Structural Analysis and Comparative Design of Industrial Buildings Using Pre-Engineered Buildings (PEB) and Tubular Steel Sections

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Abstract:

Industrial growth and development require efficient, economical, and sustainable building methods. This paper examines the structural analysis and comparative optimization of the design for industrial buildings using Pre-Engineered Building (PEB) systems and Tubular Steel Sections. PEB construction is well known as a lightweight and quick-to-build system with significant advantages in cost, whereas Tubular Sections are much stronger in terms of strength to weight ratio, better aesthetic appeal, and for their buckling resistance. The research objective is to critically assess the constructional performance, material efficiency, and joint operational behavior of those two building techniques under various loading conditions such as dead loads, live loads, wind loads, and seismic forces. Advanced structural designing software was used in the analysis to ensure that all design parameters complied with technical design requirements and codes. The deflection, compared to other criteria such as stress distribution, height and weight optimization, and overall cost, becomes a key criterion in identifying the most efficient structural system for industrial applications. To a much extent, it has been seen that PEBs are very quick to erect and have lean uses but poor performance capacity, while tubular members enable the load to be resisted. Advantages and disadvantages of PEBs and tubulars should be studied by using benchmarks useful for engineers and designers needing to choose the right structural option pertaining to the peculiarity of the project. The discussion from the study aimed at developing theoretical and practical context for well-designed, budget-friendly, sustainable solution for industrial buildings, supplying soil for the upgradation of innovations for modern building practices.

Keywords: *Pre-Engineered Buildings, Tubular Sections, Structural Analysis, Industrial Buildings, Load Optimization, Steel Structures*

I. INTRODUCTION

Industrial building systems play an important role in the support of the manufacturing processes, warehousing, and logistics, serving as the operational backbone for economic and industrial expansion. These systems are designed explicitly to accommodate heavy machinery, massive storage capacities, and running operations while providing safety, stability, and cost-effectiveness of the building structure. Industrial buildings require much bigger open spans, high loading capacity, and resistance to a sum of dynamic effects such as vibrations, impacts, wind pressure, and seismic effects that come hand in hand with industries expanding and modernized in nature [1]. This high demand for new advanced facilities ushered in the era of advanced and economical building systems achieved through innovative technologies and materials. Historically, industrial buildings were constructed with the reinforced concrete and conventional hot-rolled steel sections, resulting in heaps of time on-site and long hours of labor costs, before completion of projects. More recent advances in industrial building systems like Pre-Engineered Buildings (PEB) and tubular steel structures, besides some other industrial-building methods, have since become necessary due to the huge market pressure for faster construction at the smallest costs and with high quality. Pre-Engineered Buildings have proven their mettle in industrial constructions by being particularly efficient and flexible to the application. Using PEB technology, columns, rafters, and purlins are designed using sophisticated software; these elements are then manufactured under controlled working environments, ensuring precision and quality of components. Such pieces are then transported to the particular location of their application, which greatly shortens the waiting time and reduces construction material wastage significantly [2]. The sag close of sections in a PEB is advantageous in transmitting loads to the columns and/or the foundation to resist uplift loads from any possible combinations of dead loads, imposed loads, wind loads, seismic loads, snow loads, and any combination of these. Therefore, tapered sections are cost-effective and armors the PEBs in any application like a factory, warehouse, and logistics center, which is tailored for a large span. PEBs offer scope for various structural configurations for expansions and modifications, based on the different industrial needs. Tubular Steel Structures have been seen as a major advancement in industrial building systems, as they take advantage of hollow sections, such as circular, square, and rectangular sections, which have high structural performance [3]. Those sections have a good strength-to-weight ratio, which reduces the self-weight-induced compression in consideration of the more elevated resistance to buckling than solid sections, besides giving rise to reduced compression stress. Tubular-sectioned circles compress the whole tube, permitting the efficient usage of material due to containment of the pressure. They provide uniform stress distributions and a high capacity-to-weight ratio that is superior to other open sections when they're used for medium- and long-span constructions. The closed-section geometry leads to increased surface area, resistance to corrosion, and buckling, in addition to less maintenance thereof. To the contrary, the smooth surface helps improve aesthetics, increasing the popular acceptance of tubular steel structures-the feasibility basis for robust- yet light-well-designed applications in varied demanding projects [4]. The successful application of a particular business system will depend upon several parameters concerning the industrial process, secure drive length, loading conditions, exposure to the atmosphere, construction schedule, and last but not the least, budget limitations. This means that an industry that requires drives that stand out for impeded space with expedited construction usually bangs drum beats in favor of PEB, while an industry requiring added strength and design flexibility for special jobs might pick tubular structures. For the past few years, sustainable design has been gaining an increasing level of relevance in the concept of industrial buildings [5]. These systems, with modern industrial buildings, acquire toward more eco-friendly construction practices with the use of recyclable materials, energy-efficient insulation, natural ventilation, and daylighting to reduce energy consumption and control environmental effects. The integration of renewable energy sources supports the sustainability of industrial properties: renewable energy examples include solar panels. Modern technologies such as BIM, CAD, and FEA have revolutionized the planning and design processes, enabling engineers to optimize structural performance and reduce material usage, thereby attaining greater efficiency [6]. Building-system safety and compliance with building standards and codes play a major role in industrial building systems, assuring that structures are designed to withstand varied sorts of loads and environmental conditions while providing a safe environment for personnel. Good maintenance including corrosion protection, inspection, and repairs is necessary for ensuring durability and functionality. Furthermore, interconnected smart industrial buildings with sensors and IoT-based monitoring systems are establishing a new dimension in the realm of industrial infrastructure. Such technologies facilitate real-time monitoring of structural health, energy usage, and environmental conditions, permitting predictive maintenance and operating efficiency improvement for energy sustainability. Right from the very beginnings to current times, industrial building systems have seen a sea of change from traditional methods to highly evolved, technology-oriented ways of planning and execution that have, in turn, come to stress efficiency, flexibility, sustainability, and safety [7]. In so doing, industries divert resources into addressing the ever-increasing contemporary needs of production and logistics, minimizing cost impacts while protecting the environment hence making industrial building systems the very core of study and innovation in civil and structural engineering.

