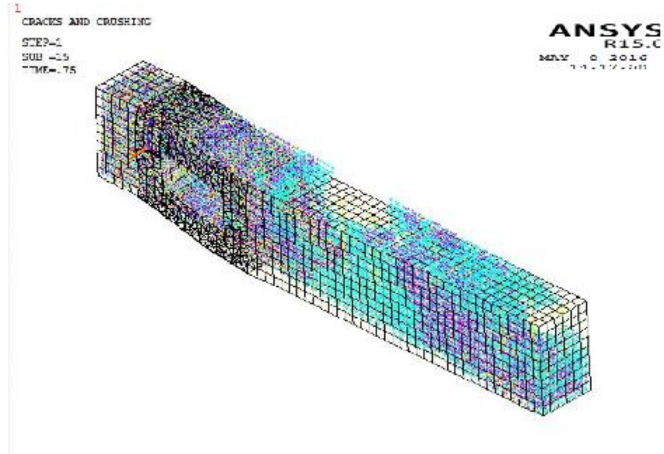

Figure 10 : Crack pattern of CFRP wrapped around the opening

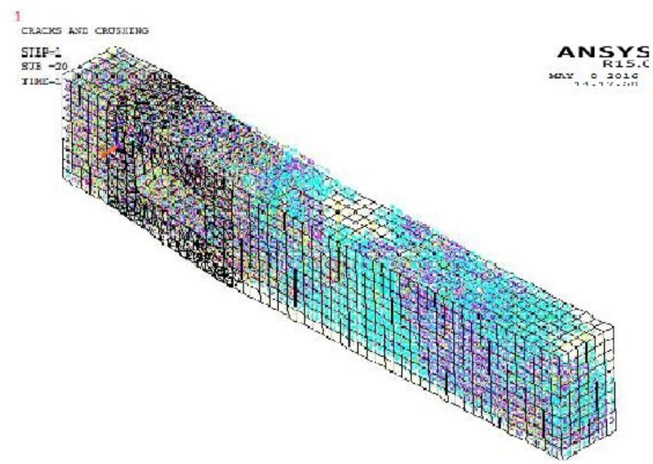

Figure 11: Crack pattern of CFRP wrapped both inside and around the opening

Results and Discussion

The beams were loaded with a concentrated load at the middle of each span and the obtained results are presented and discussed subsequently in terms of the observed mode of failure and load-deflection curve. The crack patterns and the mode of failure of each beams are obtained.

All the beams are modeled for their ultimate strengths and it is observed that the control beam had less load carrying capacity than the strengthened beam. In the analysis one beam is treated as un-strengthened control beam and rest beams were strengthened with various CFRP wrapping techniques. The different failure modes of the beams were is compared with the control beam strength the corresponding results are obtained on the behalf of the comparison.

The results are evaluated by preparing various tabular columns and graphs. The Load deflection of control beam is shown in Table 2.

Table 2: Load Deflection of control beam

Load (kN)	*Maximum deflection (mm)*
0	0
10	2.55
20	6.8
30	14.6
38	17.8

The load carrying capacity of the CFRP strengthened beams are shown in Table 3.

Table 3: Load deflection for different CFRP techniques

	Deflection(mm)		
Load	*CFRP inside*	*CFRP around*	*CFRP both inside and around*
0	0	0	0
10	0.3	0.29	0.29
20	0.8	0.72	0.7
30	1.4	1.2	1.2
40	2.8	2.2	2
50	4.1	3.6	2.2
60	5.4	3.8	3.2
70	6.2	4.2	3.8
80	6.9	5.6	4.2
90	8.2	6	4.6
100	8.8	6.2	5.9

From the above discussions, at the starting of loading there are no significant changes in deflection about up to 40kN and also it is observed that beam with CFRP wrapped both inside and outside the opening subjected to load gives minimum deflection. The control beam is failed under 38kN. It is found that strengthened beam can carry loads three times greater than that of control beam. Also the CFRP technique of wrapping both inside and around gives maximum effectiveness. And also from crack pattern the crack is more concentrated near the supports.And these results are plotted in Figure 12.

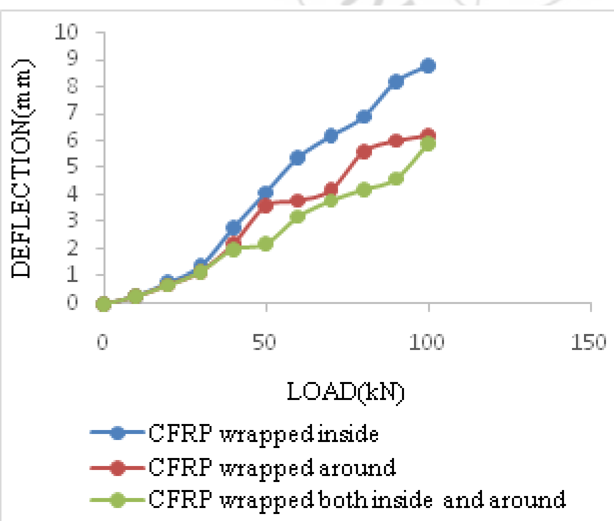

Figure 12: Load- Deflection Curve

5. Conclusions and Future Scopes

5.1 Conclusions

The present study focuses on the shear behaviour of reinforced concrete beam with openings in shear zone strengthened by CFRP sheets. Total of four beams where modelled, one is non strengthened beam, remaining three is CFRP strengthened beam. The ANSYS results are obtained and compared.

- The load carrying capacity of the beam were found to decreases due to opening compared to solid beam and improving the load carrying capacity about three times greater than control beam.
- The failure of control beam occurs at 38kN.
- The strengthening of opening with CFRP increases the load carrying capacity of beam.
- For non-strengthened beam, crack is concentrated near the opening.
- From the overall study, it can be concluded that the strengthening with CFRP both around and inside the opening is more effective scheme.

5.2 Future Scopes

- Study the behavior of beam with opening in flexural zone with different CFRP techniques.
- Strengthening of beam with different types of FRP.
- Steel plates can be used instead of FRP, this will reduce the disadvantage of debonding of FRP.

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