A Comparative Study on Seismic Analysis of Multistory Buildings of LGSS and Other Conventional Structure

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Abstract
The rising demand for Light Gauge Steel Structures (LGSS) is driven by their versatility, efficiency, and environmental benefits, positioning them as a prominent alternative in the construction industry. This review paper examines LGSS in comparison to traditional Reinforced Cement Concrete (RCC) and Steel Structures, highlighting their advantages in rapid assembly and enhanced seismic resistance. By analyzing various studies and data, the paper evaluates the potential of LGSS for constructing safer and more resilient buildings in seismic-prone regions. The review employs STAAD.Pro Advanced Connect Edition and the Response Spectrum method to assess key performance metrics, including storey displacements, drifts, and base shear, across different structural systems. Additionally, it integrates considerations of cost, building period, and serviceability criteria to provide a comprehensive overview of LGSS's effectiveness and suitability for modern construction needs in earthquake-sensitive areas.

Keywords: Seismic Analysis, LGS Structure, RCC Structure, Steel Structure, STAAD.Pro.

Introduction
Light gauge steel structures have gained significant attention in the construction industry due to their versatility, efficiency, and environmental benefits. This review paper explores the role of light gauge steel in modern construction practices, focusing on its structural integrity, economic feasibility, and sustainability. As a lightweight yet robust material, light gauge steel offers distinct advantages over traditional building materials, including rapid assembly, improved seismic resilience, and a reduced environmental footprint.
The review presents a comparative analysis of multi-storey buildings incorporating light gauge steel framing (LGSF) versus conventional Reinforced Cement Concrete (RCC) systems. Utilizing advanced modelling tools such as STAAD.Pro software, the study examines the seismic performance of G+2 storey residential buildings in seismic zones III and IV. The analysis covers eight structural configurations:

1. Traditional RCC Structure
2. Light Gauge Steel Structure
3. Hot Rolled Steel Structure
4. Ground Storey RCC with Upper Storeys in LGSF

The paper employs the Response Spectrum Method to assess seismic loads and evaluates critical performance parameters, including storey displacement, drift, shear, model participation mass ratio, and building weight..By synthesizing case studies, structural analyses, and lifecycle assessments, this review aims to offer valuable insights into the potential of light gauge steel structures to advance sustainable and resilient building practices, addressing the evolving demands of modern construction.

Fig 1.1 LGSS by CFS Structure (Istanbul) :

Fig 1.2 LGSS by CFS Structure (Istanbul):

Background of the study

The construction industry is increasingly turning to innovative materials and techniques to address mod-

ern demands for efficiency, sustainability, and resilience. Among these innovations, Light Gauge Steel Structures (LGSS) have emerged as a noteworthy alternative to traditional construction methods known for their versatility, efficiency, and reduced environmental impact, LGSS provides several benefits over conventional materials like Reinforced Cement Concrete (RCC) and Hot Rolled Steel Structures . These advantages include rapid assembly, enhanced seismic performance, and a lower overall environmental footprint.
The thinness of the steel components in LGS not only reduces weight but also allows for precision in manufacturing and ease of on-site assembly. This adaptability has made LGS an attractive choice for projects ranging from residential housing to commercial and industrial buildings. This introduction sets the stage for a comprehensive examination of light gauge steel structures, aiming to bridge the gap in research and contribute valuable insights to the construction industry.

Significance of the study

The significance of this study lies in its comprehensive evaluation of Light Gauge Steel Structures (LGSS) compared to traditional construction materials, such as Reinforced Cement Concrete (RCC) and Hot Rolled Steel Structures (S-3). As the construction industry increasingly seeks efficient, sustainable, and resilient solutions, understanding the advantages and limitations of LGSS is crucial. This research provides essential insights into how LGSS performs under seismic loads and evaluates its structural efficiency, sustainability, and cost-effectiveness. By analyzing key performance metrics and incorporating real-world case studies, the study helps structural engineers and construction professionals make informed decisions about adopting LGSS. Furthermore, it addresses the growing need for innovative building practices that align with contemporary demands for rapid construction and environmental responsibility. The findings aim to advance the knowledge base on LGSS, contributing to safer, more resilient, and sustainable infrastructure in diverse seismic and environmental contexts.