II. OVERVIEW OF PRE-ENGINEERED BUILDINGS (PEB)

Pre-Engineered Building (PEB) is a modern and efficient approach to industrial construction and provides many benefits over traditional building systems in terms of cost, time, quality, and structural behavior; hence a PEB can be defined as a building structure where all components and associated material are designed and pre-fabricated in the factory before transporting them to the construction site for the purpose of assembling. The entire building concept is based on the optimized standard sections or members so that maximum reuse of any of the members is possible to reduce overall material consumption. Past few decades have witnessed the vital acceptance of PEB systems in industrial sectors such as manufacturing units, warehouses, logistic hubs, workshops, and commercial complexes because of the added benefit of flexibility and fast timeline of completion of the project. The basic concept of PEBs is premised on a design approach that takes a holistic view of the building rather than treating components completely in isolation [8]. Traditionally, the primary members of a structure built through "PEB technology" are generally made of cold-rolled formed sections. They are mostly tapered built-up sections-which means their cross-sections change with respect to the bending movement distribution. The design would assess the stress demand at different cross-sections and point out irregularities on all the supports, resulting in an economical design. In most standard steel PED buildings, cold-formed secondary members are called to satisfy minimum strength and stiffness requirements for purlins. Purlins could be connected to the truss members to support the roof and cover purlins. Generally, these purlins can also be transferred to a girt to support the wall panel. One major advantage of the PEB system is construction speed, as the majority of the components that would go into the system are formed in the confines of an atmosphere built to suit the needs of a factory. Construction activities at the site are thus minimal, having to do only with assembly and erection where these components are erected and joined together. This significantly decreases construction time and can sometimes lead to 30–50% preliminary savings when compared with the traditional construction methods. Accuracy of design and quality is another marked advantage of the prefabrication system offered within the process; the factory ensures the assembly of parts according to certain standards and higher precision where advanced machinery is used. [9] Therefore, to some extent, the system minimizes errors, rework, and improves the structural durability and stability. A 3D schematic illustrating the key structural components and functional elements of a pre-engineered industrial building, including roofing, framing, ventilation, and material handling systems is descried I figure 1.

