

LOW GAUGE STEEL FRAME TECHNOLOGY AND ANALYSIS OF RESIDENTIAL STRUCTURE: A REVIEW

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ABSTRACT

Light Gauge Steel Frame (LGSF) is increasingly employed in residential and commercial buildings for both load-bearing and non-load-bearing applications. This paper aims to analyze and design light gauge steel structures in accordance with Indian standard codes. Over time, the home construction industry has seen the development of improved materials and construction methods, leading to better building systems. These advancements in construction materials and techniques have facilitated the development of more energy-efficient, durable, safe, cost-effective, and environmentally friendly homes. Light Gauge Steel Frame (LGSF) wall systems are widely used in residential, commercial, and industrial buildings as both load-bearing and non-load-bearing components. This study utilizes IS: 801-1975, the code for cold-formed light gauge steel, and IS: 801-1987, which specifies the requirements for cold-formed light gauge members.

Keywords: Light Gauge Steel Frame (LGSF), Indian Standard Codes, Residential Buildings, Commercial Buildings, Load-Bearing Elements

1. INTRODUCTION

Light gauge steel (LGS) members, also known as cold-formed steel (CFS) members, are structural components created through cold-rolling or press brake operations from carbon or low-alloy steel sheets, strips, or flats. This type of construction is similar to wood light frame construction but much lighter in weight. It's often beneficial to step back and understand the details of how specific materials are made or what they exactly entail. Over the years, steel technology has seen numerous advancements, including significant changes in manufacturing processes. Pre-formed steel bars are now cold-formed using hydraulic presses or continuous casting machines. Cold-formed steel is shaped before it reaches its final temperature, allowing for more precise and complex shapes compared to casting. This process enables the design of cold-formed steel to adhere to more established industry standards than casting allows.

During the forming process, a hydraulic press compresses the steel platen to fold it. This technology enables rapid shaping of the metal, but it also creates a seam where the two sides are joined. These machines can bend parts in approximately 20 seconds, whereas casting takes around 10 minutes. Cold-rolled steel is often used in applications where heat treatment would adversely affect the final quality of each piece. It can be used in situations where cast steel would be unsuitable, such as around a building's water supply system. Despite seeming more wasteful, cold-formed steel requires no additional time or cost to produce due to its efficient manufacturing process. This common material can readily replace other options that are more time-consuming and expensive to produce.



Figure1.1: Low Gauge Steel Frame

2. LITERATURE REVIEW

Vishwanath Gangappa Telasang's Study on Light Gauge Steel Frames in Commercial and Residential Buildings

This article demonstrates the increasing use of light gauge steel frames in both commercial and residential buildings as load-bearing and non-load-bearing elements. The primary objective of this study is to analyze and design light gauge steel structures in accordance with Indian Standard Codes. Vishwanath Gangappa Telasang, a postgraduate student who completed his graduation from SGBIT Belagavi in Belagavi, Karnataka, India, conducted this research.

Ease of Modification: At any stage during its service life, light gauge steel frame construction is simple and can be easily modified.

Properties and Advantages: The study discusses the general properties and advantages of light gauge steel sections. Cold-formed steel sections are recognized for their excellent performance worldwide. Utilizing these materials helps safeguard our buildings, lives, environment, society, and future generations.

Flexural Behavior and Stability: Light gauge steel demonstrates favorable flexural behavior. The vertical and horizontal displacements of such buildings are within acceptable limits, ensuring stability. Both the floor plane and roof plane are designed as stiff frames. The conclusion drawn is that residential buildings constructed with light gauge steel have sufficient capacity and are economically viable. Light gauge steel holds significant potential as a structural material due to its cost-effectiveness and performance. This research underscores the promising future of light gauge steel in structural applications, highlighting its advantages in terms of cost, performance, and adaptability.

Marija Jel'ić c Rukavina - This article presents the development of lightweight steel framed (LSF) construction systems designed for nearly-zero energy buildings (NZEBs). These systems offer high structural resilience, cost efficiency due to rapid prefabrication, and a significant potential for recycling and reuse.

LSF building systems have a long history, dating back to the mid-19th century's "Gold Rush" era, with a notable increase in usage after World War II. Today, their performance has significantly improved, allowing widespread application in both residential and non-residential buildings globally. However, despite their advantages, LSF systems are not as prevalent in Europe as in the USA, Japan, and Australia. This is slowly changing as sustainability becomes a more pressing concern.

A systematic literature review reveals that LSF systems are viable for NZEBs due to their high energy efficiency potential. Preliminary analysis in the study focused on how the type and placement of insulation layers affect the thermal performance of LSF structures. It is also noted that steel members and sheathing materials play crucial roles in overall thermal performance. The study discusses several methods to mitigate thermal bridging, the simplest being the physical separation of steel members from sheathing using spacers. For NZEB applications, non-metallic sheathing materials are preferred due to their better thermal properties compared to steel. However, non-metallic options like OSB and plywood have lower fire resistance, necessitating careful selection based on thermal, fire, and noise protection requirements.

