Comparative Structural Analysis of Steel and Aluminium Framed Industrial Sheds for Optimized Design

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Abstract. This paper reports and compares the material properties of aluminum and steel in terms of how well they function for building industrial shelters, structural behavior, cost, and environmental effects. In order to make well-informed suggestions about which material is most suited for various construction requirements, The purpose of this study is to assess each material's benefits and drawbacks in terms of sustainability, performance, and durability. Some of the most important conclusions demonstrate that although steel's substantially greater strength makes it ideal for massive constructions that must support weight loads, nevertheless will require ongoing maintenance due to corrosion. However, aluminum is only suitable for smaller or structures along the coast due to its superior corrosion resistance, lower weight compared to steel, and higher initial expenditures. The research investigates steel's cost-effectiveness because its initial price is lower than aluminum but aluminum offers better durability. Both materials can be recycled yet aluminum has a smaller environmental impact during production. The research establishes that material selection requires evaluation of life-cycle costs together with environmental impacts and specific project needs. Future studies need to investigate hybrid material approaches and progress in sustainable development methods.

Keywords. Steel, Aluminum, Buildings, Corrosion, Durability, and Sustainability etc.

1 Introduction

1.1 An Overview of Industry Sheds and Their Importance in Building

The structures serve as large facilities which primarily function to support manufacturing activities and warehousing operations and storage needs and industrial work processes. Industrial sheds serve as essential infrastructure facilities which support construction work and manufacturing activities and logistics operations and agricultural practices. Designed to provide enormous areas or places for operations, It could support a range of operational requirements, from large open storage spaces to assembly lines. [1] The shed's construction

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must take into account a number of elements, including load-bearing capability, durability, safety, as well as functionality.

Industrial sheds are characterized by wide spans, minimal interior supports, vast roof areas, and simple yet practical shapes. This guarantees the maximum amount of usable area and structural integrity. The performance, durability, and cost-effectiveness of a building are all greatly impacted by the components that can be utilized to make industrial sheds [2]. Because of their exceptional strength, flexibility, and longevity, steel and aluminum continue to be widely employed among the numerous supplies available.

1.2 The Significance of Material Choice in Industrial Shed Design and Construction

These materials' nature takes into account how well industrial sheds operate in terms of lowering expenses and extending their service life. The material must meet strict requirements for its overall structural performance as well as its necessary durability and toughness to environmental elements like corrosion and extremely high or low temperatures. Steel and aluminum are preferred materials because they have many advantageous qualities. Every material has characteristics that make it suitable for particular uses [3].

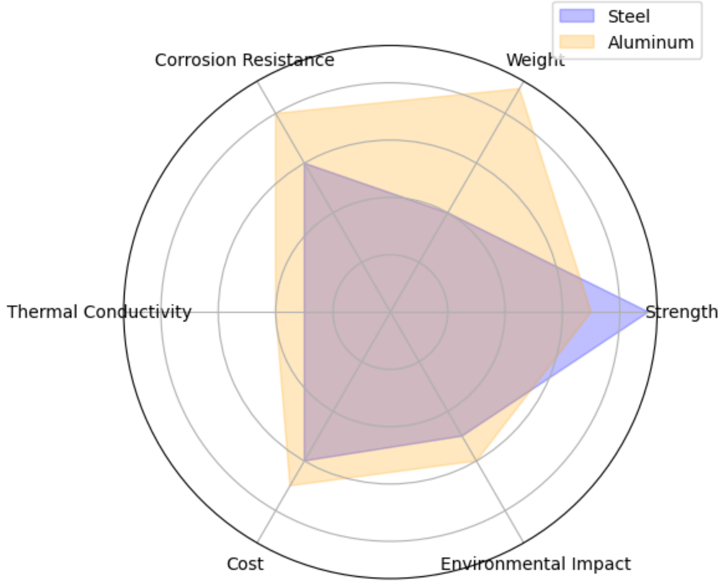

Fig. 1. A Comparison of Aluminum and Steel Materials for Industrial Shed Construction

Steel can support significant loads in architecturally massive constructions due to its great tensile strength as well as load-bearing capability. Because it readily molds itself into a variety of sizes and shapes in accordance with the structural requirements, it may also apply into any design. Steel has a strong propensity to corrode, particularly in humid especially coastal regions, which increases the amount of maintenance needed to extend its lifespan.

Compared to these stronger corrosion defense systems, aluminum is completely lighter than steel. It is a substitute material for areas with high humidity or being exposed to corrosive elements. Because of its increased energy efficiency and improved thermal insulation, it is typically used in structures that place a high priority on energy conservation. However, compared to steel, aluminum is commonly referred to to have higher initial material prices. Additionally, it cannot support as much weight as steel, so it must be avoided in some heavy-duty applications. A comparison of steel and aluminum's strength, weight, protection against corrosion, thermal conductivity, a cost, and effect on the environment is shown in Fig. 1 [4]. To give readers an instant comparison of the performance of these substances based on various properties, it would be excellent to display these characteristics in a juxtaposed bar graph or radar chart.

The choice of materials for construction projects affects both the environmental performance of the building and its mechanical properties and physical characteristics. Aluminum has emerged as a preferred choice for sustainable projects because it functions as a recyclable material which emits fewer greenhouse gases in comparison to steel. Steel can be recycled but its production process creates more environmental problems than aluminum.

1.3 The Comparative Analysis of Steel and Aluminum Members' Goals

This study aims to evaluate steel and aluminum as industrial building materials. The research study will examine the distinct advantages and disadvantages of materials through multiple environmental and economic and sustainable development and structural performance assessments.

The primary objective of this study project is to evaluate the mechanical properties of steel and aluminum, particularly with respect to strength, durability, weight, and communicated external forces such as temperature variation, wind, and seismic loads. Examining the bearing power and the standard of any material is essential when developing various cost-effective shed types that are exposed to heavy loads or challenging environmental conditions.

The economic comparison of steel and aluminum in the construction of industrial sheds will be another objective of this study. Initial material costs, fabrication costs, and maintenance costs over the course of the serviceable life till usage are all taken into account by this factor. Steel benefits often have lower initial costs, but maintenance costs will be crucial because of the high possibility for corrosion. Aluminum has a higher initial cost, but because to its resistance to environmental deterioration, it offers significant maintenance savings and a longer lifespan.

To forecast industrial sheds' long-term durability and performance, this study also examines the thermal and corrosive behavior of steel as well as aluminum under various environmental conditions. These factors include expansion indices, moisture and biological resistances, and thermal conductivities. Steel would be determined to be the greatest choice in areas that require more heavy-duty load-bearing, but aluminum would be more appealing due to its greater corrosion resistance plus better insulating qualities in some specific locales.

The environmental effects of using steel and aluminum would also be covered in this research project. Steel may remain recycled, but it won't be as environmentally friendly as aluminum because aluminum will produce and recycle with a lower carbon footprint. Today's construction business is becoming more and more concerned with sustainability; therefore, knowing this will help you choose materials responsibly.