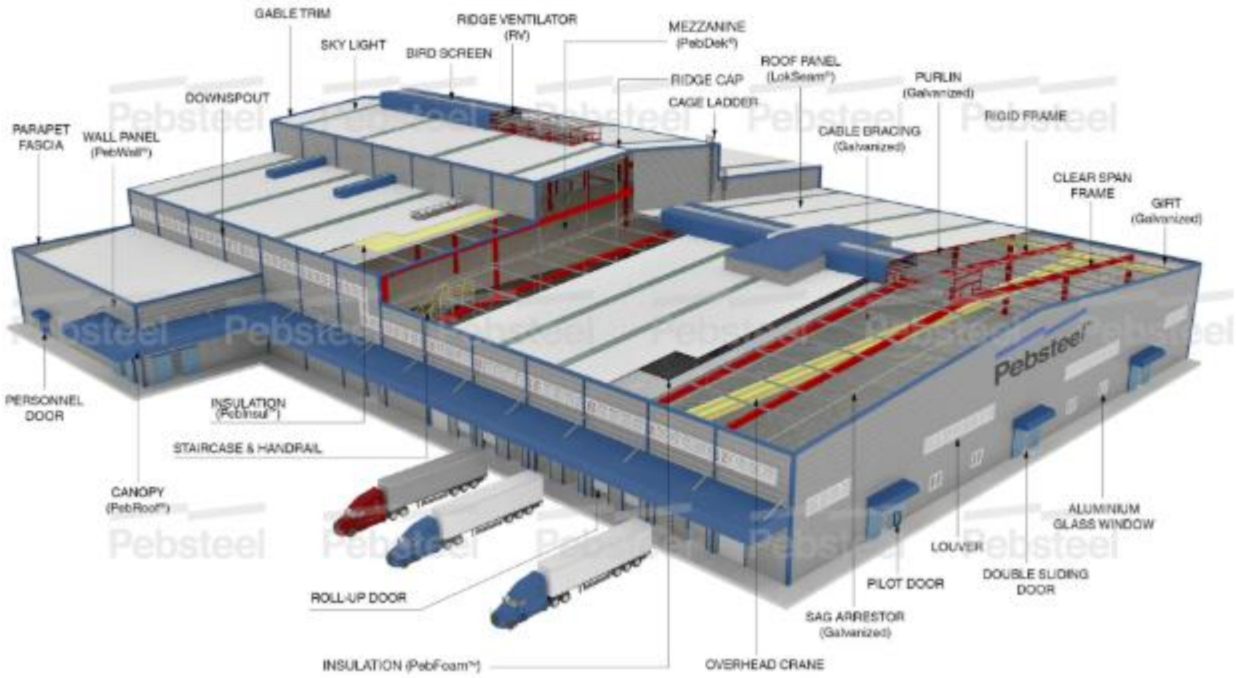

Figure 1: Pre-Engineered Building (PEB) Structural Layout [9]

Another vital feature of Pre-Engineered Buildings is the cost-effectiveness they bring. The optimized design cuts down on steel consumption, leading to smaller material costs. The shortened leeway for construction positively affects labor charges because of reduced timing for construction, adding speed to the project completion; this provides industries to kick-start their operations and realize quicker ROIs. The low weight of PEB components results in less transportation and handling charges. Moreover, with less wastage and more material-use efficiency, preserving the resources as part of the notion of sustainability beneficiary. There exists a significant benefit in the PEB system which is the flexibility and expandability. It is a fact that industrial requirements often change owing to technological advancements and other instances of increased production requirements. This fact underlines the importance of how PEB structures can conveniently be expanded by adding bays or modifying existing components, all without undertaking any large-scale structural alterations. Consequently, the adaptability of the PEB structures finds their realization best in helpful and responsive dynamic industrial environments. By the same account, this high degree of customization envisioned through loose building variables allows the design considerations of the buildings' building dimensions, layout, roof slopes, and architectural features, thus accommodating specific expression of function and beauty [10].

