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A Comparative Analysis and Design of Industrial Building Using Hot Rolled Section and Cold Formed Section for Sustainability

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Abstract: ***Structural Steel is a typical building material utilised in the building sector. Its main function is to serve as the framework for the structure i.e, the portion of the structure that keeps everything else in place. Steel is 100% recyclable, making it one of the greenest materials available. This study conducts a comparative analysis and design of an industrial building, evaluating the sustainability implications of employing hot-rolled and cold-formed steel sections. Examining mechanical properties, life cycle environmental impact, and cost-effectiveness, the research aims to provide insights into the structural and environmental benefits of each section type. By optimizing the integration of hot-rolled and cold-formed sections, the study seeks to enhance overall sustainability, considering factors such as energy consumption and material efficiency. Through case studies, this research offers a concise yet comprehensive exploration of how the combined use of these sections can contribute to environmentally conscious and resource-viable industrial building design. The findings aim to inform industry professionals, architects, and engineers about making sustainable choices in the construction process.***
Keywords: ***Cold Formed Section, Sustainability, Material Efficiency***

I. INTRODUCTION

The contemporary discourse on sustainable construction practices underscores the need for innovative approaches to balance structural efficiency, economic viability, and environmental impact. This research embarks on a pivotal exploration, presenting a comparative analysis and design framework for industrial buildings, integrating two prominent steel manufacturing methods: hot-rolled and cold-formed sections.

As industrial structures play a crucial role in global development, the choices made in their design significantly influence resource utilization and environmental sustainability. This study delves into the mechanical characteristics of hot-rolled and cold-formed sections, scrutinizing their unique attributes. The focus extends beyond structural considerations to encompass life cycle environmental impact and also resource utilization. By juxtaposing these sections in the design process, we seek to optimize the building's overall sustainability, accounting for energy consumption, material efficiency, and economic factors. The intersection of structural engineering and sustainability is at the forefront of this research, aiming to provide actionable insights for industry professionals, architects, and engineers. Through rigorous comparative analysis and thoughtful design considerations, this study aspires to contribute to the evolution of sustainable construction practices in the realm of industrial building design.

II. OBJECTIVE

This dissertation has the following main objectives to design an industrial building using conventional hot rolled section as per Indian standard and to evaluate the structural parameters of the industrial building by structural design using cold formed section as per IS and AISI100 code and finally to compare sustainable structural and cost parameters of use of cold formed sections over hot rolled sections in industrial building.

III. CONVENTIONAL SECTIONS

Ordinary steel sections are widely used in industrial building in India. "Conventional structures" are buildings made using standard construction methods. It uses standard building materials and complies with a set of regulations. Conventional steel buildings are usually constructed on site.

The traditional steel structure is a very common form of industrial architecture. The main components are hot-rolled sections; buckling is less likely to occur in a well-designed structure. As a result, the simple connections between the structures facilitate steel structure design. The hot rolled parts are significantly heavier in a few places than the design actually specifies. Because there is more steel consumed, costs are greater.

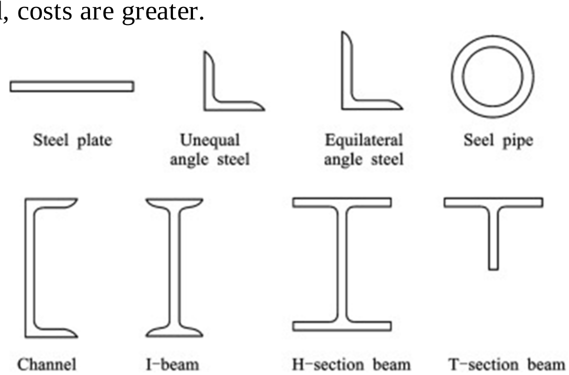

Figure 1 Hot Rolled Sections[11]

IV. COLD FORMED SECTIONS

Cold-formed sections refer to structural components that are produced by shaping steel sheets or strips at room temperature through a process known as cold forming. Unlike hot-rolled sections, which are shaped while the steel is heated, cold-formed sections are created without the use of heat. This manufacturing process involves bending or folding the steel into the desired shapes, such as C-sections, Z-sections, square hollow section, and various other profiles.

