Use of Pe-Engineered Wall Panel in Construction to Reduce Construction Time & Cost

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Abstract

Introduction: The construction industry has traditionally relied on conventional building methods. However, there has been a growing push towards the adoption of modern construction techniques. One such innovation is the use of Light Gauge Steel (LGS), which has gradually been introduced into the industry. Despite its potential, there remains limited understanding regarding stakeholders' willingness to adopt this method and the advantages it offers.

This study aims to explore the integration of Mechanical, Electrical, Plumbing, and Firefighting (MEPF) services into pre-engineered LGS panels and to highlight the benefits of utilizing LGS in construction. Some of the key advantages of adopting LGS include its high strength-to-weight ratio, durability, and environmental sustainability. Additionally, LGS offers ease of construction, enhanced site safety, reduced waste, and the ability for components to be manufactured off-site.

LGSF (Light Gauge Steel Framing) systems consist of thin steel sheets formed into structural sections. These sections are produced in a controlled factory setting and assembled on-site using screws or rivets. This method not only simplifies the construction process but also significantly reduces project timelines, enhances reliability, boosts productivity, and lowers material consumption.

Methods: The plan layout with the highest number of MEPF elements is identified to determine the most complex panel for coordination in various construction aspects. A 3D detail model is then created using virtual design software such as Revit, along with plugins like MWF (Metal Wood Framer), to enhance coordination between Architecture, Structure, and MEPF elements, ensuring issues are resolved before panel generation. Since CNC data is extracted from MWF, it also defines punch-outs for MEPF services and any necessary supportive blocking. The CNC file includes details of member size, shape, placement, noggin positions, and punch-out locations for MEPF services. Once fabricated, the wall frame is anchored to the foundation using bolts at defined spacing per design requirements. Finally, MEPF components are integrated into the panel, which is pre-fitted with insulation and exterior cladding to facilitate easy on-site construction.

Results: Pre-engineered panels cannot have punch-outs exceeding 20% of the surface area of the stud flat surface, and the spacing between two consecutive punch-outs should be more than 2 feet. All stacked panels require stud alignment for load-bearing purposes, which limits the scope for MEPF routing. Additionally, the coordination of anchorage points must be carefully inspected to prevent misalignment. Lastly, proper connection of plumbing elements is critical, as improper connections may lead to future leakages.

Conclusions: This type of panel construction will help in reducing dependency on perishable material and pollution generated due to construction activities and wastage.

Keywords: Cold Form Steel, conventional construction, green building, Light gauge steel, MEPF, BIM

Introduction

Cold-formed steel (CFS) refers to steel products shaped at room temperature into final or semi-final forms through processes such as rolling, stamping, or pressing. Unlike hot-formed steel, CFS is produced without applying heat, using methods that transform steel sheets, billets, or bars into practical construction or industrial materials. Common applications include cold-rolled steel (CRS) bars and sheets, which are widely used in the production of durable goods such as vehicles and appliances. However, in the context of construction, the term "cold-formed steel" primarily denotes materials used for structural and non-structural building components.

Cold-formed steel framing offers numerous benefits to architects, engineers, and builders. It enables quicker construction timelines, reduces material waste, improves building safety, and accelerates project turnover. Steel as a material is strong, durable, cost-effective, and highly versatile. Its resistance to pests, moisture, warping, and rotting makes it a reliable alternative to traditional materials like timber. Moreover, steel's high recyclability makes it an environmentally responsible choice, as it can be reused repeatedly without degradation in quality.

Since its standardization in 1946, CFS has become widely accepted across the construction industry. Thin steel sheets are shaped into components such as joists, studs, beams, columns, and floor decking, forming both load-bearing and non-load-bearing structures. Unlike hot-rolled steel, which is formed at high temperatures, cold-formed steel elements are manufactured at ambient conditions, and their structural performance often depends on buckling behavior. The framing method used is similar to that of timber, where connections are typically made using screws.

CFS is utilized across a diverse range of industries and infrastructure projects, including buildings, bridges, racks, storage bins, transportation equipment, drainage systems, telecommunications structures, and mechanical products. These components are fabricated from steel sheets, strips, plates, or flat bars, using roll-forming machines, press brakes, or bending tools. The typical thickness of these steel elements ranges from 0.0147 inches (0.373 mm) to about ¼ inch (6.35 mm), although steel up to 1 inch (25.4 mm) thick can also be successfully formed into structural shapes.