Structural performance is another critical aspect of PEB systems. These buildings are engineered to bear various loads by which are meant live loads, dead loads, wind loads, seismic forces, and crane loads where necessary. The structural design, advanced software, and analytical techniques are used to certify that all designs meet the relevant codes and standards. This will increase the amount of loads while providing for light times and applying advanced high-strength steel to minimize the weight/wind effect. Bracing/connections are well-managed to ensure stability, while also providing resistance to lateral forces. In order to help the PEB structures stand the test of time, advanced setups in PEB should be provided with effective roofing and wall cladding solutions. Generally, it is seen that light-weight metals like galvanized cold rolled steel are used for making the roofing and walling structures ensuring a long-life span against weather elements and providing with an easy set up. Further, these panels act as thermal insulation material, thus reducing the building's energy consumption on air-conditioning, which lowers overall operational cost. Modern PEB design incorporates other features for the advantages of daylight, such as skylights, dormers, and ridge monitors, acting in unison with ventilation systems to achieve the intended operative environment, relying minimal on artificial systems.

One of the more recognized advantages of the use of PEBs is the focus of sustainability. From the use of recyclable steel and efficient material use to lower construction sizes, these signify responsible and sustainable construction processes, meanwhile renewable energy systems like solar panels can also be easily infused into the designs of PEB. Reduced construction time does not only entail swifter building completion but also lesser hassles and disturbance to the environmental conditions on the site. PEB establishes itself as the most preferable choice for green projects. Regarding the key benefits associated with Pre-Engineered Buildings are concerns with maintenance and durability. High construction life standards go hand in hand with the utilization of high-quality material and protective coatings, leaving PEB resistant to corrosion, weathering, and other types of corrosion that typically befall their conventional counterparts. Generally, there is less maintenance required compared to conventional buildings? This contributes to reduced life-cycle costs. Additionally, the modular nature of building components makes it easier to repair or replace them [11]. Though the PEB system offers numerous advantages, it possesses certain limitations. For very complex design work or for buildings of extreme heights, it may perhaps not be suitable. Moreover, initial design work and subsequent fabrication require close planning and care to accord scale and fit among components. However, the advent of advanced technology, computerized programs, and design seminars has made matters more straightforward and to a measure advancing PEB's horizons.

III. FUNDAMENTALS OF TUBULAR STEEL SECTIONS

Hollow steel sections that gather basic reinforcement are widely used and employed in contemporary industrial and infrastructure applications because of excellent performance in the integrity of the structure. Primarily, in this particular genre, the sections inherently offer an alternative in enhancing strength per mass count over ordinary sections such as I-beams and channels. The shaping of the tube goes a long way to achieve the best quality in assembly under different loading conditions. One of the primary advantages of tubular steel sections is their excellent strength-to-weight ratio. These sections exhibit high moment of inertia and radius of gyration; they move the material away from the center, thereby providing defiance to bending and buckling. This feature makes tubular members particularly suited for long-span structures and columns under compression [12]. Compared to open sections, tubes exhibit relatively better performance against torsional loads due to their closed cross-sections, which allow more torsional rigidity. This property is beneficial in industrial buildings where masses may attract some unusual eccentric loads or dynamic forces. Tubular steel sections are generally classified on the basis of their cross-sectional shape. Circular Hollow Sections (CHS) are common due to their uniform geometry and ability to distribute stress evenly in all directions. They are also good against axial compression and torsion, so they are used for column, truss, and space frame applications. Square Hollow Sections (SHS) and Rectangular Hollow Sections (RHS) have advantages in terms of ease of connection and aligning-their flat surfaces work well with welding and bolting. These sections are quite commonly used in beams, frames, and bracing systems where the structural performance and ease of fabrication are of major concern. Load carrying of the tubular steel sections under different loads is one of the principal aspects of their application. Tubular sections perform better than other conventional open sections under column load as they have higher resistance to buckling. Lack of sharp corners in a circular section significantly reduces material failure in terms of stress concentration resulting in a higher load capacity and long-lasting material efficiency. Around the neutral axis, vast distribution of the material materialifies the modesty, thereby improving the ability to handle bending stresses. The completely closed shape also suggests a relatively high lateral torsional resistance that should be better than that of the open section. Connections bear great importance in the application of tubular steel sections. Unlike conventional sections, where connections are relatively straightforward, tubular members require careful considerations due to their closed geometry [13]. Typically, welding is used to connect tubular sections, thus providing strong and continuous joints. Nevertheless, those scenarios can employ bolted connections, depending on the use of specialized fittings and gusset plates. Joint designs should ensure load transfer properly and avoid concentrating stress that would lead to failure. Advances in connection technology, involving prefabricated joints and a newer technology of automated welding, make the possibility and reliability of tubular structures so much better [14]. Fabrication and construction processes for tubular steel structures are also very important considerations. These structures are usually made using hot rolling, cold forming, or welding of steel plates. The method of manufacturing significantly affects the mechanical properties, dimensional accuracy, and cost of the structures. Cold-formed structures are lightweight and cost-effective, whereas hot-finished sections offer better structural performance and uniformity. The above-mentioned functions of a cylindrical section include the smooth surface reducing the accumulation of dust and moisture, thus leading to better corrosion resistance, and consequently less maintenance. Added protection by means of a high-quality coating-such as galvanization or painting-ensures their longevity when subjected to extreme industrial environments.

