Numerical Study on the Cold-formed Steel I-Beams with Intermediate Web Stiffener Under Bending

Dr.D. Amali[1], Snekalaxmi C [2]
[1] Assistant professor, Department of Civil Engineering, Government college of engineering, Salem
[2] Postgraduate Student, Structural Engineering, Government college of engineering, Salem

***Abstract*—Cold-formed steel (CFS) built-up I-beams are increasingly used in lightweight steel construction because of their high strength-to-weight ratio, ease of fabrication, and structural efficiency. However, their thin-walled sections are susceptible to local buckling and web instability under flexural loading. This study investigates the flexural behaviour of cold-formed steel built-up I-beams with web stiffeners through finite element analysis using ABAQUS. A three-dimensional numerical model was developed by defining the material properties, section geometry, boundary conditions, loading, and mesh configuration. The developed finite element model was validated by comparing the numerical results with published experimental data. The comparison showed good agreement in terms of load–deflection behaviour and failure mode, demonstrating the accuracy and reliability of the numerical model. The validated model provides a reliable approach for predicting the flexural performance of cold-formed steel built-up I-beams with web stiffeners and can be used for further numerical investigations.**

***Index Terms*—Cold-formed steel, Built-up I-beam, Web stiffener, Flexural behaviour, ABAQUS, Finite element analysis, validation.**

I. INTRODUCTION

Cold-formed steel (CFS) sections are widely used in modern construction due to their high strength-to-weight ratio, ease of fabrication, dimensional accuracy, and cost-effectiveness. These sections are manufactured by forming thin steel sheets at room temperature without the application of heat, making them suitable for lightweight structural systems such as roof purlins, floor joists, wall studs, and industrial framing. Their lightweight nature also facilitates faster construction and reduces transportation and installation costs.

Built-up cold-formed steel sections are formed by connecting two or more individual steel sections to act as a single structural member. Among the various built-up configurations, the I-beam section is commonly used for flexural applications because of its high bending stiffness and efficient distribution of material. However, the thin-walled nature of cold-formed steel members makes them susceptible to local buckling, web buckling, and lateral instability when subjected to bending loads, which can reduce their structural performance.

The use of web stiffeners is an effective method to improve the flexural behaviour of cold-formed steel built-up I-beams. Web stiffeners increase the stiffness of the web, delay the onset of local buckling, and enhance the load-carrying capacity of the beam. As a result, the structural performance and stability of the beam under flexural loading are significantly improved.

Finite element analysis (FEA) has become a reliable tool for studying the behaviour of steel structures. ABAQUS software enables accurate simulation of material nonlinearity, geometric nonlinearity, deformation, and failure behaviour under loading conditions. In this study, a finite element model of a cold-formed steel built-up I-beam with a web stiffener is developed using ABAQUS. The numerical model is validated by comparing the load–deflection behaviour and failure mode with published experimental results. The validated model provides a reliable numerical approach for predicting the flexural performance of cold-formed steel built-up I-beams with web stiffeners.

