iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** X **Month of publication:** October 2025

DOI: https://doi.org/10.22214/ijraset.2025.74638

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue X Oct 2025- Available at www.ijraset.com

An Experimental and Numerical Investigation on Performance of Steel Beams with Circular Web Openings

Chandana R[1], Chidananda G[2]
[1]*Student, M Tech. in Structural Engineering, Department of Civil Engineering, Bapuji Institute of Engineering and Technology, Davanagere-577004, Karnataka*
[2]*Professor, Department of Civil Engineering, Bapuji Institute of Engineering and Technology, Davanagere-577004, Karnataka*

Abstract: ***In the present study, experimental and numerical investigation is carried out to study the effect of diameter of circular openings on the performance of steel beams. Steel I section ISMB150 @ 14.9 kg/m, of 900 mm overall span and 800 mm effective span is chosen for the experimental and numerical investigation with a simple support condition at both the ends. Performance of ISMB 150 section without and with circular web openings of diameter 50 mm, 75 mm and 100 mm is studied in the present investigation.***
Experimental analysis is performed by subjecting the steel sections to mid-point loading in Universal Testing Machine (UTM). Whereas numerical analysis is performed for the steel sections using ANSYS FEM software. ANSYS FEM software predicts the similar variation of load-deflection curves for as that of experimental results for all the steel beams. From both experimental and numerical investigation, solid beam without web opening takes more load and deflects less as compared to steel beams with circular web openings. Further, as diameter of circular opening increases, load carrying capacity decreases and deflection at mid-span increases.
Keywords: Steel beam with web openings; Circular openings; Experimental investigation; Numerical investigation; ANSYS.

I. INTRODUCTION

Steel structures are a popular choice in modern construction due to their strength, durability and adaptability. They support heavy loads and span wide areas efficiently. With a high strength-to-weight ratio, steel is ideal for high-rise buildings, bridges, industrial facilities and large-span roofs. These structures are often prefabricated allowing quicker on-site assembly and reduced construction time. Steel's ductility also enhances its performance under seismic and wind forces. Figure 1 shows a typical industrial steel structure. A structural engineer's responsibility goes beyond simply designing for safety and serviceability to accommodate the functional needs based on the structure's intended use. In facilities like power plants or multi-story buildings, traditional steel frames with solid-web beams and girders often create obstacles for installing necessary services such as pipelines and heating, ventilation and air conditioning (HVAC) ducts.

Since service installations typically occur after the structural framework is completed, service engineers may struggle to fit ducts into the limited available space. This often results in costly solutions like rerouting services or increasing floor heights during the design phase which may not be practical. To address this, the steel beams with openings in the web (Fig. 1.2) has become an effective and accepted engineering practice. Design of steel beams with openings in the web is critical as stress distribution and failure mechanism changes with web openings.

Following are the conditions for web openings as per INSDAG (Institute for Steel Development and Growth) guidelines.

1) The opening should be at the center of the web and eccentric placement should be avoided.
2) Web openings should be positioned at a minimum distance of either twice the beam depth or 10% of the span length from the support.
3) The most suitable position for a web opening is within the middle one-third of the beam's span.
4) Minimum clear spacing between the openings should be equal to the beam's depth.
5) The point of lowest shear force is the ideal position for an opening.
6) Diameter of circular opening should not be more than 0.5 times the beam's depth.

©IJRASET: All Rights are Reserved

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue X Oct 2025- Available at www.ijraset.com



Fig. 1: Industrial Steel Structure



Fig. 2: Typical Steel Beams with Openings in the Web

II. ANSYS

ANSYS software is a widely used FEA (Finite Element Analysis) package to evaluate the behaviour of structures and components under various loads and conditions. Engineers use ANSYS to analyze static and dynamic responses, thermal effects, fatigue life and failure modes in structures such as beams, frames, shells and complex assemblies. This reduces the necessity for physical testing and prototyping, thereby enhancing the performance and assuring safety by optimizing the designs.

III. EXPERIMENTAL INVESTIGATION

In the present study, steel I section ISMB150 @ 14.9 kg/m [as per SP6 (Part 1:1964)], of 900 mm overall span and 800 mm effective span is chosen for the experimental and numerical investigation. Salient features of solid steel beam and steel beams with circular opening are listed in Table 1 and also in Figs. 3 to 6

Table 1: Geometric Properties of ISMB 150 Steel Beams

Beam Identity	**Description**
SB150	Solid steel beam (i.e. steel beam without web opening)
SB150C50-4H	Steel beam with 4 circular holes of 50 mm diameter at 150 mm c/c and at a clear spacing of 100 mm
SB150C75-4H	Steel beam with 4 circular holes of 75 mm diameter at 150 mm c/c and at a clear spacing of 75 mm
SB150C100-4H	Steel beam with 4 circular holes of 100 mm diameter at 150 mm c/c and at a clear spacing of 50 mm