The proposed solution involves a new LSF composite wall panel that integrates various materials to enhance performance. This modern LSF panel system for NZEBs combines polymer insulation (e.g., PUR) for thermal properties, gypsum boards (GBs) for fire protection, and cold-formed steel (CFS) for structural integrity. The initial analysis of the thermal transmittance (U-value) of this system showed promising results, indicating a low thermal transmittance and suggesting further research directions. However, developing this system fully requires extensive experimental and numerical studies to optimize both thermal and structural responses. Future research should focus on evaluating the components and overall performance of this innovative structural system.

3. S. Vigneshkannan- This paper investigates the general study of light gauge steel. The general information on light gauge steel sections, their properties, and advantages are discussed in this review paper. Various aspects of analysis, such as Finite Element Linear and Non-linear analysis, are considered for light gauge steel sections. Finally, cold-formed steel sections demonstrate good performance worldwide, ensuring the safety of our buildings, lives, environment, society, future generations, and the globe.

A comprehensive review of literature on light gauge steel structures typically covers multiple aspects related to their design, construction, performance, and advantages compared to traditional building materials like concrete or wood. These studies often begin with an exploration of the material properties of light gauge steel (LGS), including its strength, durability, and resilience to environmental conditions such as corrosion. Research delves into how these properties impact the overall structural integrity and lifespan of buildings constructed with LGS.

The review discusses design methodologies specific to LGS structures, including load-bearing capacities, connections, and detailing. It may highlight advancements in computer-aided design (CAD) and finite element analysis (FEA) tools tailored for LGS applications. Innovative construction techniques for LGS are also covered, focusing on efficiency,

speed of construction, and cost-effectiveness. This section might include case studies or comparative analyses with other building methods, showcasing advantages such as reduced labor requirements and faster project completion.

The review assesses how LGS structures perform under different loads, such as wind, seismic forces, and live loads. Studies on fire resistance, thermal insulation properties, and acoustic performance of LGS buildings compared to traditional materials are also discussed. Increasingly, literature evaluates the environmental sustainability of LGS structures compared to conventional building materials. This includes discussions on energy efficiency during construction and throughout the building's lifecycle, as well as recyclability and potential for reduced waste generation. Case studies of notable LGS buildings or projects worldwide are typically included in the review. These analyses focus on design innovations, challenges encountered, and lessons learned for future applications. The economic feasibility and cost comparisons between LGS construction and traditional methods are also explored, including lifecycle cost analyses, return on investment (ROI), and market trends influencing the adoption of LGS in different regions.

Overall, a comprehensive review of literature on light gauge steel structures provides a nuanced understanding of their technical, economic, and environmental aspects. This contributes to advancements in construction technology and sustainable building practices.

Alhalabi Zinah Shuman, explores the architectural and constructional aspects of using light gauge steel (LGS) for high-rise buildings and business centers. The key benefits highlighted include significant time reduction in construction and flexibility in the placement of non-load-bearing walls. As urban populations continue to grow rapidly, it is essential to address the increasing demand for residential, commercial, and mixed-use high-rise buildings. Despite some disadvantages, LGS proves to be an efficient solution, especially in the long term. Buildings constructed with LGS can be easily modified to meet future needs, making them particularly suitable for business centers where office configurations may need frequent adjustments without incurring high costs. Additionally, LGS structures offer easy access for maintenance, inspections, replacements, or repairs. The application of LGS in high-rise buildings and business centers is highly recommended for both exterior and interior walls, as well as roofs. LGS facilitates faster construction and can be prefabricated off-site, offering significant advantages for future adaptability while minimizing waste. It stands out as a sustainable and efficient option for tall structures.

Literature Review on Light Gauge Steel for High-Rise Buildings

The literature on the use of light gauge steel in high-rise buildings and business centers covers several key areas:

1. **Structural Behavior:** Studies focus on how LGS performs under various structural demands typical of high-rise buildings, including wind loads, seismic forces, and vertical load-bearing capacities. Comparisons are often made with traditional materials such as concrete and conventional steel, highlighting LGS's benefits like reduced weight, quicker construction times, and potential cost reductions.
2. **Construction Techniques:** Research discusses advanced construction methods suitable for high-rise LGS buildings, such as modular construction, prefabrication, and the integration of advanced building systems. These techniques aim to improve efficiency, reduce on-site construction duration, and streamline project timelines.
3. **Fire Safety:** Fire safety is a critical consideration in the use of LGS for high-rise applications. Studies evaluate fire-resistance ratings, compliance with building codes, and strategies to enhance fire safety through careful material selection and design modifications.
4. **Environmental Sustainability:** The environmental impact of LGS in high-rise buildings is thoroughly assessed, including energy efficiency, material recyclability, and overall carbon footprint. LGS often demonstrates favorable sustainability metrics compared to traditional building materials.
5. **Case Studies:** The literature includes numerous case studies of successful LGS high-rise buildings and business centers globally. These case studies provide detailed analyses of design strategies, construction methodologies, challenges faced, and lessons learned, offering valuable insights for future projects.