II. LITERATURE REVIEW

1) Sangeetha P. et al. (2025) investigated the flexural behaviour of cold-formed steel (CFS) gapped built-up channel beams with web and flange stiffeners through experimental testing and finite element analysis. The study compared the structural performance of beams provided with different stiffener arrangements under flexural loading. The results showed that the inclusion of stiffeners significantly improved the load-carrying capacity, stiffness, and buckling resistance of the beams. Beams with flange stiffeners exhibited better flexural performance than beams with only web stiffeners due to their higher resistance to local buckling and reduced deflection. The study concluded that the proper selection and arrangement of stiffeners play a vital role in enhancing the strength and structural efficiency of cold-formed steel built-up beams. These findings provide a useful basis for validating and understanding the flexural behaviour of cold-formed steel built-up I-beams with web stiffeners. Finite element analysis (FEA) has become a reliable tool for studying the behaviour of steel structures. ABAQUS software enables accurate simulation of material nonlinearity, geometric nonlinearity, deformation, and failure behaviour under loading conditions. In this study, a finite element model of a cold-formed steel built-up I-beam with a web stiffener is developed using ABAQUS. The numerical model is validated by comparing the load–deflection behaviour and failure mode with published experimental results. The validated model provides a reliable numerical approach for predicting the flexural performance of cold-formed steel built-up I-beams with web stiffeners.
2) Safaa I. Ali and Abbas A. Allawi (2021) studied the effect of web stiffeners on the flexural behaviour of composite GFRP–concrete beams under impact loading using both experimental testing and finite element analysis. The study compared the behaviour of beams with and without web stiffeners to evaluate their influence on structural performance. The results showed that the provision of web stiffeners significantly reduced mid-span deflection, delayed local buckling, and improved the load-carrying capacity and energy absorption of the beams. The authors concluded that web stiffeners effectively enhance the flexural performance and stability of composite beams by increasing web rigidity and minimizing deformation under loading. The findings demonstrate the importance of web stiffeners in improving beam behaviour and provide valuable support for the numerical validation of cold-formed steel built-up I-beams with web stiffeners.
3) Prabha G. and Emil Reyan R. (2018) investigated the flexural behaviour of rolled steel I-beams with different stiffener positions through experimental testing and finite element analysis. The study examined the influence of vertical and inclined web stiffeners placed at various locations on the flexural response of steel I-beams. The results indicated that stiffened beams exhibited higher load-carrying capacity, reduced deflection, and improved resistance to local web buckling compared with unstiffened beams. The authors concluded that the position and orientation of stiffeners have a significant effect on the flexural performance and structural stability of steel I-beams. Their findings emphasize that the proper arrangement of web stiffeners can effectively enhance beam strength and serviceability, providing valuable guidance for the validation of cold-formed steel built-up I-beams with web stiffeners.
4) Qadir S. et al. (2024) presented a study on the design optimization of cold-rolled steel beam sections with web and flange stiffeners using finite element modelling validated through four-point bending experiments. The research employed Design of Experiments (DOE) and Response Surface Methodology (RSM) to evaluate the influence of stiffener geometry and placement on the flexural behaviour of cold-formed steel beams. The results demonstrated that optimized web and flange stiffeners significantly enhanced the load-carrying capacity, stiffness, and buckling resistance of the beam sections, with flexural strength improvements of up to approximately 50% depending on the section configuration. The study concluded that the optimization of stiffener geometry is an effective approach for improving the structural efficiency and flexural performance of cold-formed steel beam sections. These findings provide valuable guidance for the numerical validation and analysis

of cold-formed steel built-up I-beams with web stiffeners.

5) Priyanka M. and Amali D. (2020) investigated the flexural behaviour of cold-formed steel built-up I-beams composed of two sigma sections using finite element analysis in ABAQUS. The built-up I-beams were formed by connecting two sigma sections with cover plates at the top and bottom flanges. The numerical model was developed to simulate the flexural behaviour and strength of the built-up sections under bending. The results of the nonlinear analysis showed that local buckling was the dominant failure mode and demonstrated that the finite element model accurately predicted the structural behaviour of the specimens. The study concluded that ABAQUS is an effective tool for analyzing the flexural performance of cold-formed steel built-up I-beams and can be reliably used for validation studies. These findings provide the foundation for the present investigation on cold-formed steel built-up I-beams with web stiffeners.
6) P. Manikandan and M. Thulasi (2019) investigated the behaviour of cold-formed steel lipped channel built-up I-beams with intermediate web stiffeners under flexural loading. The study focused on evaluating the influence of edge and intermediate web stiffeners on the bending performance of built-up I-sections through experimental testing and finite element analysis. The results showed that the inclusion of intermediate web stiffeners significantly improved the flexural strength, stiffness, and buckling resistance of the beams while reducing lateral deformation. The authors concluded that intermediate web stiffeners effectively enhance the structural performance of cold-formed steel built-up I-beams and that the finite element model accurately predicts the experimental behaviour. This published study is adopted as the validation reference for the present numerical investigation because it provides reliable experimental data for comparing the load–deflection response and failure mode of the developed ABAQUS model.

III. RESEARCH GAP

The literature indicates that several studies have investigated the flexural behaviour of cold-formed steel built-up beams using experimental testing and finite element analysis. Most of these studies focused on evaluating the influence of web stiffeners, flange stiffeners, and different beam configurations on structural performance. Although validated numerical models have been reported, limited studies have specifically examined the validation of cold-formed steel built-up I-beams with intermediate web stiffeners using ABAQUS by directly comparing numerical predictions with published experimental results. Therefore, there is a need to develop and validate a reliable finite element model that can accurately predict the load–deflection behaviour and failure mode of cold-formed steel built-up I-beams with web stiffeners. The present study addresses this gap by developing an ABAQUS model and validating it against published experimental data, thereby establishing a dependable numerical approach for analyzing the flexural behaviour of cold-formed steel built-up I-beams with web stiffeners.