In conclusion, the following goals will be the main emphasis of this study:

The study compares steel and aluminum through their strength and weight and load-bearing strength testing. The study analyzes the economic impact of steel and aluminum by assessing their total life cycle costs and maintenance expenses and initial implementation costs. The study evaluates the corrosion and heat resistance of steel and aluminum through testing in multiple environmental conditions. The study assesses the sustainability of steel and aluminum through their energy consumption and carbon emissions and recycling potential. The study establishes material selection criteria for industrial shed construction through specified requirements.

2 Material Properties

Understanding the mechanical and physical characteristics, benefits, and drawbacks of steel and aluminum for building is crucial for choosing the best material for particular uses. The decision-making process also heavily relies on elements including cost, availability, and impact on the environment.

2.1 Steel and Aluminum's Mechanical and Physical Characteristics

Steel is one of the greatest often utilized building materials due to its strength, resilience, and adaptability. The material's mechanical characteristics include the ability to tolerate a tensile force that, depending on the particular steel grade, varies from 250 MPa through 2000 MPa. Steel functions as a suitable material for structural applications which face dynamic stress because of its exceptional ability to resist fatigue. The material's modulus of elasticity which equals approximately 200 GPa. determines both its stiffness and strength characteristics which develop under stress conditions [15].

$$\sigma = E \cdot \varepsilon \tag{1}$$

where ε is the strain, σ is the load, and EEE is the Young's modulus.

The density of steel maintains a constant value of 7.85 g/cm³. The material's high density causes problems for applications which require weight reduction because it provides both extreme strength and heavy weight. Aluminum has a reputation for being a lightweight material. The tensile strength of the material varies according to its alloy composition from a minimum of 70 MPa to a maximum of 700 MPa. Aluminum (2.7g/cm³) weighs less than steel but has lower strength. Aluminum can be alloyed with copper, manganese, which or silicon to boost strength to a certain extent, making it useful in situations requiring both strength and low weight. Aluminum exhibits a Young's modulus of approximately 70 GPa which falls short of steel's value but remains adequate for most structural applications.

2.2 Benefits and Drawbacks with Atomic Explanation of Methods Used in SS Advantage:

• Steel's excellent strength-to-weight ratio allows for the creation of smaller areas for structural components.
• Steel works well in a variety of settings and can be shaped into intricate shapes for a wide range of uses.
• Steel is an environmentally benign material since it can be recycled repeatedly without losing quality.

2.2.1 Steel Limitations:

• The greater weight of steel compared to aluminum makes it harder to manage large projects and it raises transportation expenses according to source 17.

• Steel requires proper coating and protection because it develops rust in extreme conditions without sufficient protective measures.

2.2.2 Aluminum Advantages:

Aluminum's low density makes it possible for huge structures to be built while maintaining their structural integrity and for cost-effective transportation that takes less labor time.18. Aluminum can be used in marine situations because of the oxide coating that naturally builds on the metal to prevent further corrosion. Because aluminum is lightweight, constructions made of it can save energy, particularly in the transportation and aerospace sectors.

2.2.3 Aluminum Limitations:

• Aluminum fails to function as an appropriate choice for applications that need high weight-bearing capacity because its tensile strength remains below that of steel [19].

• Due to production costs and raw material costs, aluminum usually costs more than steel.

2.2.4 Cost, Availability, and Environmental Impact

Steel costs around $500 and $1,500 per ton, depending on the type and market conditions, whereas aluminum costs from two to three thousand dollars per ton. Because of the extraction of it process, aluminum is more expensive than other materials, but thanks to improved extraction and recycling techniques, its price has been declining [20].

Table 1. Steel And Aluminum Comparative Properties

Property	**Steel**	**Aluminum**
Tensile Strength (MPa)	250 - 2000	70 - 700
Young's Modulus (GPa)	200	70
Density (g/cm^3)	7.85	2.7
Corrosion Resistance	Moderate (needs treatment)	High (self-protecting)
Cost ($ per ton)	500 - 1500	2000 - 3000
Recyclability	100%	100%

Steel production has greater environmental impacts because its energy-intensive iron extraction process needs more energy than other industrial processes. The production of aluminum requires substantial energy consumption yet recent recycling technology advancements have decreased its greenhouse gas emissions. The recyclable material of aluminum disintegrates during the recycling process while using recycled aluminum instead of fresh raw material results in 95 percent energy savings.

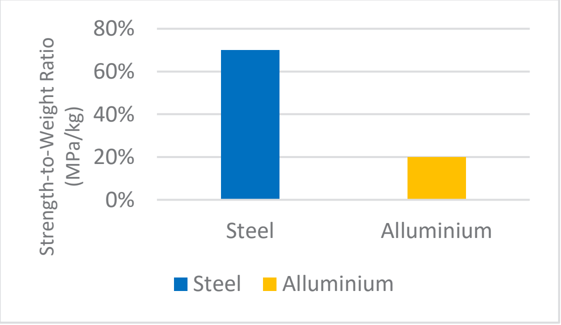

Fig. 2. Steel and Aluminum Strength-to-Weight Ratio Comparison

The graph in Figure 2 shows the weight-to-strength ratio comparison between steel and aluminum materials. Aluminum's lightweight nature makes it appropriate for some purposes, despite steel's generally greater strength [21]. The project requirements will determine which material, steel or aluminum, should be used. Aluminum offers better corrosion resistance for lightweight applications, while steel provides stronger and more durable performance. The two materials are suitable for environmentally responsible building because they both function as recyclable and renewable resources.

3 Structural Design Considerations

In structural design, the choice of materials has a direct bearing on how the structure will react to varied loads. Both steel and aluminum have intrinsic qualities that do influence how these materials behave under certain loading scenarios. Important design factors like load kinds, This section contains the cross section characteristics and connectivity information for both materials.

3.1 Load Considerations

Live load: The occupants, mobile furniture, and other transient items might be seen as the cause of these fluctuating loads. For example, depending on how the building is used, A live load of approximately 2 to 5 kN/m will be applied per square meter.

Dead Loads: These loads are constant and take into account the structure's weight, which is more static than the weight of its floors, beams, columns, and other cargo. Additionally, depending on whether aluminum or steel is utilized, the total dead load will typically vary between structures [22].

Wind Loads: Depending on the building heights, the location of the site, and the type of wind exposure, the wind influence is multifaceted. This formula is utilized to calculate wind load [23]:

$$F_{wind} = 0.613 \cdot C_p \cdot A \cdot V^2 \qquad (2)$$

where V is a wind speed, A is the estimated area, C_p is the pressure of the wind coefficients, and F_wind is overall wind force.

