RESEARCH ARTICLE OPEN ACCESS

Analytical Study of Strengthening of RCC Beam Openings by BFRP Composites using ABAQUS

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Abstract:

This paper aims to appraise the influence of Basalt Fibre Reinforced Plastic [BFRP] wrapping on the effect of strengthening of openings in RCC beam. Finite element analysis has been used in order to study this problem. Five beams were analyzed using finite element program ABAQUS software. The beams are of span 1000mm and are having rectangular cross section of size 150mm x 250mm. One solid beam is treated as control beam. The rest of the beams were divided into two groups depending upon opening dimensions i.e. single circular opening of diameter 94.40 mm and double circular opening of diameter 66.75 mm. As per SP 34,openings are provided. Each group has two beams with one unstrengthened beam and other beam were wrapped with BFRP. All these beams are simply supported and are analyzed by applying midpoint loading. The load carrying capacity and the deformation of the beams are studied and analyzed in detail. Strengthening of the beam introduced with small sized double opening is found to be more efficient compared to large sized single opening while openings having the same area.

Keywords — BFRP, Strengthening, Load carrying capacity, ABAQUS

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I. INTRODUCTION

Construction of present-day buildings requires many pipes and ducts in order to lodge essential services such as air conditioning, electricity, telephone, fire station and computer network .Usually, these pipes and ducts are placed underneath the soffit of the beam and these are enclosed with suspended ceiling of false ceiling for aesthetic purpose.

This results in the creation of unnecessary dead space because the depth of ducts or pipes may range from few centimetres to may be half a meter. Hence an alternate arrangement has to be made. Web openings in concrete beams enable the installation of these services. Hence this practice of providing web openings in beams for the passage of service ducts and pipes, reduce the dead space. For small buildings, the savings thus accomplished may not be huge, however for multi storey structures, any saving in story height multiplied by the number of stories can speak to a significant saving in total height, length of air-conditioning and electrical ducts, plumbing risers, walls and partition surfaces, and overall load on the foundation.[2]

However, the creation of such openings in RC beams produces discontinuity in the normal flow of stresses which would reduce the beam shear capacity and stiffness. If provision for opening is to be planned during the casting of concrete, then the required stability can be supplemented by using adequate steel reinforcement around the opening. If the openings are needed for the already cast beams, then the Basalt Fibre Reinforced Plastic [BFRP], Carbon Fibre Reinforced Plastic [CFRP], Glass Fibre Reinforced Plastic [GFRP], Aramid Fibre Reinforced Plastic [AFRP] wrapping can be provided along the surface area of the opening which would reduce the stresses along its periphery considerably. But it can be seen that there is not enough study on the influence of BFRP wrapping on the effect of strengthening of openings in RC beam.

II. SPECIMEN DESIGN

Five rectangular beams of size 1000mm x 150mm x 250mm are tested. One solid beam is treated as control beam. The rest of the beams are divided into two groups depending upon opening dimensions i.e. single circular opening of diameter 94.40 mm and double circular opening of diameter 66.75 mm. As per SP 34, openings are provided. Each group has two beams with one unstrengthened beam and other beam are wrapped with BFRP.

TABLE 1
DESIGNATION OF BEAMS

Designation	Description
BOO	Control Beam
BCO1	Concrete beam with single opening
BCO2	Concrete beam with double opening
BFCO1	Concrete beam with single opening strengthened with BFRP
BFCO2	Concrete beam with double opening strengthened with BFRP