IV. OBJECTIVES

The main objectives of the present study are:

1. To develop a three-dimensional finite element model of a cold-formed steel built-up I-beam with a web stiffener using ABAQUS.
2. To simulate the flexural behaviour of the built-up I-beam under four-point bending conditions.
3. To validate the developed finite element model by comparing the numerical results with published experimental data.
4. To evaluate the load–deflection response and failure mode of the cold-formed steel built-up I-beam with a web stiffener.
5. To establish the accuracy and reliability of the ABAQUS finite element model for predicting the flexural behaviour of cold-formed steel built-up I-beams with web stiffeners.

V. SCOPE OF THE STUDY

The scope of this study is limited to the numerical investigation and validation of the flexural behaviour of cold-formed steel built-up I-beams with web stiffeners using ABAQUS finite element software. A three-dimensional finite element model is developed by defining the material properties, section geometry, loading, boundary conditions, and mesh configuration.

The numerical model is validated by comparing the load–deflection behaviour and failure mode with published experimental results. The study focuses on establishing the accuracy and reliability of the finite element model for predicting the flexural response of cold-formed steel built-up I-beams with web stiffeners under four-point bending. Experimental testing and parametric studies are beyond the scope of the present investigation.

VI. METHODOLOGY

The methodology adopted in this study is based on the numerical validation of a cold-formed steel built-up I-beam with a web stiffener using ABAQUS finite element software. The study was carried out through the following steps:

1. Selection of Validation Model: A published experimental study on a cold-formed steel built-up I-beam with an intermediate web stiffener was selected as the reference model for validation.
2. Geometrical Modelling: A three-dimensional model of the built-up I-beam was created in ABAQUS based on the dimensions reported in the validation study.
3. Material Property Definition: The material properties, including Young's modulus, Poisson's ratio, and yield strength, were assigned according to the validation specimen.
4. Assembly and Boundary Conditions: The beam assembly was completed by applying the support conditions and four-point bending loading arrangement identical to the experimental investigation.
5. Meshing: The beam model was discretized using appropriate finite elements to achieve accurate numerical results while maintaining computational efficiency.
6. Finite Element Analysis: Linear and nonlinear analyses were performed in ABAQUS to obtain the load–deflection response, stress distribution, and deformation behaviour of the beam.
7. Validation: The numerical results obtained from ABAQUS were compared with the published experimental results. The accuracy of the developed finite element model was assessed by comparing the load–deflection behaviour and failure mode.

VII. FINITE ELEMENT MODELLING USING ABAQUS

Finite Element Modelling (FEM) is a numerical analysis technique used to predict the structural behaviour of engineering components under different loading conditions. In this study, the finite element model of the cold-formed steel built-up I-beam with a web stiffener was developed using ABAQUS to simulate its flexural behaviour under four-point bending. The modelling procedure consisted of the following modules:

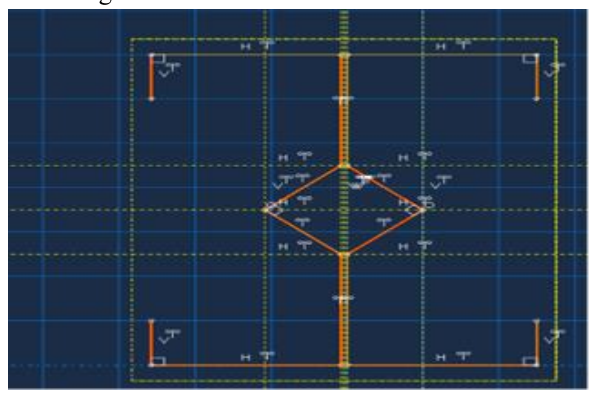

Fig 1:Abaqus section part

7.1 Part Module

The Part module is used to create the geometry of the structural member. In this study, the cold-formed steel built-up I-beam and web stiffener were modelled according to the dimensions of the validation specimen.

