# Study of the Natural Frequency and Structural Performance of Castellated Beams with Diagonal Stiffeners and Vertical Rods for Enhanced Shear and Flexural Strength

Dr. N. Kumaragurubaran[1], Dr. R. Subramanian [2], M.S. Praveen[3], N. Durairaj[4]

*[1,3,4] Assistant Professor, Department of Mechanical Engineering, Asian College of Engineering and Technology, Coimbatore - 641110*

*[2] Professor, Department of Automobile Engineering, Annapoorana Engineering College, Salem.*

*Abstract*—**This study investigates the impact of diagonal stiffeners and vertical rods on the natural frequency, shear strength, and flexural strength of castellated beams used in chassis applications. The research involves both theoretical and experimental approaches, including finite element analysis (FEA) to determine the dynamic behavior of the beams. The results show a significant increase in the natural frequency and a reduction in deflections, indicating improved resistance to dynamic loads. The inclusion of stiffeners and rods results in enhanced shear and flexural strength, making the beams more effective in heavy-load applications.**

*Index Terms*—**Castellated Beams, Natural Frequency, Shear Strength, Flexural Strength, Diagonal Stiffeners, Vertical Rods, Finite Element Analysis**

## I. INTRODUCTION

The use of castellated beams in structural designs, particularly for chassis and load-bearing applications, has gained popularity due to their lightweight and cost-effective properties. However, the dynamic performance of these beams, specifically their natural frequencies, remains an area of concern, particularly when subjected to dynamic loading conditions. This study aims to enhance the shear and flexural strength of castellated beams through the incorporation of diagonal stiffeners and vertical rods. These modifications are hypothesized to not only improve static strength but also optimize the natural frequency, thereby enhancing the beam's resistance to dynamic forces.

## II. LITERATURE REVIEW

Castellated beams are known for their reduced weight compared to solid beams, making them ideal for large-span structures. Previous studies have demonstrated the effectiveness of stiffeners in enhancing shear and flexural strength by redistributing stresses more efficiently. However, limited research has focused on the impact of stiffeners and rods on dynamic characteristics such as natural frequencies. Research by M. R. Osorio, A. H. Mirza ,2016 highlighted that finite element analysis (FEA) to assess the influence of diagonal stiffeners on the shear and flexural performance of castellated beams, finding significant improvement in structural efficiency. H. Li, L. Zhang, S. Lee,2016 evaluates how diagonal stiffeners affect the shear and bending performance of castellated beams, providing insights into their capacity to withstand combined bending and shear forces. P. K. R. Meher, M. S. Alam, A. M. V. Sarma,2017 investigates the dynamic response and natural frequency of castellated beams with diagonal stiffeners and vertical rods, finding that these modifications enhance the vibration damping and dynamic stability. investigates the dynamic response and natural frequency of castellated beams with diagonal stiffeners and vertical rods, finding that these modifications enhance the vibration damping and dynamic stability,2018, examine the buckling behavior of castellated beams with diagonal stiffeners subjected to axial loads, revealing that the stiffeners help delay buckling and enhance load-bearing capacity. K. S. V. Subramanian, M. V.

Sankaran,2018, a comparative study of castellated beams with and without diagonal stiffeners and vertical rods, focusing on their performance under lateral loads, and concluding that the modifications improve shear strength and buckling resistance. R. A. S. Santos, D. F. Santos,2018, combined effect on dynamic performance has yet to be thoroughly explored.

