RESEARCHERID
THOMSON REUTERS
[Gaurav et al., 11(8), Aug 2026]

ISSN : 2455-9679
SJIF Impact Factor : 6.190

IJRTSM

INTERNATIONAL JOURNAL OF RECENT TECHNOLOGY SCIENCE & MANAGEMENT

"STRUCTURAL PERFORMANCE ANALYSIS OF DIFFERENT CUT-SECTION BEAM GEOMETRIES USING FINITE ELEMENT ANALYSIS"

Gaurav Priyadarshi [1]***, Dharmendra Singh*** [2]

[1] *P.G. Scholar, Department of Civil Engineering, RNTU, Bhopal, MP, India*

[2] *Assistant Professor, Department of Civil Engineering, RNTU, Bhopal, MP, India*

ABSTRACT

Beam cross-sectional geometry plays an important role in determining structural stiffness, stress distribution, and deformation under applied loading. The present study investigates and compares the structural performance of four different cut-section beam geometries: rectangular, triangular, hexagonal, and circular. A finite element analysis approach is considered to evaluate the deformation and equivalent stress developed in each beam configuration under identical loading and boundary conditions. The obtained results show significant variation in structural response with changes in cross-sectional geometry. The rectangular beam exhibits the maximum deformation of 1.18 mm and maximum stress of 32.3 MPa. The triangular and circular sections produce deformation values of 1.05 mm and 1.017 mm, respectively, while their corresponding stresses are 30.2 MPa and 28.66 MPa. The hexagonal beam demonstrates the most favorable performance, with the minimum deformation of 0.7798 mm and minimum stress of 25.792 MPa. Compared with the rectangular configuration, the hexagonal section reduces deformation by approximately 33.92% and stress by approximately 20.15%. The results indicate that appropriate selection of cross-sectional geometry can significantly improve beam stiffness and structural efficiency. The study provides useful guidance for lightweight structural design and optimization of beam components used in mechanical and automotive engineering applications.

Key Words: *Beam, Cut Section, Finite Element Analysis, Deformation, Equivalent Stress, Structural Optimization, Hexagonal Section..*

I. INTRODUCTION

Structural beams are among the most important load-carrying elements used in civil, mechanical, aerospace, automotive, and industrial engineering applications. Beams are primarily designed to withstand transverse loads and transfer these loads safely to supporting structures. Depending on the application, beams are manufactured in different cross-sectional configurations, including rectangular, circular, T-sections, C-sections, box sections, and I-sections. Among these configurations, the I-shaped cross-section is one of the most efficient and widely used geometries because it provides high bending stiffness and strength while maintaining comparatively low structural weight.

An **I-beam**, also known as an **I-section beam**, consists primarily of two horizontal components called flanges and a vertical component called the web. The flanges are generally responsible for resisting bending stresses, while the web primarily carries shear forces and maintains the separation between the flanges. This arrangement places a large proportion of the material away from the neutral axis, thereby increasing the second moment of area and improving

ISSN : 2455-9679
SJIF Impact Factor : 6.190

resistance to bending. Consequently, I-beams can achieve high structural performance with less material than many conventional solid cross-sections of comparable overall dimensions.

The efficient use of material is particularly important in modern engineering because industries are continuously seeking lightweight, economical, and sustainable structural designs. Reduction in structural weight can result in lower material consumption, reduced manufacturing costs, easier transportation, and improved energy efficiency. However, reducing material or modifying the geometry of a beam can also affect its strength, stiffness, stability, and failure characteristics. Therefore, understanding the influence of beam geometry on structural performance is essential for safe and optimized engineering design.

1.1 I-Beam as a Structural Member

The basic geometry of an I-beam comprises an upper flange, lower flange, and web. The distance between the centroids of the flanges and the dimensions of the web and flanges determine the bending and shear characteristics of the beam. The overall depth of the beam is one of the most important geometrical parameters because increasing the depth generally increases the moment of inertia and bending resistance without requiring a proportional increase in material.