Fig 2: part module

7.2 Property Module

The Property module is used to define the material and section properties of the model. The material properties of cold-formed steel, including Young's modulus, Poisson's ratio, and yield strength, were assigned to the beam.

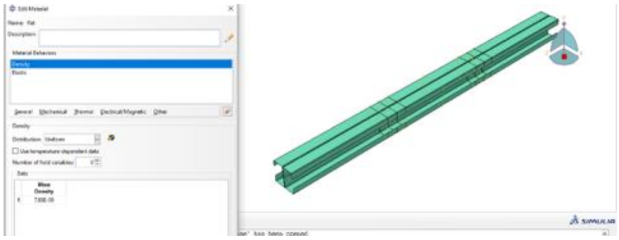

Fig 3: property module(corner)

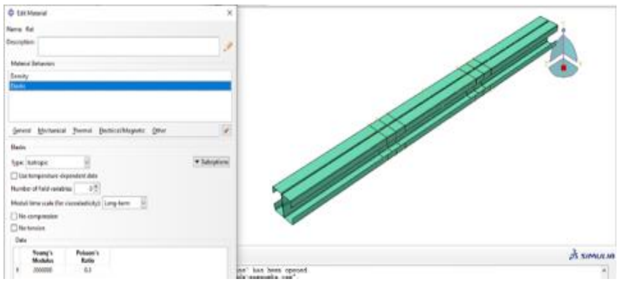

Fig 4: property module(flat)

7.3 Assembly Module

The Assembly module is used to assemble all the model components into a complete structure. The beam and other required parts were positioned to represent the actual experimental setup.

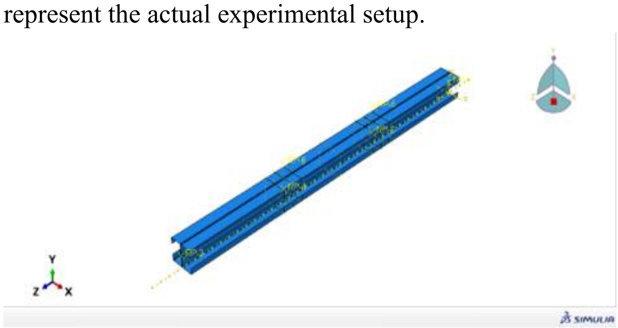

Fig 5: assembly module

7.4 Step Module

The Step module defines the type of analysis to be performed. A Static General step was created to simulate the flexural response of the beam under four-point bending.

Fig 6: step module

7.5 Interaction Module

The Interaction module defines the contact and constraint relationships between different components. Appropriate interactions were assigned between the beam, supports, and loading points to ensure proper load transfer.

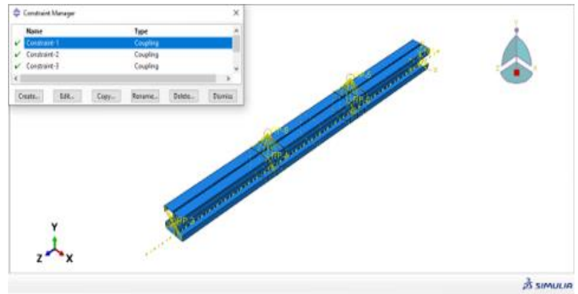

Fig 7: interaction module

7.6 Load Module

The Load module is used to apply external loads and boundary conditions. Simply supported boundary conditions and a four-point bending load were applied to reproduce the experimental conditions.

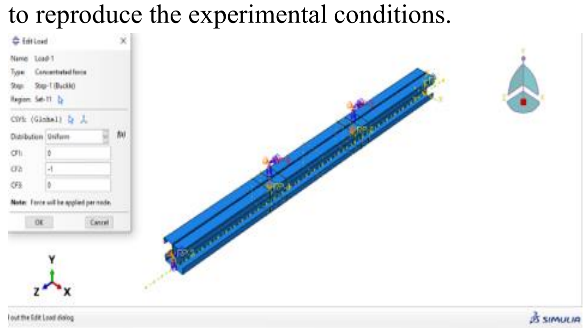

Fig 8: load module

7.7 Mesh Module

The Mesh module divides the beam into a number of small finite elements. An appropriate mesh size was selected to obtain accurate stress, deformation, and buckling predictions while maintaining computational efficiency.