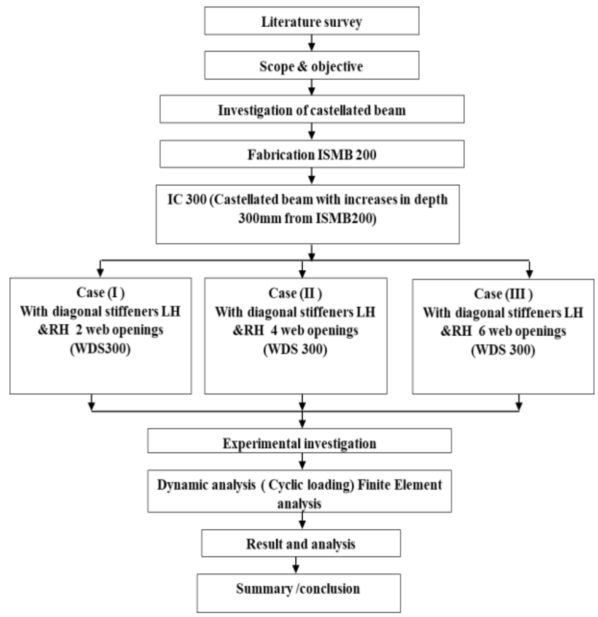
## III. OBJECTIVES

- To analysis is performed on both the with stiffener, without stiffener and castellated cantilever beams with two distinct kinds of lateral stimulating and their energetic properties and mode shapes are analyzed.
- To analysis shows that the existence of big web openings may have a severe penalty on the load carrying capacities of castellated beams under the lively gravitational loads.
- To be noted that the loading pattern is a very important factor for investigation of dynamic properties of cantilever castellated beams.
- To Fabricated of Castellated beam of size ISMB 200 with hexagonal opening of 3m span length.
- The third beam relates to diagonal and vertical stiffener with three opening (on each end) at right and left end of the beam. These three beams are tested with cyclic loading deflections are measure at mid span of beam for about three cycles or cyclic loading.
- The graphs are drawn for all beams with the load and deflection curves.
- Using the OrgineLab the equation is developed for each cyclic loading and unloading curves.
- The experimental data for valued with result from OrgineLab output equations.
- The experimental data and data which are predicted from OrgineLab output for clearly exposed the behavior of castellated beam with various numbers of stiffeners.
- The beam with three end stiffness on both sides shows better performance with other two beams.

## IV. PROBLEM STATEMENT

1. Present automobile chassis beams have a number of specific high weight and without strong.
2. That production cost also very expensive.
3. It's not Easy to assemble at the construction automobile site**.**

## V. RESEARCH METHDOLOGY



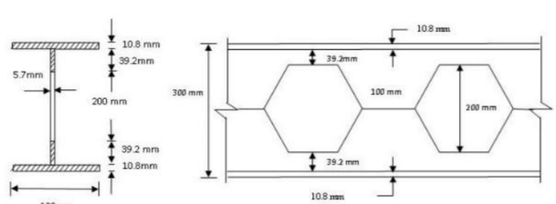

### 5.1 SELECTION OF CB -STEEL AND PROPERTIES

Castellated chassis beams are mainly fabricated for a span of 3.0 m for three different specimens IC 300. Each beam are handled material grade Fe250 rolled steel wide range flange beam section which is of following dimensions. The models of common material properties of the steel as shown Table.

| Youngs modulus (N/mm$^2$) | Yield Stress (MPa) | Ultimate Stress ( MPa) |
|---|---|---|
| 2 x $10^5$ | 295 | 426 |

### 5.2 MAKING OF CASTELLATED BEAM CHASSIS

Marking on ISMB 200




Increased depth (300mm) of castellated beam from ISMB 200 (IC300)

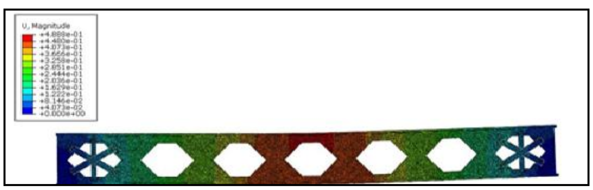
## VI. INSTA GENERATIVE MODELING /DEVELOPMENT

The steps involved in the conversion process:

- Using geometric dimensions and tolerance read the IGES file to obtain a precise result.
- Trimming process is executed to remove unwanted extensions and also adding of new face using cleanup geometry.
- Using the above cleanup functionality, we can automatically cleanup the solid models until it is achieved its tolerance and accuracy limits.
- Gaps and additional fillet are removed.
- Mesh the parts with element length of 10mm.
- Macro areas are provided keen
- supervision to improve the mesh.

either occupied (obstacle) or free (safe to navigate). Obstacle avoidance algorithms then use this grid map to plan paths that avoid the occupied cells.

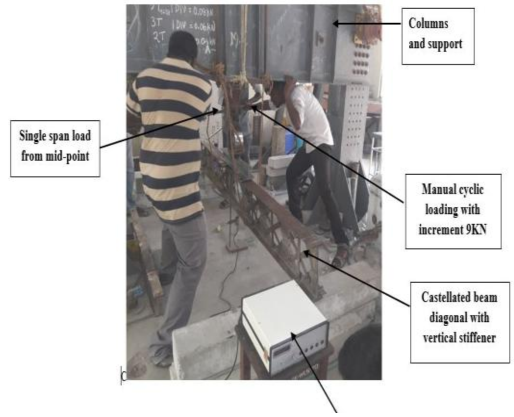
## VII. MODELLING AND FEA ANALYSIS OF CASTELLATED BEAM CHASSIS



Finite Element analysis in
cyclic load condition VS deflection (Case-1)