When a beam is subjected to transverse loading, bending stresses develop across its cross-section. For a conventional symmetric I-section, the maximum tensile and compressive bending stresses occur near the extreme surfaces of the flanges, while the bending stress approaches zero near the neutral axis. In contrast, shear stresses are concentrated primarily within the web. Thus, the separation of structural functions between the flanges and web makes the I-section highly efficient for bending-dominated applications.

I-beams are commonly used in building structures, industrial platforms, cranes, bridges, machine frames, railway structures, aircraft structures, and heavy engineering equipment. Their widespread application demonstrates the importance of accurately understanding their structural response under different loading conditions.

Figure.1 I Section beam

II. OBJECTIVES

The major objectives of the study are:

1. To develop different cut-section beam geometries for structural analysis.
2. To investigate the deformation behavior of rectangular, triangular, hexagonal, and circular beams.
3. To determine and compare the equivalent stress developed in each beam.
4. To identify the most structurally efficient beam geometry.
5. To establish a basis for future optimization of beam cross-sections.

ISSN : 2455-9679
SJIF Impact Factor : 6.190

III. Methodology

The methodology adopted for the present investigation consists of geometry development, material assignment, meshing, application of boundary conditions and loading, numerical solution, and comparison of results.

Methodology Flow

Beam Geometry Selection
↓
3D CAD Model Development
↓
Material Properties Assignment
↓
Finite Element Mesh Generation
↓
Application of Fixed Support
↓
Application of External Load
↓
Static Structural Analysis
↓
Calculation of Deformation and Equivalent Stress
↓
Comparison of Four Beam Geometries
↓
Identification of Optimum Section

The same loading and boundary conditions should be maintained for all four models to ensure a meaningful comparison.

Beam Geometries Considered

Four different beam cross-sectional configurations were investigated:

1. Rectangular cut-section beam
2. Triangular cut-section beam
3. Hexagonal cut-section beam
4. Circular cut-section beam

The geometrical modification is expected to influence the stiffness and stress distribution of the beam. The numerical results are subsequently compared using deformation and equivalent stress.

IV. Conclusion

The numerical results obtained for the four beam configurations are presented below.

Table 1 Results obtained for the four beam configurations

S. No.	Beam Geometry	Deformation (mm)	Stress (MPa)
1	Rectangular	1.1800	32.300
2	Triangular	1.0500	30.200
3	Hexagonal	**0.7798**	**25.792**
4	Circular	1.0170	28.660

ISSN : 2455-9679
SJIF Impact Factor : 6.190

4.1 Deformation Analysis

The rectangular beam exhibits the highest deformation of 1.18 mm. The triangular section reduces the deformation to 1.05 mm, whereas the circular section produces 1.017 mm.

The hexagonal beam produces the minimum deformation of 0.7798 mm. Compared with the rectangular beam, this represents a reduction of approximately 33.92%.

The lower deformation indicates that the hexagonal configuration provides greater resistance to bending under the specified loading conditions. This suggests improved structural stiffness and dimensional stability.

