Analytical study on the behaviour of RC beams with circular openings in various positions in the shear zone without special reinforcement

[1]Shahana.H, [2]Alfrite.P, [3]J. Sreeram Babu

[1]Pg Student, [2]Assistant Professor, [3]Head of the Department
Department of Civil Engineering
Thanthai Periyar Government Institute of Technology
Vellore, India.

***Abstract*- It is common for reinforced concrete beams to have openings for utility ducts and pipes to pass. Essential services such as water supply, electricity, telephone, and computer network require these ducts and openings. This paper aims to investigate the behaviour of reinforced concrete beams with circular openings with diameters 30% of the overall depth of the beam, provided in the shear zone at various positions 100mm, 250 mm, and 400mm from both ends of beams. A reinforced concrete beam with M25 concrete will be used for this purpose. Under the neutral axis, points will be provided. The beam size is 1300x200x150 mm and the steel is Fe415 steel. The analytical study is performed using finite element analysis, ANSYS. The result shows that the beam with a small opening size of 30% overall depth of the beam behaves similarly to the solid beam. When openings are located towards the end deformation increases. Maximum deformation for the beams was 2.2858mm for the solid beam, 2.3859 mm for the beam with a hollow in the first location, 2.3729 mm, and 2.379mm for other hollow beams. The highest stress distribution was obtained under the supports.**

***Index Terms*- shear zone, small opening, reinforced concrete beam, deformation, Ansys.**

I. INTRODUCTION

Transverse openings in reinforced concrete beams are frequently used in modern building construction for service purposes, such as the passage of utility ducts and pipes. In order to support vital services like the water supply, power, telephone, and computer network, these ducts and holes are required. For aesthetic reasons, these ducts and pipes are typically installed beneath the soffit of the beam and are covered by a suspended ceiling, leaving an empty area. Depending on the quantity and depth of ducts, the height of this dead space on each floor contributes to the building's overall height. Therefore, the web openings permit the designer to reduce the height of the structure, especially with regard to high-rise building construction, thus leading to a highly economical design. Transverse openings cause a sharp change in the cross-sectional size of the beam, which changes the behaviour of a simple beam from simple to more complex. However, as the opening represents a source of weakness, the failure plane always passes through the openings, and stiffness, crack width, ultimate strength, and shear strength may all be negatively impacted. Additionally, the inclusion of openings results in interruptions or alterations in the usual flow of stresses, which causes stress concentration and early cracking in the vicinity of the opening. Comprehension of its structural behaviour is crucial to secure a safe design of the beam. According to the shape, openings can be divided into Circular opening, Square opening, Rectangular opening, and Elliptical opening [5]. But mostly in all cases square and circular openings are used. Among that, a circular opening is more preferable since it doesn't have corners, thus stress concentration around the corners can be eliminated.Openings can be classified in to large and small openings, Beams with opening diameter greater than 44% of the overall depth is considered as large opening, and beams with opening diameter lesser or equal to 44% of the overall depth of the beam is considered as Small openings [8]. If openings are less than one-half the beam depth D, shear failure and reinforcement congestion are likely to occur. In addition, openings should be positioned no closer than 0.5D to concentrated loads. Openings should not extend beyond 50% of the overall depth of the beam [2]. Using multiple openings should require the post separating each opening to be at least 0.5D wide to ensure that each behaves independently.

II. OBJECTIVE AND SCOPE

- This project aims to investigate the effects of various positions of circular openings in reinforced concrete beams in the shear zone with transverse openings below the neutral axis without any special reinforcement.
- To simulate a simply supported concrete beam with an opening diameter of 0.3 overall depth of the beam and conduct numerical testing at various 3 positions in the shear zone and to compare the behaviour with conventional RC beam.

III. GEOMETRY

A beam of size 1300mm X 200mm X 150mm is proposed.

a) DESIGN OF BEAM

For the beam size= (1300 X 150 X 200mm)

Provide 2 no's of 12 mm diameter bar as Main bar / bottom bar and 2 no's of 10 mm bars as top bars and 8 mm diameter stirups at 150 mm spacing & 175 mm spacing.

b) DEPTH OF NEUTRAL AXIS

(Xu) max = 0.48d = 0.48 x 175 = 84mm
Clear cover= 25mm
Depth of neutral axis = (0.87 x fy x Ast) /(0.36 x fck x b)
= (0.87 x 415 x 226) / (0.36 x 25 x 150)= 61mm

IV. LOCATION OF OPENING

Hence circular opening is provided below the neutral axis depth of 65mm from the top of the beam at 3 different position at shear zone. Openings are located at 100 mm, 250mm, 400mm from both ends of the beam.