©IJRASET: All Rights are Reserved | SJ Impact Factor 7.538 | ISRA Journal Impact Factor 7.894 |

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue X Oct 2025- Available at www.ijraset.com

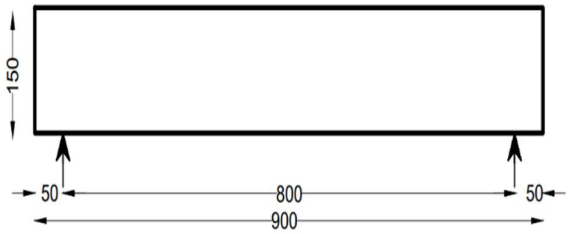


Fig.3: Dimension of SB150

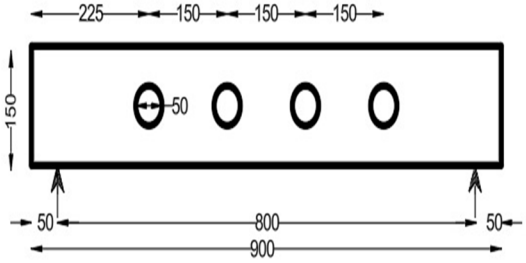


Fig. 4: Dimension of SB150C50-4H

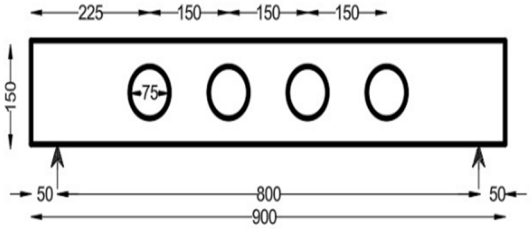


Fig. 5: Dimension of SB150C75-4H

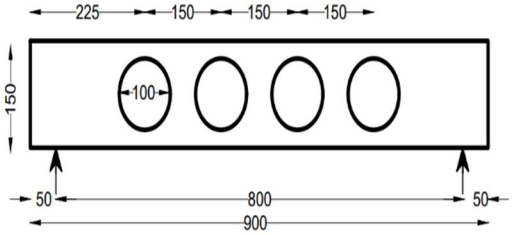


Fig. 6: Dimension of SB150C100-4H

Steel beams are subjected to three-point loading in Universal Testing Machine (UTM) of 1,000 kN capacity. Deflection at the center of the beam is measured using Linear Variable Displacement Transducer (LVDT). Beams are simply supported over roller supports / roller bearings. Figures 7 to 10 respectively show the arrangements made in UTM for the experimental analysis.



Fig. 7: Experimental Setup of SB150



Fig. 8: Experimental Setup of SB150C50-4H



Fig. 9: Experimental Setup of SB150C75-4H



Fig. 10: Experimental Setup of SB150C100-4H

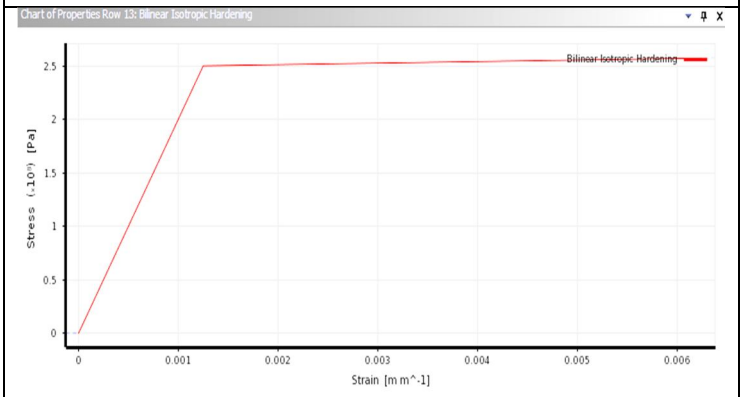
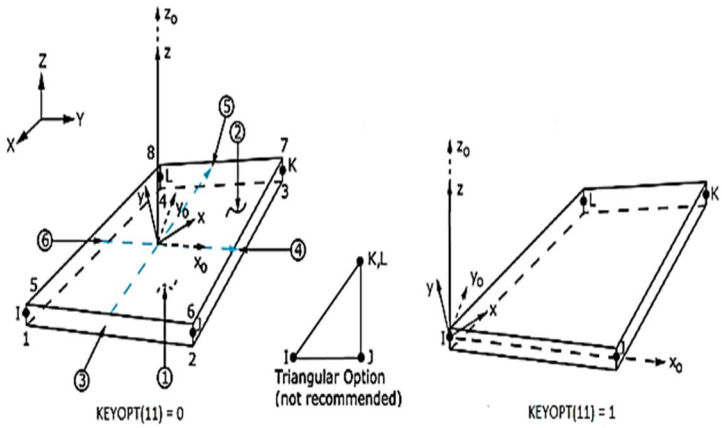
©IJRASET: All Rights are Reserved

