International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Geometry Meets Strength: A Comparative Study of Stiffener Positions in Castellated Beams

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A B S T R A C T :

Castellated beams find extensive use in current structural applications as a result of their enhanced strength-to-weight ratio and capacity to house services via web openings. The geometry of such openings and the location of stiffeners have a profound effect on the beam's structural behavior. This paper provides comparative study of castellated beams with circular, sinusoidal, and diamond opening shapes in terms of how stiffener locations influence their strength, stiffness, and performance under load. Various models were tested via finite element simulations to compare stress distribution, deflection, and failure modes. The findings show that the best placement of stiffeners can resist stress concentration near openings and increase load-carrying capacity, with variation existing for differing opening geometries. The study emphasizes the necessity of combined design considerations of geometric profile and stiffener configuration to attain the efficiency and safety of castellated beam systems..

Keywords: Stiffener Position, Web Openings, Circular Openings, Sinusoidal Openings, Finite Element Analysis (FEA),Structural Performance, Load Carrying Capacity, Stress Distribution, Beam Optimization, Structural Stability

1. General

Applications of Castellated Beams in Steel Structures

1.1 Steel is increasingly used as a material for structural usage because of its strength, versatility, and rapidity of construction. Among contemporary steel construction methods, the Pre-Engineered Buildings (PEBs) have received widespread popularity owing to their ease and economy, particularly for those projects needing large spans with comparatively light loads. Nevertheless, though steel sections are generally capable of fulfilling strength criteria, they also need to fulfill serviceability requirements—namely deflection limits—which generally necessitates deeper beams.

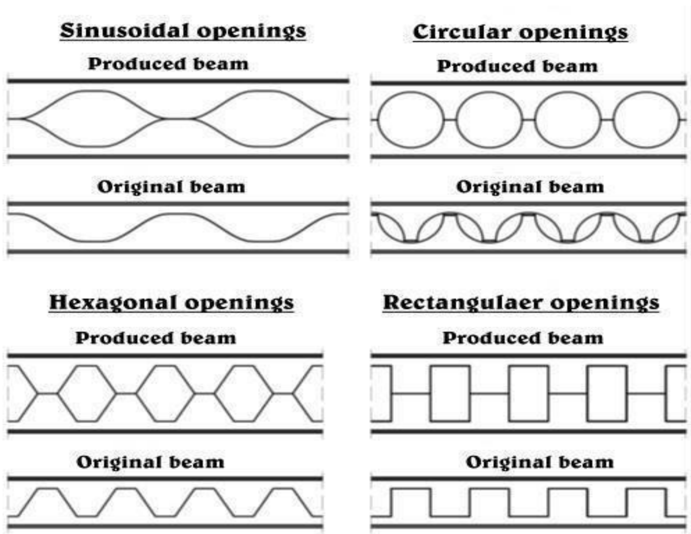


Fig 1.1 Terminology of a Typical Castellated beam with Hexagonal openings

1.2 To meet this demand, engineers are always looking for new structural solutions, and among these is the castellated beam, which was first presented in the 1930s by Geoffrey Murray Boyd. Beams that have been castellated are made by cutting a rolled steel section along its web in a predetermined pattern (most often zigzag or sinusoidal), splitting the halves, and welding them back together to produce deeper sections with openings within the web. This procedure deepens and stiffens the beam without the addition of more material, enhancing its bending performance and overall efficiency.

1.3 Castellated beams have a number of advantages. Web openings enable building services (such as HVAC ducts or wiring) to be routed through the beams, minimizing the overall floor height and enhancing spatial efficiency. Although this configuration minimizes material and weight, it does change stress distribution, especially around the openings, which may influence the beam's failure mode. Proper stiffener placement—local reinforcing elements provided at important locations such as web posts—is important to manage deflection and avoid failures in buckling or joint rupture.

1.4 Some of the frequently used shapes for openings in castellated beams are hexagonal, circular (cellular), and sinusoidal shapes. Every shape affects the flow of stress through the structure, and blunting sharp corners is an effective way of minimizing stress concentration. In this current work, castellated beams are compared with circular, sinusoidal, and diamond openings, both with and without stiffeners. This work tries to establish the best positions of stiffeners, investigate failure modes such as buckling of the web post, and determine how stiffeners increase strength and decrease deflection, particularly in regions of high stress shear zones.