IV. DESIGN CONSIDERATIONS AND LOADING CONDITIONS

A proficient system of industrial building design selecting the existing behavior of a structure, characteristics of materials, functional considerations, and ambient effects to address and provide safety, economy, and sustaining capacity of acceptable standards; the aforementioned (evaluation) design comprises care to be sure all the multiple design considerations and distinct loading conditions that occur due to the structure during the period of its service life are checked as primary requisite among various others, that which includes the functional requirements of the building-about specific uses [15].The various types of loads including dead loads, which, always constant (self-weight of the structural components, which are the walls, roofing, cladding, and any such kind of other permanently attached equipment hanging on the roof/sided), become fixed values upon which our requirements for design are calculated; live loads, on the other hand, like those imposed by the people working or operating some machine or moving related equipment or storage items, are widely variable (depending on the type of industrial operation and labor accommodations), repeating through patterns of time [16]. The question of environmental load is also causal in the design process of an industrial building. Wind loads can play a must role in very wide-span industrial buildings by exerting positive and negative pressures onto the building envelope; thus these loads should be determined using computation data obtained through wind speed, terrain category, building height, and shape, with seismic loads foremost considered in earthquake-prone regions. Load combinations are critical as structures are almost never leveraged by a singular type of load, and all design codes have elaborate specifications for finishing computations such that dead, live, wind, seismic, and several other kinds of loads are resolved into lowest total effects of adequacy [17]. Serviceability checks, including deflection, vibration, and stability, are in no way less important, for excess deflection can lead to undesired functional constraints in building use and also in equipment performance, while vibration comes into increased scrutiny in the structures subjected to vibrations caused by machinery in addition to other dynamic loads, which might disrupt the comfort and feel of a user, or the transfer of any load; Foundations are deemed equally important to accomplish safe transfer for all kinds of loading concerns coming from a superstructure down to Earth, while considering the soil type, bearing capacity of soil, and soil settlement characteristics. An early stage of geotechnical exploration should be taken up to overcome any foundation crisis; constructability and ease of erection are also misers in the light reflected on divisive decision-making elements, especially in systems like PEBs with their distinctive character productive for their pre-fabricated built-in member lineup and the rapid erectability, in which regard the design must in such a way define an enhanced procedure for the easy transport, handling, and stake-empowered erection of all components [18]; economical considerations such as initial cost, lifecycle cost, and sustentation costs play a fundamental rule in the preference of a suitable design approach, with the shaping of a plan for what is sustainable-wise means being more integrated to the design considerations like energy efficiency, utilization of recyclable materials, and environmental influencing.

V. STRUCTURAL ANALYSIS METHODS AND TOOLS

1. Analytical (Classical) Methods

Analytical or classical methods are the fundamental approaches used in structural analysis, based on the direct application of equilibrium equations, compatibility conditions, and material constitutive relationships. These methods include techniques such as the method of joints, method of sections, slope-deflection method, and moment distribution method. They are primarily used for analyzing statically determinate and simple indeterminate structures. In industrial building design, these methods help engineers understand the basic behavior of structural elements under various loading conditions, including axial forces, shear forces, and bending moments [19]. Although analytical methods may not be suitable for highly complex structures, they are extremely valuable for preliminary design, validation of results, and educational purposes. They provide clear insight into load paths, structural response, and internal force distribution, enabling engineers to develop a strong conceptual understanding of the system. Additionally, these methods are often used to verify the accuracy of results obtained from advanced computational tools, ensuring reliability and safety in structural design.

