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ANALYSIS OF RCC BEAM WITH OPENING STRENGTHENED BY FRP USING FINITE ELEMENT APPROACH

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Abstract: To accommodate important utilities such as power, telephone, computer network, and air conditioning, modern construction structures require numerous pipes and ducts. This will produce extra void space or waste space thus, a substitute arrangement must be devised to transmit these pipes and ducts via a transverse passage of the beam, and the cost ofthe construction of structures can be decreased. Hence, strengthening a beam with an opening should be done. There are two types of strengthening of beams: The pre-planned opening is done by steel reinforcement should be provided with proper design. When a post-planned opening occurs, the beam should be reinforced with different FRP such as CFRP, GFRP, and other materials. Different investigation has been done for reinforced structural member beams with openings. The main aim of this paper is to tell about the performance of the beam opening, analyse using the software, and design of concrete beam opening. Furthermore, various classifications of opening, different opening site suggestions, and the performance of Reinforced concrete beams with openings will be highlighted and explored. The article will also detail and explain many design methodologies. There are different types of strengthening techniques of the beam such as Fibre Reinforced Polymer and steel plates are investigated for strengthening RCC beams with openings.

Keywords: Reinforced concrete beam with different shape opening, different FRPs like CFRP, GFRP, strengthening of beams, ultimate load capacity, failure crack pattern, finite element approach, ANSYS, load versus deflection graphs, analysis of RC beams.

I. INTRODUCTION:

In today's modernistic construction, many pipes and ducts are provided to fulfill the necessary services like water supply, sewage, electricity, telephone etc. These necessary services are generally provided in the lower portion of the beam. And for aesthetic purposes, these are enclosed with suspended ceilings or false ceilings. This leads to a reduction in the dead space in the headroom and results in some-cost effective design. In the case of small buildings, the savings are not large compared to the overall cost of the building. But in a multi-story building, saving in storey height multiplied by a number of stories shows the considerable saving in total height, length of walls, electrical ducts, load coming on foundation, and by minimizing concrete quantity the overall cost of the building can be reduced. Hence, strengthening of the beam with the opening should be done. The strengthening is of two types, strengthening of beam for pre-planned opening is done by steel reinforcement should be provided with proper design. In the case of post-planned opening, strengthening of the beam should be done by using Carbon fiber reinforced polymer (CFRP), Glass fiber reinforced polymer (GFRP), etc. Thus, special care should be taken in designing and analyzing such beams which currently fall beyond the scope of major building codes.

II. METHODOLOGY

- Examining the RCC beam with various different shapes and preparing the model in Ansys.
- Collecting the data, defining the material property, and meshing the model.
- Analysis of the model in ANSYS software.
- Strengthening the beam with different FRP
- Comparing the results of analytical with experiment data.

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Material properties and element properties:

Table 1: Different materials with their engineering properties

Materials	Density in kg/m3	Elastic modulus in N/mm2	Poisson's ratio
Concrete	2500	24834.83	0.2
Steel reinforcement	7850	200000	0.3
Glass Fiber reinforced polymer	1800	95000	0.3
Carbon fiber polymer	2000	179000	0.3

Table 2: Element type used in ANSYS

Material Type	Element Type
Concrete	Solid 65
Steel	Link180
FRP	Shell 180

III. ANALATICAL MODELLING

Model Specifications:

A 3D simply supported beam is modelled in ANSYS with the following dimensions Length of beam 1600mm, Breadth of beam 230mm, Depth of beam 300mm Total of seven beams are being analyzed one solid beam another two beams of opening in a rectangular, rounded rectangular shape, another 4 beams strengthened with different FRP layers. The roller support is located at 100 mm from the left edge of the beam and the hinged support at 100mm from the right edge of the beam that acts as a simply supported beam of a span of 1600mm

2 bars of 8mm dia steel bars are used in the compression zone and 2 bars of 10mm dia steel bar are used in the tension zone in all beams and 8mm bars are used in stirrups at 300mm center to center. Initially, a solid beam (without opening) is modelled and analysed in ANSYS. Then one with a different opening like a rectangular, rounded rectangular opening with and without CFRP, GFRP beams are modeled and analyzed in ANSYS. A total of seven cases of beams including solid beam are considered for analysis and comparison.

Geometrical Modelling:

The concrete beam size is modeled by sketching a 2D model of size 230X300 mm and extruding for a length of 1600 mm to get the complete 3D model. The model is prepared in CATIA software and then it is excluded in the ANSYS software. Pattern option is used to create similar elements like stirrups and rebar at a known distance. The support plates and loading plate is modeled similarly. The concrete beam without opening is abbreviated as a Solid beam.

