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Analytical Study on Shear Behaviour of T Beam with Web Openings

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Abstract: Reinforced concrete (RC) T beams with web opening facilitates the services to pass through the building. Due to rapid changes in the beams cross section the edges of the opening can be subjected to high stress concentrations, possibly introducing transverse cracks in the beam as a result. The region nearby the openings are measured as the weaker part of the beam. Therefore, a decline in bearing capability and also a change in the load transport mechanism is experienced. This thesis investigates the analytical study on the influence of various opening shapes with constant area on shear behaviour of RC beams with extra shear reinforcement around the opening. In this thesis nonlinear analysis using ANSYS 18.1 is used to analyze the beam.

Keywords: T beam, opening shape, shear reinforcement, nonlinear analysis

I. INTRODUCTION

Reinforced concrete beams with transverse opening is a facility that allows the services to pass through the building. Usually pipes and ducts are placed underneath the beam soffit which is necessary to accommodate essential services like water supply, sewage, air-conditioning, electricity, telephone, and computer network. Passing these ducts through transverse openings in the floor beams leads to a reduction in the dead space and results in a more compact design. An opening in beam changes their easy behavior to a difficult one and thus causing serviceability problem. Cracks that grow near the opening reduce the load carrying capacity ability of the beams. The opening leads to the disturbances in the continuous flow of stresses and this produces early cracks in the opening region. Hence it is very necessary to learn the result of opening on the beams so that it can be given as structural element without reducing their carrying capacities.

Openings are classified as small or big openings and the best position of the opening is decided based on its size. Web openings have been found to take many shapes such as circular, rectangular, diamond, triangular, trapezoidal and even irregular shapes. However, circular and rectangular openings are the most common ones in practice. With regards to the size of openings, many researchers use the terms ‘‘small’’ and ‘‘large’’ without drawing any clear-cut demarcation line. Small openings are defined as those which are circular, square or nearly square in shape. A circular opening may be considered as large when its diameter exceeds 0.25 times the depth of the web. When the opening is small enough to maintain the beam type behaviour, or in other words, if the usual beam theory applies, then the opening may be termed as small. When beam-type behaviour ceases to exist due to the provision of openings, then the opening may be classified as a large opening. Generally for Small opening, $l_o \leq h_{max}$ and for large opening, $l_o > h_{max}$, h_{max} is the largest of distance from the top of the beam to the opening or distance from the bottom of the beam to the opening.

The presence of web openings increases the cracking and decreases ultimate strength, as well as the stiffness of the beams. Both the shear span to depth ratio and concrete compressive strength of T-beams with openings had a pronounced effect on the load bearing capacity of the tested beams. Both the top chord and bottom chord member independently resisted the shear force of T beams with openings made from high strength concrete. The efficiency of using CFRP and GFRP sheets to control local cracks around openings and to resist excessive shear stresses in the opening. The application of CFRP sheets greatly decreases beam deflection, controls cracks around the opening, and increases the ultimate capacity of the beam. The use of FRP sheets to strengthen the area around openings may retrieve the full capacity of the beam for relatively small openings.

With the intension of determining the effect of opening, researches were done experimentally, numerically and analytically by various researchers. Bengi *et al.*(2014) they have conducted the study on RC beams among and without numerous web opening. The stirrups have significance on the ductility of RC beam with opening, if diagonal reinforcement is not used. It is found that with the same details of reinforcement, RC beam with circular opening have superior load capacities and ductility’s as compared with rectangular openings. Haider (2013) conducted the study on the effects of the opening shape and location on the structural behavior of reinforced concrete deep beam with openings, while keeping the opening size unchanged. It is concluded that the best shape for the opening, in the deep beam considered, is the narrow rectangular one, with the long sides extended in the horizontal direction. However, this shape may not be suitable in some practical cases. The use of circular opening has advantage over using square opening regarding the structural strength of the beam. The best location of the opening, regardless its shape, is far from the arching action and the flexure region, which is near the upper corners of the beam.