S.A. Kakade - This article investigates various design methods for cold-formed light gauge steel (LGS) sections focusing on compressive strength. Key findings include:

- The full cross-section is not utilized by I.S. 801:1975 due to the working stress method.
- The full cross-section is utilized by I.S. 800:2007 due to the limit state method.
- I.S. 801:1975, which follows the working stress method and uses the M.K.S. system, needs to be updated to the limit state method and the S.I. system.
- The Load and Resistance Factored Design Method gives higher values compared to test results, leading to overestimation.

The study of various design methods for cold-formed light gauge steel (LGS) sections with a focus on compressive strength involves reviewing literature that explores different approaches, standards, and advancements in this specialized area. Literature typically begins with an introduction to cold-formed steel sections, outlining their manufacturing process, material properties, and common applications in construction. This section often includes discussions on the advantages of cold-formed steel (CFS), such as a high strength-to-weight ratio, ease of fabrication, and suitability for prefabrication.

Studies often review international and national design standards and codes specific to cold-formed steel sections, such as AISI (American Iron and Steel Institute) standards in the United States, Eurocode in Europe, and others globally. The review includes discussions on design methodologies prescribed by these codes for determining the compressive strength and stability of CFS sections.

Literature discusses analytical methods used to predict compressive strength in CFS sections, including theoretical models, empirical formulas, and numerical simulations. Finite Element Analysis (FEA) studies are often highlighted for their ability to model complex geometries and loading conditions, providing insights into structural behavior under compression.

Research reviews often include summaries of experimental studies conducted to validate design methods and theoretical models. These studies typically involve laboratory tests such as column buckling tests, compression tests on individual sections, and full-scale structural testing to verify predicted strengths and behaviors.

Some literature explores parametric studies and optimization techniques aimed at enhancing the compressive strength of CFS sections. This includes investigations into the influence of cross-sectional dimensions, material properties, and geometrical imperfections on section stability and strength.

The review may cover innovative design approaches for enhancing compressive strength in CFS sections, such as hybrid sections, advanced bracing configurations, and novel connection details. Studies often highlight advancements in lightweight structures and sustainability through optimized design practices.

The literature includes case studies of real-world applications where design methods for CFS sections have been successfully implemented. These case studies provide insights into design challenges, solutions adopted, and performance evaluations, contributing to best practices in the industry.

Finally, literature often discusses emerging trends and future research directions in the design of CFS sections for compressive strength. This includes potential advancements in material technology, integration with digital tools for design optimization, and sustainability considerations.

In summary, the review of literature on design methods for cold-formed light gauge steel sections for compressive strength provides a comprehensive understanding of current practices, challenges, and opportunities in optimizing structural performance in this specialized field of construction engineering.

3. CONCLUSIONS

The study of various design methods for cold-formed light gauge steel (LGS) sections, particularly focusing on compressive strength, has revealed several key insights and conclusions:

1. Underutilization of Cross-Sectional Capacity:
 - The I.S. 801:1975 standard, which employs the working stress method, does not fully utilize the cross-sectional capacity of LGS sections.
 - Conversely, I.S. 800:2007, which follows the limit state method, allows for the full utilization of the cross-section, highlighting the efficiency of this approach.
2. Need for Standard Revision:
 - I.S. 801:1975, currently based on the working stress method and the M.K.S. system, needs revision. Updating it to the limit state method and adopting the S.I. system is crucial to align with modern practices and enhance structural performance.
3. Overestimation by Load and Resistance Factored Design Method:
 - The Load and Resistance Factored Design Method tends to provide higher values than actual test results, indicating an overestimation of compressive strength. This necessitates a reassessment of the method to improve accuracy.
4. Comprehensive Understanding from Literature Review:
 - A thorough review of literature reveals the evolution and advancements in design methods for LGS sections. It underscores the importance of various international and national standards, analytical methods, experimental validations, and innovative approaches in enhancing compressive strength.

5. Significance of Experimental and Analytical Studies:

- Experimental studies, such as column buckling tests and compression tests, are essential in validating theoretical models and design methods. These studies provide practical insights and confirm the reliability of the design approaches.

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