Literature Review

Harshavardhan Palvai ”Modelling and design analysis of light gauge steel systems against conventional structural systems” This paper explores the benefits of advanced construction techniques like Light Gauge Steel (LGS) for achieving faster and more sustainable development. Unlike traditional, labor-intensive, and costly methods, LGS provides a dry construction solution ideal for remote locations. The study uses Vertex BD, STRAP 2018, and Staad Pro for design and analysis, demonstrating LGS's efficiency and cost-effectiveness for mid-rise buildings. Comprising galvanized steel sections from 0.5 mm to 3 mm, LGS is renowned for its corrosion resistance and is increasingly used globally. This system, which involves assembling cold-formed steel parts and paneling, is especially effective in high wind and seismic zones. Its lightweight nature reduces foundation requirements and speeds up construction by around 80%, while offering superior thermal and sound insulation. LGS is also environmentally friendly, with recyclable components, and has been incorporated into CPWD’s standard rate plans to promote resilient and efficient construction in India.
W. Leonardo Cortés-Puentes “Compressive strength capacity of light gauge steel composite columns” This paper evaluates the axial compressive strength of concrete-filled light gauge steel composite columns through experiments on long and stub columns. Findings show that confinement boosts strength by up to 16%, though local buckling limits steel-only columns to about 33% of their full capacity. Full-scale tests reveal that strength is primarily influenced by end bearing and local buckling.

Concrete-filled steel box columns enhance stiffness and ductility, and recent interest has shifted to light gauge steel columns in modular walls for low-rise buildings. The study aims to address gaps in design and experimental data for these columns, particularly focusing on their axial load strength and confinement effects.

Infent Rosel "Analytical investigation on light gauge steel fluted columns" This study uses Finite Element Analysis (ABAQUS 14) to investigate the behavior of concrete-filled steel columns with different flute shapes. Eight models are analyzed, varying the D/t ratios, flute shapes (rectangular and triangular), and steel thicknesses (1 mm and 1.2 mm). Results show that the maximum stress occurred in the 1 mm thick column with triangular flutes, while the 1.2 mm thick triangular fluted column supported the highest load. Cold-formed steel offers advantages such as reduced seismic mass, high stiffness, and easy shaping, making it ideal for decks, columns, and framing. Fluted designs enhance the column's moment of inertia and aesthetic appeal, improving its load-bearing capacity and reducing buckling.

Li Sun" In-situ retrofit strategy for transmission tower structure members using light weight steel casings" This paper presents a technique to enhance the robustness of existing light truss electric power transmission towers by preventing critical members from buckling. The approach involves enclosing these members with a rectangular casing made from two identical light gauge steel C- or U-shaped sections, connected with screws. This casing aims to delay the loss of compression load capacity by restraining lateral-torsional and weak-axis buckling. Five full-scale restrained specimens and one baseline unrestrained specimen were tested, with one restrained specimen subjected to cyclic loading and the rest to monotonic compression. Numerical simulations using ABAQUS matched the experimental results. The study showed that increasing the casing thickness significantly improves the compression capacity, with optimal performance achieved when the casing thickness exceeds 85% of the member leg thickness. This retrofit method is practical for improving the mechanical strength of transmission towers, especially in challenging locations, by using lightweight, easy-to-install casings without filler materials.

N. Soares" Energy efficiency and thermal performance of lightweight steel-framed (LSF) construction: A review" This paper reviews the energy efficiency and thermal performance of lightweight steel framed (LSF) buildings with cold-formed elements, focusing on their potential for enhancing sustainability. It discusses the benefits, such as reduced weight, faster construction, and recycling potential, as well as challenges like high thermal conductivity and lower thermal mass, which can affect energy demand and comfort. The paper provides an overview of various LSF systems, materials, and methods, strategies for reducing thermal bridges, and the use of phase change materials (PCMs) for thermal storage. It also evaluates the energy consumption, thermal comfort, and environmental performance of LSF buildings, including life cycle assessments and associated challenges.