Cold-formed sections are widely used in construction for a range of applications, including framing systems for buildings, industrial structures, and infrastructure. These sections are known for their precision and uniformity, allowing for efficient assembly and installation. Additionally, cold-formed sections often exhibit excellent strength-to-weight ratios and can be designed to meet specific load-carrying requirements. The use of cold-formed sections has become increasingly popular due to several advantages, including cost-effectiveness, material efficiency, and the ability to create complex shapes with tight tolerances. Moreover, cold-formed steel is recognized for its sustainability, as the manufacturing process typically generates less waste and consumes less energy compared to hot-rolling.

In structural engineering, cold-formed sections play a vital role in providing innovative solutions for diverse construction needs, contributing to the overall efficiency and sustainability of modern building practices.

Figure 2 Cold Formed Steel Section[12]

V. COMPONENTS PART OF INDUSTRIAL BUILDING

For the purpose of the study, an industrial building was analysed and designed using conventional hot-rolled and cold-rolled sections. The building geometry and various member parameters were chosen based on prevalent industry practices for commonly found industrial buildings in the location. The different components of the building are purlin, runner, frame truss, intermediate roof truss, roof girder, roof monitor for ventilation, laced column consisting of roof leg, outer leg, crane leg, etc.

1) *Purlin:* A roof's horizontal purlin is a structural component. Purlins are supported by the main rafters, building walls, steel beams, etc. and bear the weight of the roof sheeting. The sloping roof system between neighbouring trusses is supported by purlins, which are beams used on trusses. Purlins are often made of channels, angle sections, and cold-formed C or Z sections. They are positioned above the truss's principal rafters at an angle. Placement of purlins at panel points alone is theoretically preferred to prevent bending in the top chords of roof trusses. However, it is more cost-effective to install purlins at closer intervals for larger trusses.
2) *Runner:* Runner or Girt typically refers to a horizontal structural component in a building, often a horizontal beam or support. It's commonly used in the context of construction and architecture to describe a piece that adds stability to a structure. Runner protects the inside properties of the building from external agencies
3) *Frame roof Truss:* A framed roof truss is a structural framework designed to support the roof of a building. It's typically made up of triangular shapes and interconnected members, like beams and posts. These trusses distribute the weight of the roof evenly and provide stability to the overall structure. They're a common and efficient way to frame roofs in construction.
4) *Intermediate Roof Truss:* An intermediate roof truss is a truss that is positioned between other frame trusses in a building structure. It plays a key role in distributing the load of the roof evenly and providing additional support to the structure. The specific design and placement of intermediate trusses depend on the architectural and engineering requirements of the building. Essentially, they help ensure that the weight and stress on the roof are well-distributed, contributing to the overall stability of the construction.
5) *Roof Girder:* A roof girder is a large, horizontal beam that provides support and stability to the roof structure. It's a crucial component in the framework of a building, often used to span wide openings or support heavy loads from, such as the weight of the intermediate roof truss. Roof girders are designed to distribute the load evenly to the supporting columns or walls. They play a key role in ensuring the structural integrity of the building.
6) *Laced Column:* A laced column, in structural engineering, refers to a type of column that is reinforced or braced with a series of diagonal members, forming a pattern that looks like lacing. These diagonal members help enhance the column's ability to resist lateral forces, providing additional stability to the structure. The laced pattern is often designed for both aesthetic and functional purposes. In the case of the proposed building, a laced column consists of a roof leg, an outer leg, and a crane leg, which support the gantry girder.
7) *Gantry Girder/Crane Girder:* A gantry girder is a structural component used in the construction of overhead crane systems, gantry cranes, or other similar applications. It typically consists of a horizontal beam (the girder) supported at each end by vertical legs. The gantry girder provides a framework for the crane to move horizontally along a rail system, allowing it to lift and transport heavy loads within a specific area. Gantry girders are essential for the stability and functionality of the crane, providing support for the lifting mechanism and facilitating the movement of the crane along its intended path. They are commonly used in manufacturing facilities, shipyards, and other industrial settings for material handling and lifting operations.
8) *Roof Bracing System:* A roof bracing system is a network of structural elements designed to provide stability and support to the roof of a building. The primary purpose of a roof bracing system is to resist various forces, such as wind loads, seismic activity, and the weight of the roof itself. The specific design of the bracing system depends on factors like the building's location, its size, and the local building codes.