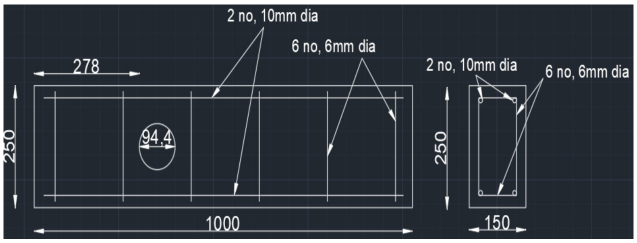


Fig1 Beam with single circular opening

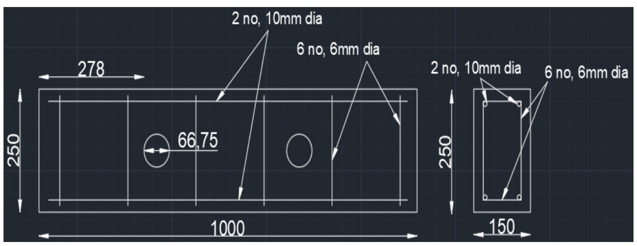


Fig2 Beam with double circular opening

III. FINITE ELEMENT MODEL IN ABAQUS

FEA is a numerical method for solving partial differential equation as well as integral equations generated from complex structure. At present, FEA is a leading method for mechanical, structural, civil, biomedical, and related engineering applications. It is a progressive engineering tool that is used in design as an alternative of experimental testing.

The finite element analysis study includes modelling of a concrete beams as mentioned above. The concrete beam is modelled as it is in experimental work. The developed model and FEA results will be verified with test results conducted by [9].

The RCC beam are modelled according to required dimensions and reinforcements using CATIA Software. The first step in analysis is to import the RCC Beam which is modelled in CATIA, part by part into ABAQUS. The Material properties and Section properties are defined for the beam by referring the literature [9].The Elastic Modulus of Beam are calculated using the characteristic strength of concrete taken from the literature and the density of concrete, Poisson's ratio are entered in the material property section of the ABAQUS software. The modulus of elasticity and density of steel is also defined in the property section.

TABLE 2:
MATERIAL PROPERTIES OF BEAM

Characteristic Strength (N/mm^2)	Elastic Modulus (N/mm^2)	Density (KN/m^3)	Poisson's ratio
30	27386.128	24	0.15

A. Defining the Interaction

To define the Interaction, the constraint has to be created in such a way that the reinforcement setup will be the embedded region and the whole concrete section will be host region, thus creating the Concrete to steel embedded region in the model. Embedment enables one or more elements to be embedded inside a host element. One of the most significant advantages of the embedment technique is the fact it does not require modelling of contact surfaces, and therefore, eliminates the numerically expensive iterations associated with surface formulation.

B. Meshing

Before starting up the meshing the first step is to check out the geometry of the model for free edges, scar lines, duplicate surfaces and intersection of parts. After checking up the geometry the next step in meshing is to choose the type of element which is suitable for the parts to be meshed. The element type selection mainly depends upon the geometry size and shape of the object, type of analysis to be carried out.

In our problem we are choosing the quad and tetra elements for meshing of 3D objects due to fact that tetra and quad elements are best suited for meshing of 3D objects.