Seismic Loads: An earthquake forces were dynamic forces that depend on the building's location and design in addition to its height. The following formula can be used to compute it: [24]:

$$F_{seismic} = W \cdot S \cdot I \qquad (3)$$

The equation states that S represents the earthquake reaction factor while I denotes the significance factor and W indicates the building weight and F_seismic stands for the earthquake force.

3.2 Cross-Sectional Properties and Member Dimensions

The mechanical behavior of steel and aluminum results from their various cross-sectional properties. A moment of inertia (I) exists as a vital component which determines how both materials resist bending. Next, the rectangular section's moment of inertia is expressed as [25]:

$$I = \frac{b \cdot h^3}{12} \qquad (4)$$

The section's height is represented by h while its base width is denoted by b. Steel components demonstrate higher load-bearing capacity than aluminum components because they can achieve equivalent strength with reduced material requirements. The aluminum beam needs a larger cross-sectional area than the steel beam to handle the same bending moment because aluminum possesses lower strength-to-weight ratio than steel. The design process should include material properties because they contribute to better construction efficiency and cost savings through their impact on cross-sectional dimension design.

3.3 Connection Detailing and Joint Design

The total stability of a structure depends on the design the joints and interconnections between elements. The finishing of steel and aluminum connectors typically varies slightly:

3.3.1 Steel Connections:

These kinds of connections typically have welded or bolted joints. Additionally, steel's exceptional weldability allows for the creation of sturdy, stiff connections with excellent shear and tensile resistance [26].

3.3.2 Aluminum Connections:

Bolted connections are required because aluminum is far less weldable than steel. Because aluminum's fatigue resistance is lower than steel's, dynamic loading circumstances require particular attention.

Maintaining the force transmission from component to member through appropriate connection details keeps the entire structure stable.

Figure 3 illustrates the typical moment from inertia between structural parts made of steel and aluminum. Because of its greater moment of inertia than aluminum, steel enables lighter and smaller members to withstand comparable bending forces [27].

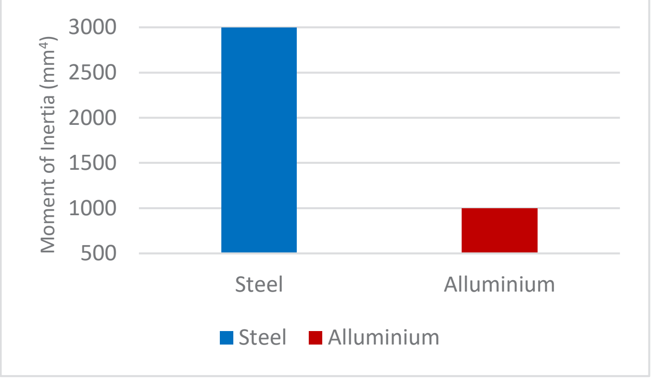

Fig. 3. Moment of Inertia Comparison for Steel with Aluminum Sections

One of the primary general factors for steel and aluminum structural design is the careful balancing of resistance to load, material properties as well as connection design. Because aluminum is lighter than steel, connection details must be carefully considered. Steel guarantees greater strength and weldability.

4 Examining the Structures of Industrial Sheds

Shed structures are intended to serve as stiff and effective installations for huge, open-span buildings. The choice of material—steel or aluminum—affects modeling and design approaches as well as how the structure behaves under different stress scenarios. This section discusses structural performance under various loads, finite element modeling, or FEM methods, and a comparison of steel and aluminum shed design approaches.

4.1 Comparison of Steel versus Aluminum Shed Design Techniques

In order to guarantee stability, one-dimensional design methodology essentially involves choosing the right material, cross-section size, and member size. Additionally, it is to determine whether the design is robust under various kinds of loads. For instance, because steel and aluminum have distinct mechanical characteristics, such as weight, constructing a shelter made of steel would be distinct than creating a shed made of aluminum.

Steel Sheds: Steel's exceptional strength and rigidity enable the use of members with small cross-sectional dimensions. The limit condition engineering method is commonly used when constructing steel structures employing safety factors to ascertain whether the structure can withstand applied loads without failing. Welded connections produce strong, long-lasting joints that also benefit from the qualities of steel [28].

Aluminum Sheds: For a given load, aluminum buildings have larger cross sections that steel ones because aluminum is lighter but has a lower tensile strength. Aluminum building design often focuses on joint quality via bolted links and takes the material's fatigue characteristics into account throughout time. A common design technique for aluminum is the allowable stress design procedure, which analyzes the stresses inside the components with the allowed values.

5 Cost Analysis

The cost analysis becomes crucial for industrial shed construction materials because it calculates all expenses which include materials' initial costs and construction expenses and future maintenance and durability costs. The document presents a comparative analysis of the complete expenses which include material costs and fabrication expenses and construction costs and maintenance costs for various aluminum and steel constructions.

5.1 Fabrication, Construction, and Material Costs

Steel prices lower than aluminum prices because steel costs less for each unit of weight. Steel prices range from $500 to $800 per ton based on both the steel grade and current market conditions. The construction industry experiences cost savings because steel parts undergo factory-based production before they reach construction sites. The material costs for steel components increase because steel requires corrosion protection through coating or galvanizing processes. Aluminum prices start at two thousand dollars and reach three thousand dollars per ton which makes aluminum more expensive than steel. The lightweight characteristics of the product enable users to save money during foundation construction and shipping operations. The following formula can be used to determine the overall cost of construction [25] as:

$$C_{total} = C_{material} + C_{fabrication} + C_{construction} \qquad (6)$$

where $C_{material}$, $C_{fabrication}$, and $C_{construction}$ Contemplate the amount of art, samples, and design that will meet the demands of the sponsor.

5.2 Maintenance and Lifecycle Cost Comparison

The degrading nature of coatings requires steel structures to undergo continuous maintenance because they need protection against rust and corrosion during their entire lifespan within challenging environmental conditions. The annual maintenance expenses for steel structures range from one percent to three percent of the building's original construction expenses. Aluminum maintenance expenses decrease because aluminum maintains better resistance to corrosion than steel. Aluminum has better resistance to corrosion than steel which results in reduced maintenance expenses for aluminum. The annual maintenance expenses for aluminum materials range between 0.5 percent to 1 percent of the building's total construction expenses.

Table 2. Comparison of Steel and Aluminum For Industrial Sheds

Cost Factor	Steel	Aluminum
Material Cost (per ton)	$500 - $800	$2,000 - $3,000
Fabrication Cost	Lower, due to simple welding	Higher, due to complex joints
Construction Cost	Moderate	Higher due to intricate methods
Maintenance Cost (annual)	1-3% of initial cost	0.5-1% of initial cost

Aluminum products provide advantages through their lightweight design and reduced need for maintenance throughout their operational lifespan. The initial costs of steel production are lower because steel can be developed through standard manufacturing processes. The total lifecycle cost of aluminum usage requires assessment of additional initial costs which must be added to the upcoming expenses.

