ISSN (Print): 2957-9325, ISSN (Online): 2957-9333

INTERNATIONAL JOURNAL OF APPLIED ENGINEERING RESEARCH TRANSACTION

(Open Access-Referred-Peer-Reviewed Journal)

Journal homepage:https://ijaer-transaction.com/

Research Article

PERFORMANCE EVALUATION OF COLD-FORMED STEEL ENCASING CHANNEL FOR RETROFITTING STRUCTURAL STEEL SECTION USING ANSYS

Ms. Komal.G.Jadhao [1] , Prof.V.P.Bhusare [2], Dr.Y.R.Suryawanshi [3]

[1] PG Student (ME Structural Engineering), Department of Civil Engg., JSPM'S Imperial College of Engineering and Research, Wagholi, Pune-412207, India.

[2] Assistant Professor, Department of Civil Engineering, Imperial College of Engineering and Research, Wagholi, Pune-412207, India.

[3] Head of Department of Civil Engineering, Imperial College of Engineering and Research, Wagholi, Pune-412207, India.

Article History	Received: 16.04.2025	Accepted: 28.04.2025	Published: 09.05.2025

Abstract

Retrofitting existing structural steel members is essential for enhancing their load-bearing capacity, stiffness, and durability, especially in aging infrastructure and seismically active regions. Cold-formed steel (CFS) sections have emerged as an efficient retrofitting material due to their lightweight nature, high strength-to-weight ratio, and ease of fabrication. This review paper provides a comprehensive evaluation of the performance of cold-formed steel encasing channels used for retrofitting structural steel sections, with a focus on numerical modeling using ANSYS finite element software. Key mechanical properties of CFS, types of encasing configurations, and various structural retrofitting techniques are discussed. The paper highlights the modeling strategies, material definitions, boundary conditions, and loading criteria implemented in ANSYS-based studies. Results from recent literature demonstrate that CFS encasement significantly enhances structural behavior under axial and lateral loads, delays local buckling, and redistributes stress efficiently. Despite these advantages, challenges remain in practical implementation and code development. The study identifies research gaps and outlines future directions for advanced modeling, hybrid retrofitting systems, and standardization efforts to further improve structural retrofitting practices.

Keywords: Cold-formed steel (CFS); Retrofitting; Structural steel; ANSYS; Finite element analysis (FEA); Encasing channel; Buckling; Strengthening; Structural rehabilitation; Load-bearing capacity

1. Introduction

ISSN (Print): 2957-9325, ISSN (Online): 2957-9333

INTERNATIONAL JOURNAL OF APPLIED ENGINEERING RESEARCH TRANSACTION

(Open Access-Referred-Peer-Reviewed Journal)

Journal homepage:https://ijaer-transaction.com/

1.1 Background and Importance of Structural Retrofitting

Structural retrofitting plays a crucial role in enhancing the load-bearing capacity, ductility, and durability of aging or deficient structural elements, especially in regions susceptible to seismic activity, environmental degradation, or evolving code requirements. With the increasing age of global infrastructure and the need to comply with updated safety standards, retrofitting has emerged as a sustainable and cost-effective alternative to replacement. It involves modifying existing structures to improve performance under static and dynamic loading conditions (Ghobarah, 2001). Effective retrofitting enhances the resilience of structures while minimizing disruption and resource consumption, which is particularly important for critical infrastructure such as bridges, buildings, and industrial facilities (Basha & Siva, 2018).

1.2 Role of Cold-Formed Steel (CFS) in Structural Strengthening

Cold-formed steel (CFS) has gained prominence as a retrofitting material due to its high strength-to-weight ratio, ease of fabrication, and versatility in design. Produced by bending thin steel sheets at room temperature, CFS sections exhibit excellent mechanical properties that make them suitable for structural applications, including encasing, bracing, and load redistribution in deficient steel members (Yu & LaBoube, 2010). The lightweight nature of CFS minimizes additional loads on existing structures, while its customizable shapes allow for effective integration in retrofitting schemes. Studies have shown that encasing structural elements with CFS channels can enhance stiffness, prevent local buckling, and improve overall load resistance (Dundu, 2013).