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue X Oct 2025- Available at www.ijraset.com

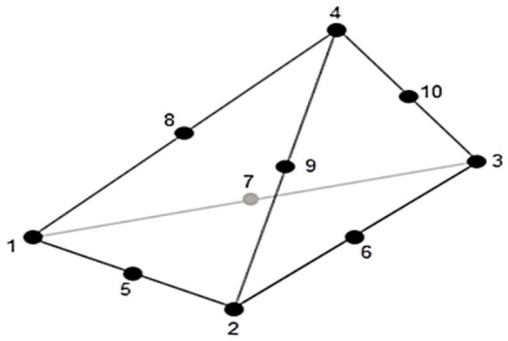
IV. NUMERICAL INVESTIGATION

3D models are developed using ANSYS FEM software to simulate the behaviour of steel beams. Table 2 shows the parameters considered in modelling and analysis of steel beams in ANSYS.

Table 2: Parameters Considered for FEM Analysis in ANSYS

Sl. No.	Parameter	Description
1	Material	Steel
2	Density	7850 kg/m^3
3	Yield strength (f_y)	250 MPa
4	Ultimate strength (f_u)	410 MPa
5	Modulus of elasticity (E_s)	210 GPa
6	Poisons ratio (μ)	0.3
7	Stress strain relationship	Bi-linear 
8	Mesh element	Shell 181 element (8 Noded brick elements for solid steel beam)  Solid 187 (4 noded tetrahedron elements for steel beams with circular web openings)

©IJRASET: All Rights are Reserved

Sl. No.	Parameter	Description
		
9	Boundary condition	Simple vertical support Left end, $U_x=U_y=U_z=0$, $\theta_{y=}\ \theta_{z=0}$ Right end, $U_x=U_y=U_z=0$, $\theta_{y=}\ \theta_{z=0}$
10	Loading pattern	Mid-point loading and deflection measurement at the bottom of mid-span

Figures 11 to 17 shows the meshing, support conditions and mid-point loading of steel beams.

