

Comparative Study on Flexural Behaviour of Solid Steel Beam and Castellated Beam Using Abaqus

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Abstract—This study focuses on the numerical analysis of castellated and solid steel beams under flexural loading conditions. The analysis is carried out using ABAQUS, considering material properties, geometry, boundary conditions. The scope includes modelling, simulation, comparison of results such as stress distribution, load-deflection behavior, failure patterns. The study is limited to static loading conditions & does not include experimental validation or dynamic analysis. FEA is extremely use full tool in the design & analysis of castellated beams. FEA enables a more complete view of the stress distribution across the hole corners.

Index Terms—Flexural behaviour Solid steel beam, Castellated beam, Bending moment, Web and Flange,Module,ABAQUS

I. INTRODUCTION

Steel, as a building material has been used extensively in various types of structures. Some of the examples of civil engineering works in steel are high-rise building skeletons, industrial buildings, transmission towers, railway bridges, over-head tanks, chimneys, tankers.

Steel structures play a vital role in modern construction due to their high strength, durability, ease of fabrication. Beams are one of the most important structural elements, primarily designed to resist bending and shear forces. Traditionally, solid steel beams have been widely used in buildings, bridges because of their predictable behavior and uniform stress distribution.

II. LITERATURE REVIEW

Prof. U. S. Ansari: To investigate, evaluate the use of the finite element method for the analysis of castellated beams. The analysis is to be carried on the castellated beams and calculated the stresses values. By knowing stresses values we can calculate the deflection, load carrying capacity of the beam. A calibration model using a commercial finite element analysis package (ANSYS) is set up and analysis is done.

Silda Ghazi Doori, Ahmad Reshad Noori; The aim to investigate the static behavior of castellated beams with different web openings. A 3D FEA is performed using ABAQUS, to find out which type of beam gives the best performance under the same distributed load and fixed support condition.

Hayder A. Hashim This research is carried out to study the effect of the external post-tensioning technique on the flexural capacity of simply supported composite castellated beam experimentally.

III. FEM USING ABAQUS

Both solid &castellated beams are analysed under identical conditions to ensure a fair comparison. The modelling process includes:

- a. Creating 3D beam geometry
- b. Assigning material properties
- c. Defining section properties
- d. Applying boundary conditions and loads
- e. Running the analysis to obtain stress and deformation results

IV. DESIGN OF BEAM

A)Solid steel beam: Flexural behavior refers to the response of a structural member when subjected to bending loads. Flexural behavior of steel beams is essential for predicting their load-carrying capacity, stiffness, deflection, failure mechanisms’ provides an effective method for the behavior of steel beams under various loading conditions. When a beam is subjected to transverse loading, bending moments are developed along its length. Due to bending:

- The upper fibers experience compressive stress.
- The lower fibers experience tensile stress.
- A neutral axis exists where the bending stress is zero.

Stress Distribution in Beam-Under bending load:

- Maximum compressive stress occurs at the top fiber.
- Maximum tensile stress occurs at the bottom fiber.
- Stress varies linearly across the depth in the elastic region.
- Stress distribution becomes nonlinear after yielding.

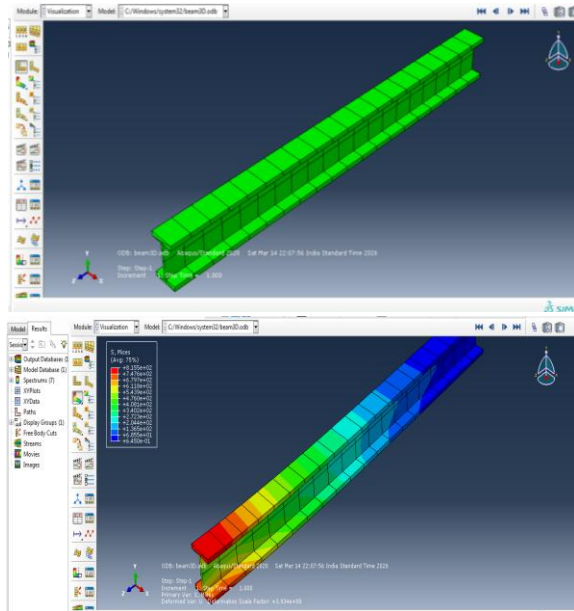


Fig1: Result of Solid steel beam using ABAQUS

Result

- Compared with castellated beams, solid beams are easier to fabricate but provide lower stiffness for the same material weight.
- Solid steel beams remain suitable for structures where simplicity, durability, and reliable performance are primary requirements.

A)Castellated beam:

The openings in the web allow passage of utilities such as ducts, pipes, cables while reducing material consumption.

Advantages: Increased depth without additional material, Higher moment of inertia, Reduced self-weight, Easier service integration through openings.

Applications: Industrial buildings, Long-span structures, Bridges and warehouses.