2. Numerical Methods (Matrix Method)

Numerical methods, particularly the matrix method of structural analysis, form the basis of modern computational structural engineering. This approach involves representing the structure in terms of matrices that relate forces, displacements, and stiffness properties. The stiffness matrix method, also known as the displacement method, is widely used for analyzing complex and indeterminate structures such as industrial buildings with multiple spans and load combinations. In this method, the global stiffness matrix of the structure is assembled by combining the stiffness matrices of individual elements, and the resulting system of equations is solved to determine nodal displacements and internal forces. Numerical methods are highly efficient and can handle large-scale structures with multiple degrees of freedom [20]. They are particularly useful in analyzing Pre-Engineered Buildings and tubular steel structures, where geometry and loading conditions can be complex. The accuracy and flexibility of numerical methods make them essential for modern structural analysis and design.

3. Finite Element Method (FEM)

The Finite Element Method (FEM) is one of the most advanced and widely used techniques for structural analysis. It involves dividing a complex structure into smaller, manageable elements connected at nodes, forming a finite element mesh. Each element is analyzed individually, and the results are combined to obtain the overall structural behavior. FEM is particularly useful for analyzing structures with irregular geometry, complex boundary conditions, and non-uniform loading. In industrial buildings, FEM is used to evaluate stress distribution, deformation, stability, and dynamic response. It allows engineers to model real-world conditions with high accuracy, including material nonlinearity, geometric nonlinearity, and dynamic effects such as vibrations and seismic forces [21]. FEM-based software tools provide detailed visualizations of stress contours and deformation patterns, aiding in better decision-making and optimization of designs. Despite its complexity, FEM has become an indispensable tool in structural engineering due to its precision and versatility [22].

4. Software-Based Analysis Tools

Modern structural analysis heavily relies on specialized software tools that integrate numerical methods and FEM to provide accurate and efficient solutions. Popular tools include STAAD Pro, ETABS, SAP2000, and ANSYS, which are widely used for designing industrial structures such as PEBs and tubular systems. These tools allow engineers to create detailed 3D models, apply various load conditions, and perform comprehensive analyses, including static, dynamic, and nonlinear analysis. They also support code-based design, ensuring compliance with national and international standards. Software tools significantly reduce manual effort, minimize errors, and enable rapid evaluation of multiple design alternatives. Additionally, they provide graphical outputs such as bending moment diagrams, shear force diagrams, and deflection profiles, which enhance understanding and communication of results. Integration with Building Information Modeling (BIM) further improves coordination and project management. Overall, software-based tools have revolutionized structural analysis by increasing efficiency, accuracy, and reliability in modern engineering practice. Tale 1 defies a systematic comparison evaluating the structural efficiency, cost, construction speed, durability, and overall performance of Pre-Engineered Buildings (PEB) and tubular steel sections in industrial applications. Table 2 a concise comparison highlighting key design, construction, performance challenges, existing limitations, and potential research opportunities in PEB and tubular steel systems.

5. Plastic Analysis Method

Plastic analysis is based on the concept that materials (especially steel) can undergo plastic deformation beyond the elastic limit before failure. Unlike elastic analysis, this method considers the ultimate load-carrying capacity of the structure by forming plastic hinges. It is particularly useful in steel structures such as PEB and tubular systems where redistribution of moments occurs. This method helps in achieving more economical designs by utilizing the full strength of materials [23].

6. Dynamic Analysis Method

Dynamic analysis evaluates the response of structures under time-dependent loads such as wind gusts, earthquakes, machinery vibrations, and impact loads. Methods such as time-history analysis and response spectrum analysis are commonly used. This approach is essential for industrial buildings where dynamic loads significantly influence structural safety and serviceability [24].

7. Nonlinear Analysis

Nonlinear analysis considers both material nonlinearity (plasticity, cracking) and geometric nonlinearity (large deformations). It provides a more realistic prediction of structural behavior under extreme loading conditions. This method is widely used in advanced FEM-based simulations for tubular structures and complex PEB systems [25].