Common types of roof bracing systems include:

a) *Rafter Bracing:* Rafter Bracing is particularly important to resist lateral forces, such as those generated by wind or seismic activity.
b) *Tie Bracing:* Tie bracing, which is generally provided at the tie level of the roof truss, is a method used in construction to provide stability and support to a structure, particularly in resisting lateral forces.

9) *Column Bracing:* Column bracing is a structural technique used to enhance the stability and strength of vertical columns in a building or structure. The purpose of column bracing is to resist lateral forces, such as those generated by wind or seismic loads, and prevent the columns from buckling or swaying excessively.
10) *Roof Monitor:* A roof monitor is an architectural feature, often a raised structure with windows, designed to admit light and / or provide ventilation to the space below, commonly seen in the roofs of industrial or large open spaces.

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VI. FEATURES OF THE PROPOSED INDUSTRIAL BUILDING

For the purpose of the study an industrial building was analyzed and designed using conventional hot rolled sectioned and cold form sections. The building geometry and various member parameters was chosen based on prevalent industry practice for commonly found industrial building in Kolkata, West Bengal.

Table1 Geometry and Parameters table of Proposed Industrial Building

Feature	Description
Location	Kolkata
Type of Structure	Industrial Building
Functionality	Storage/Godown
Eaves Height of Proposed Industrial Building(h)	23m
Row to Row Distance(w)	27m
Roof Slope(θ)	1 in 5 = 11.3˚
Length of the building(w)	60m
No. of Frame Truss	06
No. of Intermediate Roof Truss	05
Frame to Frame Distance	12m
Spacing of Truss	6m
Height of Truss	2.5m
Purlin Spacing	1.5m
Runner Spacing	1.5m
Column Type	Laced Column
Component of Column	1. Roof Leg 2. Outer Leg 3. Crane Leg
Grade of Hot Roll Sections used	Fe250[fy = 250Mpa]
Grade of Cold Form Section Used	YST 355 [fy = 355Mpa]