2. Methodology

1. Beam Geometry and Opening Shapes Selection A normal I-section steel beam is taken as a reference for castellation and modeling.
Three web opening types are used: Circular (Cellular), Sinusoidal, Diamond-shaped,,Opening positions are regularly spaced along the length of the beam for all models.

2. Castellation and Stiffener Modeling

Cutting the web of the beam in a particular pattern and re-welding it to add depth by about 50% constitutes the process of castellation. Castellated beams with and without stiffeners are modeled using equivalent castellated beams. Stiffeners are located at various strategic locations: Along web posts Close to support zones At mid-span (region of maximum moment)Along shear zones (depending on stress analysis)

3. Material Properties Steel grade utilized: Fe 250 (or any applicable standard depending on IS code or ASTM).Material is considered homogeneous and isotropic. Young's Modulus, Poisson's ratio, and yield stress are assumed as per general design codes.

4. Finite Element Modeling All the beam models are generated with ANSYS (or equivalent structural analysis software).
3D models have appropriate meshing and boundary condition definitions.
Single support beam conditions are imposed with uniformly distributed load.
Tetrahedral or hexahedral mesh elements are employed based on the complexity of the geometry.

5. Load and Boundary Conditions Beams are loaded in static conditions which simulate bending and shear action. Boundary conditions simulate actual support and loading setups. Load is applied progressively to monitor progressive deformation and stress concentration.

6. Analysis Parameters Following performance parameters are monitored: Deflection at mid-span
Stress concentration around openings and web posts buckling response of web posts Failure modes (rupture, local buckling, weld failure) Base shear and reaction forces

7. Comparison and Interpretation Results for various opening shapes and stiffener locations are compared.
Efficiency of stiffener placement is compared in terms of: Decreased deflection, contained stress distribution, Increased load-carrying capacity

8. Validation Manual calculations through the model superposition response approach (according to IS 1893:2002 Part II) are conducted for comparison.
Analytical outputs are cross-checked with finite element results to establish the accuracy of modeling.

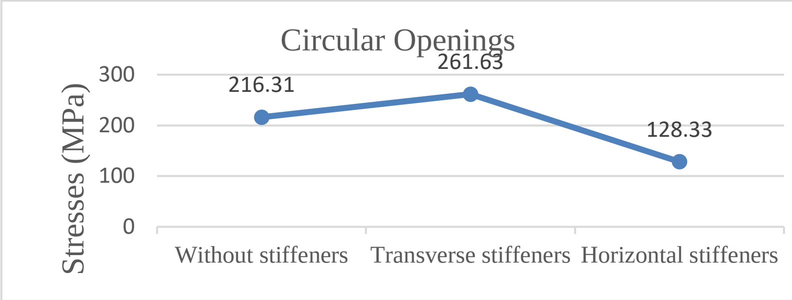
3. RESULT AND DISCUSSION

Finite Element Analysis is carried out by using ANSYS 16.0 software to determine the stresses and deflection occurred in the castellated beams. Castellated beam with circular, sinusoidal and diamond openings analyze with transverse, horizontal stiffeners and also without stiffeners.

3.1 Finite Element Analysis of Castellated beam with circular openings

Table 3.1 Results of FEA of castellated beam with circular openings

1. Without stiffeners		2. With transverse stiffeners		3. With horizontal stiffeners	
4. Deflection 5. (mm)	6. Stresses 7. (MPa)	8. Deflection 9. (mm)	10. Stresses 11. (MPa)	12. Deflection 13. (mm)	14. Stresses 15. (MPa)
16. 3.15	17. 216.31	18. 2.609	19. 261.63	20. 1.93	21. 128.33



Graph 3.1 Variation in stresses of beam with circular openings

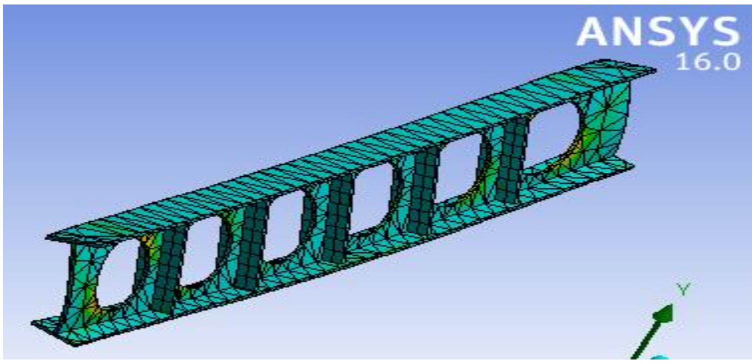


Fig. 3.1 Variation in stresses of beam with transverse stiffeners

From the result of this analysis it is observed that the beam with transverse stiffeners gives the values of stresses occurred is 261.63 MPa, which is more satisfactory than the other. Introducing transverse stiffeners in the beam significantly minimizes the value of stresses and also deflection as compares with the horizontal stiffeners.