Fani Derveni " Behavior of cold-formed steel shear walls sheathed with high-capacity sheathing" This study aims to explore the potential of CFS construction for higher capacity lateral force resisting systems, focusing on shear walls sheathed with fiber cement board (FCB) and composite steel-gypsum (SG) panels. It uses three-dimensional finite element shell modeling to assess the impact of sheathing type, screw type, and fastener pattern. Experimental testing on fasteners under monotonic and cyclic loading provides data for modeling CFS-to-sheathing connections. The research reveals that CFS shear walls sheathed with FCB and SG panels show significant improvements in capacity and exhibit different failure modes compared to traditional wood-sheathed walls. The study offers a computational tool for evaluating FCB- and SG-sheathed shear walls and includes prescriptive design recommendations. To facilitate practical use, the study also provides Pinching4 parameters for reduced-order models, addressing the computational complexity of the finite element approach. CFS construction is widely used in North America for its lightweight, economical, and recyclable properties. While extensive research exists for wood and steel-sheathed shear walls, there is limited data on FCB and SG composite panels. This study includes an experimental program with 18 test specimens to determine shear response and provides design guidelines based on finite element modeling. This work aims to enhance CFS construction capabilities and provide performance benchmarks for design codes.

Pezhman Sharaf "Lateral force resisting systems in lightweight steel frames: Recent research advances" This paper reviews recent research on improving LSF lateral load resistance, focusing on shear walls with face sheathings, strap-braced wall systems, and bolted moment frames. It highlights solutions for enhancing lateral performance and summarizes key developments from leading journals and codes. LSF systems face limitations due to thin-walled sections that struggle with lateral loads. Research into lateral force resisting systems (LFRS) for CFS framing offers promising solutions. The paper categorizes LFRS options into shear walls with face sheathings, strap-braced systems, and bolted moment frames, excluding podium-type and mixed systems where LSF plays a less significant role.

B.W. Schafer" Seismic Response and Engineering of Cold-formed Steel Framed Buildings" While past research focused on individual components, the CFS-NEES (Cold-Formed Steel Network for Earthquake Engineering Simulation) initiative has addressed the need for comprehensive building models. This effort includes shear wall and cyclic member testing, and full-scale shake table tests, which reveal a gap between idealized models and real-world performance. Initially used in nonstructural applications and secondary systems, cold-formed steel is now being explored for mid-rise buildings using two main methods: on-site fabrication with automated roll-formers and panelized systems with factory-made wall panels. Recent research aims to develop full-building solutions, improve seismic performance predictions, and create robust models for cold-formed steel structures. The CFS-NEES project, funded by the NSF and the American Iron and Steel Institute, is a key part of this effort, providing valuable data and insights to advance seismic design for these buildings.

M. R. Bambach "Behavior of Self-Drilling Screws in Light-Gauge Steel Construction" Self-drilling fasteners are commonly used in light-gauge steel constructions, but real-world conditions like construction tolerances, overtorqueing, non-perpendicular insertion, and impacts can affect their performance. This note reports on 120 single lap connection tests examining these conditions across various steel gauges and thicknesses. A proposed design equation adjusts the nominal shear strength to account for these factors, addressing scenarios not covered by current standards (AS/NZS 4600:2005 and NAS 2004). The study includes effects of spacing, screw alignment, overtorqueing, and other variables. Detailed findings and the proposed design adjustments are presented in Bambach and Rasmussen (2006).