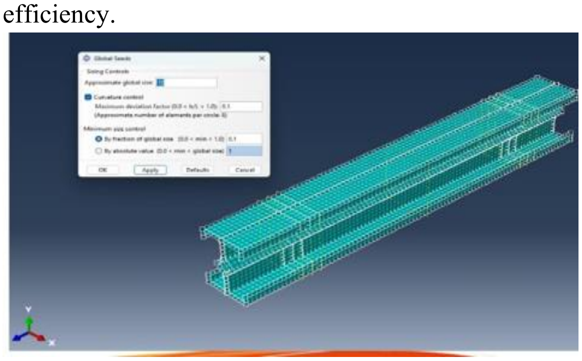

Fig 9: mesh module

7.8 Job Module
The Job module is used to create, submit, and monitor the finite element analysis. It executes the simulation and generates the numerical results.

7.9 Visualization Module
The Visualization module is used to display and evaluate the analysis results, including stress contours, displacement, strain, deformation pattern, and load–deflection curves.

7.10 Linear Analysis
Linear analysis assumes that the material remains elastic and that deformations are small. The load–displacement relationship is linear and is used to determine stresses, strains, and deflections within the elastic range.

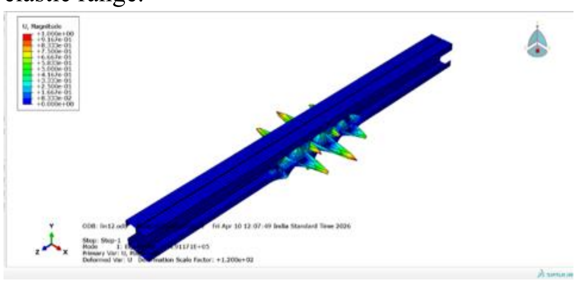

Fig 10: linear analysis

7.11 Nonlinear Analysis
Nonlinear analysis considers material nonlinearity, geometric nonlinearity, and large deformations. It is used to accurately predict yielding, local buckling, deformation, and the ultimate flexural behaviour of the cold-formed steel built-up I-beam with a web stiffener. The finite element model developed in ABAQUS was validated by comparing the numerical load–deflection response and failure mode with published experimental results. The close agreement between the two confirmed the accuracy and reliability of the developed numerical model.

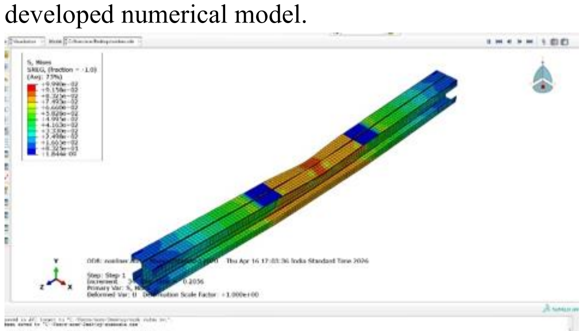

Fig 11: non-linear analysis

VIII. VALIDATION

The developed finite element model was validated by comparing its numerical results with the published experimental study conducted by P. Manikandan and M. Thulasi (2019) on cold-formed steel lipped channel built-up I-beams with intermediate web stiffeners. The validation model was developed in ABAQUS using the same section dimensions, material properties, boundary conditions, loading arrangement, and four-point bending configuration as reported in the experimental investigation.
The validation specimen consisted of a cold-formed steel built-up I-beam with an overall length of 1200 mm, section depth of 75 mm, flange width of 40 mm, lip size of 20 mm, intermediate web stiffener length of 100 mm, and a uniform thickness of 1.6 mm. These dimensions were used to develop the three-dimensional finite element model in ABAQUS.
The load–deflection response obtained from the finite element analysis was compared with the experimental results. The comparison showed good agreement between the numerical and experimental load–deflection curves, with only minor variations that can be attributed to modelling assumptions, material idealization, and experimental uncertainties. The finite element model also accurately predicted the deformation pattern and failure mode observed in the experimental study.
The close agreement between the numerical and experimental results confirms the accuracy and reliability of the developed ABAQUS model for predicting the flexural behaviour of cold-formed steel built-up I-beams with web stiffeners. Therefore, the validated finite element model can be used as a dependable numerical tool for analysing the flexural response of similar cold-formed steel built-up beam sections.