1.3 Significance of Finite Element Analysis in Retrofitting Evaluation

Finite Element Analysis (FEA) has become a standard tool in structural engineering for simulating the behavior of materials and structural components under various loading conditions. In retrofitting applications, FEA enables detailed performance evaluation, allowing engineers to predict stress distribution, deformation patterns, and failure modes before implementation (Zienkiewicz et al., 2005). Software like ANSYS provides powerful modeling capabilities that help optimize retrofitting designs by analyzing different configurations, material properties, and boundary conditions. This

ISSN (Print): 2957-9325, ISSN (Online): 2957-9333

INTERNATIONAL JOURNAL OF APPLIED ENGINEERING RESEARCH TRANSACTION

(Open Access-Referred-Peer-Reviewed Journal)

Journal homepage:https://ijaer-transaction.com/

computational approach not only reduces experimental costs but also enhances the accuracy and reliability of the retrofitting process (Alshamrani & Al-Azzani, 2020).

2. Cold-Formed Steel Sections in Retrofitting Applications

2.1 Properties and Advantages of Cold-Formed Steel

Cold-formed steel (CFS) exhibits superior mechanical properties, including high yield strength, excellent ductility, and significant energy absorption capacity, making it ideal for structural retrofitting. Unlike hot-rolled steel, CFS is formed at room temperature, leading to enhanced dimensional precision and a high strength-to-weight ratio (Yu & LaBoube, 2010). Its corrosion resistance, recyclability, and ease of transport further contribute to its growing use in rehabilitation works. Moreover, the thin-walled nature of CFS allows for easy cutting, bolting, and welding on site, facilitating quick and economical retrofitting solutions (Dundu, 2013).

2.2 Types of CFS Sections Used for Retrofitting

Several CFS profiles are used in retrofitting, depending on the structural need and geometry of the existing component. Common sections include C-channels, Z-sections, hat sections, and box-type elements. Among these, C-channels are frequently employed due to their ease of connection and structural compatibility. Boxed encasing of existing steel members with CFS channels not only strengthens the element but also improves torsional and lateral resistance (Ghosh & Sahoo, 2016). The choice of section is typically governed by load demands, available retrofitting space, and connection feasibility.

2.3 Case Studies on Retrofitting with CFS Channels

Numerous experimental and analytical studies have validated the effectiveness of CFS encasing for strengthening deficient or aging steel structures. In a study by Kim and Yu (2015), retrofitted H-beams with CFS encasement showed enhanced moment capacity and improved energy dissipation during cyclic loading. Similarly, Sultana and Ahmad (2017) reported significant improvements in flexural and shear resistance in steel-concrete composite beams encased with CFS sections. These case studies demonstrate that properly designed CFS retrofitting can restore or even exceed the original design capacity.

2.4 Limitations and Challenges in Practical Implementation

Despite its benefits, CFS retrofitting presents several challenges in field applications. Thin walls are prone to local buckling and require stiffeners or bracing for stability under heavy loads. Improper joint detailing or welding can reduce the effectiveness of the retrofit. Moreover, the design codes for retrofitting using CFS are still evolving, leading to uncertainties in structural assessment and compliance (Hajjar et al., 2018). Other practical barriers include labor expertise, availability of specific profiles, and long-term durability concerns under harsh environmental conditions.

3. Structural Steel Retrofitting Techniques

3.1 Overview of Common Retrofitting Methods

Retrofitting techniques for structural steel include jacketing, bracing, strengthening using fiber-reinforced polymers (FRP), bolted or welded steel plates, and encasement using concrete or steel sections. These techniques aim to improve axial, flexural, or shear performance depending on the identified deficiencies. Each method has its own set of design requirements, cost implications, and practical constraints (Li & Xiong, 2016). Selection is typically based on damage level, retrofit objective, and structural configuration.

3.2 Encasing Techniques and Their Structural Benefits

Encasing structural steel sections is an effective retrofitting method that involves wrapping or surrounding the member with additional material, such as steel plates or CFS channels. This technique improves cross-sectional area, inertia, and confinement, thereby enhancing load-carrying capacity and resistance to buckling (Subramaniam & Prakash, 2013). CFS encasing is particularly beneficial as it adds minimal weight while providing high stiffness, and it can be fabricated off-site for rapid deployment.

3.3 Comparative Analysis of Retrofitting Materials

A comparative analysis reveals that while traditional concrete jacketing offers good durability and fire resistance, it is heavy and labor-intensive. FRP composites, though lightweight and corrosion-resistant, suffer from poor fire performance and are costlier.

CFS offers a balanced approach with ease of installation, structural efficiency, and cost-effectiveness, making it a competitive choice for steel retrofitting (Fawzia & Nasir, 2015). However, CFS lacks the robustness of concrete in certain conditions, necessitating hybrid or composite solutions in demanding applications.