a) SHEAR ZONE

The shear zone or shear span can be defined as it is the span between the points of application of concentrated load to its adjacent reaction force in a beam

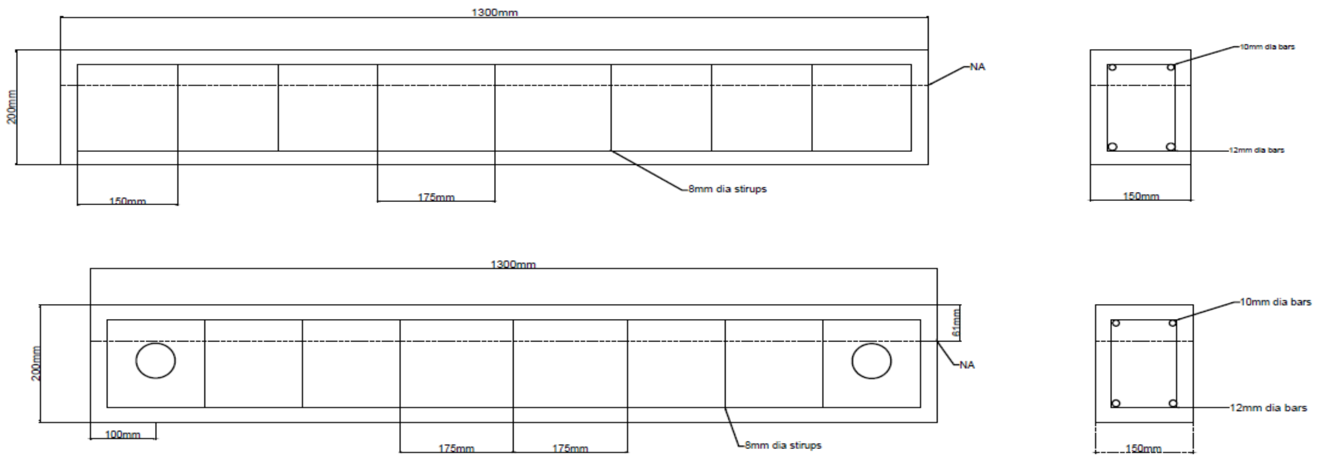

Fig.2 Longitudinal section of the beam with the first opening

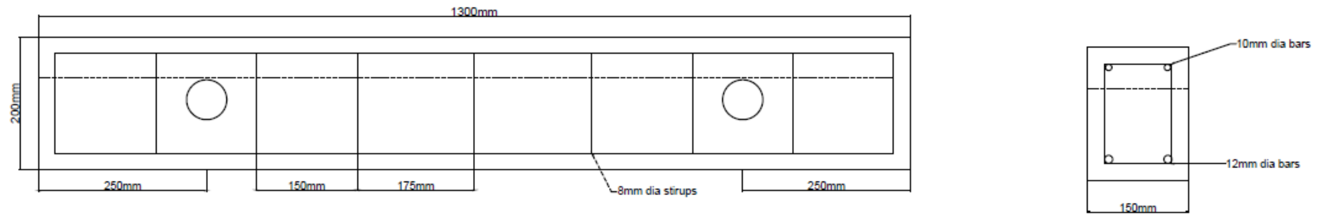

Fig.3 Longitudinal section of the beam with the second opening

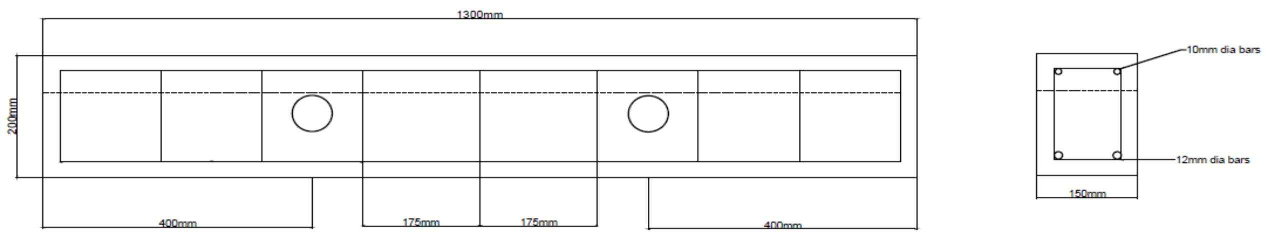

Fig.4 Longitudinal section of the beam with the third opening

V. FINITE ELEMENT ANALYSIS

- Finite element analysis (FEA) simulates the behavior of a part or assembly under given conditions so that it can be assessed using the finite element method (FEM). Engineers use FEA to simulate physical phenomena and reduce the need for physical prototypes, as well as to optimize components during the design process.
- Mathematical models are used to simulate and quantify the effects of real-world conditions on parts and assemblies. Through the use of specialized software, engineers can identify potential problems within a design, such as tension areas and weak points.