Natalia Degtyareva " Local buckling strength and design of cold-formed steel beams with slotted perforations" In light gauge steel construction, staggered slotted perforations in Cold-Formed Steel (CFS) beams are increasingly used to improve fire and energy performance. However, these slots can reduce the load-bearing capacity of CFS beams, and current design methods do not adequately address this issue. This study aims to develop a methodology for determining the flexural capacity of slotted CFS beams, focusing on local buckling, by creating and validating three-dimensional Finite Element (FE) models. The validated models were used for a parametric analysis involving 432 FE simulations to examine the effects of slot dimensions, beam sizes, and yield strength on local buckling. The study concludes with new Direct Strength Method (DSM) based design equations to predict the bending capacity of CFS beams with staggered slotted perforations and improve their commercial viability.

Prof. S. A. Salokhe "EXPERIMENTAL AND ANALYTICAL STUDY OF BEHAVIOR OF LIGHT GAUGE STEEL COLUMN SECTION" Cold-formed steel, made by bending flat sheets at room temperature, differs from hot-rolled steel and is often used in lightweight prefabricated structures. This report evaluates the ultimate compressive strength of built-up cold-formed steel I-sections, conducts a parametric study, and compares these sections with hot-rolled steel. It also develops and validates a finite element model against experimental results. The study addresses gaps in current literature, including the lack of comprehensive assessments and comparisons, driven by the ongoing revision of the IS-801:1975 code for cold-formed steel design.

Abhijeet Shinde "Analysis and Design of Light Gauge Steel Structures for Commercial Building" This paper focuses on analyzing and designing light gauge steel structures according to Indian standard codes. Advances in materials and construction techniques have led to improvements in home construction, making buildings more energy-efficient, durable, safe, affordable, and environmentally friendly. Cold-formed steel, produced by shaping steel at room temperature using hydraulic presses or continuous casting machines, has benefited from technological advancements. Unlike traditional casting, which limits shape precision, cold-forming allows for more exact and complex designs, following established industry standards. This method not only improves the precision of steel components but also offers a cost-effective and time-efficient alternative to other manufacturing processes.

Mrunal S. Hatwar "Use of Cold Form Section for Low Cost Housing" According to the Ministry of Housing, 1.77 million people lack basic housing amenities. Cold-formed steel (CFS) structures provide a fast, efficient construction solution with earthquake resistance, safety, and low operational costs over a 50-year lifespan. These buildings can be disassembled and relocated due to their bolted connections. This study analyzes cold-formed C-sections using ANSYS, IS801, and AISI codes, focusing on their behavior under compression with varying flange b/t ratios. The findings aim to support affordable, low-maintenance housing solutions, addressing challenges like project delays and high costs in disaster-prone areas.

Krishanu Roy "Experimental and numerical investigations on the axial capacity of cold-formed steel built-up box sections" Built-up box sections, which connect two lipped channels with self-drilling screws, are becoming popular in cold-formed steel (CFS) construction for structures like trusses and frames. This study evaluates their axial capacity through 16 experiments and 148 finite element (FE) analyses, incorporating material nonlinearities and initial imperfections. The findings align well with test results and suggest that current design standards (AISI and AS/NZS) are about 17% conservative in predicting axial strength. The research emphasizes the advantages of built-up box sections over back-to-back channels, including higher load capacity and stability. While much prior work focused on back-to-back channels and other configurations, this study fills a gap by examining screw-connected box sections.

Mohamed Elflah "Behaviour of stainless steel beam-to-column joints — Part 1: Experimental investigation" This paper presents the first full-scale tests on stainless steel beam-to-column joints subjected to static loads. The study includes tests on various joint configurations, such as flush and extended endplate connections, and compares their performance with design standards (EN1993-1-8). Results show that these joints exhibit excellent ductility and strength beyond predictions for carbon steel joints. As sustainability gains importance, there's a growing interest in stainless steel for structural use. However, stainless steel's unique strain-hardening behavior and lack of a yield plateau have not been fully integrated into design standards, which often rely on analogies with carbon steel. Previous studies have mainly focused on individual components or specific connection types, leaving a gap in understanding full-scale joint behavior. This research addresses this gap, providing valuable data to refine design standards and validate numerical models for stainless steel joints.