8. Stability and Buckling Analysis

This method focuses on evaluating the critical load at which structural elements (especially columns and tubular members) may fail due to buckling. Eigenvalue buckling analysis and nonlinear buckling analysis are commonly used techniques. It is highly relevant for tubular steel sections due to their sensitivity to local and global buckling [26].

9. Reliability-Based Design and Probabilistic Analysis

This approach incorporates uncertainties in loads, material properties, and environmental conditions using probabilistic models. Methods such as Monte Carlo simulation and reliability index evaluation help in designing safer and more robust structures. It is increasingly used in modern structural engineering research for risk-informed decision-making [27].

10. AI and Machine Learning-Based Structural Analysis

Recent advancements involve using Artificial Intelligence (AI) and Machine Learning (ML) techniques to predict structural performance, optimize design parameters, and detect structural anomalies. These methods enhance efficiency, reduce computation time, and support smart infrastructure development [28].

TABLE 1: COMPARATIVE PERFORMANCE ANALYSIS OF PEB AND TUBULAR SECTIONS

Parameter	Pre-Engineered Buildings (PEB)	Tubular Steel Sections	Implication
Structural Concept	System-based design with built-up tapered members	Individual hollow sections (CHS, SHS, RHS)	PEB is holistic; tubular is component-based
Section Type	Built-up I-sections (variable depth)	Closed hollow sections	Tubular provides uniform geometry
Weight Efficiency	Highly optimized, lightweight	High strength-to-weight ratio	PEB slightly more optimized
Material Distribution	Varies along length (tapered)	Uniform throughout	Tubular may use more material in low-stress zones
Load Carrying Capacity	Excellent for distributed loads and large spans	Excellent for axial, torsion, and combined loads	Depends on application type
Buckling Resistance	Good with proper bracing	Very high due to closed section	Tubular performs better in compression
Torsional Resistance	Moderate	Very high	Tubular ideal for torsion-dominant structures
Bending Performance	Good for long-span beams	Good but depends on section size	PEB optimized for bending
Seismic Performance	Good with ductile detailing	Excellent due to uniform stress distribution	Tubular preferred in seismic zones
Wind Resistance	Good	Excellent (aerodynamic shape)	Tubular reduces drag forces

TABLE 2: CHALLENGES, LIMITATIONS, AND RESEARCH GAP

Aspect	PEB Systems – Challenges & Limitations	Tubular Steel Sections – Challenges & Limitations	Research Gaps / Future Scope
Design Complexity	Limited flexibility for highly complex geometries	Complex analysis due to joint behavior and stress concentration	Development of advanced design algorithms and AI-based optimization
Connection Design	Standardized but sometimes less efficient for special cases	Highly complex welded/bolted joints	Improved joint modeling and prefabricated connection systems
Material Optimization	Over-design possible in certain components	Uniform sections may lead to inefficient material usage	Hybrid section optimization techniques
Fabrication Issues	Requires precise factory setup	High precision and skilled labor required	Automation and robotics in fabrication
Construction Constraints	Transportation limits for large components	Difficult on-site alignment and assembly	Modular and adaptive construction techniques
Cost Factors	Initial investment in design and fabrication setup	Higher fabrication and labor costs	Cost-effective manufacturing methods

VI. CONCLUSION AND FUTURE DIRECTIONS

The study comparing Pre-Engineered Buildings (PEB) with tubular steel sections shows how both building methods contribute to modern industrial construction through their unique benefits in structural efficiency and cost and performance characteristics. PEB systems serve as the main choice for industrial needs because they enable rapid building development, material optimization, and simple facility expansion which makes them perfect for warehouses and factories and logistics centers. Tubular steel sections deliver better strength-to-weight performance and higher torsional strength and greater design flexibility to structures that must endure demanding operational requirements and architectural needs. The two systems both achieve high durability and sustainability through their recyclable steel materials, but their operational efficiency depends on the project's particular functional needs and environmental factors and design limitations. The research community needs to work on more advanced solutions to connection issues and fabrication problems and workforce shortages which create obstacles to PEB systems and tubular systems. The future development of this field will use advanced computer programs that include artificial intelligence and machine learning for better design results and predictive capabilities and Building Information Modeling (BIM) will be used to enhance project coordination and lifecycle oversight.

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