Overall, cold-formed steel delivers outstanding mechanical and chemical properties, providing superior advantages over many traditional building materials.

Strength: Steel has the highest strength-to-weight ratio of any building material. This strength allows for architectural flexibility, enabling designs with longer spans and various another feature.

Durability: Steel is an inorganic material, making it resistant to termites, rot, and mold. Protective coatings like zinc enhance its long-term durability, which can last for centuries without deterioration

Stability: Due to its consistent composition, steel behaves predictably when exposed to structural stresses like wind and seismic forces. Steel's resistance to moisture prevents the expansion and contraction that leads to cracking or warping in other materials.

Non-combustibility: Steel is fire-resistant and does not contribute to the spread of flames, which helps cold-formed steel projects meet fire rating requirements. Fire-resistant structures tend to have better insurance claims history, potentially resulting in lower insurance premiums.

Sustainability: Steel is the only building material that is infinitely recyclable. As a green material, cold-formed steel framing projects can earn credits in sustainability programs such as LEED.

Cost-effectiveness: Cold-formed steel framing offers several cost benefits. It helps reduce fire risks, resulting in lower insurance costs. Additionally, the speed of panelized cold-formed steel construction can shorten building timelines, enabling faster project completion compared to other framing methods. Moreover, steel framing generates significantly less material waste than traditional wood framing.

Various organizations, including SFIA, continue to advocate for the development of industry standards, building codes, and construction methods that leverage the unique qualities of cold-formed steel framing.

