© July 2026 | IJIRT | Volume 13 Issue 2 | ISSN: 2349-6002

Validation Of Cold-Formed Steel C-section with Web Perforation Under Shear by Using ABAQUS

Dr. D. Amali[1], Lokatharani.R[2]
[1] *Assistant Professor, Department of Civil Engineering, Government College of Engineering, Salem*
[2] *Postgraduate Student, Department of Civil Engineering, Government College of Engineering, Salem*

***Abstract*—The present study focuses on the finite element validation of cold-formed steel C-section with web perforations subjected to shear loading using ABAQUS. A three-dimensional finite element model is developed based on a published validation study. The numerical model is validated by comparing its response with the reference study to establish the accuracy of the adopted modelling procedure. The validated model provides confidence for future numerical investigations involving web perforation configurations and structural parameters.**

The study establishes a reliable finite element modelling methodology for analysing cold-formed steel C-section beam with web perforations under shear loading. The validated ABAQUS model developed in this research forms the basis for the subsequent phase of the project involving parametric investigations and design-oriented studies.

***Index Terms*—Cold-Formed Steel C-section, Web Perforations, ABAQUS, Finite Element Validation, Shear Loading.**

I. INTRODUCTION

In recent years, the demand for integrating building services within structural systems has increased significantly. Mechanical, electrical, and plumbing (MEP) services are commonly routed through beam webs to reduce the floor-to-floor height and improve space utilisation. For this purpose, web perforations are provided in structural beams. Although these openings improve the functional requirements of buildings, they influence the structural behaviour of the member by reducing the effective web area available to resist shear forces. As a result, the structural response of C-section with web perforations requires careful investigation.

Finite element analysis has become an effective numerical technique for studying the behaviour of structural members under different loading conditions. ABAQUS is widely used for modelling steel structures because it enables accurate representation of geometry, material properties, loading conditions, and boundary conditions. Before using a finite element model for detailed structural investigations, it is necessary to validate the numerical model against published research to ensure that the adopted modelling procedure accurately predicts the behaviour of the structural member.

The present study is therefore aimed at validating a finite element model of a cold-formed steel C-section with web perforations subjected to shear loading. The validated numerical model will provide the foundation for future investigations involving different beam configurations and web perforation geometries.

Figure 1:

II. NEED FOR THE STUDY

Cold-formed steel C-section are increasingly used in structural applications due to their improved structural efficiency and ease of fabrication. The provision of web perforations is essential for accommodating service ducts in buildings; however, these openings alter the shear-resisting mechanism of the beam. Consequently, an accurate understanding of the structural behaviour of perforated C-section is required.
Experimental investigations provide reliable information regarding structural performance but require significant laboratory facilities, time, and cost. Finite element analysis provides an efficient alternative for evaluating the behaviour of structural members under controlled numerical conditions. Before numerical models can be applied to further investigations, they must be validated against published studies. Hence, the present research focuses on developing and validating an ABAQUS finite element model for cold-formed steel C-section with web perforations under shear loading.

III. PROBLEM STATEMENT

The introduction of web perforations in cold-formed steel C-section affects the stress distribution and shear behaviour of the structural member. Although several researchers have investigated the behaviour of steel members with web openings, reliable numerical validation is essential before finite element models can be used for advanced structural investigations.
The primary challenge addressed in this study is the development of a validated ABAQUS finite element model capable of accurately representing the behaviour of cold-formed steel C-section with web perforations subjected to shear loading. Validation of the numerical model provides confidence in the adopted modelling procedure and establishes a reliable basis for future research involving different structural configurations and web perforation arrangements.