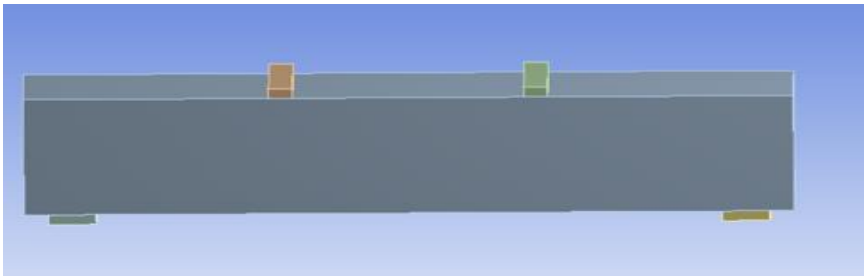

Fig 1: Model of solid beam

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Contacts:

Manual contacts were established between different types of elements. Grouping of elements was done using the named selection option as rebar, stirrups, concrete, and FRP. First, the contact between rebar and stirrup was established, then reinforcement was given contact with concrete. In static analysis, contact was established between plates (loading & support) with concrete. Lastly, the contact between FRP and concrete was established.

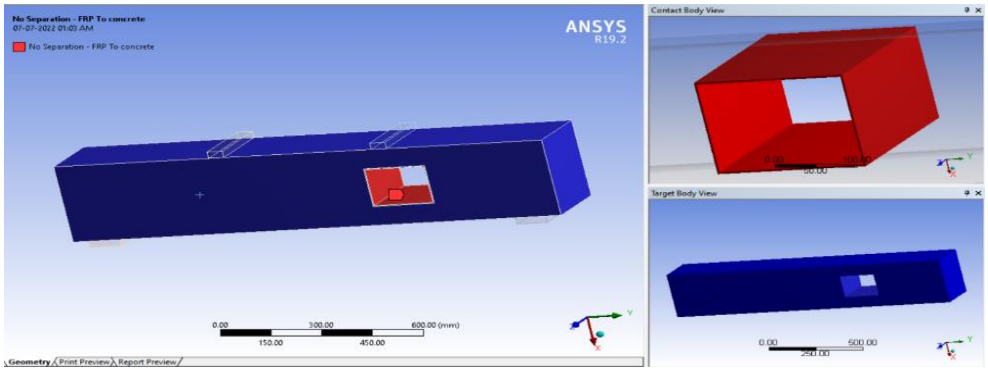

Fig 3: Contact between FRP and Concrete

Meshing:

To obtain accurate results from the Solid65 concrete element, a mesh having a tetrahedron shape is given. These rectangular or square mesh elements were created. In ANSYS to mesh the loading steel and support plates, a volume sweep command is used. This sets the plate width and length of the element consisting of the concrete elements and nodes. The dimensions of all the elements were chosen in such a way that the aspect ratio is within 2:1 in all directions. The meshing of all the volumes is shown in Figure 4.

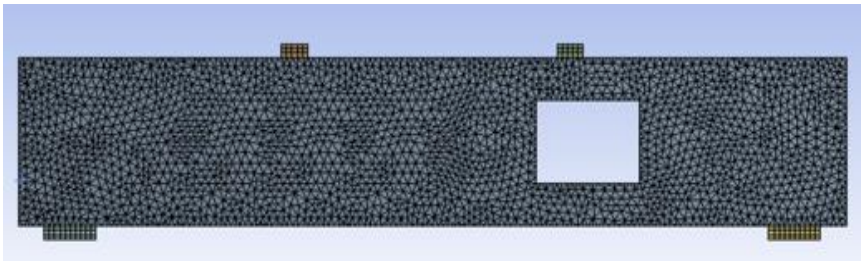

Fig 4: Mesh model for the rectangular beam opening

Beam with an opening:

The beam with a rectangular opening and rounded rectangular opening is modelled and is called RO and RRO for convenience. The beam is 1600mm in length. Once the beam has been modeled, the meshing is to be done with an element size of 10 mm. The beam is made with a simply supported and is subjected to two-point loading loaded at an interval of 5kN at 1/3rd distance from both ends. The deflection at every interval is tabulated and plotted. The ultimate load and the maximum deflection of the beam are noted down. The load vs. deflection curve is plotted.