- Using mathematical methods, it is possible to understand and quantify the behavior of fluids and structures, as well as waves and thermal transport.

a) ANSYS SOFTWARE

In ANSYS, all disciplines of physics are simulated, including structural, vibration, fluid dynamics, heat transfer, and electromagnetic interactions.. Testing prototypes in virtual environments is made possible with ANSYS by simulating tests or working conditions. Moreover, 3D simulations in the virtual environment for determining weak points, improving computing life, as well as predicting probable problems are possible. ANSYS software with its modular structure gives the chance to use only the features necessary. By adding CAD and FEA connection modules, ANSYS software can be integrated with other engineering software. It is generally possible to break finite element solutions into three stages.

1. Pre-processing: defining the problem; the major steps in pre-processing are

a) Define Key-points/lines/areas/volumes
b) Define element type and material/geometric properties
c) Mesh lines/areas/volumes as required

The amount of detail required will depend on the dimensionality of the analysis (i.e. 1D, 2D, axisymmetric, 3D).

2 .Solution: Setting loads, constraints, and solving; here the loads are specified (pressure or point), constraints are specified (translations and rotations), and the equations are solved.

3. Post processing: This stage may include the following: Further processing and viewing of the results.

a) Nodal displacements listed
b) A description of the forces and moments of an element
c) A plot of deflection
d) Contour diagram showing stress

VI. MATERIAL PROPERTIES

a) Concrete

For modeling M25 grade of concrete is used. The modulus of elasticity or Young's modulus of concrete is 25000 Mpa, poisons ratio is assumed 0.12.

b) Steel

For modelling 4 main reinforcement bars are used in each beam, 2 at the tension side and 2 at the compression side, Length will be 1250 mm, providing a 25mm cover at both ends. The bottom bar diameter will be 12mm and the top bar diameter 10mm.The steel of grade fe415 is used.

c) Stirrups / Link bars

Stirrups are with dimensions 100 x 150mm, providing a 25mm cover to the sides around the stirrups. No of stirrups in each beam is 9. The diameter of the stirrups is 8mm.

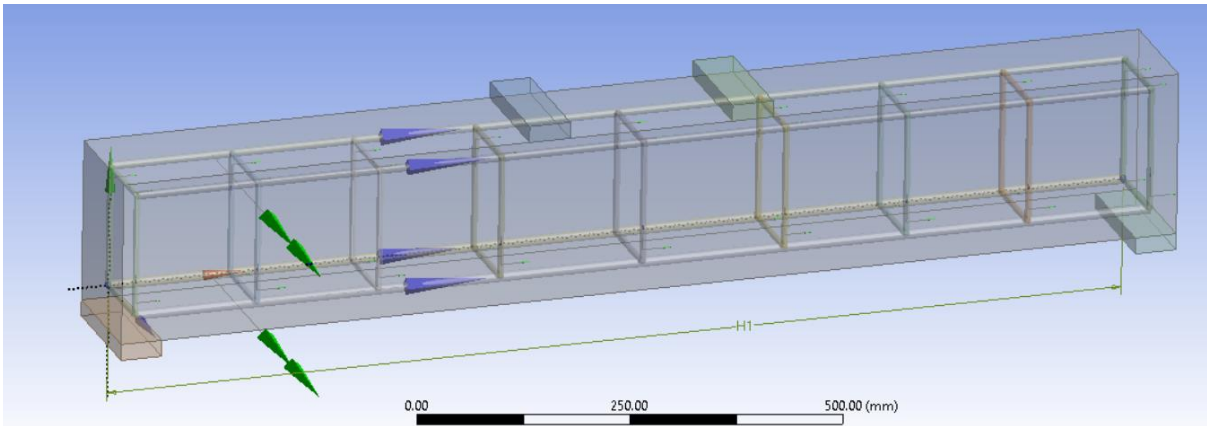

Fig.5 Reinforcement details of beam

VII. BOUNDARY CONDITION

Simply supported support condition is provided.

a) SIMPLY SUPPORTED BEAMS

A simply supported beam is a beam structure that is simply placed over the supports at its two ends. It is also called a freely supported beam and holds the simplest arrangement compared to all other beam support arrangements.