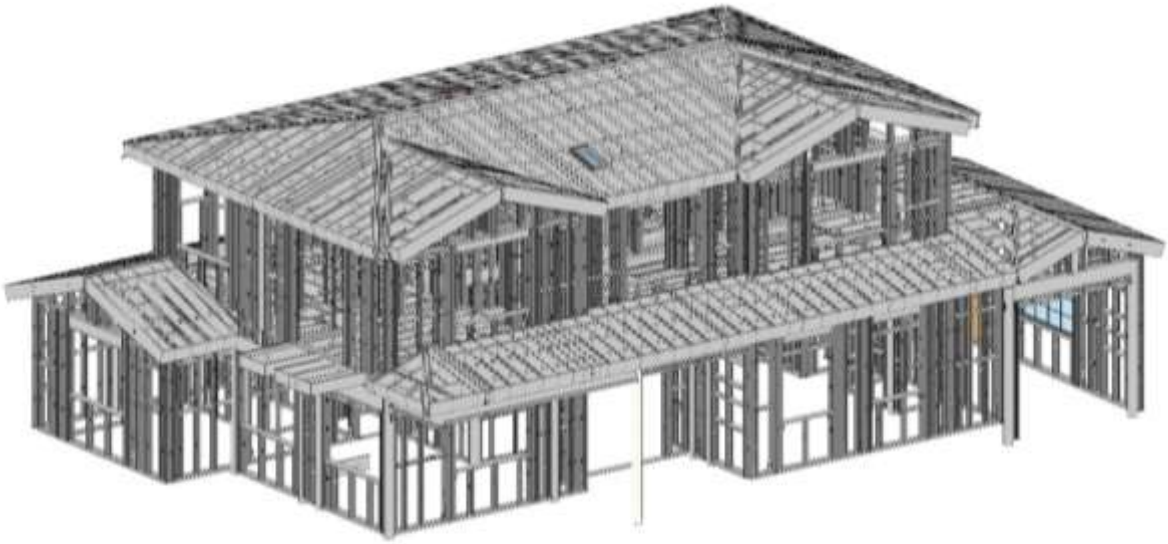
Literature

This paper aims to evaluate the comparison between conventional method and modern techniques of construction. It also stated how LGS is more advantageous over RCC construction work. It considered some factors for comparison like duration of construction work, cost of material, ease with which construction can be done. "Comparison of Design, Cost and Duration of LGS and SCIP Construction with Conventional RC Construction", by L. A. Qureshi et.al. [1]. The paper tries to focus on the importance and necessity to adopt new advanced construction techniques to attain fast and sustainable development in construction industry. Concrete frame construction and hot rolled steel erection are regular conventional methods which are time consuming, requires heavy manpower, machinery, and high fabrication cost. Recent developments in the field are focused to attain ecofriendly sustainable and economical construction. LGS (Light gauge steel) system is one of those which is a dry construction and can be carried out in remote locations with greater feasibilities. LGS system is a construction technology which uses cold formed steel as the construction material, is formed by compressing the steel at very cold temperatures and are made to thickness varying from 0.5 − 3 mm. "Modelling and design analysis of light gauge steel systems against conventional structural systems", by Harshvardhan Palvai, T. Venkat Das et.al.[2]. The axial compressive strength capacity of concrete-filled light gauge steel composite columns was assessed through an experimental program involving twelve long and fourteen stub columns with width-to-thickness ratio of 125 for the encasing steel section. A comparison between concrete-only and confined stub columns demonstrated that the stub column experiences an increase of strength of up to 16% due to confinement. The compressive strength contribution of the light gauge steel section was limited by local buckling. Specifically, the steel-only stub column sections lacking the concrete core experienced, on average, approximately 33% of its full compressive strength. The full-scale composite columns illustrated that the axial compressive strength capacity was controlled by end bearing capacity and local buckling of the light gauge steel.

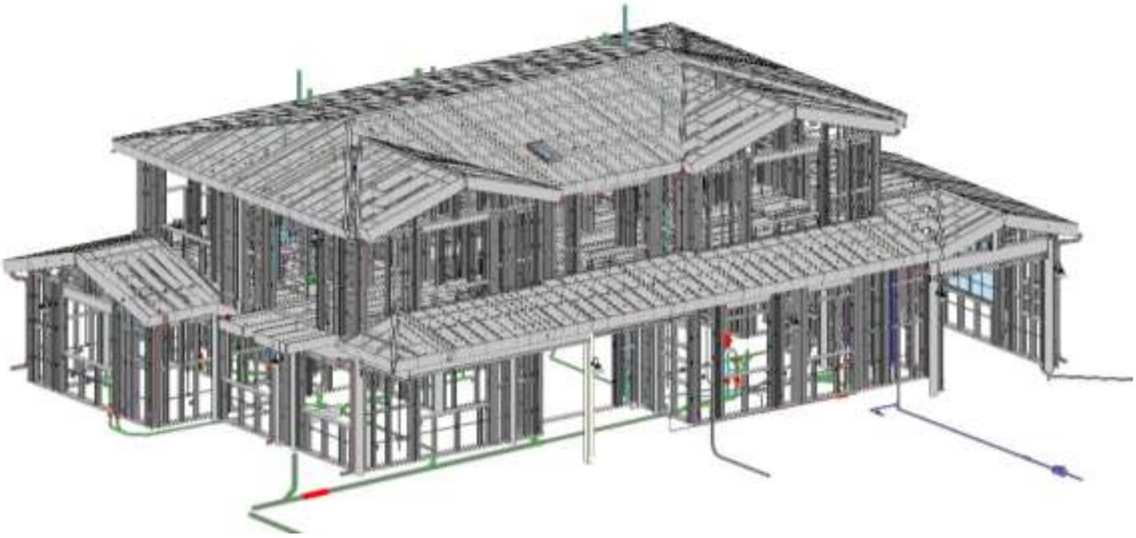
"Compressive strength capacity of light gauge steel composite columns", by W. Leonardo Cortés-Puentes, Dan Palermo[4]. This paper focuses on importance of LGSF, it also focus on how this arterial helps to make the structure more effective and increased productivity. "Light-gauge steel framing leads the way to an increased productivity for residential housing", by H Burstrand.[5]. The advantages of LGS are energy efficiency, cost reduction, fire properties and accessibility. Ariyanayagam et al. (2016) explained that, LGS cavity wall protection gave higher imperviousness to fire, contrasted with cavity wall insulation. Kwon and Jee (2012) noted that structural steel buildings have the benefits of quick development and cost-adequacy which results in more prominence than the traditional method of construction. The Building and Construction Authority (2016) stated that, constructing with LGS empowers steel makers to create lightweight, yet high ductile steel sheets whose surface is covered with zinc composite that totally covers the steel surface and seals it from the destructive activity of its condition. The advantages of LGS, according to Subramanian (2011) are: high strength, high flexibility, uniformity, environmental-friendly, versatility, prefabrication, permanence, additions to existing structures, and least disturbance to the community and fracture toughness. Barnard (2011) noted that, the construction speed of LGS offers a much more secure and cleaner construction site with a high level of precision that can be accomplished together with quicker access for accompanying trades such as cladding "Lightweight steels are thinner, productivity rates are quicker, and the complete result is smoother." by Lyons (2009) [6].