II. ANALYTICAL INVESTICATION

A T beam consist of 2.9 m long and contained a central stub to represent the continuous support. The cross section consisted of a 400-mm-deep and 200-mm-wide web and, a 100-mm-thick and 700-mm-wide flange. For symmetry, one opening, 150 mm in diameter, was created on each side at a distance 625 mm from the face of the central. Support of the beam is provided at a distance of 150mm from the end of the beam. A clear cover of 30mm is provided at all the sides. Effective depth of the beam is 363.5mm. Fig. 1 shows the reinforcement details. The modeling and analysis of T beam is carried out in Ansys 18.1. To decrease the time of computation symmetry of the section is selected as the geometry, material property, loading and boundary conditions are symmetric. Fig. 2 shows the finite element model with boundary, loading and reinforcement details along with symmetric section.

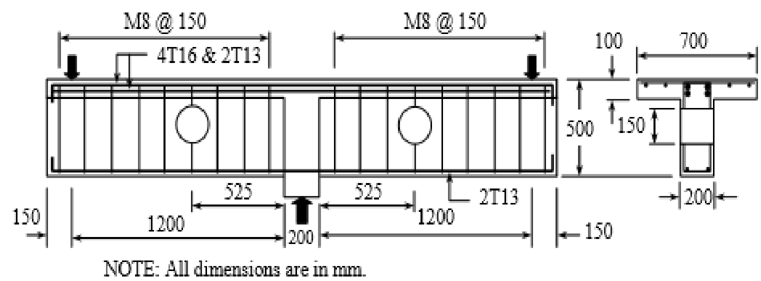

Fig.1 Reinforcement details of beams

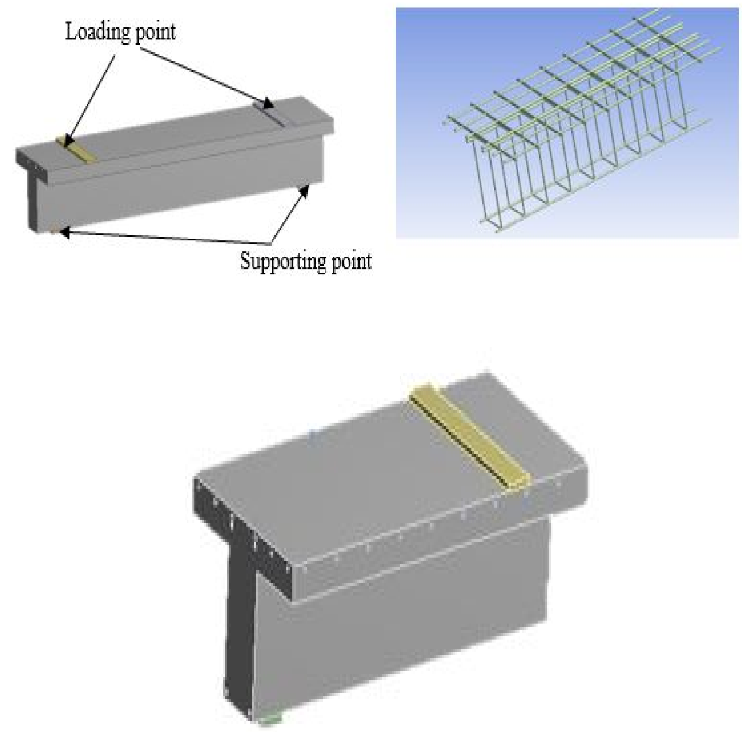

Fig.2 Typical FE model with reinforcement and symmetry

A. Details of the model

A T beam of M30 grade concrete and Fe415 grade steel with a target modulus of 1450MPa is used for the analysis.

TABLE 1
MATERIAL PROPERTIES

	Concrete	Steel	CFRP	GFRP
Modulus of Elasticity (MPa)	27386	$2x10^5$	X=230000	X=21000
			Y=17900	Y=7000
			Z=17900	Z=7000
Poisson’s Ratio	0.2	0.3	υ_{XY}=0.22	υ_{XY}=0.26
			υ_{XZ}=0.22	υ_{XZ}=0.26
			υ_{YZ}=0.30	υ_{YZ}=0.30