Loading is 2 pointed loading with a distance of 300mm between them, load is provided with an increment of 10KN up to 100kN.

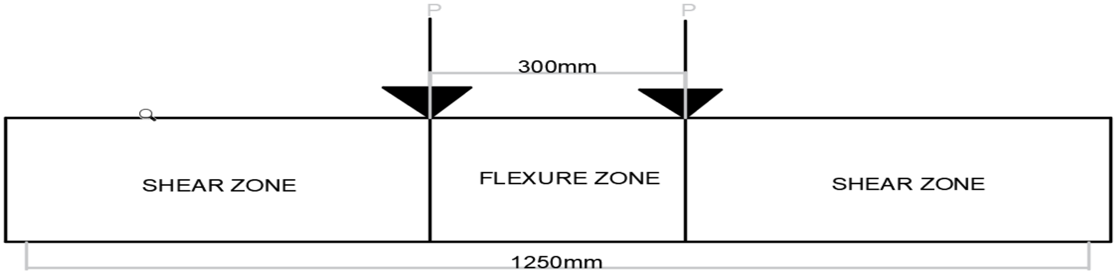

Fig. 6 Loading conditions

VIII. Meshing

In this research, mesh density for rectangular concrete beams is of size 20mm.

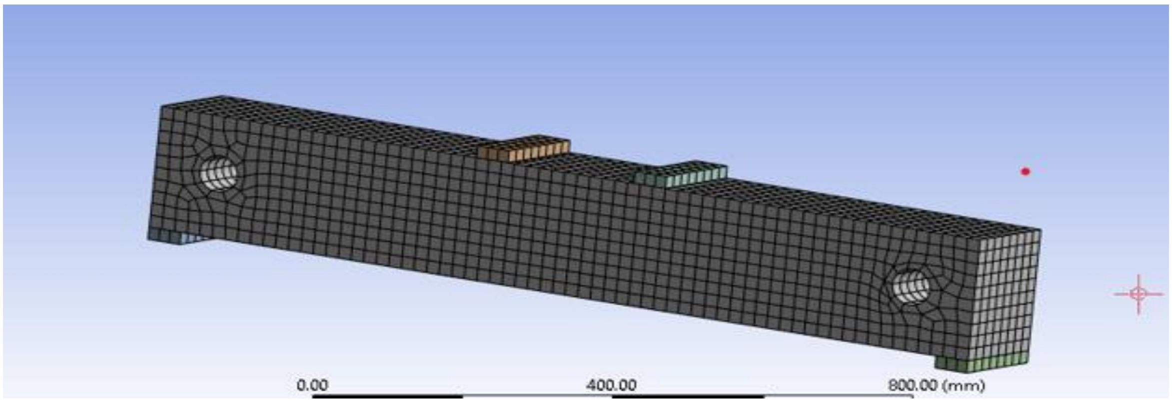

Fig.7 Mesh

IX. RESULTS & DISCUSSION

Table. 1 Result of maximum deformation and maximum stress

	Maximum deformation(mm)	Maximum stress(Mpa)
Beam without opening	2.3858	227.52
Beam with opening location 1	2.3859	227.11
Beam with opening location 2	2.3729	225.52
Beam with opening location 3	2.379	225.39

a) Total deformation

Figure 8 & 9 shows the total deformation of the solid and hollow beams. The maximum deformation for a solid beam is 2.3858mm, In hollow beams maximum deformation was shown by the beam with an opening location 100mm from the ends of the supports. The highest deformation was developed near the center of the beam under loading points.