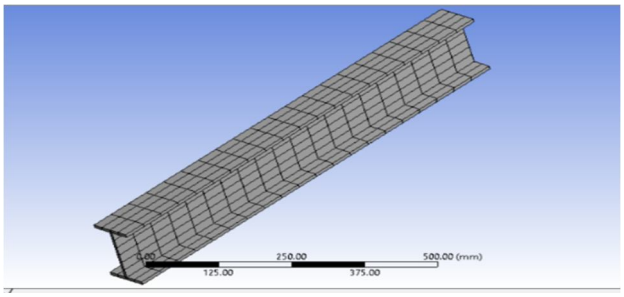


Fig. 11: FE Discretization of SB150

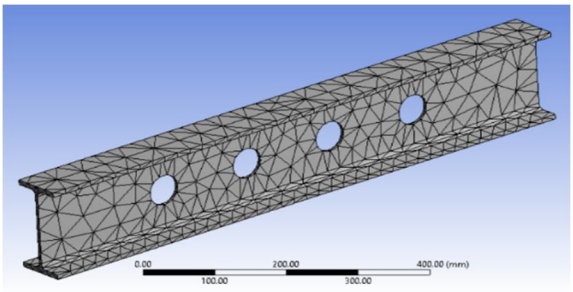


Fig. 12: FE Discretization of SB150C50-4H

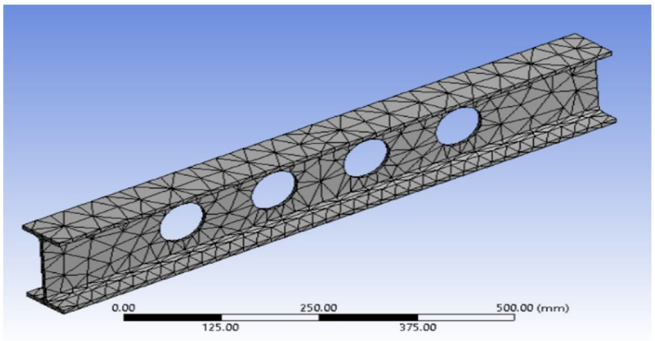


Fig. 13: FE Discretization of SB150C75-4H

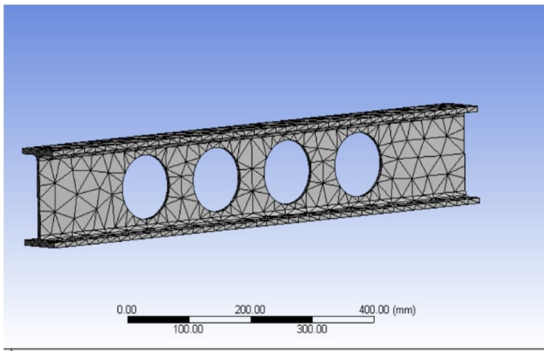


Fig. 14: FE Discretization of SB150C100-4H

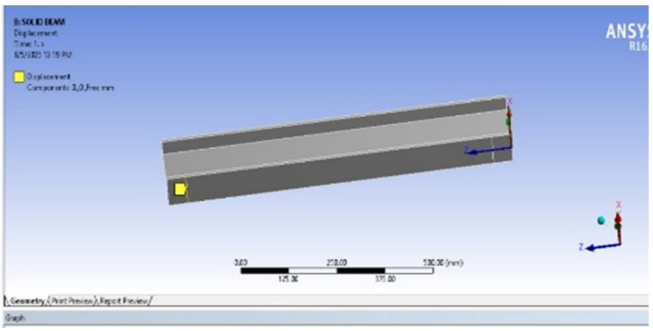


Fig. 15: Boundary Condition at Left Support

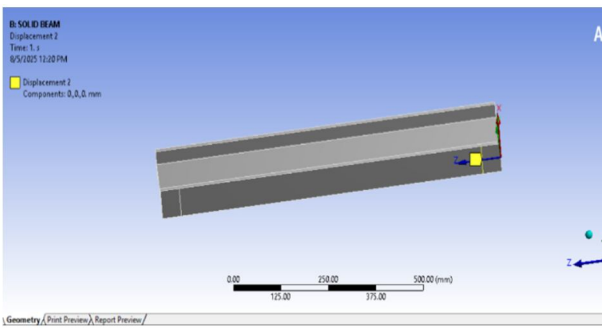


Fig. 16: Boundary Condition at Right Support

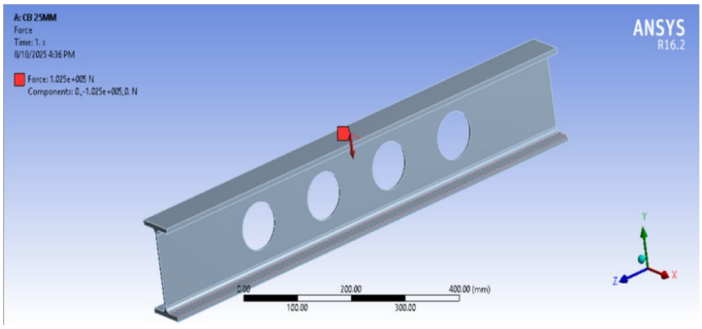


Fig. 17: Mid-point Loading on the Beam

V. RESULTS AND DISCUSSION

Figure 18 shows the combined experimental load-deflection (P-Δ) curve obtained for the steel beams without and with circular openings tested in UTM

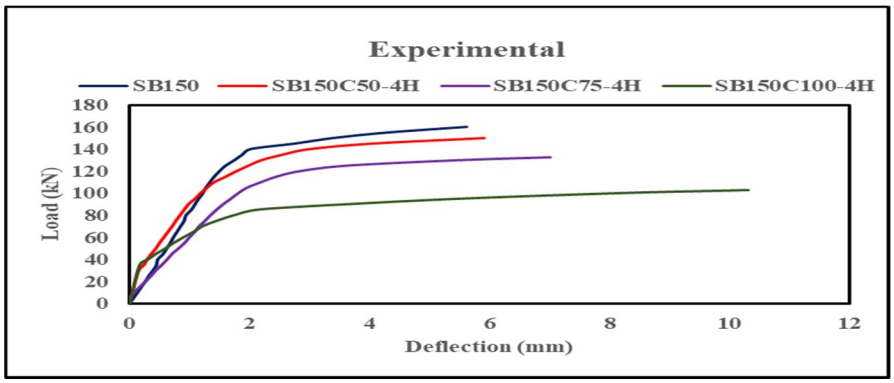


Fig. 18: Comparison of Experimental Load-Deflection Curves of Steel Beams

From Fig. 18, it is observed that, all the steel beams show similar variation in load-deflection curve when tested experimentally in UTM.

Figure 19 shows the combined numerical load-deflection curves obtained for the steel beams without and with circular openings analyzed in ANSYS FEM software.