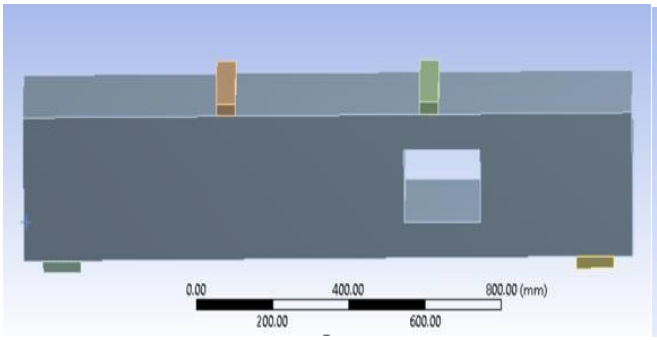

Fig 5: Model of the rectangular beam opening.

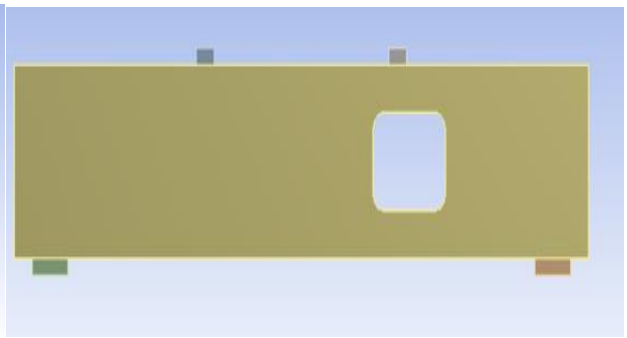

Fig 6: Model of the rounded rectangular beam opening.

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Beam with opening sheathed by FRP:

The types of opening namely rectangular (ROG) & rounded rectangular (RROG) have an opening dimension of 200X150 mm sheathed by CFRP and GFRP of a thickness of 3mm. The beam is made simply supported and is subjected to two-point loading loaded at an interval of 5kN at 1/3rd distance from both ends. The deflection at every interval is tabulated and plotted. The ultimate load and maximum deflection of the beam are noted down. The load vs deflection curve is plotted.

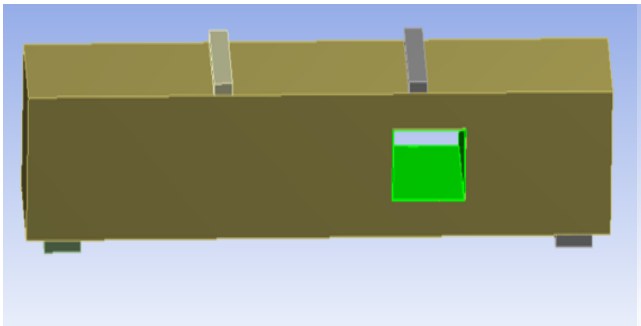

Fig 7: Model of the rectangular beam with FRP.

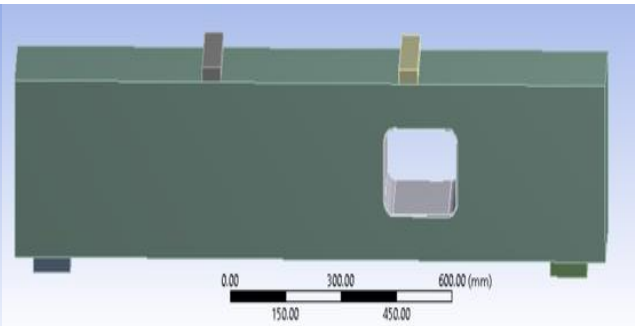

Fig 8: Model of the rounded rectangular beam with FRP.

IV. RESULT AND DISCUSSION

The static analysis the two-point loading was done to know the deflection and ultimate strength of all seven beams. In this study, we have analyzed all seven beam the load vs deflection graphs have been plotted. For the different openings, the beam is retrofitted by different FRP. The solid beam has an ultimate strength of 120.12 KN, the presence of an opening decreases the load carrying capacity of the beam. The rounded rectangular shape is preferred for the opening of the beam, CFRP sheathing has improved the performance of the beam with an opening.