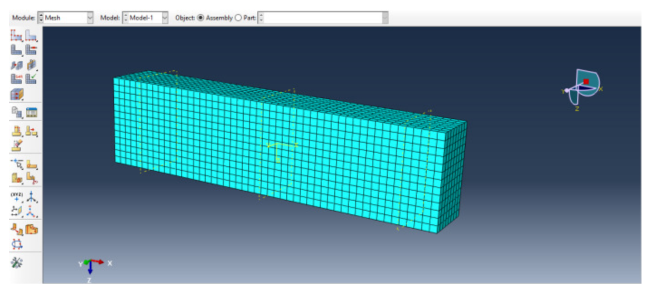


Fig 3 Meshing of Solid concrete beam

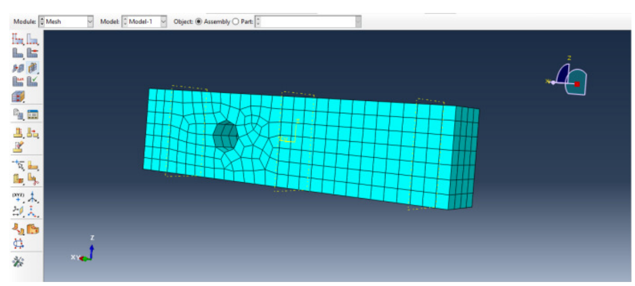


Fig 4 Meshing of Beam with single opening

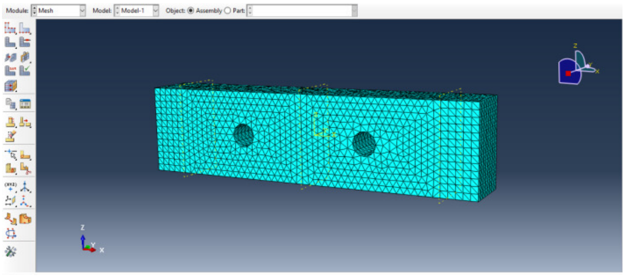


Fig 5 Meshing of Beam with double opening

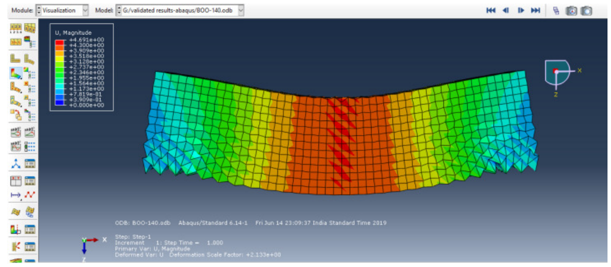


Fig 6 Control Beam Deflection at ultimate load

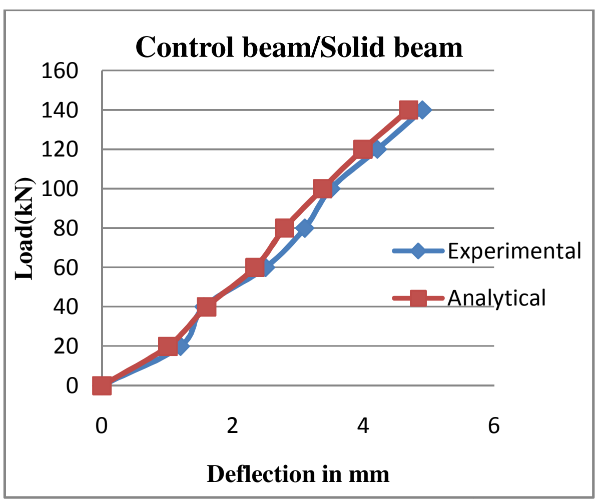
In case of control beam, the Analysis Results from the software underestimates the deflection value by 4.28 % with respect to theoretical deflection results at ultimate loads.

IV. RESULTS AND DISCUSSIONS

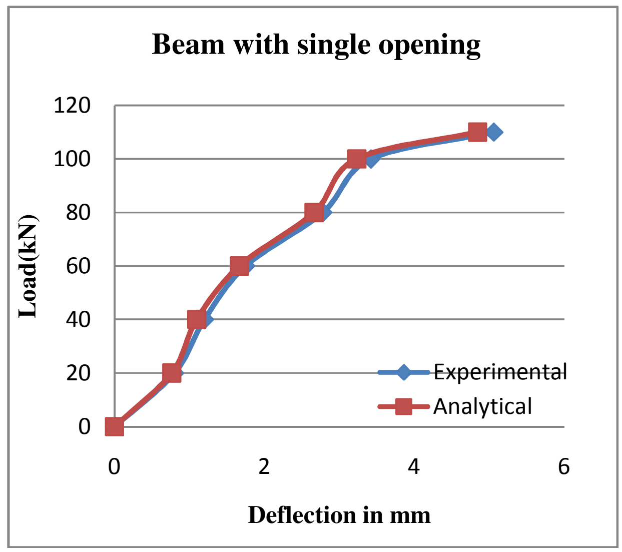
All the beams are loaded upto their ultimate load and deflection. The beam is provided with pinned supports and is subjected to midpoint loading. The deflection at ultimate load is tabulated.