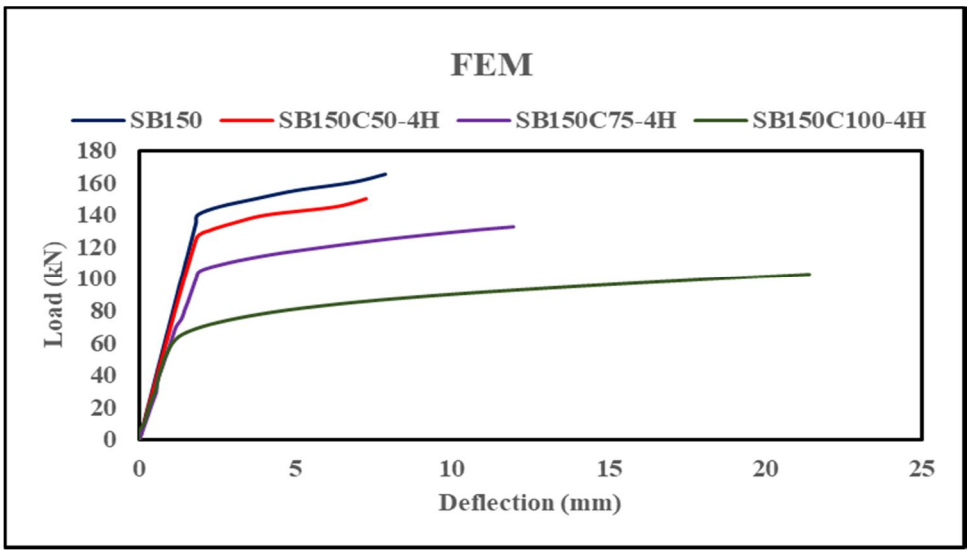


Fig. 19: Comparison of Numerical Load-Deflection Curves of Steel Beams

©IJRASET: All Rights are Reserved | SJ Impact Factor 7.538 | ISRA Journal Impact Factor 7.894 |

From Fig. 19, it is observed that, all the beams show similar variation in load-deflection curve when analyzed numerically in ANSYS FEM software.

Figures 20 to 23 show the comparison of experimental and numerical load-deflection curves obtained for steel beams considered in the present investigation.