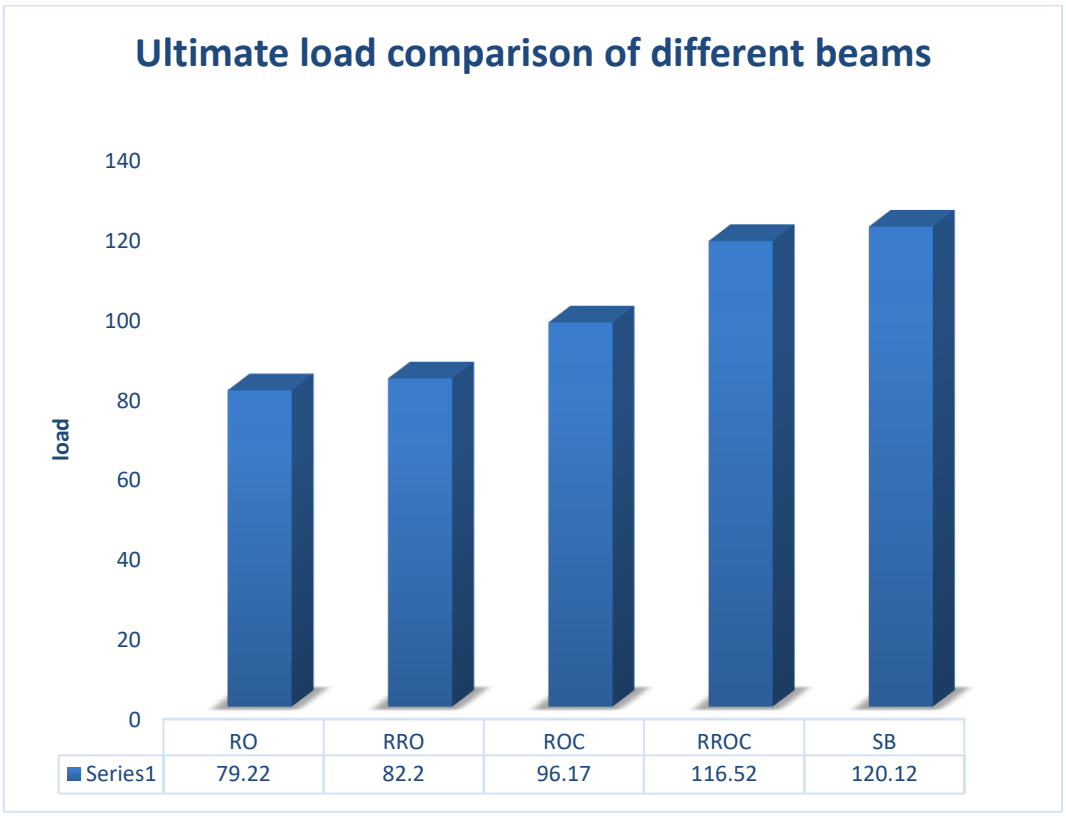

Figure 9: Ultimate load comparison of different beams

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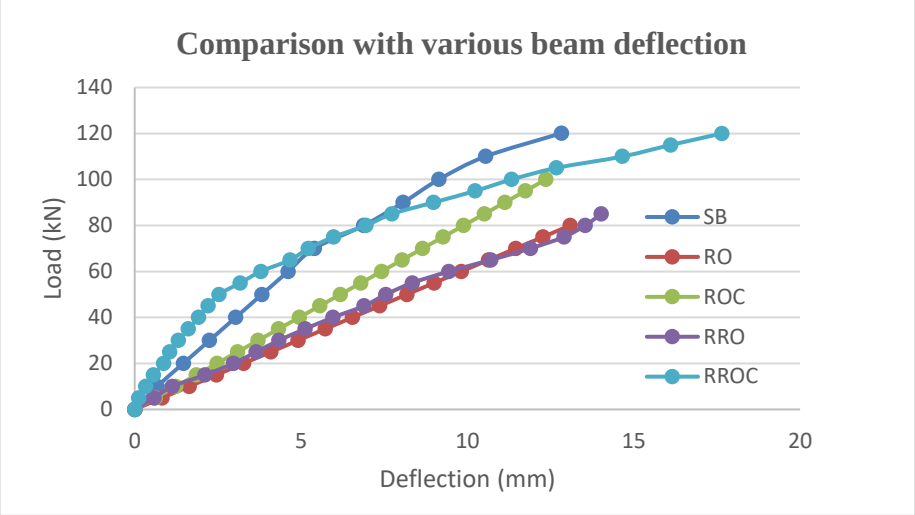

Figure10: Comparison of various beam loads versus deflection graphs

V. CONCLUSIONS

From the obtained analysed results, the following conclusion was made

- Presence of an additional FRP layer inside the opening region is predominant.
- Beam with rectangular opening has least load carrying capacity of 96.17 kN and beam with a rounded rectangular opening has the highest load carrying capacity of 116.52 kN under static load for beams with opening sheathed by CFRP
- From the above study CFRP is more efficient and has a higher load carrying capacity compared to GFRP material.
- From the above study, it is observed that beam with rectangular openings have least load carrying capacity
- From the load vs deflection curve, it can be observed that beams sheathed to rounded rectangular with CFRP behave similarly to that of reference or solid beam.

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