Francisco J. Meza "Experimental Study of Cold-Formed Steel Built-Up Beams" This paper details an experimental study on cold-formed steel (CFS) built-up beams with two different cross-sectional geometries. The study involved testing 12 specimens in a four-point bending setup to examine the interaction between components and the impact of connector spacing on the beams' moment capacity and behavior. The specimens, consisting of three or four plain channels joined with M6 bolts, were tested with varying connector spacings to assess failure modes, including local buckling and strut buckling. Results indicated that while connector spacing influenced local buckling patterns, its effect on the ultimate capacity was less significant. This research aims to improve the understanding and design of CFS built-up members, addressing current gaps in design codes and providing data for practical design rules.

Francisco J. Meza "Experimental study of cold-formed steel built-up columns" This study explores the behavior and capacity of cold-formed steel (CFS) built-up columns, focusing on the effects of connector spacing and component interaction. A total of 24 columns with four different cross-sectional geometries were tested under pin-ended conditions with nominal eccentricities. The columns were assembled from flat plates and channels using bolts or self-drilling screws, and varying connector spacings were tested. The study aimed to understand cross-sectional buckling, global buckling, and the influence of connector spacing on column capacity. Results showed that while connector spacing influenced buckling patterns, its effect on ultimate capacity was minor when global buckling between connectors was not critical. This research contributes to the understanding of CFS built-up members and aims to inform practical design guidelines.

M. Macdonald "Recent developments in the design of cold-formed steel members and structures" Cold-formed steel members are widely used in construction but present complex design challenges due to their slenderness and susceptibility to various buckling modes. These effects, including local, torsional, and lateral-torsional buckling, can significantly reduce load-bearing capacity compared to ideal conditions. The evolution of cold-formed steel design began in the mid-20th century, with key developments in design specifications and increased steel strength since the 1980s. The main structural advantages of cold-formed steel—its light weight and high strength—are counterbalanced by the need for sophisticated design analysis to address the unique failure modes associated with thin, open sections. Additionally, cold-formed steel connections, often semi-rigid and varied in type, further complicate design. This paper discusses these complexities and their implications for design.

Ben Young "Design of cold-formed steel unequal angle compression members" This study investigates the behavior and design of cold-formed steel unequal angle columns, focusing on different buckling modes such as local, flexural, and flexural-torsional buckling. Using nonlinear finite element analysis (FEA), the research incorporated real geometric imperfections and material properties to model columns of varying lengths. The FEA results closely matched experimental data, leading to a comprehensive parametric study on cross-sectional geometries. Findings revealed that current design rules are often unconservative for shorter and intermediate columns. New design rules are proposed based on the study's results, which were compared to existing standards from the North American Specification.

Nirosha Dolamune Kankanamge "Behaviour and design of cold-formed steel beams subject to lateral–torsional buckling" Cold-formed steel beams are increasingly used in construction, particularly as floor joists and bearers. Their susceptibility to lateral–torsional buckling when inadequately restrained requires careful analysis. This study focused on the lateral–torsional buckling of simply supported cold-formed steel lipped channel beams under uniform bending using a finite element model developed in ABAQUS. The model was validated with existing numerical and experimental data and used for an extensive parametric study. The study compared the model results with current design rules from European, Australian/New Zealand, and North American codes. It found European rules to be conservative, while Australian/New Zealand and North American rules were unconservative. Based on the findings, new design recommendations were proposed. The paper details the parametric study, evaluates existing design codes, and suggests improved design rules for lateral–torsional buckling in cold-formed steel beams.

Dan Dubina "Behavior and performance of cold-formed steel-framed houses under seismic action" Recent research has focused on the earthquake performance of light-gauge steel-framed houses, particularly examining wall panels and connectors. Studies from the Politehnica University of Timisoara involved tests on shear panels, connection details, and ambient vibrations of houses under construction. Key findings include the significant role of connectors in overall performance, acceptable damping ratios of up to 6%, and recommended drift limits of 1/50 rad for severe earthquakes. The research highlights ongoing challenges in understanding shear wall behavior and proposes new design recommendations based on extensive testing and simulations.