IV. LITERATURE REVIEW

The structural behaviour of cold-formed steel (CFS) members with web perforations has attracted considerable attention in recent years because of their increasing use in modern construction. Researchers have investigated the influence of web openings on the strength, stiffness, and failure characteristics of steel members through experimental studies, numerical simulations, and analytical investigations. The findings of these studies have significantly contributed to understanding the behaviour of perforated members and have established finite element analysis as a reliable tool for predicting structural response. The following review summarises the key contributions relevant to the present validation study.
1.Abbas et all (2023). investigated the shear behaviour of steel I-beams with web perforations using finite element analysis. The study focused on understanding the influence of web openings on the structural response of the beam under shear loading. Numerical models were developed to evaluate stress distribution, deformation characteristics, and failure behaviour. The results indicated that the presence of web perforations modified the load transfer mechanism within the web region and affected the shear resistance of the beam. The study demonstrated that finite element modelling can effectively simulate the behaviour of perforated steel members when appropriate material properties and boundary conditions are adopted. The findings provide useful guidance for the numerical modelling procedure adopted in the present study.
2.Reddy and Singh et all (2023) examined the structural performance of steel beams containing web openings under different loading conditions. Their investigation evaluated the influence of opening geometry on the behaviour of the beam and discussed the associated stress concentration around the perforated region. Finite element analysis was used to study the structural response, and the numerical predictions showed good agreement with the reported behaviour of the beam. The authors concluded that numerical analysis provides an efficient approach for evaluating the behaviour of perforated steel members and can be used to understand the effect of web openings before undertaking detailed experimental investigations.
3.Zhang.L and Cheng.X et all (2020**)** studied the behaviour of steel members with web openings using nonlinear finite element analysis. Their work primarily focused on developing an accurate numerical model capable of predicting the structural response under applied loading. Appropriate material models, loading conditions, and boundary conditions were

incorporated in the finite element model to improve prediction accuracy. The study confirmed that validated numerical models are capable of reproducing the behaviour observed in experimental investigations and highlighted the importance of mesh refinement and realistic modelling assumptions during finite element analysis.

4.Poologanathan Keerthan and Mahen Mahendran et all (2024) presented one of the most significant studies related to the present research by investigating the shear behaviour of cold-formed steel lipped channel beams with web openings. The study combined experimental testing with detailed finite element modelling to develop improved shear design recommendations. ABAQUS was used to simulate the structural behaviour of the specimens, and the numerical predictions were validated against experimental observations. The validated numerical model accurately captured the stress distribution, deformation behaviour, and failure modes of the tested members. The methodology adopted in their investigation forms the basis for the ABAQUS validation procedure used in the present study. Their research demonstrates the importance of validating finite element models before extending them to further numerical investigations involving different structural configurations.

5.Yuva Ranjini et al. (2024**)** conducted both experimental investigations and finite element simulations to evaluate the effect of web opening size and location on the shear performance of perforated steel members. The study analysed stress redistribution, load-deflection behaviour, and failure patterns under shear loading. Based on the findings, modified shear reduction factors were proposed to achieve safer and more economical structural design.

The literature presented in the project also includes recent research relevant to cold-formed steel C-section and finite element modelling. These studies collectively indicate that finite element analysis has become an effective numerical tool for evaluating the behaviour of steel members with web perforations. The published investigations consistently emphasise that the accuracy of numerical predictions depends on appropriate modelling of geometry, material properties, boundary conditions, loading arrangements, and mesh discretisation. Validation against published experimental or numerical data is therefore an essential requirement before conducting further numerical studies.

V. RESEARCH GAP

Previous studies have established finite element analysis as a reliable technique for predicting the behaviour of perforated members and have proposed improved approaches for evaluating shear resistance. However, the available studies indicate the need for validating finite element models before applying them to new structural configurations.

The present study addresses this requirement by developing and validating an ABAQUS finite element model for a cold-formed steel C-section with web perforations subjected to shear loading. The validated model developed in this investigation will provide a reliable basis for future numerical studies involving different web opening configurations and C-sections.

VI. OBJECTIVES OF THE STUDY

The objectives of the present study are:

1. To study the behaviour of cold-formed steel C-section with web perforations under shear loading.
2. To develop a three-dimensional finite element model using ABAQUS.
3. To define the material properties, geometry, loading conditions, and boundary conditions for the numerical model.
4. To validate the developed finite element model using the selected reference study.
5. To compare the numerical response obtained from ABAQUS with the published validation study.
6. To establish a reliable numerical modelling procedure for future investigations.

VII. SCOPE OF THE STUDY

The present investigation is limited to the validation of a finite element model for a cold-formed steel C-section with web perforations under shear loading. The study includes numerical modelling in ABAQUS, definition of material properties, application of loading and boundary conditions, and comparison of the numerical response with the selected validation study. Experimental investigation and detailed parametric analysis are beyond the scope of this phase and are proposed as future work.