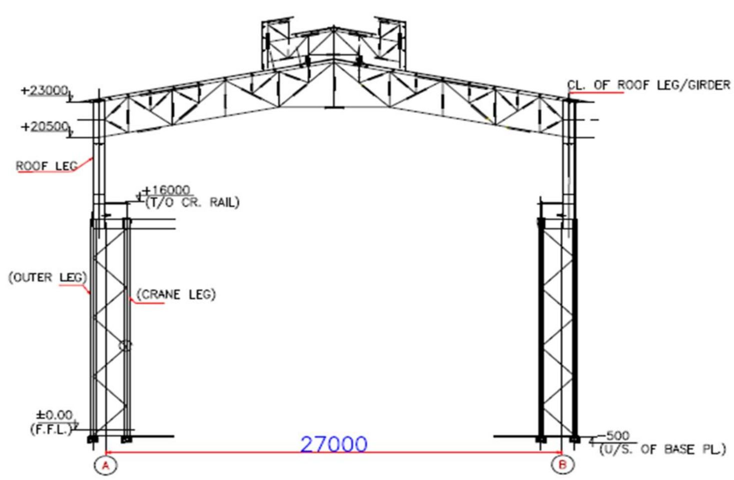

Figure 3 Cross Section of Proposed Industrial Building

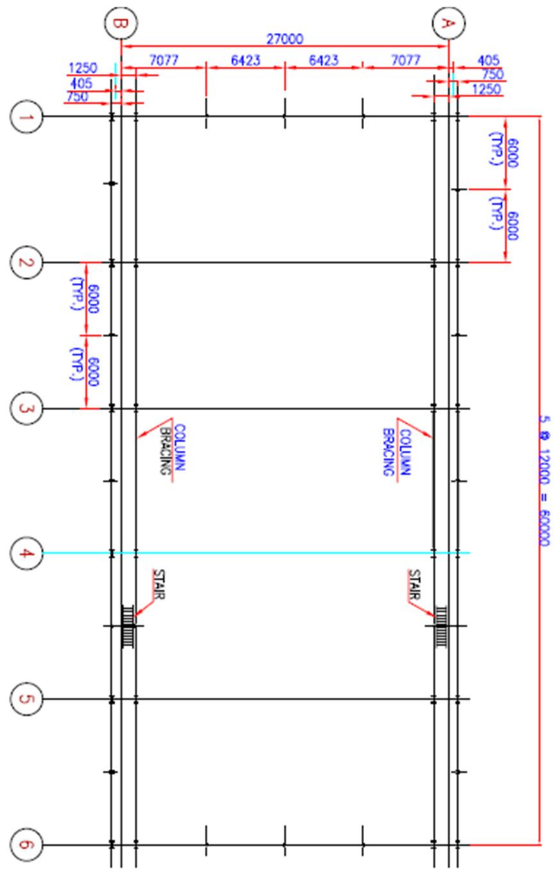

Figure 4 Base Plan of Proposed Building

Table 1 Load Consideration

Load Type	Features	Description
Dead Load	Sheeting Type	Color coated
	Gauge of sheet	0.56mm
	Self weight of sheet	@4.5 kg/m^2
	Self weight of purlin/runner	@ 4.5kg/m
	Self weight of roof monitor, truss etc	To be applied by increasing 10% due to connection in Staad model
	Weight of roof bracing[Assumed]	5 kg/m^2
	Total Dead load applied on roof excluding self weight	9.5 kg/m2
	Total dead load assumed due to crane girder	150kg/m

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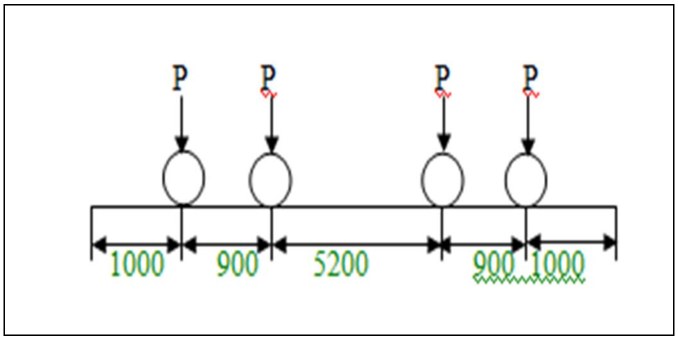
Live Load	On Roof	75 kg/m^2[access not provided Roof slope grater than 10˚, so, applied LL =2/3 x 75 = 50kg/m^2
	On Crane Walkway	200 kg/m^2
Dust Load	On roof	30kg/m^2
Wind load	Basic wind speed	50 kg/m2
	Terrain Category	3
	Life of structure	50 yrs
	Topography	Ground slope less than 3˚
	Cyclonic Region	Assume the proposed building fall in cyclonic zone
	Wind load 0 to 10m height	92.6kg/m^2
	10 to 15m	105.1kg/m^2
	15 to 20m	114kg/m^2
	20 to 30m	125.6kg/m^2
Seismic Load	Seismic Zone	III

Table 2 Crane Load Data Collected from Industry Expert

Load Type	Features	Description
Crane Load	Crane Capacity	25ton
	Crane bridge weight	75ton [excluding trolley]
	Weight of trolley	12ton
	Maximum wheel load(P)	18ton
	Impact as per IS875(Part II)	25%
	Lateral Surge force	5%
	Maximum Wheel load Concentration	81.86ton
	Minimum Wheel load Concentration	36.383ton
	Lateral surge concentration	4.093ton
Wheel Configuration		



VII. LOAD COMBINATION

Load combination refers to the process of combining different types of loads that a structure may experience to assess the overall effect on the structure's design.

In structural engineering, structures are subjected to various loads, including dead loads, live loads, wind loads, snow loads, and seismic loads.

Load combinations are used to evaluate the structure's response under different scenarios. Load combinations are defined by building codes and standards, and they take into account factors such as the probability of simultaneous occurrence of different loads. The combinations vary depending on the type of structure and the applicable design codes. IS800:2007 is used for load combination.