Theory

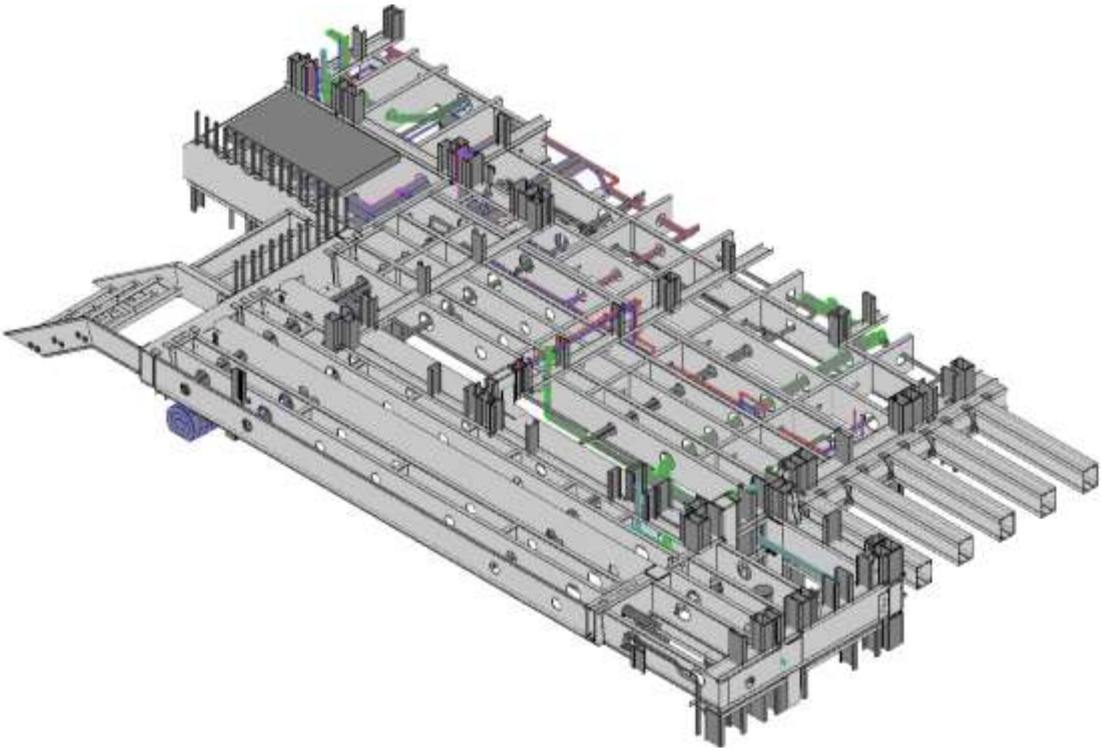
BIM Co-ordinated model: -



Light gauge steel model



Light gauge steel model along with all MEPF Services



Detailed over view of Floor panels for Light gauge steel along with all MEPF Services the way all of them managed well

Using of BIM light gauge steel models can be more efficiently integrated along with Hot rolled steel model which will help Hot rolled steel and light gauge steel can be intergrade well in order to reduce the errors and for better integration.

Integration of BIM for Light gauge steel projects will help to extract the Fabrication drawings for Light gauge steel wall panels, Floor Panels, Roof panels, stair panels, columns, beams which can be clash free and help us to speed up the Fabrication, assembly of panels in order to speed up the erection work at site for Light steel construction-based projects,