3.3 Finite Element Analysis of Castellated beam with sinusoidal openings

Table 3.2 Results of FEA of castellated beam with sinusoidal openings

22. Without stiffeners		23. With transverse stiffeners		24. With horizontal stiffeners	
25. Deflection 26. (mm)	27. Stresses 28. (MPa)	29. Deflection 30. (mm)	31. Stresses 32. (MPa)	33. Deflection 34. (mm)	35. Stresses 36. (MPa)
37. 3.52	38. 270.25	39. 2.69	40. 311.88	41. 3.36	42. 135.11

5. Conclusion:

The current research assessed the structural efficiency of castellated beams with various web opening shapes—circular and sinusoidal—subjected to various stiffener positions through Finite Element Analysis (ANSYS 16.0). The aim was to assess the performance of stiffener locations in reducing stress concentration and deflection, hence improving the efficiency of castellated beams in carrying loads.

The findings from the analysis are as follows:

For beams with circular openings, horizontal stiffeners provided the minimum deflection (1.93 mm) and notably lower stress values (128.33 MPa), which is the most effective in maintaining serviceability and strength.

The transverse stiffeners, on the other hand, provided the highest value of stress (261.63 MPa), reflecting a better load resistance but a slightly greater stress concentration.

Beams with sinusoidal openings sustained maximum stress (311.88 MPa) when they were given transverse stiffeners, which demonstrated their capacity to withstand higher loads, albeit at the cost of deflection control. Of all the configurations, horizontal stiffeners offered a more balanced enhancement by minimizing deflection as well as stresses, particularly for circular openings. Sinusoidal beams without stiffeners showed the largest deflection (3.52 mm) and stress (270.25 MPa), validating the use of stiffeners in such shapes to prevent failure from web buckling or excessive deflection.

In short, the inclusion of stiffeners—especially horizontal stiffeners—within castellated beams enhances structural performance substantially by minimizing deflection and stress concentrations. The selection of opening geometry and stiffener location must be made on the basis of particular structural demands, with circular openings and horizontal stiffeners being most effective in the examples considered.

Failure modes (rupture, local buckling, weld failure)

Base shear and reaction forces

Comparison and Interpretation

Results obtained with various opening shapes and positions of stiffeners are compared.

The effectiveness of stiffener location is assessed in terms of:

Minimized deflection

Stressed distribution control

Improved load-carrying capacity

Validation

Manual computations through the model superposition response method (according to IS 1893:2002 Part II) are carried out for comparison.

Analytical results are cross-checked against finite element outputs to confirm modeling accuracy.

6.REFERENCES

1. 1.Prof. R. R. Jichkar, Prof. N. S. Arukia, Prof. P. D. Pachpor, (2014), "Analysis of Steel Beam with Web Openings Subjected To Buckling Load ", International Journal of Engineering Research and Applications (IJERA), Volume 4, pp.185-188.
2. Resmi Mohan, Preetha Prabhakaran, (2016), "Finite Element Analysis to Compare the Deflection of Steel Beam with and without Web Openings", International Conference on Emerging Trends in Engineering & Management (ICETEM), pp. 07-11.
3. Siddheshwari A. Patil1, Popat D Kumbhar, (2016), "Comparative Study of Transverse Stiffeners and Stiffeners along the Opening Edge used for Castellated Beam", International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET), Volume 5, pp. 8516-8522.
4. Siddheshwari. A. Patil, Popat. D. Kumbhar, (2015), " Study Of Castellated Beam Using Stiffeners: A Review", International Journal of Research in Engineering and Technology, (IJRET), Volume 4, pp. 50-54.
5. Sung C. Lee, M. ASCE; Chai H. Yoo and Dong Y. Yoon, (2002) "Behavior of Intermediate Transverse Stiffeners Attached on Web Panels", Journal of Structural Engineering, Vol. 128, pp 337-345.
6. Wakchaure M R, Sagade AV, Auti VA. (2012) "Parametric study of castellated beam with varying depth of web opening", International Journal of Scientific and Research Publications, Volume 2, pp. 01-06.
7. IS 800:2007, Indian Standard code for Structural Steel Design.