6 Thermal and Corrosion Performance

When selecting materials for a manufacturing shed for longevity and structural integrity, these two factors—thermal and corrosion performance—have a big impact. The different ways that steel and aluminum react to environmental conditions determine their suitability for specific climate conditions.

6.1 Thermal Conductivity and Expansion Characteristics

Steel Steel demonstrates exceptional heat transfer capabilities because its thermal conductivity reaches approximately 50 W/m·K. Because it allows steel to expand and then contract, this feature is essential for nations that endure extremely high summer temperatures and extremely low temperatures. The approximate value of the Factor of Thermal Expansion (CTE) is 12x10^-6 per degree Celsius which leads to material size changes that occur when temperatures rise and fall according to reference 34.

Aluminum exhibits thermal performance that equals steel for cooling applications which need to maintain extreme temporary temperature fluctuations because its thermal conductivity reaches approximately 205 W/m·K. The materials will experience significant expansion due to temperature variations because their thermal contraction coefficient which scientists refer to as alpha reaches $23 \times 10{-}6$/°C which exceeds the value for steel.

The following equation describes the link between dimensional change (ΔL) and temperature change (ΔT) in materials [35]:

$$\Delta L = L_0 \cdot \alpha \cdot \Delta T \tag{7}$$

The formula describes that L0 represents the initial length measurement while α denotes the thermal contraction coefficient and ΔT functions as the temperature variation measurement which results in ΔL as the length extension.

6.2 Durability and Corrosion Resistance

Corrosion represents a destructive process which typically affects steel located in coastal regions that experience high moisture levels because steel reacts with either water or oxygen to form rust or iron oxide. The metallic framework of protective materials receives paint and powder coating and galvanizing as its protective treatment. The combination of protective systems and environmental factors determines how quickly corrosion develops in different settings.

The natural process of oxygen attachment to aluminum creates an aluminum oxide layer which protects aluminum from corrosion. The material maintains its performance in both humid conditions and saltwater environments but starts to experience localized corrosion when it interacts with other metals through galvanic processes. The figure shows how heat expansion affects aluminum and steel at the same temperature changes which shows that steel expands less than aluminum does during the same distance. Aluminum demonstrates a thermal expansion rate which exceeds all other materials in comparison [36].

Table 3. Steel vs. Aluminum thermal as well as corrosion properties

Property	**Steel**	**Aluminum**
Thermal Conductivity (W/m·K)	50	205
Coefficient of Thermal Expansion ($\times 10^{-6}$ /°C)	12	23
Corrosion Resistance	Moderate (requires coating)	High (naturally resists corrosion)
Corrosion Rate (in humid climates)	High without coating	Low, stable oxide layer

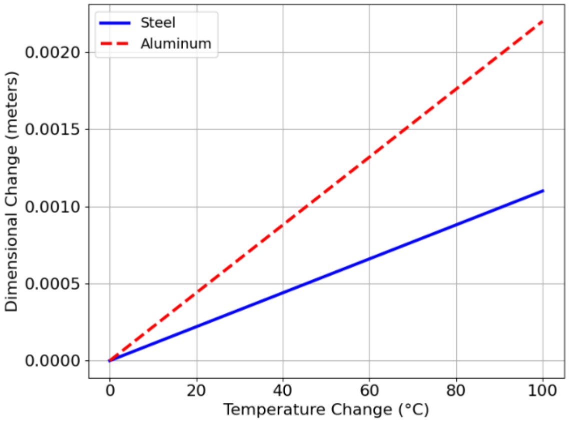

Fig. 4. Steel and aluminum's thermal expansion with identical temperature changes

Steel provides good strength capabilities, but its performance requires protective coatings to prevent corrosion damage in extreme environmental conditions. Aluminum is the most thermally expanding material available because it expands more than any other substance when temperatures change, yet it displays excellent protection against corrosion while thriving in environments that experience high humidity and salt contact.

7 Sustainability and Environmental Impact

The design process for industrial sheds needs to include sustainability assessments which examine the environmental effects of aluminum and steel materials. the design process needs to establish material selection criteria with energy requirements and green building standards as essential performance metrics.

7.1 Recyclability and Carbon Footprint

Steel is recyclable because more than 90 percent of steel products get recycled after their operational period ends. The process of producing steel requires substantial energy because mining and metallurgical operations demand large energy resources. The use of recycled steel together with recycling technology advancements decreases the environmental footprint of the process.

Aluminum shares the same recycling potential as steel because 75 percent of all aluminum ever produced remains in active use today. The process of producing aluminum requires large electricity consumption because bauxite ore needs to be processed. The primary source of aluminum production carbon emissions comes from the energy-demanding smelting procedure according to [16].

The equation below provides quantitative data about the environmental effects of steel and aluminum production through their carbon emission measurements [32]:

$$Carbon\ Footprint = (EnergyConsumption) \times (EmissionFactor) \tag{8}$$

7.2 Adherence to Green Building Guidelines

Stainless steel and aluminum can be utilized in buildings and green areas that adhere to LEED and BREEAM standards. The standards establish requirements for using recycled materials and energy-efficient products which first provide details on their proper usage. The use of steel and aluminum materials enables construction of energy-efficient buildings It will result in significant carbon emission savings and enhanced environmental performance.

Table 4. Steel vs. Aluminum's ecological impact

Aspect	Steel	Aluminum
Recyclability	High (90% recycled content)	High (75% recycled content)
Carbon Footprint	High due to energy-intensive production	High due to energy-intensive production
Green Building Compliance	Can meet LEED, BREEAM standards	Can meet LEED, BREEAM standards

8 Modeling and Analysis

8.1 Key Structural Design Aspects

• The Ford Production Facility near Michigan, USA, has a single wall and cladding, comprising steel and aluminum components covering 6.3 metres for stability and masonry up to 2.1 meters.

• Roof Slope and Protection: 9.91° slope with GI sheets; aluminum resists corrosion without additional coating.• Purlin as well as Girts Spacing: 1.5 m as purlin or 2.1 m with girt; cost-effective adjustments are made possible by aluminum's light weight.

• Support Conditions: Aluminum lowers foundation load, steel offers great stability, and pinned supports.

8.2 Design Details

In the study, the strength of the structure of an industry warehouse is examined using ETABS employing steel as well as aluminum materials. Three distinct kinds of three-dimensional building structures under both static and dynamic stresses are designed as part of the study.

The Standard Measurements of Steel and Aluminium Structures include the following parameters which extend from their 60 meter length and 6 meter bay spacing and 24 meter width and 8.402 meter eave height dimensions. The structure reaches a height of 8.4 meters when brickwork extends to 2.1 meters above ground level and the cladding covers the remaining 6.3 meters. The roof has a slope that measures 9.91 degrees. The building uses GI sheets as roofing materials. The building design requires purlins to be installed at intervals of 1.523 meters which means purlins will be placed at this specific distance throughout the structure. The girt spacing reaches 2.1 meter distance between its installation points. The support condition uses a pinned configuration.