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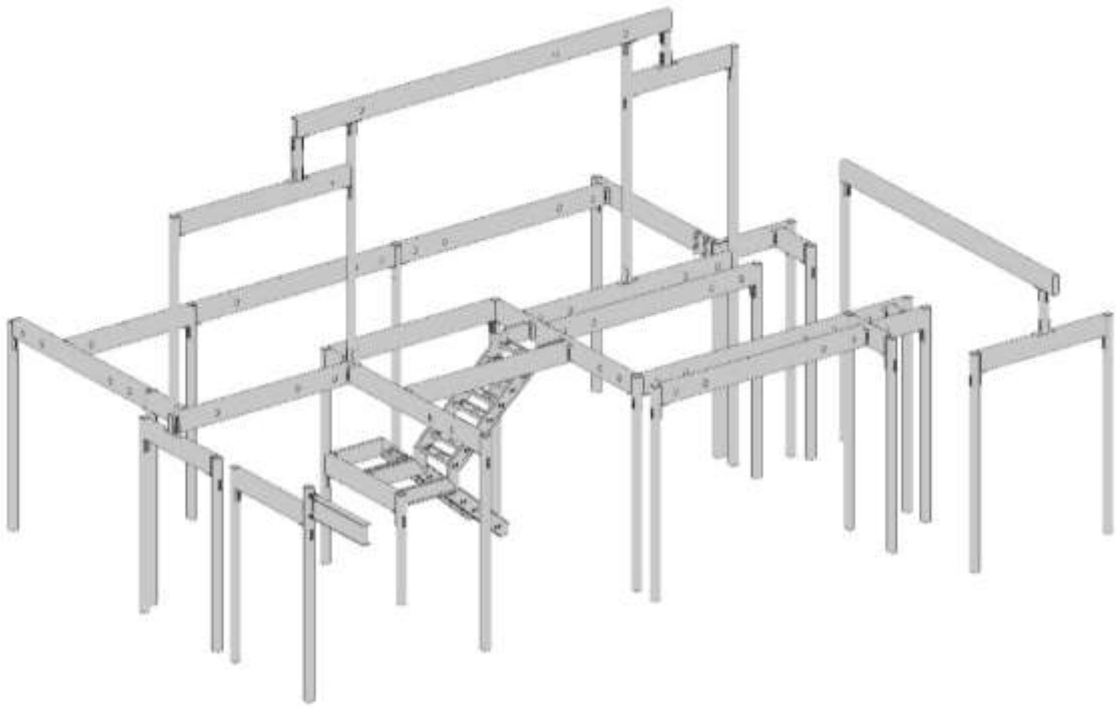
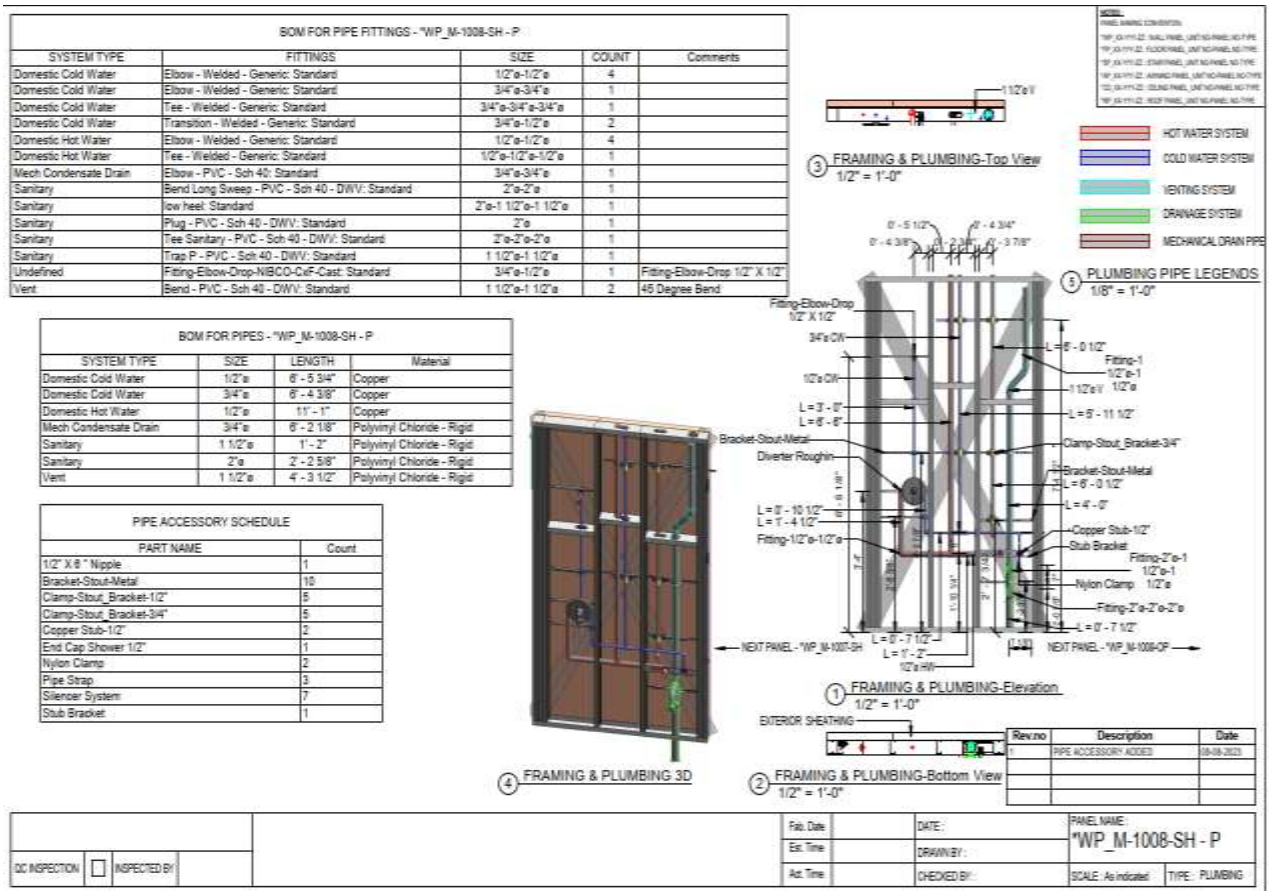