III. RESULTS AND DISCUSSIONS

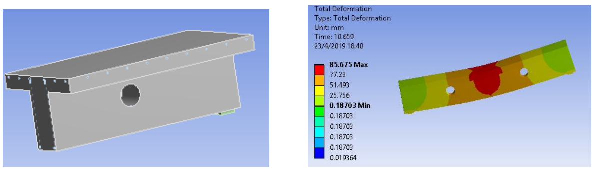

Fig.3 Deformation of beam with circular opening

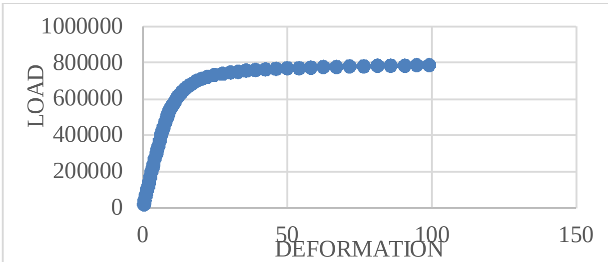

Fig.4 Load v/s Deformation graph for circular opening

Maximum deformation obtained from circular opening is 85.675mm, Reinforcement equivalent stress obtained is 459.95 MPa, and the ultimate load carrying capacity is 783 KN, which is 0.927% less compared to beam without opening.

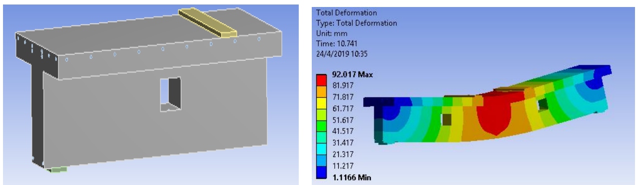

Fig.5 Deformation of beam with square opening

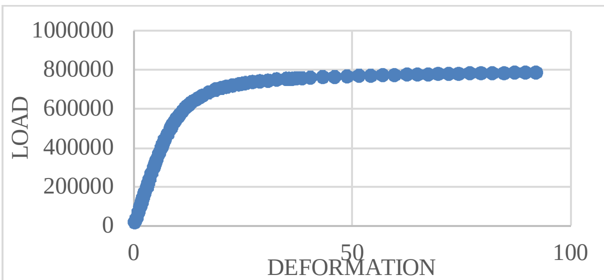

Fig.6 Load v/s Deformation graph for square opening

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Maximum deformation obtained from square opening is 92.017mm, Reinforcement equivalent stress obtained is 452.45 MPa, and the ultimate load carrying capacity is 779.19 KN, which is 1.4% less compared to beam without opening.

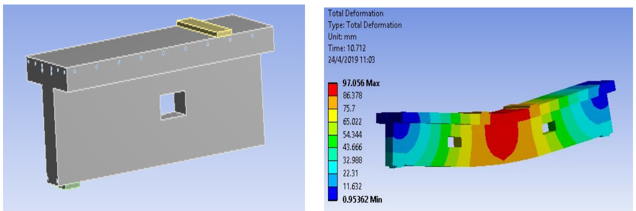

Fig.7 Deformation of beam with rectangular opening

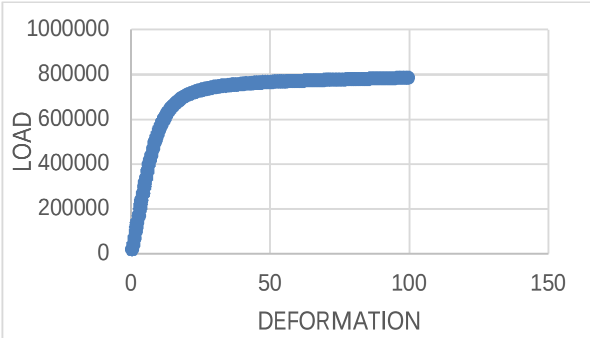

Fig.8 Load v/s Deformation graph for rectangular opening

Maximum deformation obtained from rectangular opening is 97.056mm, Reinforcement equivalent stress obtained is 455.82MPa, and the ultimate load carrying capacity is 774.28 KN, which is 2% less compared to beam without opening.