3.4 Integration of CFS Channel in Structural Steel Retrofitting

Integrating CFS channels in retrofitting schemes requires careful consideration of load transfer mechanisms, joint detailing, and interaction with existing steel. Studies have demonstrated that CFS encasing can significantly improve stiffness and delay failure modes like local buckling and lateral-torsional buckling (Elchalakani & Zhao, 2014). Numerical modeling using FEA software like ANSYS allows simulation of these interactions, enabling optimized retrofit design that ensures structural safety and code compliance.

4. ANSYS-Based Finite Element Modeling and Analysis

4.1 Modeling Strategy for Retrofitted Sections in ANSYS

Finite Element Analysis (FEA) using ANSYS has become an integral part of retrofitting studies for evaluating the structural behavior of encased steel sections. In the context of cold-formed steel (CFS) encasement, the typical modeling strategy involves creating a 3D geometric model of the existing structural steel section and applying a shell or solid element overlay to represent the encasing CFS channel. Mesh refinement around stress concentration zones, such as beam-column joints or contact interfaces, enhances accuracy (Schafer & Peköz, 1998). The CFS is often modeled using shell elements like SHELL181 or SOLID185 to capture local buckling effects and stress distribution accurately (ANSYS Inc., 2021).

4.2 Material Property Definition and Boundary Conditions

In simulation, correct assignment of material properties is essential. For structural steel (e.g., ASTM A36), a bilinear isotropic hardening model is often used with a yield stress of around 250 MPa and a modulus of elasticity of 200 GPa. Cold-formed steel, depending on the specific grade (e.g., ASTM A653), may have higher yield strength (typically 345 MPa or more) but thinner wall sections, influencing buckling behavior

ISSN (Print): 2957-9325, ISSN (Online): 2957-9333

INTERNATIONAL JOURNAL OF APPLIED ENGINEERING RESEARCH TRANSACTION

(Open Access-Referred-Peer-Reviewed Journal)

Journal homepage:https://ijaer-transaction.com/

(Moen & Schafer, 2008). Boundary conditions are defined to replicate realistic support conditions—either pinned, fixed, or partially restrained. Contact interactions between CFS and the existing section are modeled using frictional or bonded contact to simulate welding, bolting, or adhesive bonding.

4.3 Load Applications and Failure Criteria

Loading conditions are defined based on structural objectives: axial compression for column studies, lateral-torsional buckling for beams, and cyclic loading for seismic assessments. The load is applied incrementally using static or dynamic solvers to observe load-deflection behavior, stress contours, and ultimate failure points. Failure criteria are generally based on Von Mises stress exceeding yield, local buckling in CFS, or excessive lateral displacements (Sultana & Ahmad, 2017). The inclusion of geometric and material nonlinearities in the model provides better correlation with real-world behavior.

4.4 Review of Existing ANSYS Studies on CFS-Retrofit Performance

Several studies using ANSYS FEA have validated the effectiveness of CFS encasing for strengthening deficient structural members. Elchalakani and Zhao (2014) demonstrated that retrofitting steel columns with welded CFS channels significantly increased their axial load capacity and delayed buckling. Ghosh and Sahoo (2016) simulated the performance of I-beams encased with CFS and observed enhanced moment resistance and energy dissipation during lateral loading. These findings highlight ANSYS as a reliable tool for optimizing retrofitting configurations and predicting long-term performance under realistic loading scenarios.

5. Conclusions and Future Research Directions

5.1 Summary of Key Findings from the Literature

The review indicates that cold-formed steel (CFS) encasing is a highly effective retrofitting method for enhancing structural performance, offering increased strength, ductility, and buckling resistance. Its light weight, ease of installation, and compatibility with existing steel sections make it particularly suited for rehabilitating older structures. Experimental and analytical studies confirm that CFS encasement improves structural stability and load-bearing capacity significantly.

5.2 Performance Insights of CFS Encasing Channel from ANSYS Studies

ANSYS-based FEA models have proven instrumental in understanding the behavior of retrofitted elements. Simulations reveal that CFS encasement improves stiffness and strength, delays local buckling, and redistributes stress across critical zones. The flexibility of ANSYS allows parametric studies on geometry, thickness, and material properties to optimize retrofit design (Kim & Yu, 2015). These tools reduce the need for full-scale testing while ensuring safety and compliance.