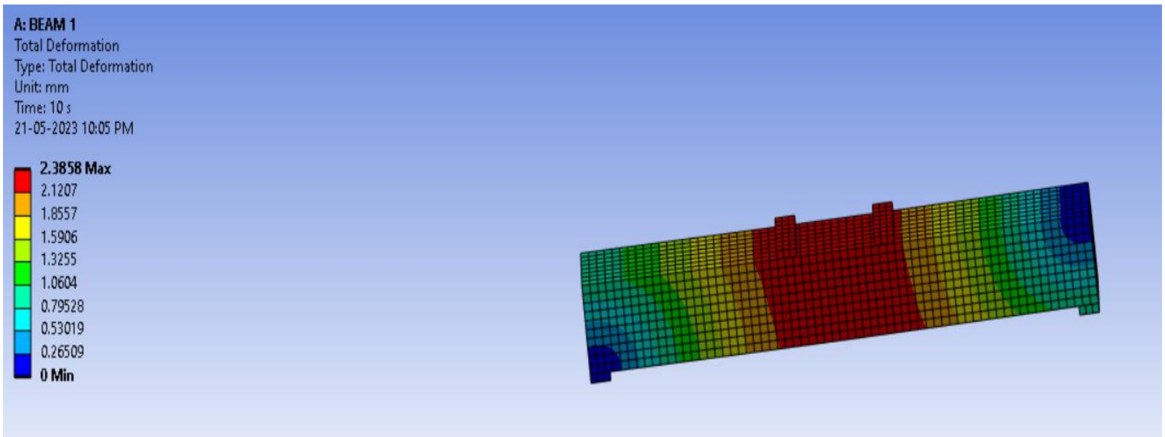

Fig.8 Deformation of controlled beam

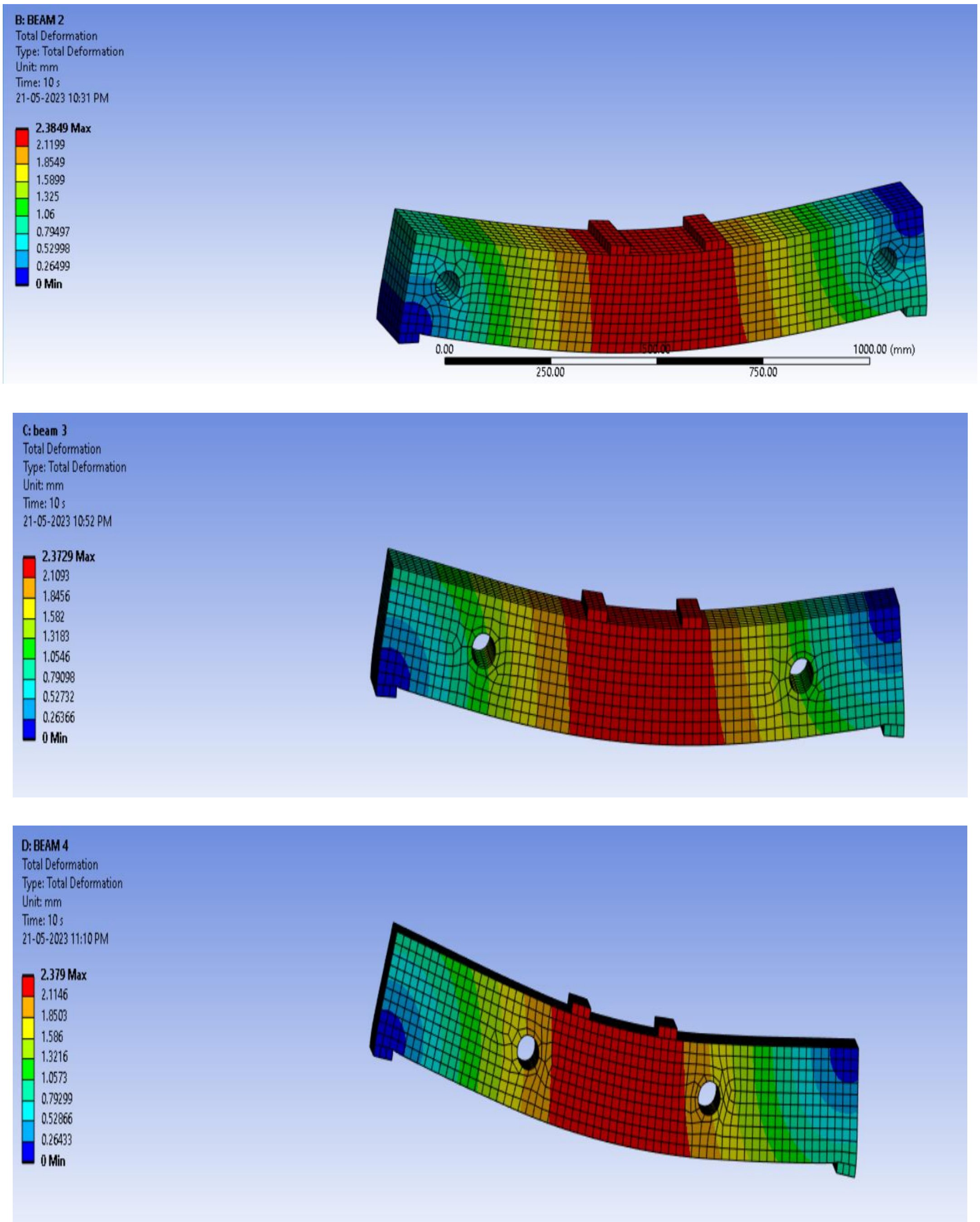

Fig.9 Deformation of hollow beams

b) Equivalent Stress.