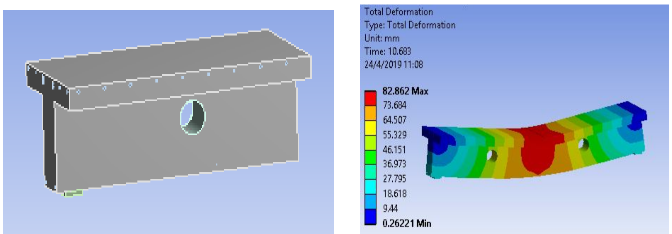

Fig.9 Deformation of circular opening wrapped with CFRP

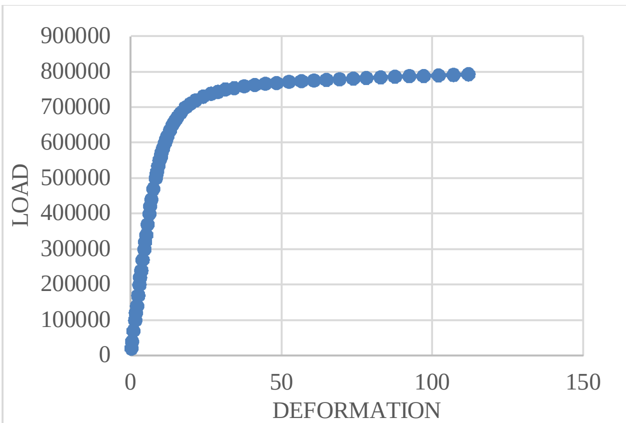

Fig.10 Load v/s Deformation graph circular opening wrapped with CFRP

Maximum deformation obtained from circular opening with CFRP is 82.862mm, Reinforcement equivalent stress obtained is 459.4MPa, and the ultimate load carrying capacity is 788.380 KN, which is 0.68% more compared to beam with circular opening.

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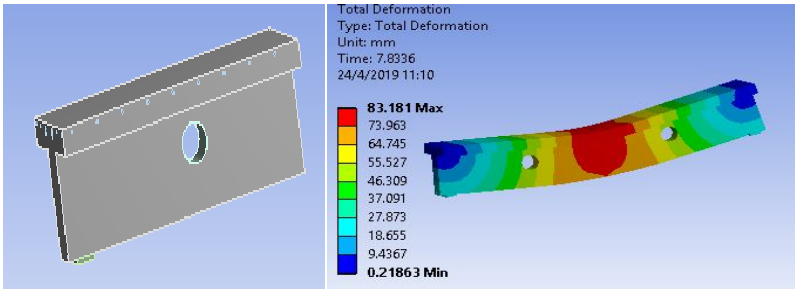

Fig.11 Deformation of circular opening wrapped with GFRP

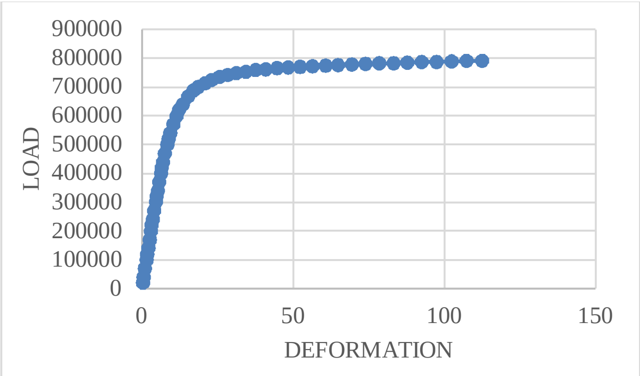

Fig.12 Load v/s Deformation graph circular opening wrapped with GFRP

Maximum deformation obtained from circular opening with GFRP is 83.181mm, Reinforcement equivalent stress obtained is 459.7MPa, and the ultimate load carrying capacity is 787.380 KN, which is 0.57% more compared to beam with circular opening.

TABLE 2
Results Obtained From Analysis

Specimen	Deformation (mm)	Load (kN)
B1	79.454	790.33
B1C	85.675	783
B1S	92.017	779.19
B1R	97.056	774.28
$B1C_{CFRP}$	82.862	788.380
$B1C_{GFRP}$	83.181	787.380

IV. CONCLUSIONS

In this study all the parameters are kept constant except opening shape and strengthening. From this study that the occurrence of opening in the RC beam decreases the failure load compared to the beam without opening.