Alireza Bagheri Sabbagh "Development of cold-formed steel elements for earthquake resistant moment frame buildings" This study explores the use of thin-walled cold-formed steel (CFS) sections as energy-dissipative elements in seismic moment-resisting frames for multi-storey buildings. Both finite element (FE) analysis and experimental tests were conducted. At the element level, beams with multiple flange bends showed improved strength, stiffness, and ductility, with curved flanges performing best. At the connection level, various CFS beam-to-column connections were tested, revealing that out-of-plane stiffeners significantly enhance seismic performance. Specifically, the addition of two pairs of vertical stiffeners improved energy dissipation capacity by 30%, moment strength by 28%, and ductility by 50%. The research also demonstrates that FE models can accurately predict the behavior of CFS connections, validating the use of stiffeners for enhanced seismic performance.

B.H. Smith "Design component and system reliability in a low-rise cold formed steel framed commercial building" This paper investigates the reliability of structural components in a two-story cold-formed steel (CFS) building, using the CFS-NEES project as a case study. The study examines the differences between target reliabilities (set by design codes) and the actual reliabilities of components in a real building. The paper calculates demand-to-capacity (D/C) ratios and reliabilities for both gravity load systems and lateral force resisting systems. Findings reveal significant variability and excess in D/C ratios and component reliabilities due to practical design constraints. The analysis also explores how component reliability affects the overall system reliability, particularly in seismic conditions. The results underscore that CFS buildings often perform better than their design specifications, highlighting potential for reserve strength and system load-sharing effects. The paper also discusses the implications for future design practices and the need for more robust modeling of system reliability.

Ehab Ellobody "Behavior of Cold-Formed Steel Plain Angle Columns" This paper presents a finite element model to accurately analyze the behavior of cold-formed steel plain angle columns, incorporating effects of initial imperfections and material nonlinearities. The study investigates failure loads, buckling modes, and load-shortening curves, and examines how residual stresses impact buckling behavior. The finite element model, validated against experimental data, is used to analyze various column lengths and cross-section geometries. Results from the model are compared with design strengths from American and Australian/New Zealand standards, revealing discrepancies due to design constraints and practical considerations. The study includes a detailed parametric analysis of angle column behavior and compares findings with previous research and design codes.

Na Yang "Damage Analysis and Evaluation of Light Steel Structures Exposed to Wind Hazards" Damage Analysis and Evaluation of Light Steel Structures Exposed to Wind Hazards Cold-formed steel structures are particularly vulnerable to extreme winds due to their lightweight components. Recent cyclones have caused significant damage to these structures, ranging from cladding loss to complete collapse. This article first presents real-world damage examples from high winds and then reviews research on the damage analysis and evaluation of light steel structures under strong winds. Issues such as connection failure, purlin buckling, and component instability are discussed. The review also covers methods for assessing structural damage, including vulnerability analysis and performance-based theories. Despite ongoing research, existing studies often lack detailed damage evaluations and accurate predictions for light steel structures under extreme wind loads.

Conclusion

The review highlights that LGSS structures not only meet the necessary safety standards but also exhibit superior performance in terms of seismic response, cost-effectiveness, and construction timelines. The integration of cost, building period, and serviceability criteria further emphasizes LGSS's suitability for modern construction needs. While LGSS presents clear benefits, the review also points out the necessity for continued research to address challenges related to material performance, long-term durability, and integration with other conventional construction method.

As the construction industry continues to evolve, LGSS could play a crucial role in meeting the demands for safer and more efficient buildings in earthquake-sensitive areas. Ongoing advancements in design methodologies and material technologies will likely enhance the effectiveness and adoption of LGSS, establishing them as a vital component in the future of sustainable and resilient building practices.

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