VIII. RESEARCH METHODOLOGY

The present study adopts a systematic numerical approach to validate the finite element model of a cold-formed steel C-section with web perforations subjected to shear loading. The research methodology was developed based on the objectives of the study and consists of a sequence of steps beginning with an extensive review of published literature and ending with the validation of the numerical model developed in ABAQUS. The methodology adopted in this investigation is illustrated in Figure 2**.**

The first stage of the research involved a comprehensive review of published journal articles related to cold-formed steel member's C-section s, web perforations, shear behaviour, and finite element modelling. The literature review provided an understanding of the structural behaviour of perforated steel members and helped identify a suitable published study for validating the numerical model. Based on the literature survey, the work reported by Poologanathan Keerthan and Mahen Mahendran (2014) Improved shear design rules for lipped channel beams with web opening**s**. was selected as the validation reference because it presented a detailed finite element model supported by experimental investigation, making it suitable for reproducing the numerical analysis in ABAQUS.

Following the selection of the validation study for 200*75*15*1.9, the geometry of the cold-formed steel C-section was developed in ABAQUS using the dimensions reported in the selected reference. The beam configuration, web perforation details, and overall cross-sectional arrangement were modelled to match the validation specimen. The material properties adopted for the numerical model were defined according to the reference study to ensure consistency during validation.

The developed geometry was discretised using suitable finite element mesh techniques. Mesh refinement was adopted in regions expected to experience higher stress concentration, particularly around the web perforations. The mesh configuration was selected to achieve a balance between computational efficiency and numerical accuracy. Appropriate boundary conditions and loading arrangements were then assigned to reproduce the support conditions and loading adopted in the validation study. These modelling assumptions ensured that the numerical simulation closely represented the reference model used for comparison.

The finite element analysis was subsequently carried out in ABAQUS under the prescribed loading conditions. The structural response of the model was evaluated by examining the deformation pattern, stress distribution, and overall behaviour of the beam. The numerical response obtained from the developed ABAQUS model was compared with the published validation study to verify the accuracy of the modelling procedure. The comparison established the reliability of the developed finite element model and confirmed its suitability for analysing cold-formed steel C-section with web perforations under shear loading.

The validated numerical model developed in this phase of the research forms the basis for future investigations involving different web opening configurations and structural parameters. The overall research methodology adopted in the present investigation is summarised in Figure 2**.**

Flow Sequence:

Literature Review
↓
Selection of Validation Study
↓
Development of ABAQUS Geometry
↓
Material Property Definition
↓
Mesh Generation
↓
Boundary Conditions
↓
Load Application
↓
Finite Element Analysis
↓
Validation with Published Study
↓
Discussion and Conclusions

Figure 2. Research Methodology Flowchart

IX. ABAQUS FINITE ELEMENT MODELLING

Finite element modelling was carried out using ABAQUS to reproduce the behaviour of the selected validation specimen. The modelling procedure followed the information presented in the reference study adopted in the project. The beam geometry was created according to the dimensions of the validation specimen, and the web perforations were incorporated to represent the actual structural configuration.

The material properties were assigned based on the values reported in the validation study. Appropriate section properties were defined before assembling the complete model. The finite element mesh was generated using suitable shell elements to represent the thin steel plates forming the C-section. A refined mesh was adopted around the web opening to improve the prediction of stress concentration and deformation.

The loading and support conditions were defined to produce the validation model accurately. The supports were assigned according to the published study, and the external load was applied to generate the required shear action within the beam. The numerical analysis was then performed in ABAQUS to obtain the structural response of the beam under the specified loading condition.

The finite element model generated stress contours, deformation patterns, and reaction responses that were used for comparison with the selected validation study. This comparison formed the basis for evaluating the accuracy of the developed numerical model.