IX. RESULTS AND DISCUSSION

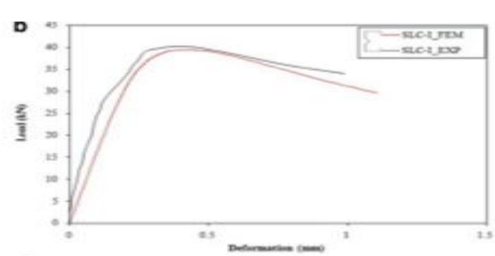

Fig 12: graph from validation

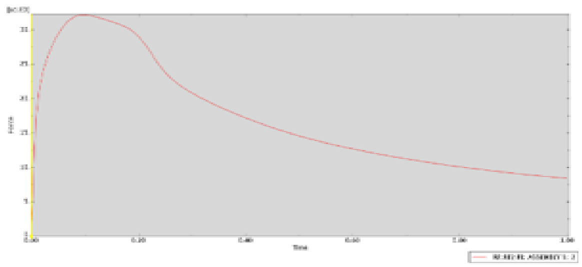

Fig 13: graph will recei ved

The finite element analysis of the cold-formed steel built-up I-beam with a web stiffener was successfully carried out using ABAQUS. The numerical model was validated by comparing the predicted load–deflection response with the published experimental results. The comparison showed good agreement between the numerical and experimental load–deflection curves, indicating that the developed finite element model accurately represents the flexural behaviour of the beam.

The validated finite element model provides a reliable numerical approach for evaluating the flexural performance of cold-formed steel built-up I-beams with web stiffeners and can be confidently used for future numerical investigations.

X. CONCLUSION

This study presented the finite element modelling and validation of a cold-formed steel built-up I-beam with a web stiffener using ABAQUS. A three-dimensional numerical model was developed by incorporating the material properties, section geometry, boundary conditions, and four-point bending loading arrangement based on the published experimental study. The numerical results were compared with the experimental load–deflection response and failure mode for validation.

The comparison demonstrated good agreement between the numerical and experimental results, confirming the accuracy and reliability of the developed finite element model. The ABAQUS model successfully predicted the flexural behaviour, deformation pattern, and structural response of the built-up I-beam with a web stiffener. Minor differences between the numerical and experimental results were attributed to modelling assumptions and experimental uncertainties.

The validated finite element model provides a reliable numerical approach for analysing the flexural behaviour of cold-formed steel built-up I-beams with web stiffeners. The outcomes of this study demonstrate that ABAQUS is an effective tool for predicting the structural performance of cold-formed steel members and can be used confidently for future numerical investigations.

REFERENCES

[1] P. Sangeetha et al., "Flexural Behaviour of CFS Gapped Built-Up Channel Beam with Web and Flange Stiffeners," International Journal of Integrated Engineering, 2025.

[2] Saffa. I. Ali and A. A. Allawi, "Effect of Web Stiffeners on the Flexural Behaviour of Composite GFRP-Concrete Beam Under Impact Load," Journal of Engineering, vol. 27, no. 3, 2021.

[3] G. Prabha and R. Emil Reyan, "Flexural Behaviour of Rolled Steel I Beam with Different Stiffener Positions," International Journal of Engineering and Technology, 2018.

[4] S. Qadir et al., "Design Optimization for Cold Rolled Steel Beam Sections with Web and Flange Stiffeners," Journal of Constructional Steel Research, vol. 213, 2024.

[5] M. Priyanka and D. Amali, "Study on Flexural Behaviour of Cold Formed Steel Built-Up I-Beams Composed of Two Sigma Sections," 2020.

[6] P. Manikandan and M. Thulasi, "Investigation on Cold-Formed Steel Lipped Channel Built-Up I Beam with Intermediate Web Stiffener," 2019.

[7] ABAQUS Documentation, ABAQUS Analysis User's Manual, Dassault Systèmes Similia Corp., Providence, RI, USA.

[8] Bureau of Indian Standards, IS 801:1975, Code of Practice for Use of Cold-Formed Light Gauge Steel Structural Members in General Building Construction, New Delhi, India, 1975.

[9] Bureau of Indian Standards, IS 800:2007, General Construction in Steel – Code of Practice, New Delhi, India, 2007.