4.2 Stress Analysis

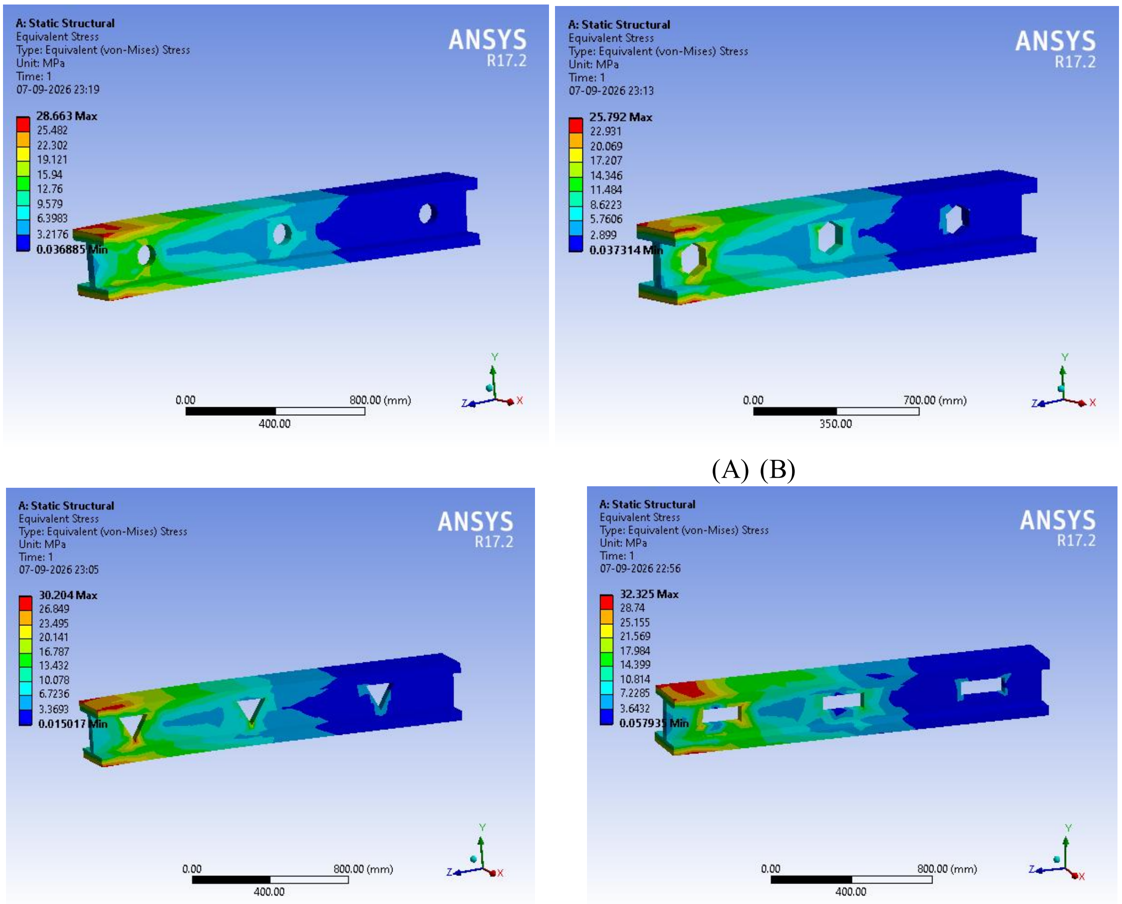
The rectangular section produces the maximum stress of 32.3 MPa. The triangular section produces 30.2 MPa, while the circular section produces 28.66 MPa.

The hexagonal section has the lowest stress value of only 25.792 MPa. Therefore, compared with the rectangular beam, the hexagonal configuration achieves an approximate 20.15% reduction in stress.

The lower stress suggests improved load distribution and reduced severity of stress concentration within the investigated geometry.

V. Comparative Performance

The results clearly indicate that the hexagonal beam provides the most favorable structural response.



(C) (D)

Figure.2 Simulation Results different beams

ISSN : 2455-9679
SJIF Impact Factor : 6.190

VI. Conclusion

The present investigation evaluated the structural behavior of rectangular, triangular, hexagonal, and circular cut-section beams using finite element analysis. The comparison was based primarily on total deformation and equivalent stress under identical analysis conditions.

The results demonstrate that cross-sectional geometry has a considerable influence on beam structural performance. The rectangular beam exhibited the maximum deformation of 1.18 mm and maximum stress of 32.3 MPa, whereas the hexagonal beam demonstrated the minimum deformation of 0.7798 mm and stress of 25.792 MPa.

The hexagonal configuration therefore showed approximately 33.92% lower deformation and 20.15% lower stress compared with the rectangular beam. The circular and triangular configurations demonstrated intermediate performance.

Based on the investigated parameters, the hexagonal cut-section beam can be considered the most efficient configuration among the four designs. Its lower deformation and stress indicate improved stiffness and structural performance. The findings can be useful for the preliminary design and optimization of lightweight structural members.