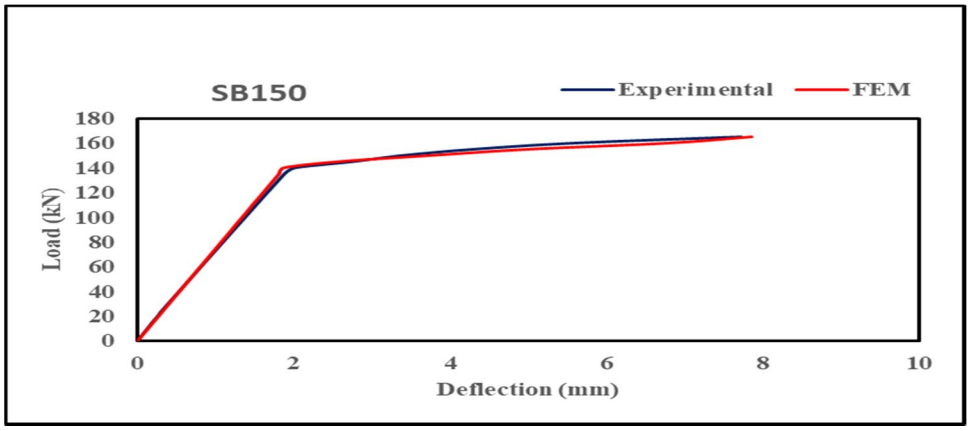


Fig. 20: Experimental and Numerical Load-Deflection Curves of SB150

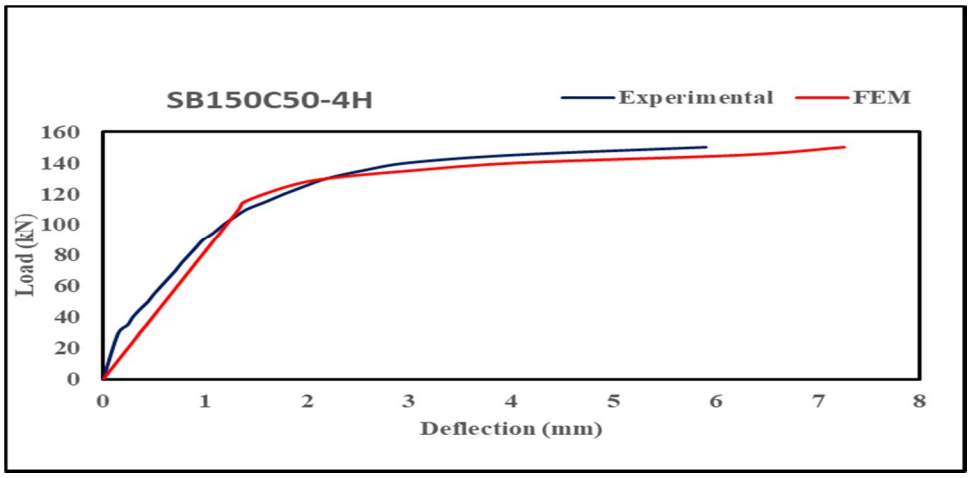


Fig. 21: Experimental and Numerical Load-Deflection Curves of SB150C50-4H

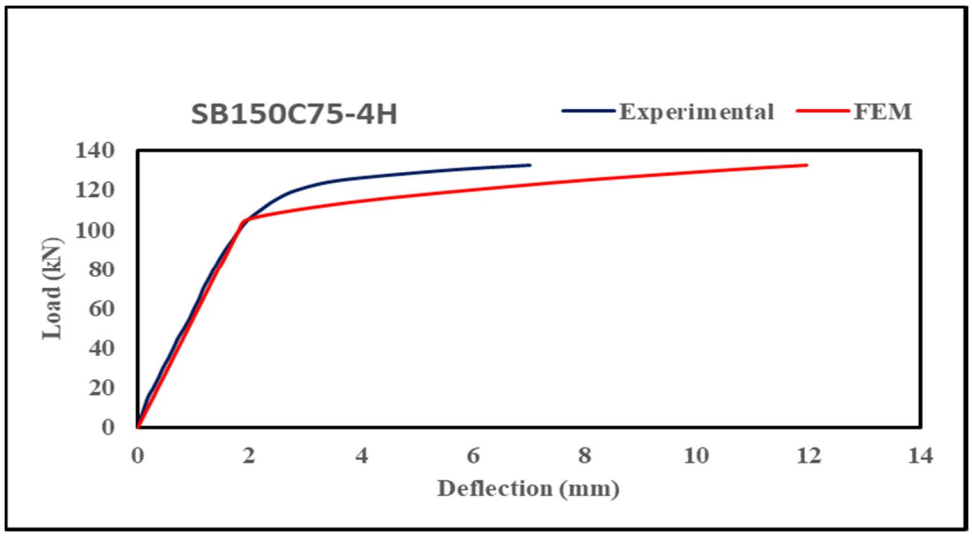


Fig. 22: Experimental and Numerical Load Deflection Curves of SB150C75-4H

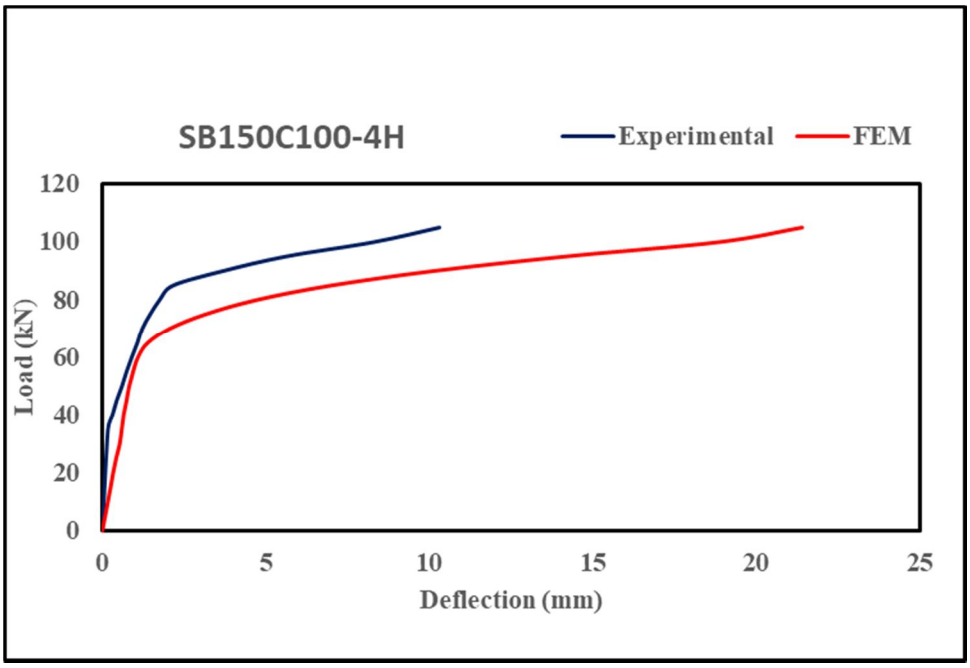


Fig. 23: Experimental and Numerical Load Deflection Curves of SB150C7100-4H

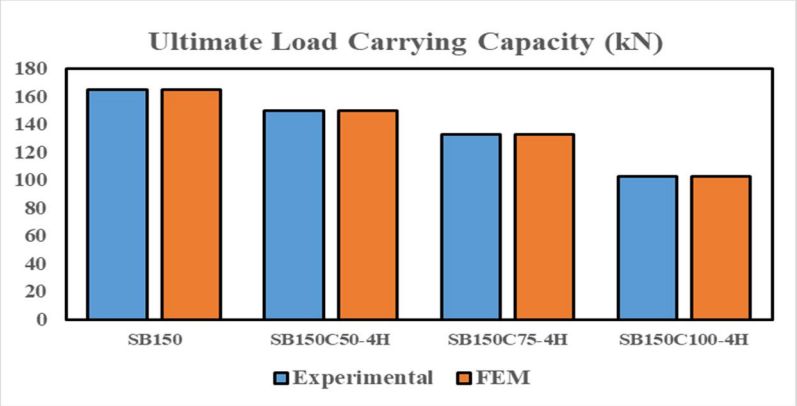
From Figs. 20 to 23, it is observed that ANSYS FEM software predicts the similar variation of load-deflection curve for all the considered steel beams as that of experimental results.

Table 3 shows the experimental and numerical ultimate load; maximum deflection values obtained for the steel beams. The same is graphically represented in Fig. 27.

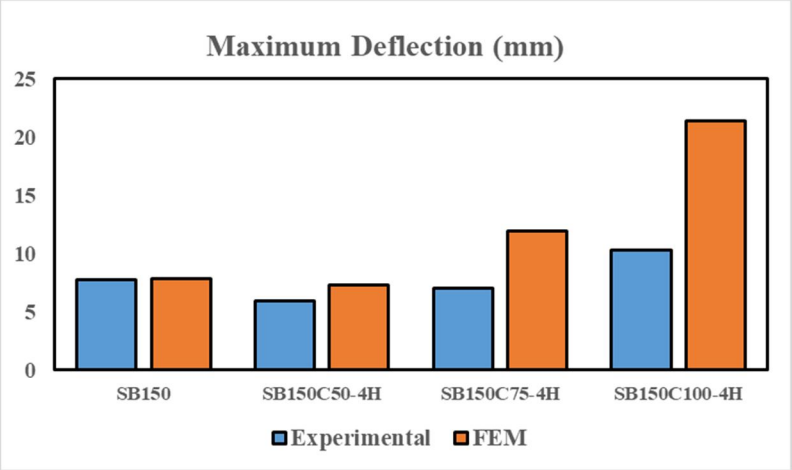
Table 3: Comparison of Ultimate Load and Maximum Deflection Obtained from Experimental and Numerical Analyses

Steel Section	Ultimate Load (kN)		Maximum Deflection (mm)		Stress in Steel at Failure (MPa)
	Experimental	FEM	Experimental	FEM	FEM
SB150	165.0	165.0	7.73	7.850	372.43
SB150C50-4H	150.0	150.0	5.91	7.260	381.20
SB150C75-4H	132.5	132.5	7.01	11.950	375.36
SB150C100-4H	102.5	102.5	10.3	21.380	379.88

©IJRASET: All Rights are Reserved | SJ Impact Factor 7.538 | ISRA Journal Impact Factor 7.894 |



(a): Ultimate Load Carrying Capacity



(b): Maximum Deflection

Fig. 24: Graphical Comparison of Ultimate Load and Maximum Deflection of Steel Beams Obtained from Experimental Numerical Analyses

From Fig. 24, it is observed that, in both experimental and numerical investigation, solid beam without web opening takes more load and deflects less as compared to steel beams with circular web openings. Further, as diameter of circular opening increases, load carrying capacity decreases and deflection at mid-span increases in both experimental and numerical analyses.

VI. CONCLUSION

In the present study, experimental and numerical investigation is carried out to study the effect of diameter of circular openings on the performance of steel beams. Steel I section ISMB150 @ 14.9 kg/m, of 900 mm overall span and 800 mm effective span is chosen for the experimental and numerical investigation with a simple support condition at both the ends. Performance of ISMB 150 section without and with circular web openings of diameter 50 mm, 75 mm and 100 mm is studied in the present investigation. Experimental analysis is performed by subjecting the steel sections to mid-point loading in UTM and numerical analysis is performed for the steel sections using ANSYS FEM software

The important conclusions drawn from the present study are as follows.

1) All the steel beams show similar variation in load-deflection curve when tested experimentally in UTM and when analyzed numerically in ANSYS FEM software.

2) ANSYS FEM software predicts the similar variation of load-deflection curves for as that of experimental results for all the steel beams. Also, FEM results match fairly well with the experimental results.