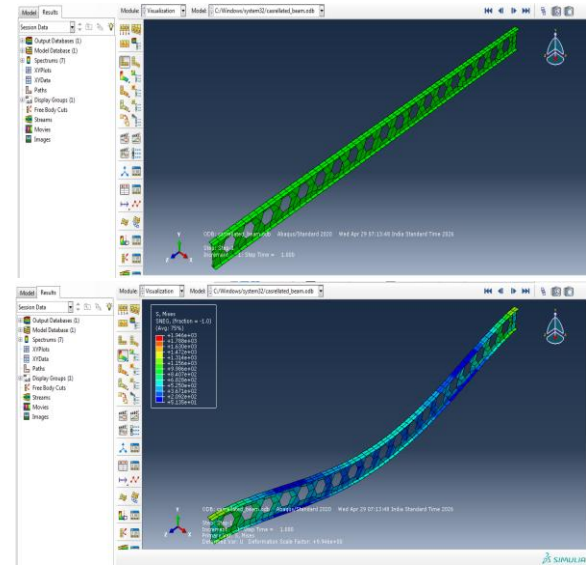


Fig2: Result of Castellated beam using ABAQUS

Result

- Castellated beams provide higher bending strength & stiffness than conventional rolled sections. The increase in depth significantly improves moment capacity without a proportional increase in weight.
- Maximum stresses occur near opening corners and web posts.
- Castellated beams are suitable for long-span structures where weight reduction and service integration are important.

V. COMPARISON OF BEAMS

A. Parameter Table

Parameter	Solid Beam	Castellated Beam
Beam Depth	Original	Increased
Weight	Higher	Lower
Moment of Inertia	Lower	Higher
Section Modulus	Lower	Higher

Parameter	Solid Beam	Castellated Beam
Bending Capacity	Lower	Higher
Stress Concentration	Low	High near openings
Deflection	Higher	Lower
Fabrication Complexity	Simple	Complex

Description	Solid beam	Castellated
Stress	Max:+8.155e+02 Min:6.450e-01	Max:+1.206e+02 Min:0.000e+00
S,Mises (Avg 75%)	+8.155e+02 +4.081e+02 +6.450e-01	+1.946e+03 +9.986e+02 +5.135e+01
Max.	+8.682e+02 +4.204e+02 -2.734e+01	+1.278e+03 +6.388e+02 +0.000e+00
Mid.	+1.118e+02 +2.195e+01 -6.788e+01	+3.283e+02 -2.321e+00 -3.329e+02
Min.	+4.651e+01 -4.050e+02 -8.566e+02	+0.000e+00 -5.838e+02 -1.168e+03
Deflection Magnitude	+2.547e+01 +1.274e+01 +0.000e+00	+1.206e+02 +6.032e+01 +0.000e+00
U,U1	+8.599e-01 +4.030e-01 -5.385e-02	+3.088e-01 +1.305e-02 -2.827e-01
U,U2	+2.542e+01 +1.271e+01 0.000e+00	0.000e+00 -6.032e+01 -1/.206e+02
U,U3	+1.650e+00 +6.912e-03 -1.636e+00	+7.162e+00 +9.358e-03 -7.143e+00

VI. FINDINGS AND OBSERVATION

- The Stress Concentrations: While solid beams exhibit linear stress distributions from the neutral axis, castellated profiles display severe localized stresses near the corners of the opening paths, which are governed heavily by the chosen angle of cut.

- Optimization Angles: Based on parametric variation, cutting angles between 45°&52° achieve the optimal ultimate load-carrying capacity while delaying premature buckling failures.
- Strengthening Interventions: If local web instabilities occur before reaching the full flexural plastic capacity, implementing vertical or diagonal stiffeners along the solid web portions stabilizes the section, shifting failure back to a classic flexural mechanism.

VII. CONCLUSION

Castellated beams are an efficient alternative to solid steel beams in flexural applications; their performance is highly dependent on geometric parameters and design considerations. Finite element analysis using ABAQUS proved to be an effective tool for capturing complex stress distributions and predicting structural behaviour, making it valuable for optimizing beam design in modern construction.

Stress values: The maximum von Mises stress in the solid beam is 815.5 MPa, whereas the castellated beam reaches only 120.6 MPa, indicating that the solid beam experiences significantly higher stress. The minimum stress values are 0.645 MPa for the solid beam and 0 for the castellated beam.

Deflection values: The minimum displacement is 0 for both beams. The maximum displacement of the solid beam is 25.47mm, while the castellated beam shows a maximum displacement of 120.6mm, indicating that the web openings significantly reduce the structural rigidity of the castellated beam, resulting in greater deflection.

The comparative study reveals that castellated beams offer significant advantages in terms of structural efficiency and material savings. The increased depth leads to improved flexural strength, making them suitable for long-span applications. However, the presence of web openings introduces stress concentration and complex failure mechanisms, which can reduce overall reliability if not properly addressed.

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