### 7.1 EXPERIMENTAL ANALYSIS PROCESS

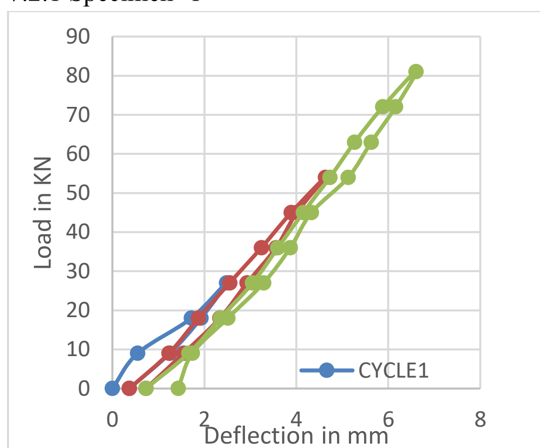
- The castellated beams are fabricated for a span of 3.o m for two different specimen ISMB 200 Each beam is simply supported beam. The supported in in end to end from the load carried through hydraulic jack of 500KN capacity.
- The beam is loaded and deflection is measured in the mid span
- The experimental simulation analysis recording the deflection of the beams LVDT Sensors



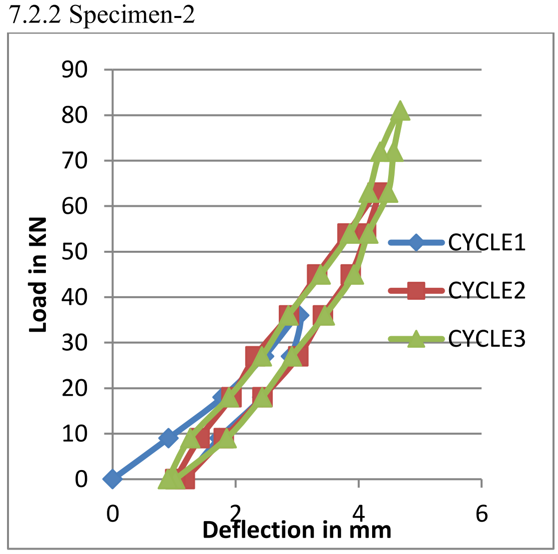

Experimentation works Done - IRTT, Erode.

### 7.2 RESULT AND DISCUSSION

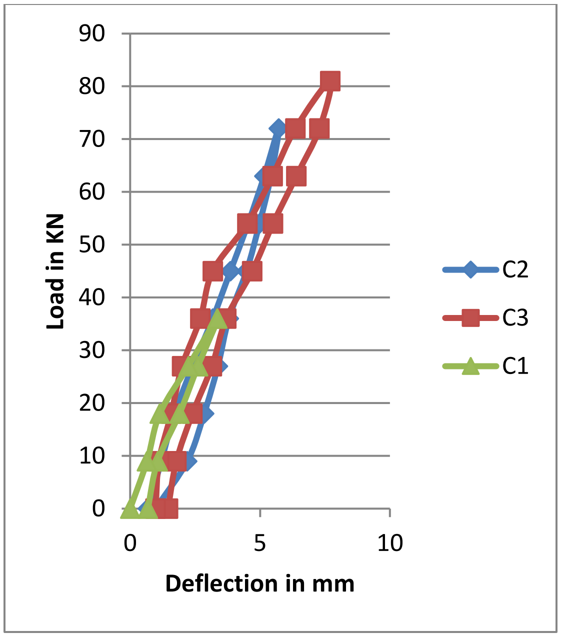
7.2.1 Specimen -1




7.2.2 Specimen-2




7.2.3 Specimen-3




## VIII. CYCLIC LOADING ANALYSIS VS DEFLECTION

| Cyclic loading analysis Vs Deflection | | Cycle -1 | | Cycle -2 | | Cycle -3 | |
|---|---|---|---|---|---|---|---|
| | | Load in KN | Deflection in(mm) | Load in KN | Deflection in(mm) | Load in KN | Deflection in (mm) |
| specimen -1 | Loading | 27 | 2.48 | 54 | 4.63 | 81 | 6.6 |
| | Unloading | 0 | 0.37 | 0 | 0.37 | 0 | 1.43 |
| specimen -2 | loading | 36 | 3.03 | 63 | 4.31 | 81 | 4.68 |
| | Unloading | 0 | 1.174 | 0 | 1.02 | 0 | 0.9 |
| Specimen -3 | Loading | 36 | 3.36 | 72 | 5.72 | 81 | 7.7 |
| | unloading | 0 | 0 | 0 | 0.968 | 0 | 0.98 |

## IX. CONCLUSION

Experimentally test carried out on a loading frame of maximum deflection for increased depth of in three cycles as given betterment solutions as given below.