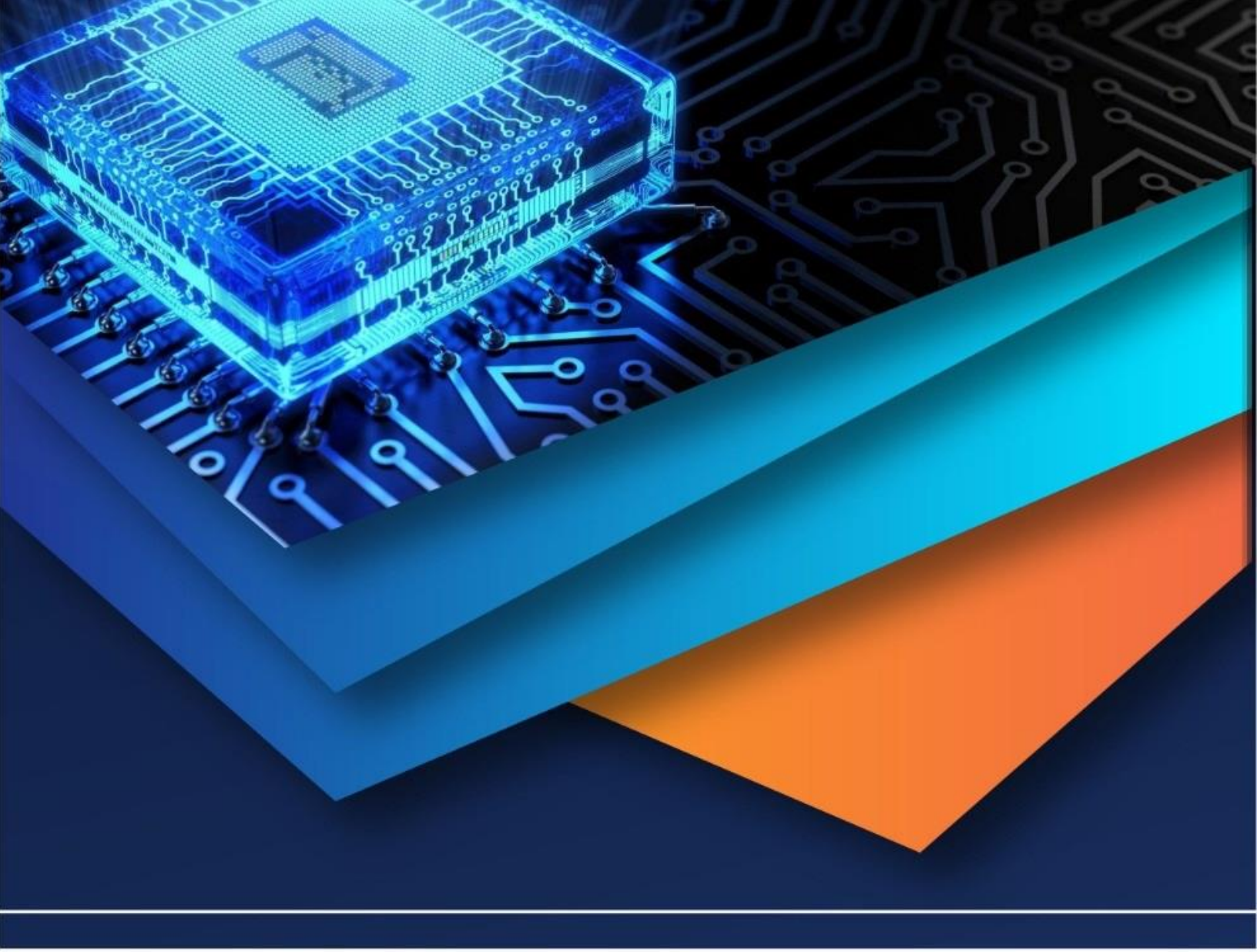
3) From both experimental and numerical investigation, solid beam without web opening takes more load and deflects less as compared to steel beams with circular web openings. Further, as diameter of circular opening increases, load carrying capacity decreases and deflection at mid-span increases.

©IJRASET: All Rights are Reserved | SJ Impact Factor 7.538 | ISRA Journal Impact Factor 7.894 |

REFERENCES

[1] Resmi M and Preetha P (2016), "Finite Element Analysis to Compare the Deflection of Steel Beam with and without Web Openings", International Organization of Scientific Research Journal of Civil Engineering.
[2] Mork hade G and Gupta M (2015), "An Experimental and Parametric Study on Steel Beams with Web Openings", International Journal of Advanced Structural Engineering.
[3] Morkhade G and Gupta M (2021), "Experimental and Analytical Investigation of Castellated Beams with Varying Openings Eccentricity", Journal of the institution of engineers, Vol. 102.
[4] SP 6 (Part 1):1964, "Code of Practice for Structural Steel Sections", Bureau of Indian Standards, New Delhi, India.
[5] IS 800 :2007, "General Construction in Steel Code of Practice", Bureau of Indian Standards, New Delhi, India.
[6] Institute for Steel Development and Growth (INSDAG) Manual.

©IJRASET: All Rights are Reserved | SJ Impact Factor 7.538 | ISRA Journal Impact Factor 7.894 |



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089 (24*7 Support on Whatsapp)