Figure 10 & 11 shows the stress development of the solid and hollow beams. It was observed that the highest stress distribution was under support.

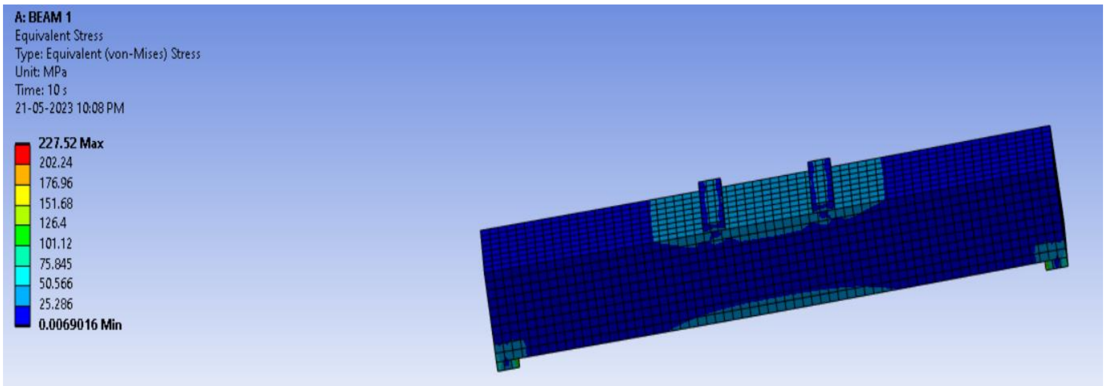

Fig.10 stress in controlled beam

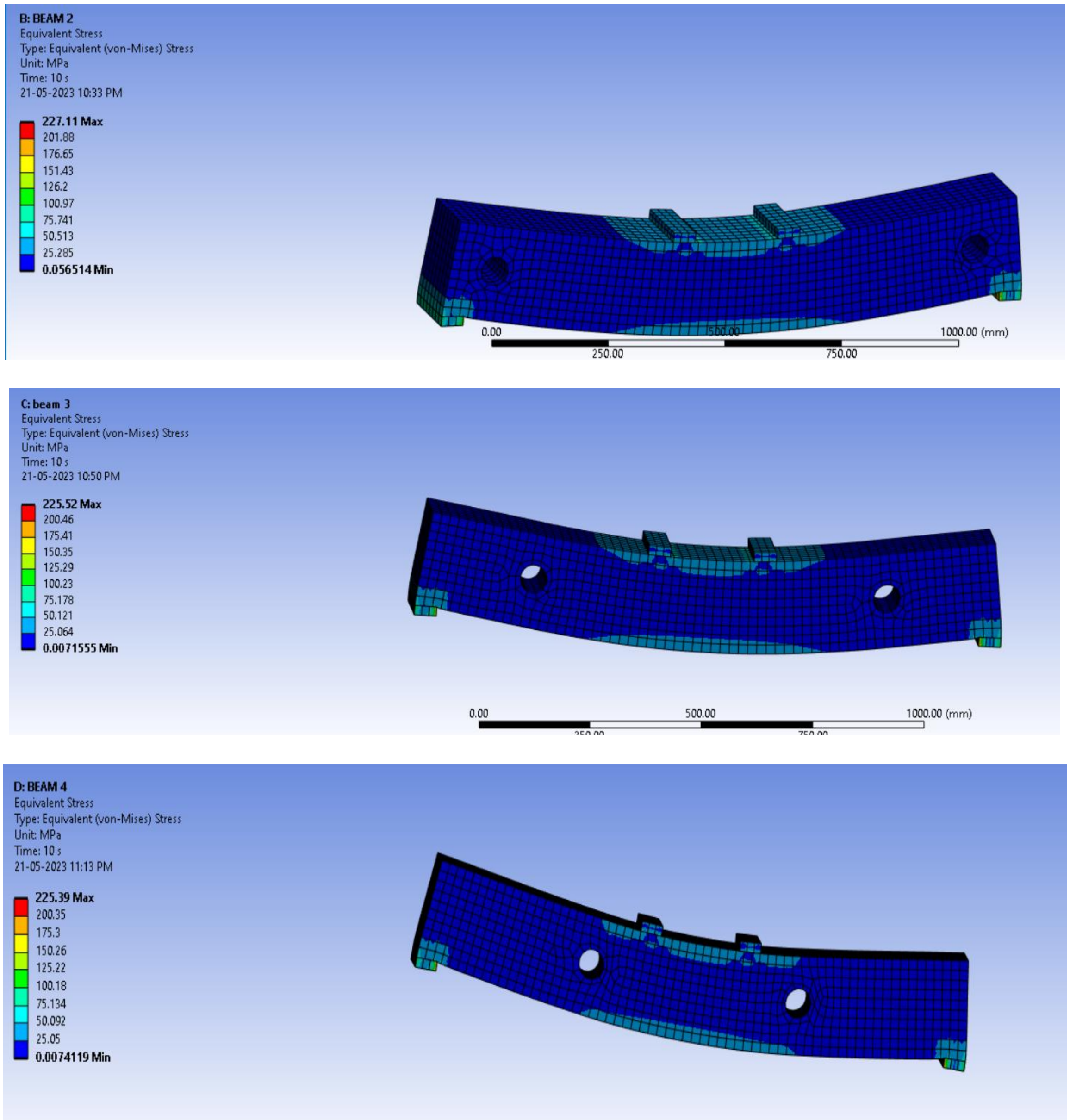

Fig.11 stress in hollow beams

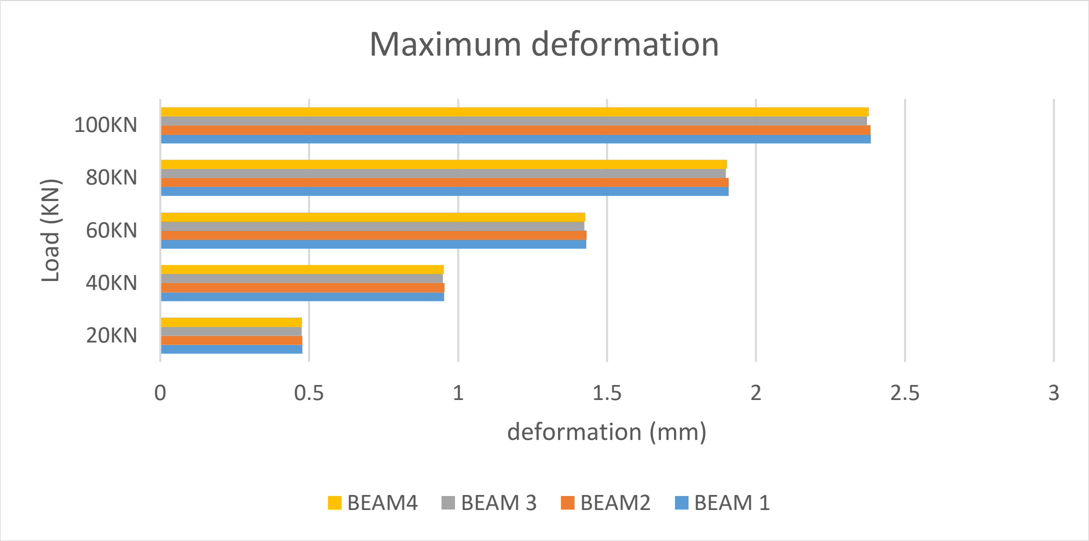

Fig.12 Maximum deformation

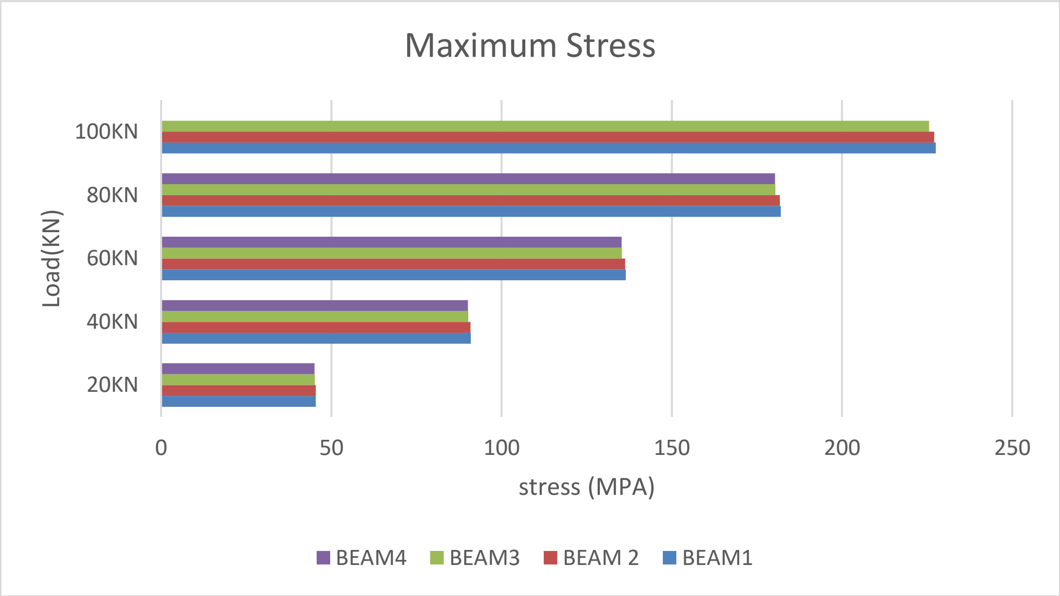

Fig.13 Maximum stress

X. CONCLUSION:

The aim of the study was to investigate the structural behaviour of the reinforced concrete beams with circular openings in the shear zone with various positions using Ansys software. It may conclude that

- From this study it was concluded that a beam with a small opening size of 30% overall depth of the beam behaves similarly to a solid beam.
- High deformation was obtained near the loading points.
- When openings are located towards the end deformation increases.
- Maximum deformation for the beams was 2.2858mm for a solid beam, 2.3859 mm for a beam with a hollow in the first location, 2.3729mm, and 2.379mm for other hollow beams.
- Highest stress distribution was obtained under the supports.

REFERENCES

[1] J. H. Ling1, H. S. Tang, W.K Leong, H.T Sia "Behaviour of Reinforced Concrete Beams with Circular Transverse Openings under Static Loads**",** Journal Of Science And Applied Engineering (Jsae), May 2020, Vol 3 (1), 1-16