Warehouse Structure Plan Layout:

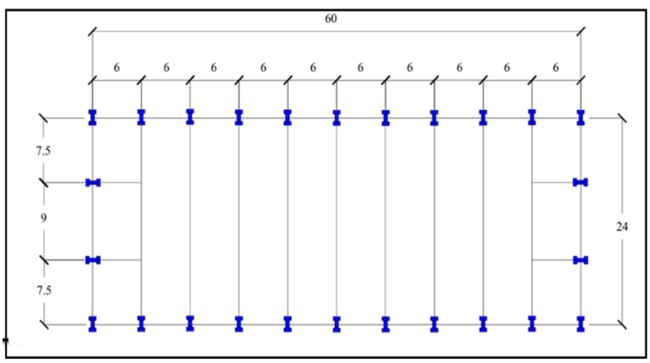

Fig. 5. Plan of model

Elevation of Warehouse Structure :

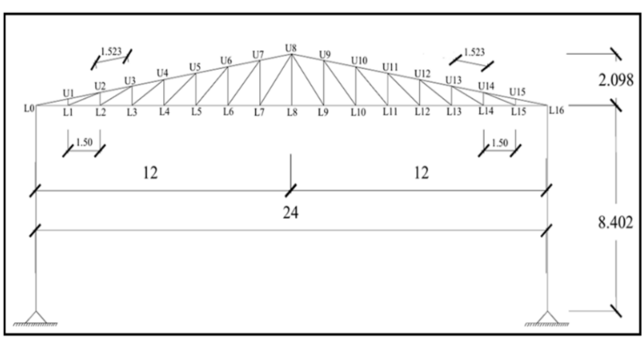

Fig. 6. Elevation of model

8.3 Calculations for Loading

The industrial warehouse structure's aluminum and steel structural members' dead loads and live load calculations are displayed. Both materials use the same IS 875-1987-based load estimates.

Calculating Dead Load (IS 875-1987 Part-I, pages 25–30):

1. Purlin's total load:• The sheet's weight is 0.058 kN/m².
   - Fixing weight = 0.025 kN/m2
   - The services' weight is 0.100 kN/m².
   - 0.058 + 0.025 + 0.100 = 0.183 kN/m² is the total mass per unit area.
2. Purlin's Total Weight:
   - Purlin's spacing is 1.523 meters.
   - Purlin's total weight is equal to its weight (kN/m2) x its spacing.

   Calculation of Total Load: Total mass on purlin = 0.183 kN/m² × 1.523 m = 0.278 kN/m
3. Purlin's weight is assumed to be 0.10 kN/m for aluminum along with steel buildings.

Weight of Truss: (Span/3+5) × 10 = (24/3+5) × 10 = 0.130 kN/m2 = 0.103 × plan length = 0.103 × 1.5 = 0.154 kN/m

1. Conversion to Uniform Load: The distributed dead load per unit area of the structural system works 0.103 kN/m² in accordance with IS 875 standards.

2. Total Dead Load: 0.278 + 0.1 + 0.154 = 0.532 kN/m is the sum of all computed loads.

Steel and aluminum dead load: 0.532 kN/m

3. Live Load (Aluminum & Steel):

The general technique for calculating live load (LL) applies a correction factor based on the roof slope. Assuming an elevated roof inclination of 9.91°, the factor seems to be:

- The basic a real-time (in kN/m2) is 750.
- The adjustment factor for each degree for roof slope is 20.
- (9.91–10) modifies the live load according to the angle. = 750 – 20 (9.91 – 10) = 0.751 kN/m2 = 0.751 × 1.523 = 1.143 kN/m = 2/3 × 1.143 = 0.762 kN/m

1. *Wind Load Calculation (IS 875-1987 Part-III) (page 49-50)*

1. Basic Wind Speed :- $V_b = 39\,\mathrm{m/s}$
2. Design Wind Speed: $V_z = K_1 \times K_2 \times K_3 \times V_b$

Design wind pressure = $P_z = 0.6\ V_z^2$
Wind pressure on roof = $(C_{pe} - C_{pi})$
Where:-
Cpe is the external wind pressure coefficient.

Cpi stands for internal wind pressure coefficient.

K1 = Risk factor (based on a 50-year mean likely design life)

K2 = construction size factor and terrain height

K3 is the topography factor.

For all conventional structures and buildings, the average anticipated design life is fifty years.

Risk coefficient K1 = 1.0
Terrain category = 3 ……... (As height of building 10 m)

Class B ……..…. (As horizontal or vertical dimension in between 20 to 50 m)
K2 = 0.99
K3 = topography factor
K3=1
= 1.0 × 0.99 × 1.0 × 39

= 38.61 m/s

Design wind pressure = Pz = 0.6 × (Vz)2

$$= 0.6 \times 38.61^2$$
$$= 894\ \text{N/m}^2$$

2. *Wind Pressure on Roof :-*

$$\text{Wind pressure} = (C_{pe} - C_{pi}) \times P_z$$

The Cpe and Cpi numbers are influenced by the specific building's orientation, architecture, and open/closed status.

Basic Wind Speed: -39.00 m/s

Design Wind Speed: -38.61 m/s

894 N/m² is the design wind pressure.

8.4 Modelling

Both steel and aluminum frameworks, such as Industrial Sheds Manufactured with Steel as well as Aluminum Members, are frequently analyzed and designed using ETABS. The program offers a strong framework for accurately modeling industrial buildings, warehouses, and other structural systems.

Engineers can effectively simulate and optimize metals such as aluminum and steel members thanks to ETABS's support for a variety of section characteristics, materials, including international design requirements. To improve performance and structural efficiency, structural components like It is possible to modify C-sections, I-sections, including tapered parts.

By specifying web and flange sizes along with different thicknesses, ETABS enables the production of lightweight yet robust structural components for industrial sheds using aluminum members, guaranteeing the best weight to strength ratio and material effectiveness. A thorough structural analysis and effective design process are made possible by modeling Slabs, walls, as well as shear barriers are plate components, while beams and columns are line elements.