VII. Future Scope

Future research can extend this investigation by:

- experimentally validating the FEA results;
- performing fatigue and dynamic analyses;
- investigating buckling behavior;
- studying different materials such as aluminum alloys and composites;
- performing topology and parametric optimization;
- investigating different beam dimensions and loading conditions;
- incorporating temperature-dependent thermal–structural analysis; and
- evaluating the effect of different mesh sizes on numerical accuracy.

REFERENCES

[1] Singh, S. (2021). Static bending analysis of arbitrary supported steel beams with circular web opening using finite element method. Materials Today: Proceedings, 37, 3700–3705. DOI: 10.1016/j.matpr.2020.10.158.

[2] Morkhade, S. G., Gupta, L. M., & Martins, C. H. (2022). Effect of Web Post Width on Strength Capacity of Steel Beams with Web Openings: Experimental and Analytical Investigation. Practice Periodical on Structural Design and Construction, 27(2). DOI: 10.1061/(ASCE)SC.1943-5576.0000688.

[3] Morkhade, S. G., et al. (2022). Stress analysis of I-beam with web opening via finite element analysis and experimental study. World Journal of Engineering, 20(5), 974–988. DOI: 10.1108/WJE-11-2021-0627.

[4] Qureshi, S., & Wadhai, P. J. (2022). Review on Web Openings in Steel Beam Structures. Journal of Pharmaceutical Negative Results, 13(Special Issue 10), 5857–5861. DOI: 10.47750/pnr.2022.13.S10.721.

[5] Abbas, J. L. (2023). Behaviour of Steel I Beams with Web Openings. Civil Engineering Journal, 9(3). DOI: 10.28991/CEJ-2023-09-03-08.

[6] Mezher, N. A. M., Noori, A. R., & Ertürkmen, D. (2023). Influence of the Web Opening Shapes on the Bending and Free Vibration Responses of Castellated Steel Beams. International Journal of Engineering Technologies, 8(2).

[7] Morkhade, S. G., Lokhande, R. S., Gund, U. D., Divate, A. J., & Deosarkar, S. S. (2023). Finite Element Investigations on Structural Performance of Steel I-Beams with Reinforced Web Openings. Proceedings of the Indian Structural Steel Conference 2020.

[8] Critical study of steel beams with web openings. (2023). Australian Journal of Structural Engineering, 24(1). DOI: 10.1080/13287982.2022.2117319.

[9] Numerical study of the effects of web openings on the load capacity of steel beams with corrugated webs. (2023). Journal of Constructional Steel Research.

ISSN : 2455-9679
SJIF Impact Factor : 6.190

[10] Santos, E., Ferreira, F. P. V., Martins, C. H., & Tsavdaridis, K. (2024). Finite Element Analysis of Steel-Concrete Composite Beams with Elliptically-Based Web Openings. International Conference on Steel and Aluminium Structures, 2024.

[11] Effect of geometry on flexural behavior of optimal designed web-expanded beams. (2024). Journal of Constructional Steel Research, 215, 108500. DOI: 10.1016/j.jcsr.2024.108500.

[12] Web-post buckling behaviour of composite beams with large elliptically-based web openings. (2025). Journal of Constructional Steel Research, 229, 109483. DOI: 10.1016/j.jcsr.2025.109483.

[13] Sharifi, M. N., Sarwary, M. H., Kaiwaan, A., & Azimi, S. J. (2026). Assessing the Configuration and Structural Behavior of Web-Opening Steel Beams: A Comprehensive Review. International Journal of Industrial Engineering, 13(1), 1–15. DOI: 10.14445/23499362/IJIE-V13I1P101.

[14] Assessment of the Stress-Strain State around Circular Openings in Double-Pitched and Arched Perforated Beams. (2026). Procedia Structural Integrity, 81, 439–446. DOI: 10.1016/j.prostr.2026.03.076.