[2] D Pertiwi, I Komara ,I Komara, R Fristaian "Design concept of reinforced concrete beams with large web openings", ICATECH 2020 ,IOP Conf. Series: Materials Science and Engineering

[3] Ceyhun Aksoylu , "Experimental analysis of reinforced concrete shear deficient beams with circular web openings strengthened by CFRP composites",2020

[4] Renjini Raj V.R, Manasa M.S "Numerical analysis of rc beams with openings strengthened using cfrp under impact loading", International Research Journal of Engineering and Technology (IRJET) Volume: 05 Issue: 05 | May-2018

[5] Swathy S Pillai ,Alice Johny "Analytical Study on Shear Behavior of Reinforced Concrete Beam with Varying Shapes of Web Opening, International Journal of Engineering Research & Technology (IJERT) 2018
[6] Lalramnghaki Hauhnar ,R.Rajkumar ,N.Umamaheswari "Behaviour of reinforced concrete Beams with circular opening in the Flexural zone strengthened by steel Pipes", International Journal of Civil Engineering and Technology (IJCIET)Volume 8, Issue 5, May 2017
[7] Ali Shubbar, Hasanain Alwan ,Ee Yu Phur, John McLoughlin,Ameer Al-khaykan "Studying the Structural Behaviour of RC Beams with Circular Openings of Different Sizes and Locations Using FE Method", 2017