The most common types of load combinations used for analysis and design are :

1) DL + LL
2) DL + LL + DUL
3) DL + LL CR
4) DL + LL + DUL + CR
5) DL + WL
6) DL + WL
7) DL + LL + WL
8) DL + LL DUL + WL
9) DL + LL + CR + WL
10) DL + LL + DUL + CR + WL
11) DL + SL
12) DL + LL + SL
13) DL + LL + DUL + SL
14) DL + LL + CR + SL
15) DL + LL + DUL + CR + SL

VIII. BOUNDARY CONDITION OF STAAD MODEL

Setting up boundary conditions in STAAD. Pro is crucial for an accurate structural analysis. For analysis and design, a 2-D model is considered separately for the frame truss, intermediate roof truss, roof monitor, and roof girder. For a 2D steel industrial model, apply supports and constraints at appropriate locations. Here's a general guide:

1) *Supports:* Pin support is taken into consideration for the main frame, and roller support is taken into consideration for the intermediate truss on one side and pinned support on the other.
2) *Member Release:* Member releases in STAAD.Pro allow you to model the partial fixity or releases at the ends of structural members. This is often used to simulate conditions where a member is not fully restrained at its end.

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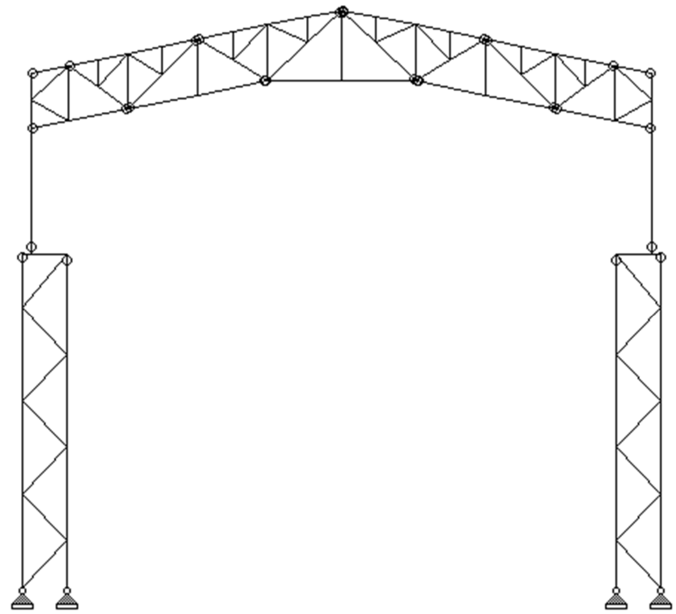

Table 3 Staad Model

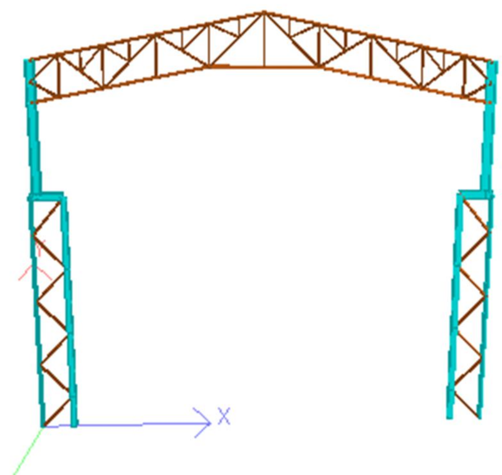

Figure 5 Rendered view

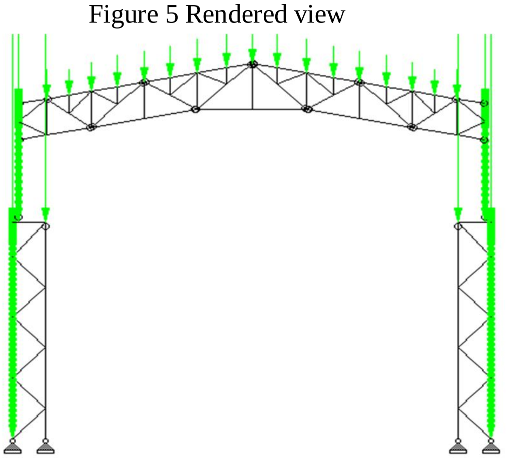

Figure 6 Application of load in Staad Model

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IX. RESULTS

Since a cold-formed section is lighter than a typical conventional section, it can be assembled more efficiently on site and conserve resources in the construction of industrial buildings. Furthermore, a cold-formed section's improved design flexibility makes it possible to better customize it to meet the needs of a given project, thus maximizing resource utilization in industrial settings. So, resource consumption and saving for design of various components part of industrial building for the two cases are as follows:

A. Material Efficiency

Since a cold-formed section is lighter than a typical conventional section, it can be assembled more efficiently on site and conserve resources in the construction of industrial buildings. Furthermore, a cold-formed section's improved design flexibility makes it possible to better customize it to meet the needs of a given project, thus maximizing resource utilization in industrial settings.

Table 4Resource Consumption and Savings

Components part of Industrial building	Sections used when designed with conventional Section	Sections required when designed with cold formed section
Sections required for design of purlin, runner, frame truss, intermediate roof truss, roof girder, roof monitor and column lacing	ISA 150 x 150x18, ISA150x150x12, ISA150x150x10, ISA130x130x12, ISA110x110x12, ISA110x110x10, ISA100x100x8, ISA90x90x8, ISA80x80x6, ISA75x75x6, ISA65x65x6 , ISA50x50x6, MC125, MC150	SHS 180x180x6.0, SHS150x150x6.3, SHS150x150x5.0, SHS100x100x6.3, SHS90x90x5.0, SHS 70x70x4.0, SHS60x60x3.0, SHS50x50x2.5, SHS40x40x2.5, Z250x2.4
Total tonnage for unit item	9.993ton	5.45ton
Material Saving	4.543ton	
Approximate % saving	45.4%	

B. Graphical Representation

The following diagrams provide a graphical depiction of the material usage for specific component parts, such as purlin/runner, roof girder, column lacing, monitor, frame roof truss, and roof truss, for both the conventional hot-rolled section and the cold-formed section.

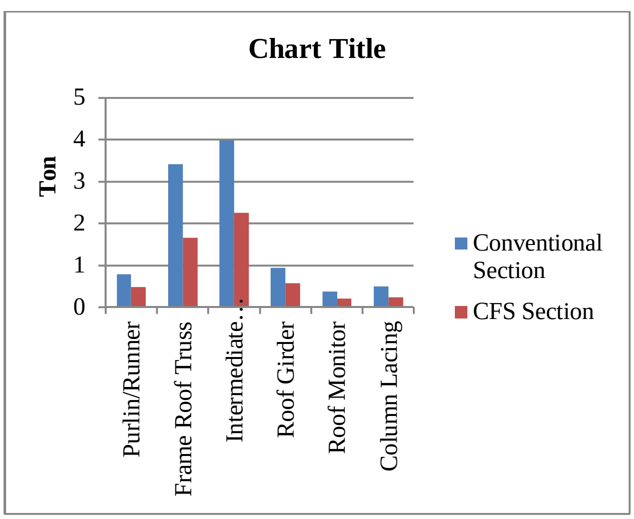

Figure 7 Graphical Representation of Material Utilization

C. Cost Optimization

It has been noted from the current market study that the price of a cold-formed section is approximately Rs. 70/- per kg[13] and a hot-rolled section is approximately Rs. 50/- per kg[14]. So, it is noted from the current study that approximately 23.6% of the cost savings may be achieved while using a cold-formed section in place of a hot-rolled section for light-weight industrial buildings.

X. CONCLUSION

In conclusion, the preference for using cold-formed sections over hot-rolled sections in the design of an industrial building emerges as a compelling choice for achieving a balance between structural efficiency, economic viability, and environmental sustainability. The comprehensive analysis conducted in this study highlighted several key advantages of cold-formed sections that contribute significantly to the overall success of industrial building projects.

Because cold-formed sections are consistent and precise, they can be used to create structural parts that are both lightweight and strong. With a material efficiency of around 45.4% and a cost-effective production technique, cold-formed sections are a financially sound choice for roughly 23.6% of applications without sacrificing structural performance.

Incorporating efficient design practices, optimizing material usage, and embracing sustainable alternatives can contribute significantly to material savings in various industries. This is not only reduces costs but also promotes environmental responsibility and resource conservation.

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