TABLE 3
DEFLECTION RESULTS AT ULTIMATE LOAD

Beam	Ultimate Load(kN)	Deflection in mm	
		Experimental	Analytical
BOO	140	4.90	4.69
BCO1	110	5.06	4.84
BCO2	120	5.86	5.52
BFCO1	120	5.16	4.82
BFCO2	0.13	4.96	4.56



Graph 1 load v/s deflection graph of control beam



Graph 2 load v/s deflection graph of concrete beam with single opening

In case of concrete beam with single opening, the Analysis Results from the software underestimates the deflection value by 4.35% with respect to theoretical deflection results at ultimate loads.

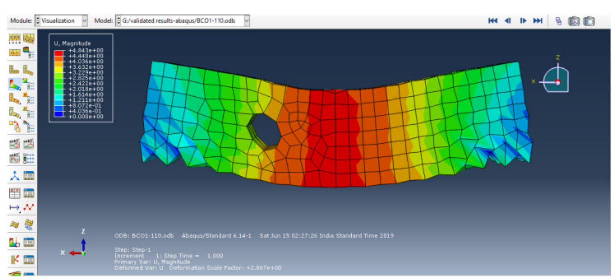
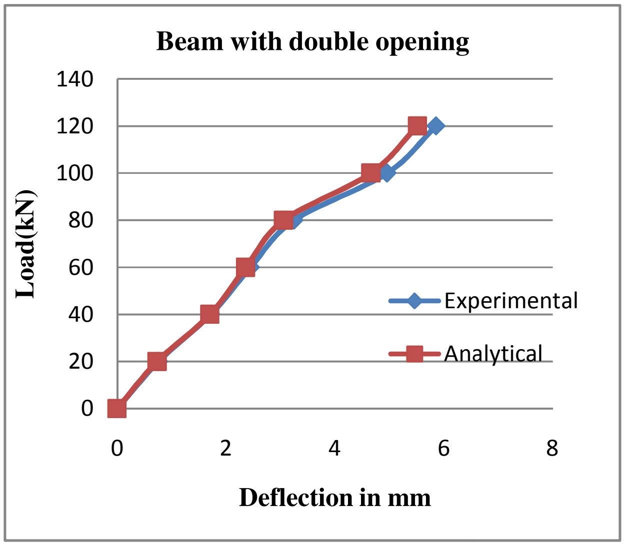


Fig 7 Deflection of concrete beam with single opening at ultimate load



Graph 3 load v/s deflection graph of concrete beam with double opening.

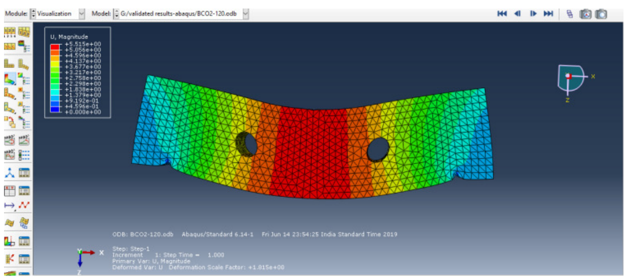
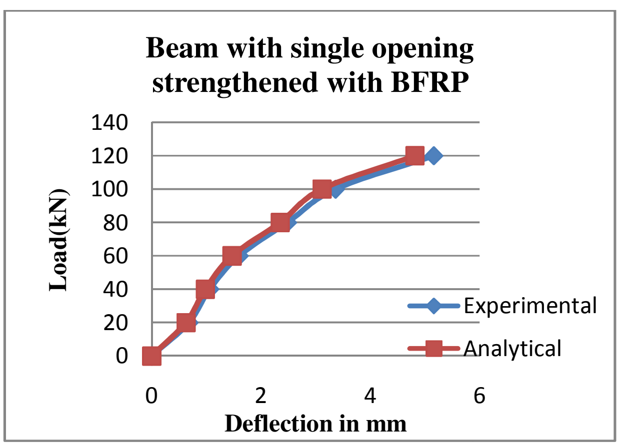


Fig 8 Deflection of concrete beam with double opening at ultimate load

In case of concrete beam with double opening, the Analysis Results from the software underestimates the deflection value by 5.8 % with respect to theoretical deflection results at ultimate loads.