5.3 Gaps Identified in Current Research

Despite promising results, several research gaps remain. Many studies lack validation through large-scale or long-term field experiments. Interaction effects between the CFS and the original steel section under dynamic or fire conditions are insufficiently explored. Additionally, fatigue performance, corrosion resistance in humid environments, and impact of real construction tolerances are not thoroughly examined (Hajjar et al., 2018).

5.4 Recommendations for Future Investigations

Future research should focus on hybrid retrofitting techniques combining CFS with advanced materials such as FRPs or shape memory alloys. Studies should incorporate environmental exposure factors, fatigue loading, and fire safety considerations. Developing standardized design procedures and codes for CFS-based retrofitting will also enhance implementation confidence. Advanced FEA techniques such as coupled thermal-structural analysis and AI-integrated optimization can further revolutionize retrofit design in coming years.

6. Author(S) Contribution

The writers affirm that they have no connections to, or engagement with, any group or body that provides financial or non-financial assistance for the topics or resources covered in this manuscript.

7. Conflicts of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

8. Plagiarism Policy

All authors declare that any kind of violation of plagiarism, copyright and ethical matters will taken care by all authors. Journal and editors are not liable for aforesaid matters.

9. Sources of Funding

The authors received no financial aid to support for the research.

References

1. Alshamrani, M. S., & Al-Azzani, A. (2020). *Application of Finite Element Method in Retrofitting Structural Members: A Review*. Journal of Structural Engineering, 146(5), 04020048. https://doi.org/10.1061/(ASCE)ST.1943-541X.0002609
2. ANSYS Inc. (2021). *ANSYS Mechanical User's Guide*. Canonsburg, PA: ANSYS Inc.
3. Basha, S., & Siva, R. (2018). *Retrofitting Techniques for Buildings: A Review*. International Journal of Civil Engineering and Technology (IJCIET), 9(7), 1097–1106.
4. Dundu, M. (2013). *Design limitations of cold-formed steel structures*. Thin-Walled Structures, 62, 157–168. https://doi.org/10.1016/j.tws.2012.10.010
5. Elchalakani, M., & Zhao, X. L. (2014). *Retrofitting of steel columns using welded cold-formed steel channels*. Engineering Structures, 70, 165–179. https://doi.org/10.1016/j.engstruct.2014.04.025
6. Fawzia, S., & Nasir, A. (2015). *Comparison of strengthening techniques for steel members*. Journal of Constructional Steel Research, 109, 45–55. https://doi.org/10.1016/j.jcsr.2015.03.010
7. Ghobarah, A. (2001). *Performance-based design in earthquake engineering: state of development*. Engineering Structures, 23(8), 878–884. https://doi.org/10.1016/S0141-0296(01)00036-0
8. Ghosh, A., & Sahoo, D. R. (2016). *Retrofitting of steel members using cold-*

formed sections. Journal of Structural Engineering, 143(4), 04016200. https://doi.org/10.1061/(ASCE)ST.1943-541X.0001705

9. Hajjar, J. F., et al. (2018). *Design considerations for steel retrofitting*. Engineering Journal, 55(2), 75–89.
10. Kim, J., & Yu, C. (2015). *Behavior of steel beams retrofitted with cold-formed steel encasement*. Thin-Walled Structures, 94, 258–267. https://doi.org/10.1016/j.tws.2015.05.005
11. Li, G. Q., & Xiong, X. L. (2016). *Retrofitting techniques in structural steel: A state-of-the-art review*. Journal of Constructional Steel Research, 122, 1–13. https://doi.org/10.1016/j.jcsr.2016.03.027
12. Moen, C. D., & Schafer, B. W. (2008). *Direct strength design for cold-formed steel members with perforations*. Thin-Walled Structures, 46(10), 1164–1179. https://doi.org/10.1016/j.tws.2008.02.003
13. Schafer, B. W., & Peköz, T. (1998). *Computational modeling of cold-formed steel: Characterizing geometric imperfections and residual stresses*. Journal of Constructional Steel Research, 47(3), 193–210. https://doi.org/10.1016/S0143-974X(98)00020-7
14. Subramaniam, K. V., & Prakash, A. (2013). *Performance of encased structural members under axial and lateral loads*. Construction and Building Materials, 41, 510–520. https://doi.org/10.1016/j.conbuildmat.2012.12.042
15. Sultana, S., & Ahmad, N. (2017). *Strengthening of composite beams using cold-formed steel encasing*. Procedia Engineering, 173, 1584–1591. https://doi.org/10.1016/j.proeng.2016.12.248