A. Provision of opening reduces the load carrying capacity of beam by about 0.927% in circular opening, 1.4%, 2% in square and rectangular opening respectively.
B. Beam with circular opening is better than other opening shapes. Stress concentration mainly occurs on corners. Since circular opening have no corners, stress concentrations of such openings are less
C. Beam provided with CFRP and GFRP wrapping in circular opening increases the load carrying capacity to 0.68% and 0.57% respectively.

V. ACKNOWLEDGEMENT

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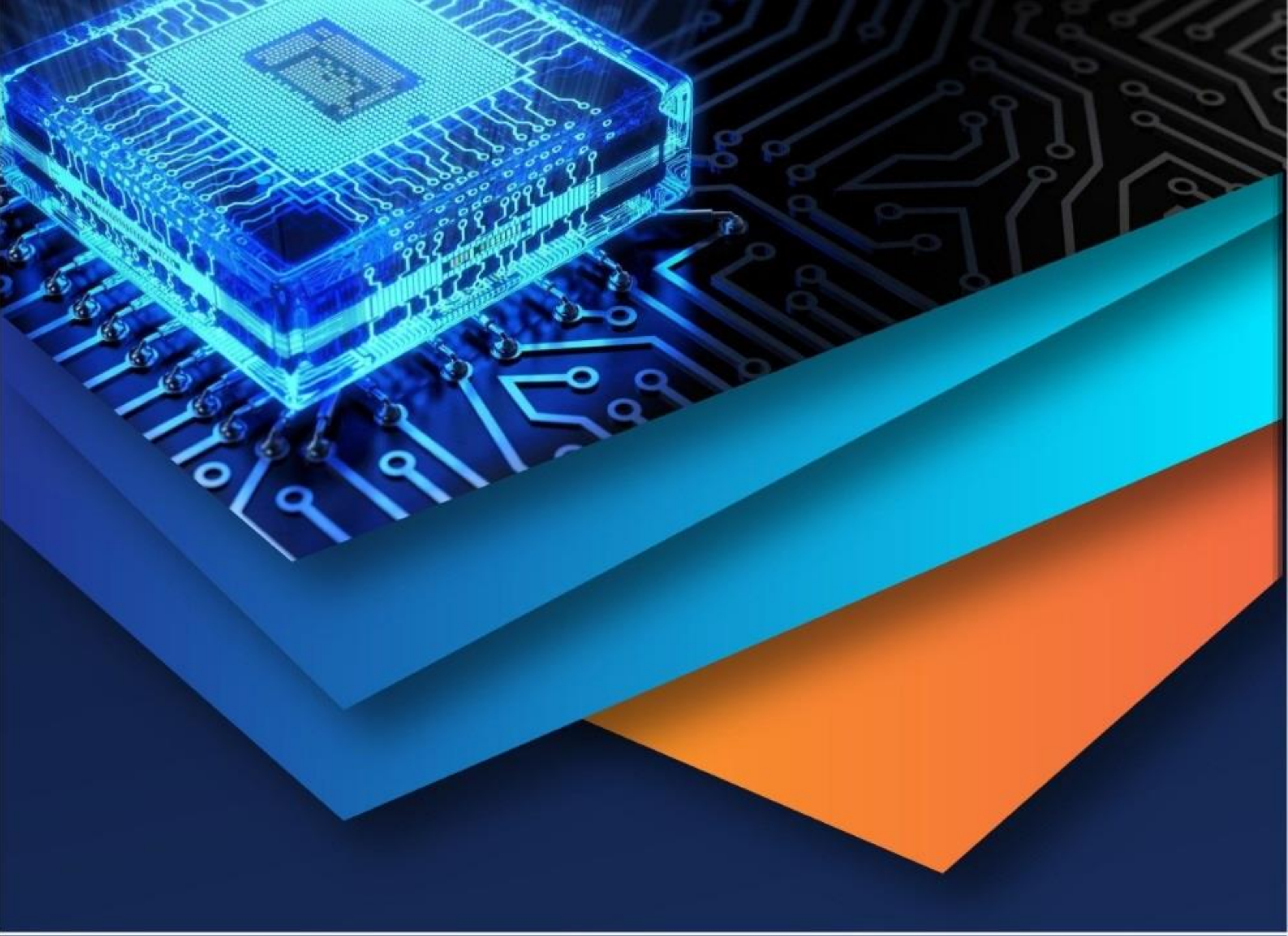

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