Graph 4 load v/s deflection graph of concrete beam with single opening strengthened with BFRP

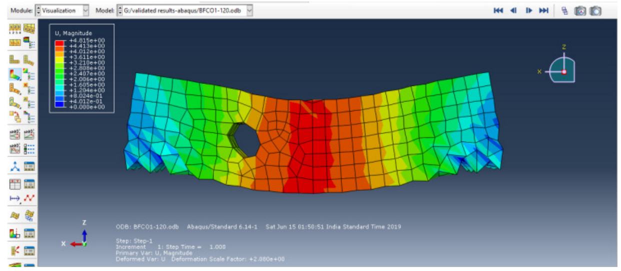
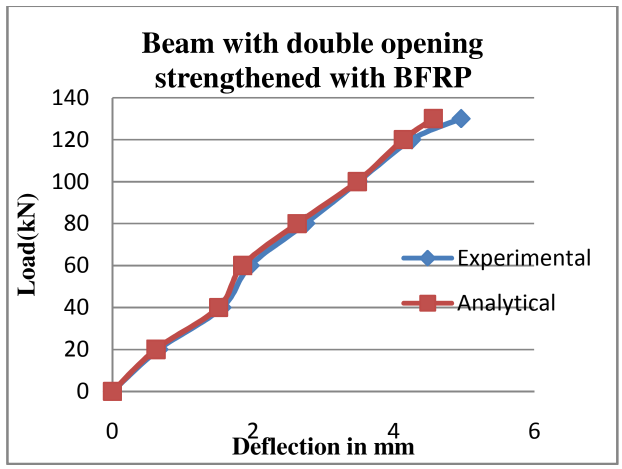


Fig 9 Deflection of concrete beam with single opening strengthened with BFRP at ultimate load

In case of concrete beam with single opening strengthened with BFRP, the Analysis Results from the software underestimates the deflection value by 6.6 % with respect to theoretical deflection results at ultimate loads.



Graph 5 load v/s deflection graph of concrete beam with double opening strengthened with BFRP.

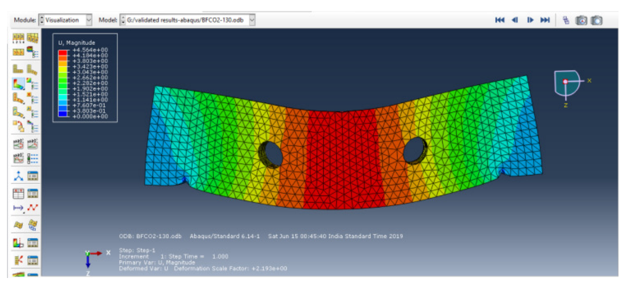


Fig 10 Deflection of concrete beam with double opening strengthened with BFRP at ultimate load

In case of concrete beam with double opening strengthened with BFRP, the Analysis Results from the software underestimates the deflection value by 8.06 % with respect to theoretical deflection results at ultimate loads.

V. CONCLUSIONS

From the obtained analyzed results, the following conclusions were drawn:

1) Load carrying capacity of a beam decreases with inclusion of an opening.
2) The reduction in load carrying capacity of the beam is lesser for the beam introduced with two opening having the same area than the beam introduced with single opening.
3) Wrapping BFRP sheets externally increases the load carrying capacity.
4) The recovery of lost load carrying capacity is higher in strengthened beam BFCO2 than the strengthened beam BFCO1.
5) It can be concluded that strengthening of the beam introduced with small sized double opening is efficient compared to large sized single opening while openings having the same area.
6) The slight deviation of load deflection behaviour produced by the FEA software from the experimental curve is observed. It can be noted that the correlation between experimental results and analytical results are quite good.

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