HRS Modelling



Wall Panel Co-ordinated GA Drawing

The GA Drawing contain following Data for Fabrication and assembly of Panels

1. **Bill of Materials (BOM)**

- Lists pipe fittings, pipes, and accessories required for the system.
- Specifies material types (copper, polyvinyl chloride - rigid).
- Includes dimensions, quantities, and specific fitting details.

2. **Framing & Plumbing Views**

- Top View, Bottom View, Elevation, and 3D View help visualize pipe placement within the panel.
- Clear labels show pipe sizes, connections, and support elements.

3. **Pipe System Breakdown**

- Categorized into Domestic Cold Water, Domestic Hot Water, Sanitary, Venting, and Mechanical Condensate Drain systems.
- Uses colour codes and legends to differentiate system types.

4. **Pipe Accessory Schedule**

- Lists additional components such as brackets, clamps, pipe straps, and stubs for secure installation.

5. **Legends & Specifications**

- Provides pipe system legends with colour-coded identification.
- Includes drawing references and naming conventions.

Assembled Panels

Conclusions

Pre-engineered panels present a modern and sustainable solution to construction, balancing efficiency, cost-effectiveness, and environmental responsibility. While they may have certain limitations in terms of structural flexibility and customization, their primary advantage lies in their 100% recyclability, making them a key component of sustainable building practices. By reducing construction waste and promoting material reuse, these panels contribute to a circular economy, where resources are efficiently utilized with minimal environmental impact.

The adoption of Building Information Modelling (BIM) further enhances the effectiveness of pre-engineered panel systems. Through BIM, design coordination is significantly improved, allowing for a precise calculation of material requirements, thereby minimizing waste and optimizing inventory management. This digital approach not only enhances accuracy but also facilitates better collaboration among architects, engineers, and construction teams, ensuring that each panel is manufactured and installed according to pre-defined specifications.

Another key benefit of pre-engineered panels is the efficiency of factory assembly, which allows for streamlined manufacturing in controlled environments. This approach reduces the need for extensive on-site labour, leading to faster project completion and minimizing delays due to weather conditions or logistical challenges. By pre-assembling components, construction sites can achieve higher levels of consistency, quality control, and cost savings compared to traditional building methods.

Moreover, pre-engineered panel construction helps in reducing dependency on perishable materials such as wood and other non-renewable resources. This shift towards sustainable materials not only conserves natural resources but also lowers carbon emissions associated with traditional construction activities. Additionally, by reducing on-site work, this method helps minimize pollution, including dust, noise, and construction-related waste, leading to a cleaner and safer working environment.

In conclusion, pre-engineered panels represent a transformative shift in construction methodology, integrating sustainability, efficiency, and innovation. Their recyclability, enhanced design coordination through BIM, time-saving factory assembly, and reduced environmental impact make them an ideal choice for modern, eco-conscious construction projects. As the construction industry continues to embrace technological advancements and sustainable practices, pre-engineered panel systems are likely to play a crucial role in shaping the future of building design and development.

Conflict of interest

The authors declare that there are no actual or potential conflicts of interest with respect to the authorship and publication of this manuscript.

- **Author 1 [Hrishikesh Kadam]**: Affiliated with [Savitribai Phule Pune University], contributed to study conception, data analysis, manuscript drafting. Author 1 declares no financial or personal relationships that could have influenced the work.
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- **Author 3 [Dilendar Jasutkar]**: Affiliated with [Savitribai Phule Pune University], contributed to provide access to the data for analysis. Author 3 declares that there are no competing interests related to this work.
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