[8] Rezwana Binte Hafiz , Shaibal Ahmed, Saikat Barua,Sharmin Reza Chowdary "Effects of Opening on the Behaviour of Reinforced Concrete Beam .IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), Volume 11, Issue 2 (Mar-Apr. 2014)
[9] Bengi Aykac, Ilker Kalkan, Sabahattin Aykac, Yusuf Emre Egriboz "Flexural behaviour of RC beams with regular square or circular web openings", Engineering Structures 56 (2013) 2165–2174 ,2013
[10] Hawraz Karim M. Amin ,V.C Agarwal , Omar Q.Aziz "Effect of Opening Size and Location on the Shear Strength Behavior of R.C Deep Beams without Web Reinforcement" International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075 (Online), Volume-3 Issue-7, December 2013.
[11] Soroush Amiri, Reza Masoudnia, Mohammad Amin Ameri "A review of design specifications of opening in the web For simply supported RC beams" Journal of Civil Engineering and Construction Technology Vol. 2(4), pp. 82-89, April 2011
[12] Soroush Amiri , Reza Masoudnia, Ali Akbar Pabarja "The study of the effects of web openings on the concrete beams", 2011
[13] Ahmed M. Sayed "Numerical study using FE simulation on rectangular RC beams with vertical circular web openings in the shear zones", 2019
[14] Ali Hassan, Ahmed. M. Atta, Tarek F. El- Shafiey "Restoration of the shear capacity for RC beams with web openings using precast SHCC plates", 2020