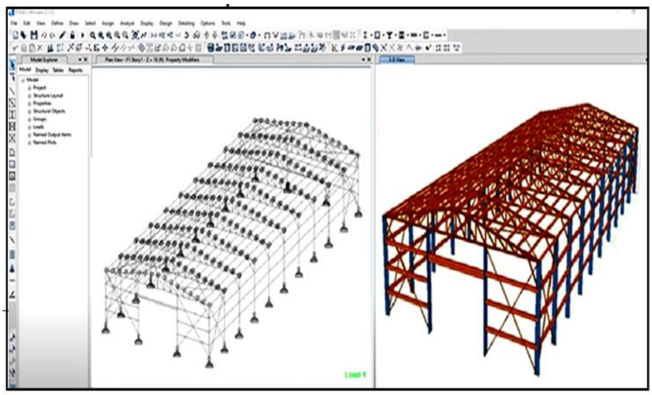

Fig. 7. Steel Structure Modeling and Rendered View

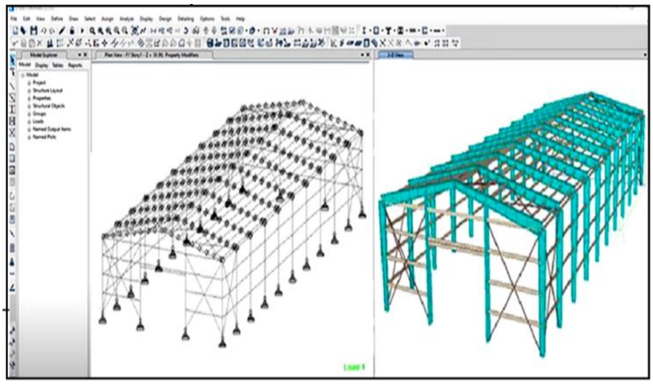

Fig. 8. Aluminum Structure Modeling and 3D View

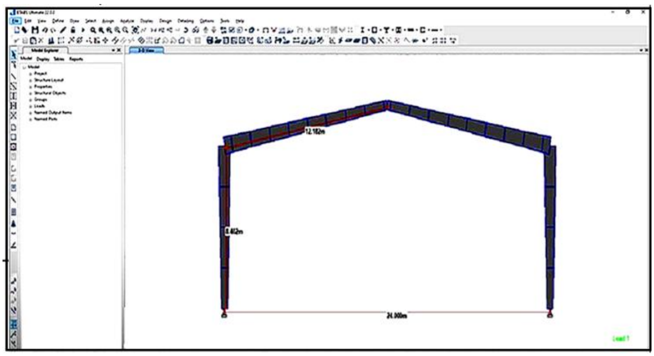

Fig. 9. Assembled Tapered Section

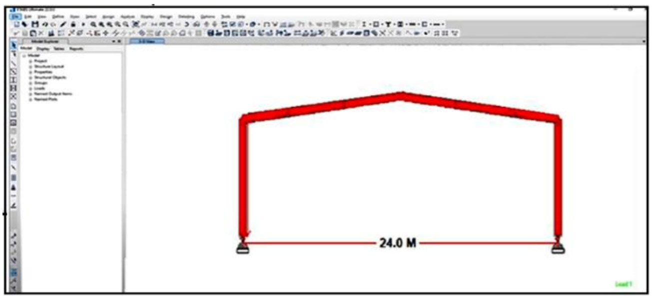

Fig. 10. Assembled I-Section OF CSB Section

The tapered section defines a structural element which extends through its length with different cross-section measurements. The design aims to achieve material efficiency through weight reduction and strength enhancement whenever required. The design probably functions in cantilever structures and portal frames and long-span beams to improve operational performance while decreasing material expenses.

As a structural component, the I-Beam (H-Beam) exhibits both "I" as well as "H" cross-sectional geometries and offers excellent strength-to-weight ratio. The material is a great option for crucial components because of its strength-to-weight ratio which handle heavy loads. The material gets used in girders and major beams and columns because it provides load distribution and structural stability while handling bending and shear forces.

The two components enhance design efficiency through strength improvements and material reduction and weight optimization for shipping purposes.

9 Results and Discussion

The engineering team utilized ETABS, a powerful yet easy-to-use software, to create and evaluate the structural design. For accurate modeling and analysis of structural aluminum and steel structures, ETABS offers an extensive database. The software generates graphs which display data that clearly shows how the structure behaves by showing normal load distribution and deflections and stress levels and member forces. The advanced analysis capabilities of ETABS enable users to conduct precise evaluations which optimize both steel and aluminum metal sections, thereby improving structural strength and design performance.

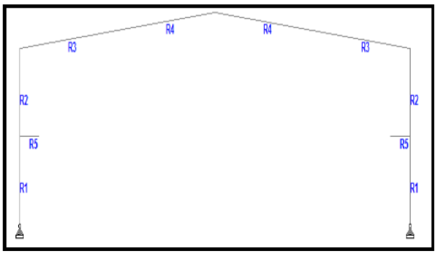

Fig. 11. Aluminum Standard Portion IS 8147:1976 Frame

Table 5: Sectional Information of the Aluminum Frame

Profile	Length (m)	Weight (t)
Tapered Member No: 1	12	5.006
Tapered Member No: 2	37.68	26.925
Tapered Member No: 3	37.68	23.763
Tapered Member No: 4	12	6.616
ST ISMB300	7.5	3.243
ISA 75X75X6	502.65	8.150604
ISA 50X50X6	501.143	22.04178
ST 200Z60X2	3680	20.16215
Total	-	**115.9015**

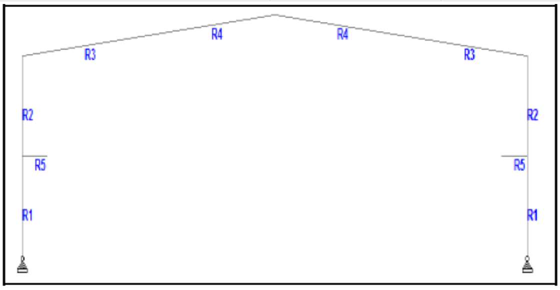

Fig. 12. Typical Aluminum Section: AISC/LRFD Frame

Table 6: Aluminium IS 8147:1976 Frame Sectional Details

Profile	Length (m)	Weight (t)
Tapered Member No: 1	12	5.006
Tapered Member No: 2	28.68	20.49387
Tapered Member No: 3	28.68	18.08712
Tapered Member No: 4	12	6.616
ST ISMB300	7.5	3.243
ISA 75X75X6	506.851	8.218725
ISA 50X50X6	506.843	22.29248
ST 200Z60X2	3680	20.16215
Total	-	**104.3854**

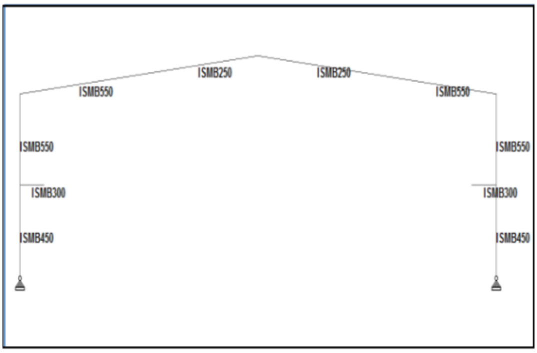

Fig. 13. Typical Section of CSB-IS 800:2007 Frame

Table 6: Sectional Details of CSB-IS 800:2007 Frame

Profile	Length (m)	Weight (t)
ST ISMB250	48.1	17.554968
ST ISMB300	10	4.324
ST ISMB450	24	17.016
ST ISMB550	74.02	75.124717
ISA 75X75X6	583.03	38.78454
ISA 50X50X6	587.02	25.67551
ST 200Z60X2	6140	33.640115
Total	-	**212.1185**