Cycle loading 1. While validating the results for castellated beam 300, three types of cycle experimental analysis should be done. They are diagonal, vertical with stiffeners attached. The result is the highly carrying capacity of specimen 2 and 3 is greater than 1, while 2 and 3 remains equal which is 36KN. so that specimen deflection values for 2 and 3 are 3.03 and 3.36 mm respectively. which was found in our experimental study.

Cycle loading 2. The high load capacity of specimen 3 is 72KN so the deflection values is 5.72 mm which is very low when compared with specimen 2 and 1.

Cycle loading 3. In this process, diagonal, vertical were arrested to gain reinforcement and high load carrying capacity and that maintained the three specimens' high load carrying capacity as 81KN and deflection obtained was 4.68mm. Comparing all the three cycle from the research we found that specimen 2 is the best one, which can be used for light and heavy vehicles.

### 9.1 SCOPE FOR FUTURE WORK

When the experimental results of castellated beam with diagonal stiffeners are compared with analytical work of ISMB200, it is noticed that the deflection values obtained experimentally for diagonal with vertical stiffeners values obtained by analytical work in simulated three cases will apply in Automobile chassis in real heavy and light duty automotive vehicles

## REFERENCES

[1] Anupriya, B & Jagadeesan, K. 2014, 'Shear Strength of Castellated Beam with and without Stiffeners Using FEA (Ansys 14)', International Journal of Engineering and Technology (IJET) vol. 6, no. 4, pp. 1970-1981.

[2] Anupriya, B & Jagadeesan, K 2015), 'Experimental investgation of shear strength of castellated beams with and without stiffners', Chennai: Anna University.

[3] Anupriya, B, Jagadeesan, K & Saranya, B 2016, 'Effect of Stiffeners on Castellated Beams', Asian Journal of Research in Social Sciences and Humanities, vol. 6, no. 12, pp. 30-37.

[4] Demirdjian Sevak 1999, 'Stability of Castellated Beam Webs', McGill University Libraries.

[5] Ghazijahani, Tohid Ghanbari & Tadeh Zirakian 2014, 'Determination of Buckling Loads of Conical Shells Using Extrapolation Techniques,' Thin-Walled Structures, vol. 74, pp. 292-299.

[6] Kerdal, D & Nethercot, DA 1984, 'Failure Modes for Castellated Beams', Journal of Constructional Steel Research, vol. 4, no. 4, pp. 295-315.

[7] Liu, TCH & Chung, KF 2003, 'Steel Beams with Large Web Openings of Various Shapes and Sizes: Finite Element Investigation', Journal of Constructional Steel Research, vol. 59, no. 9, pp. 1159-1176.

[8] Luo Lie & Xiao-lin Luo 2005, 'Comparative Research of the Design Specifications for Castellated Beam (J)', Progress in Steal Building Structures, vol. 2, pp. 8.
[9] Mohebkhah Amin 2004, 'The Moment-Gradient Factor in Lateral--Torsional Buckling on Inelastic Castellated Beams', Journal of Constructional Steel Research, vol. 60, no. 10, 1481-1494.
[10] Panedpojaman Pattamad, Thaksin Thepchatri & Suchart Limkatanyu 2014, 'Novel Design Equations for Shear Strength of Local Web-Post Buckling in Cellular Beams', Thin-Walled Structures, vol. 76, pp. 92-104.
[11] Sharda, P Siddh 2011, 'Prof. PD Pachpor, 'Finite Element Analysis of Steel Beam with Web Opening of Different Shapes',' International Journal of Science and Advanced Technology (ISSN 2221-8386), vol. 1, pp. 5.
[12] Sweedan, Amr M. I. 2011, 'Elastic Lateral Stability of I-Shaped Cellular Steel Beams', Journal of Constructional Steel Research, vol. 67, no. 2, pp. 151-163.
[13] Tsavdaridis Konstantinos Daniel & Cedric D'Mello 2012, 'Optimisation of Novel Elliptically-Based Web Opening Shapes of Perforated Steel Beams', Journal of Constructional Steel Research, vol. 76, pp. 39-53.