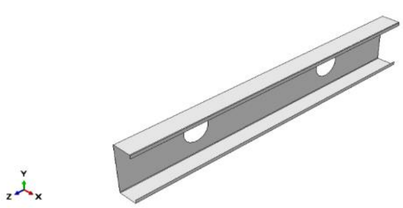

Figure 3. Geometry of the Validation Model

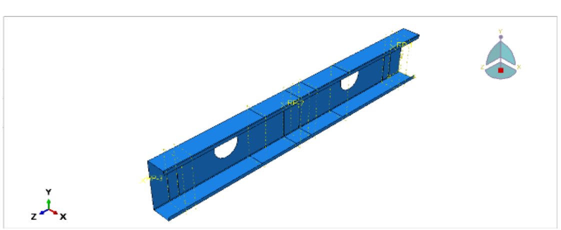

Figure 4. Finite Element assembly

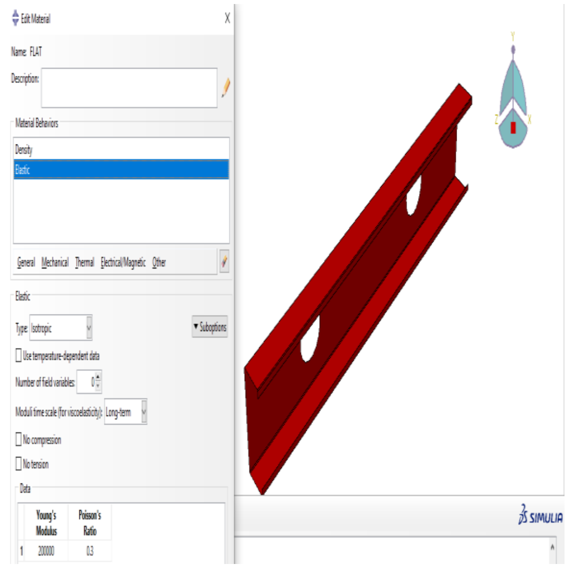

Figure 5. Material properties

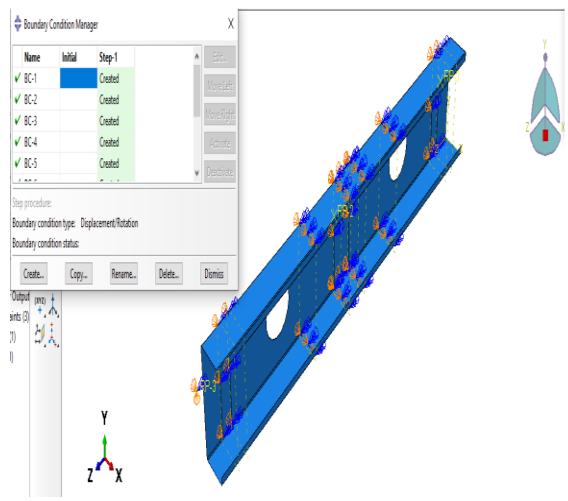

Figure 6. Boundary Conditions and Loading

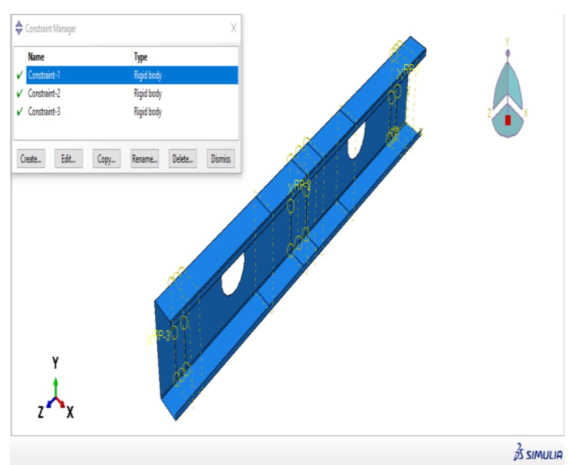

Figure 7. Interaction module

Table 1. Summary of Numerical Modelling Procedure

Step	Description
Software	ABAQUS
Model Type	Three-dimensional finite element model
Geometry	Cold-formed steel C-section with web perforation
Material Properties	E=200000 N/mm^2 $\boldsymbol{\mu}$=0.3 Density= 78.5*10^{-6}
Mesh	Shell element type = S4R
Boundary Conditions	Left & Right supports= U_X, U_Y, $\boldsymbol{\theta}_Z$ = Restrained Mid-Span loading = U_X, U_Z, $\boldsymbol{\theta}_Z$ = Restrained
Loading	Shear loading (midpoint loading)
Output	Stress distribution, deformation, validation response

X. VALIDATION OF THE FINITE ELEMENT MODEL

The geometry of the validation specimen was developed in ABAQUS as defined according to the published study to maintain consistency between the numerical model and the reference specimen. The finite element mesh was generated carefully, with sufficient refinement in the region surrounding the web opening to accurately capture the stress distribution during loading.