Table 7: Weight Comparison between AL Frame with Steel

Frame Type	Weight (kN)
Steel Frame (IS 800:2007)	1394.289
Aluminum Frame (IS 800:2007)	935.619
Aluminum Frame (AISC LRFD)	879.151

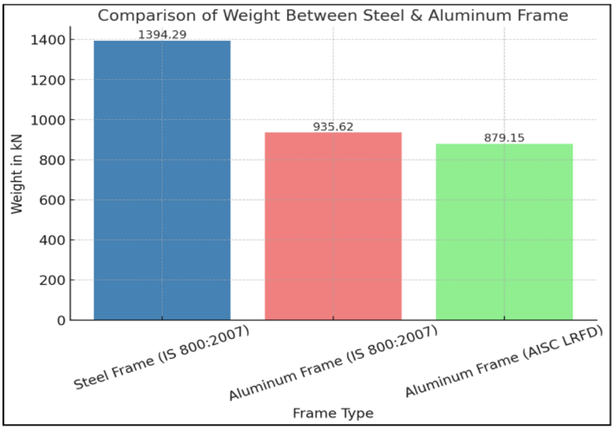

Fig. 14. Weight Correlation

According to the study's design findings, the weight of an industrial sized shed made of aluminum and steel insulating materials is reduced by 33% when constructed in accordance in Indian standards and by 37% when designed within accordance with American norms when compared to a conventional steel building (CSB) structure. This illustrates how adding aluminum components can drastically cut weight without compromising structural integrity.

Table 8: Steel Quantity For Purlin

Type of Frame	Weight (kN)
CSB FRAME (Hot Rolled Steel Section) IS 800:2007	333.796
PEB FRAME (Cold Formed Steel Section) IS 800:2007	144.19
PEB FRAME (Cold Formed Steel Section) AISC LRFD	105.09

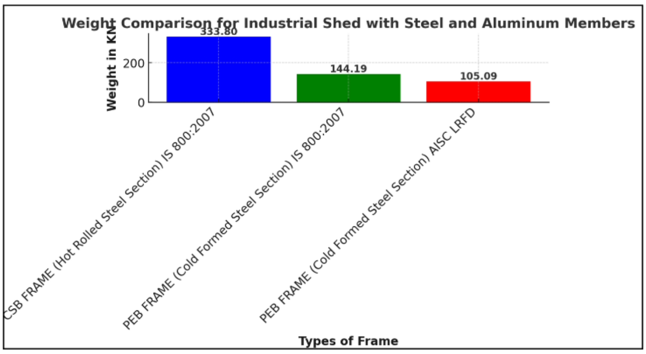

Fig. 15. Steel Quantity Required for the Hot Rolled and Cold Formed Steel Segments of Purlin Members

According to the study's design results, the purlin weight in the aluminum structure is decreased by 56.80% according to the Indian code and by 68.51% according to the American code when compared to the steel frame. This demonstrates how aluminum members effectively reduce material consumption while preserving structural strength in a manufacturing sector shed built with steel as well as aluminum members.

Table 9: Steel Quantity for Grit Members

Types of Frame	Weight (KN)
CSB FRAME (Hot Rolled Steel Section) IS 800:2007	352.118
PEB FRAME (Cold Formed Steel Section) IS 800:2007	56.807
PEB FRAME (Cold Formed Steel Section) AISC LRFD	39.439

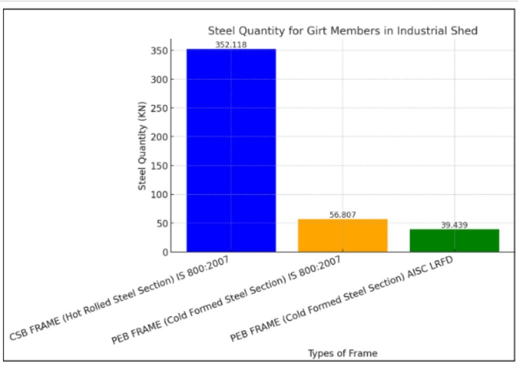

Fig. 16. The quantity of steel required for the hot-rolled sections and the cold-formed Girt sections

The Girt Component mass in a aluminum building is reduced by 83.86% with 88.79%, respectively, according to the American standard construction (AISC LRFD) and the Indian code standard (IS 800:2007), when contrasted with the Girt Member mass in a steel structure. In an industrial shed built wit steel and aluminum elements, this illustrates the lightweight benefit of aluminum sections while guaranteeing structural integrity.

Table 10: Kn's Maximum Shear Force

Types of Frame	Shear Force (kN)
CSB Frame (IS 800:2007)	403.064
PEB Frame (IS 800:2007)	204.744
PEB Frame (AISC LRFD)	151.018

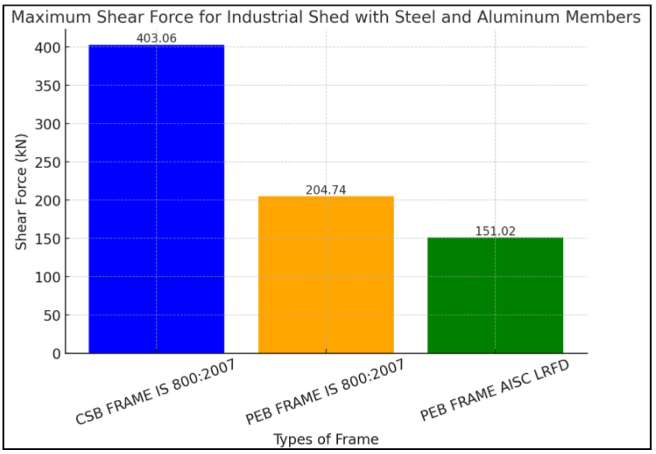

Fig. 17. Maximum Shear Force

This study on a typical industrial shed construction using metal and steel members shows that the highest shear stress within PEB according to an Indian code system is reduced by 49.27%, while the maximum shear force in PEB compared to the American code framework is decreased by 62.53% in contrast to the Indian CSB structure.

Table 11: Maximum Support Reaction in KN

Types of Frame	Support Reactions (KN)
CSB FRAME (IS 800:2007)	193.067
PEB FRAME (IS 800:2007)	159.603
PEB FRAME (AISC LRFD)	121.266

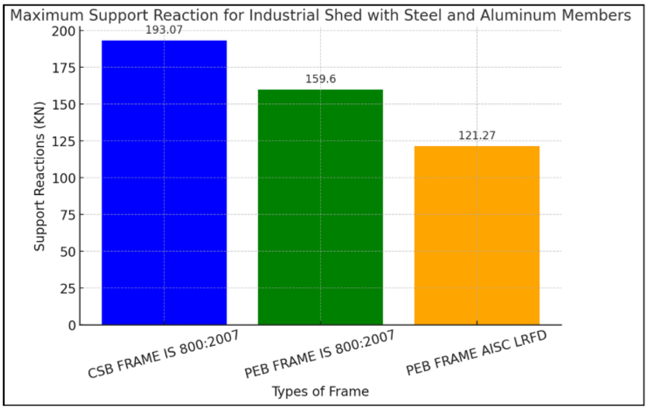

Fig. 18. Maximum Support Reaction

This study finds that the resulting Maximum Supporting a Reaction for an Industrial Shed constructed with steel and aluminum established components is reduced by 17.33% if constructed in accordance to the Indian code structure, compared to 37.18% if designed in accordance alongside the American code structure. This is in contrast to the Maximum Supporting a Reaction of a Typical Steel Building (CSB) structure.