The loading and support conditions were assigned to reproduce the shear behaviour of the beam under the specified loading arrangement. Numerical analysis was then carried out to obtain the deformation pattern, stress distribution, and overall structural response as given in the **Table 1**. The results obtained from the ABAQUS model were compared with those reported in the validation study to evaluate the accuracy of the modelling procedure.

The comparison indicated that the developed finite element model successfully produced the structural behaviour reported in the selected validation study. The close agreement between the developed model and the published study confirms that the modelling approach adopted in the present investigation is suitable for analysing cold-formed steel C-section with web perforations under shear loading.

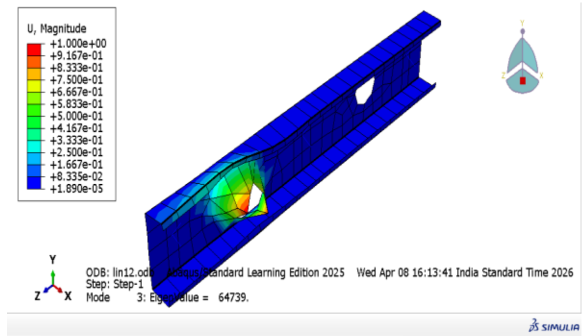

Figure 8. ABAQUS Validation Model linear analysis

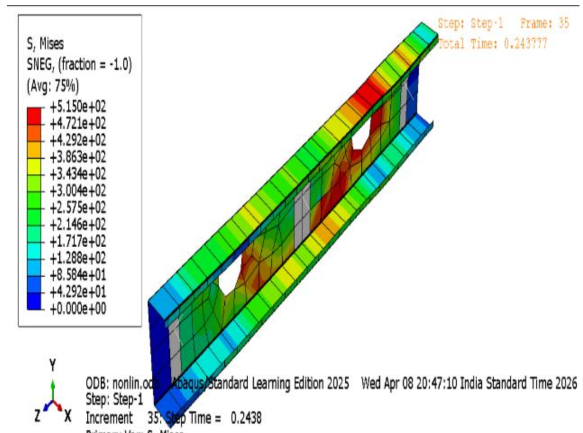

Figure 9. ABAQUS Validation Model Non-linear analysis

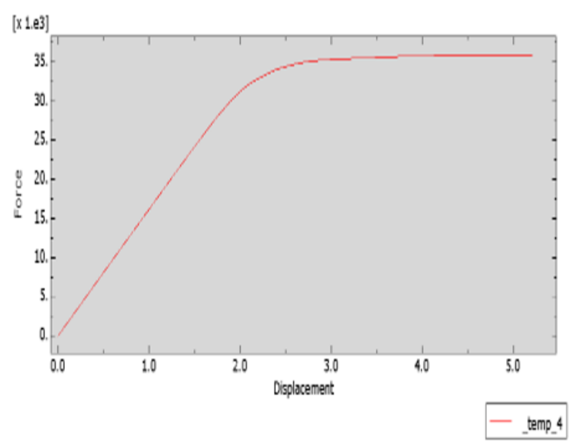

Figure 10. Graphical Result

XI. RESULTS AND DISCUSSION

The finite element analysis performed using ABAQUS provided the structural response of the validation model under shear loading. The numerical model generated the deformation profile and stress distribution of the beam, enabling comparison with the published validation study.

The deformation pattern obtained from the developed ABAQUS model was found to be consistent with that reported in the reference study. The maximum deformation occurred in the region influenced by the applied loading and web perforation, indicating that the model successfully represented the structural behaviour of the beam under shear loading. Similarly, the stress distribution obtained from the numerical analysis followed the expected pattern around the web opening, demonstrating that the finite element model was capable of capturing the critical response of the structural member.

The validation study confirms that the adopted modelling procedure accurately represents the behaviour of the selected beam configuration. The close agreement between the developed ABAQUS model and the published reference indicates that the selected material properties, geometry, boundary conditions, loading arrangement, and meshing strategy are appropriate for finite element modelling of cold-formed steel C-section with web perforations.

XII. CONCLUSION

A numerical model was developed as reported in the selected validation study, analysed and compared with the published reference to verify the accuracy of the adopted modelling procedure.

The adopted modelling methodology accurately represented the deformation behaviour and stress distribution of the beam under shear loading, thereby confirming the reliability of the finite element model.

The validated numerical model developed in this study provides a reliable basis for future numerical investigations involving different C-sections and web perforation configurations. The outcome of this phase establishes confidence in the modelling procedure and forms the foundation for the subsequent phase of the research.

XIII. FUTURE SCOPE

The validated finite element model developed in the present study provides a foundation for further investigations on cold-formed steel C-section with web perforations. Future work will include the analysis of different C-sections, variations in web perforation geometry, and detailed numerical investigations to evaluate the influence of these parameters on shear behaviour. The validated model may also be extended to support future experimental studies and the development of design recommendations for cold-formed steel members.

REFERENCES

[1] P. Keerthan and M. Mahendran, "Improved shear design rules for lipped channel beams with web openings," *Journal of Constructional Steel Research*, vol. 97, pp. 127–142, Jun. 2014. doi: 10.1016/j.jcsr.2014.01.011.

[2] P. Keerthan and M. Mahendran, "Improved shear design rules of cold-formed steel beams," *Engineering Structures*, vol. 99, pp. 603–615, Sep. 2015. doi: 10.1016/j.engstruct.2015.04.027.

[3] K. S. Wanniarachchi, M. Mahendran, and P. Keerthan, "Shear behaviour and design of lipped channel beams with non-circular web openings," *Thin-Walled Structures*, vol. 119, pp. 83–102, Oct. 2017. doi: 10.1016/j.tws.2017.03.035.

[4] P. Keerthan and M. Mahendran, "New design rules for the shear strength of LiteSteel beams with web openings," *Journal of Structural Engineering*, vol. 139, no. 5, pp. 751–760, 2013. doi: 10.1061/(ASCE)ST.1943-541X.0000563.

[5] P. Keerthan and M. Mahendran, "Improving the shear capacities of lipped channel beams with web openings using plate stiffeners," *Journal of Structural Engineering*, vol. 141, no. 11, 2015. doi: 10.1061/(ASCE)ST.1943-541X.0001199.

[6] B. W. Schafer, "Review: The direct strength method of cold-formed steel member design," *Journal of Constructional Steel Research*, vol. 64, nos. 7–8, pp. 766–778, 2008.

[7] Y. L. Moen and B. W. Schafer, "Elastic buckling of thin plates with holes in cold-formed steel members," *Thin-Walled Structures*, vol. 47, no. 12, pp. 1597–1607, 2009.

[8] B. Young and J. Yan, "Finite element analysis of cold-formed steel members with web openings,"

Journal of Constructional Steel Research, vol. 58, nos. 5–8, pp. 683–698, 2002.

[9] N. Silvestre and D. Camotim, “Local, distortional and global buckling behaviour of cold-formed steel members,” *Thin-Walled Structures*, vol. 44, no. 5, pp. 493–503, 2006.

[10] G. J. Hancock, “Cold-formed steel structures: Research and recent developments,” *Journal of Constructional Steel Research*, vol. 59, no. 4, pp. 473–487, 2003.

[11] P. Keerthan and M. Mahendran, “Finite element analyses of lipped channel beams with web openings in shear,” in *Proceedings of the 21st International Specialty Conference on Cold-Formed Steel Structures*, St. Louis, MO, USA, 2012.

[12] L. Sundararajah, M. Mahendran, and P. Keerthan, “New web crippling design rules for cold-formed steel beams,” in *Proceedings of the 24th International Specialty Conference on Cold-Formed Steel Structures*, 2018.

[13] Anbarasu, M., Yuvaranjani, P. M., et al. Shear Behaviour of Ultra-High Strength Cold-Formed Steel Lipped Channel Beams. Thin-Walled Structures, 2024.

[14] Yuvaranjani, P. M., Gatheeshgar, P., et al. Design and Shear Strength of Cold-Formed Steel Lipped Channel Sections under Shear Loading. Thin-Walled Structures, 2024.

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