Table 12 : Cost Analysis

Types of Frame	Weight of Frame (kN)	Purlin Weight (kN)	Grit Member Weight (kN)	Total Weight (kN)	Total Weight (kg)	Rate of Steel (₹/kg)	Total Cost (₹)
CSB FRAME (IS 800:2007)	1394.289	333.796	352.118	2080.2	2,12,118.30	55	1,16,66,506
PEB FRAME (IS 800:2007)	935.619	144.19	56.807	1136.62	1,15,900.73	55	63,74,540.3
PEB FRAME (AISC LRFD)	879.151	105.09	39.439	1023.68	1,04,384.65	55	57,41,155.7

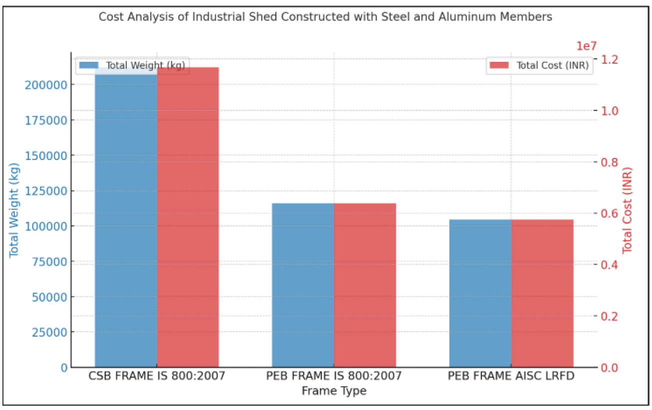

Fig. 19. Cost Analysis

This study demonstrates that the cost of an Industrial Shed Built with Steel and Aluminum Members using PEB based on Indian standards is reduced by 45.36%, whereas the price utilizing PEB pursuant to American norms is reduced by 50.78% as compared to the cost based on the CSB structure.

9.1 Strengths and Weaknesses of Steel and Aluminum

For steel to be daggedly bone for a manufacturing shed, two key characteristics are strength and capacity. Steel's popularity for use in the construction of industrial structures is based on both its cheaper initial cost and its resistance to harsh environments. For the majority of industrial applications, all of these turn into reasonably priced options. Nevertheless, it is one among the metals that corrodes easily, particularly when exposed to chemicals or high humidity, necessitating regular upkeep and protective coatings [38].

The oxide coating of aluminum creates natural protection against corrosion which makes it an ideal material for environments. The installation process would become easier because of its lightweight properties but aluminum costs more due to higher material expenses and energy-heavy production processes. To achieve strength comparable to steel structures aluminum buildings require larger components. The design requirements will experience effects from this situation.

9.2 Insights into Selection Criteria

The selection of either steel or aluminum must follow the project requirements, which include budget limits, weight capacity needs, and environmental factors. Aluminum serves as the preferred material for locations that need both corrosion protection and lightweight properties while steel functions as the appropriate choice for constructing large and heavy structures [39].

Table 13. Comparison of Steel and Aluminium Industrial Sheds

Property	Steel	Aluminum
Strength	High	Moderate
Corrosion Resistance	Low (requires protection)	High (naturally resistant)
Weight	Heavy	Light
Cost	Lower material cost	Higher material cost
Maintenance	Requires periodic maintenance	Low maintenance

Aluminum performed better in terms of damage to the environment, but steel is superior when it pertains to design with extremely heavy loads, according to a comparison of the steel and aluminum sheds in various loading situations, as shown in Fig. 6 [40].

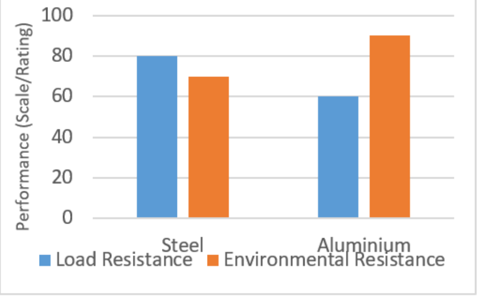

Fig. 20. Comparative Evaluation of Steel and Aluminium Sheds under Various Loading Situations.

10 Conclusion

Steel is a versatile material which is either either directly or indirectly necessary to our day-to-day existence. Cost-effectiveness, strength, durability, design flexibility, and recyclability are just a few advantages of using aluminum parts in industrial shed construction. Like steel, aluminum is a relatively sustainable material since it can be recycled forever and is easily obtained from local sources.

The following conclusions are reached based on design and analytical findings that contrast traditional steel structures with aluminum-integrated structures:

- Structural Weight Reduction: Compared to traditional steel constructions, industrial sheds with aluminium members weigh 33% less according to Indian requirements and 37% less according to American standards.

- Purlin Weight Reduction: Compared to traditional steel constructions, purlin cost in an aluminum-framed industrial shed is decreased by 56.80% according to Indian specifications and by 68.51% according to American norms.
- Girt Member Mass Reduction: According to Indian and American standards, the Girt Members mass of an aluminum-integrated industrial shed is reduced by 83.86% and 88.79%, respectively, when compared to conventional steel construction.
- Shear Force Reduction: Compared to traditional steel constructions, a maximum shear strain in a business shed with aluminum framed members is 49.27% lower according to Indian requirements and 62.53% lower according to American standards.
- Support Reaction Reduction: Compared to traditional steel structures, The integrated aluminum industrial shed's maximum support response is 17.33% lower according to Indian specifications and 37.18% lower according to American standards.
- Cost Reduction: When compared to traditional steel constructions, the cost study of industrial sheds using aluminum members reveals a 45.36% reduction according to Indian norms and a 50.78% reduction according to American standards.
- Aluminum members serve as an effective alternative to traditional steel materials which industrial warehouse construction needs because they improve structural performance while reducing building weight and construction expenses and supporting environmental protection efforts.

Future research should focus on developing affordable aluminum production methods through innovative manufacturing techniques while assessing the performance of hybrid designs that combine elements from both materials. The development of advanced surface coatings and treatment methods will establish the necessary foundation to improve steel's corrosion protection while expanding its industrial applications. The research will create methods for recycling materials in an environmentally friendly way which will help establish sustainable practices for both materials used in the study.

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