Comparative Analysis and Design of PEB and CSB Structure

Shubham B. Chandak[1], Mr. S. H. Shaikh [2], Mrs, S. D. Kuralkar [3]
[1]*M.Tech Scholer, Department of Civil Engineering of G H Raisoni College of Engineering and Management, Pune.*
[2,3]*Assistant professor, Department of Civil Engineering of G H Raisoni College of Engineering and Management, Pune.*
doi.org/10.64643/IJIRTV12I12-203079-459

***Abstract*— Steel is one of the oldest construction materials and gained widespread popularity as a construction choice during the late seventeenth and eighteenth centuries. It is valued for its environmental friendliness, rapid construction capabilities, easy availability, and superior fire resistance. In the modern era, steel structures constitute the majority of industrial buildings and sheds worldwide. The concept of Pre-Engineered Buildings (PEB) involves steel building systems that are predesigned and prefabricated. This study focuses on the design of an industrial storage structure located in Pune. The structure is a pre-engineered building with a total width of 20 meters, divided into three spans of 5 meters each, a length of 12 meters, an eave height of 10 meters, and a roof slope of 1:10. The analysis and design consider live loads, dead loads, wind loads, and earthquake loads in accordance with relevant IS codes applicable to the PEB structure. Material selection and structural integrity are also addressed to ensure safety and durability. Additionally, the integration of energy-efficient features such as insulation and proper ventilation enhances the building's functionality and sustainability. A conventional steel structure was analyzed using STAAD. PRO connect edition software and designed according to the limit state method as per IS 800-2007. Results indicate that moments, shear forces, and axial forces decrease in various components of the PEB structure compared to a Conventional Steel Building (CSB) structure due to increased stiffness. Similarly, deformation, base shear, and displacement are reduced in the PEB structure relative to the CSB structure. The PEB structure exhibits a 20-30% reduction in weight compared to the CSB structure, leading to cost savings. The reduction in steel quantity also decreases the dead load, thereby reducing the foundation size requirements.**

***Keywords:* Pre-Engineered Building, (PEB) Conventional steel building (CSB), STAAD Pro.**

I. INTRODUCTION

The comparative study on Pre-Engineered Buildings (PEB) and Conventional Steel Buildings (CSB) based on height and span aims to analyze their structural efficiency, cost, and performance. PEBs are modern steel structures that are pre-designed and fabricated in factories using standardized components such as tapered columns, rafters, and purlins. These components are then assembled on-site, ensuring faster construction and reduced material wastage. In contrast, CSBs are designed and fabricated on-site using hot-rolled sections and customized detailing, which allows for greater design flexibility but often increases construction time and cost. The study focuses on understanding how varying heights and spans influence the design, weight, and overall economy of both systems. For wider spans, PEBs are generally more efficient and economical due to their optimized design and lightweight nature, while CSBs are preferred for complex or high-rise structures requiring higher load capacities. Overall, PEBs provide advantages in terms of speed, cost-effectiveness, and ease of expansion, whereas CSBs offer versatility and strength for specialized applications. This comparative analysis helps in selecting the most suitable structural system for specific project requirements based on span, height, and functional needs.

- PEB (Pre-Engineered Building): Factory-designed, pre-fabricated primary members (built- up cold-formed or rolled sections), connections and secondary members (purlins, girts) delivered to site with engineered shop drawings; site assembly with bolted/bolted sealed connections. Emphasis on repeatable, optimized member shapes and efficient manufacture/erection.
- CSB (Conventional Steel Building): Buildings designed from standard rolled sections (I-sections, plates, angles, hollow sections) often fabricated on a project-by-project basis; more bespoke member sizes and welded/bolted

connections; greater flexibility in member layout and detailing.

II. LITERATURE REVIEW

2.1 General

Pre-Engineered Buildings (PEB) and Conventional Steel Buildings (CSB) represent two prominent approaches in structural steel construction, each with distinct design philosophies and applications. The evolution of PEB has introduced innovative engineering techniques that optimize material usage and construction efficiency, contrasting with the traditional, more labor-intensive CSB methods.

Several studies have explored the structural behavior of PEB and CSB systems, highlighting differences in load distribution, stiffness, and deformation characteristics. Research indicates that PEB structures typically exhibit enhanced stiffness and reduced deformation due to their pre-fabricated, integrated components, which contribute to improved performance under various load conditions including wind and seismic forces.

Design methodologies for both systems adhere to established codes such as IS 800-2007, with PEB design increasingly leveraging advanced software tools like STAAD.Pro to achieve optimized structural solutions. The limit state design method is commonly employed to ensure safety and serviceability while minimizing material consumption.

Economic analyses consistently demonstrate that PEB structures offer cost advantages over CSB through reductions in steel weight—often exceeding 15%—which translate into lower material costs and smaller foundation requirements. Additionally, the prefabrication inherent in PEB systems reduces construction time and labor costs, contributing to overall project efficiency.

Despite these advantages, CSB remains prevalent in scenarios where customization and complex architectural requirements are paramount. The choice between PEB and CSB thus depends on project-specific factors including design complexity, budget constraints, and timeline considerations.

In summary, the literature underscores the growing preference for PEB in industrial and commercial construction due to its structural efficiency, economic benefits, and accelerated construction timelines, while recognizing the continued relevance of CSB for specialized applications.

2.2 Works Carried Out by Researchers

Tekale and Ambadkar "*Comparative Analysis of PEB and CSB using STAAD.Pro*"

This paper conducted a detailed structural comparison between Pre-Engineered Buildings (PEB) and Conventional Steel Buildings (CSB) to evaluate structural efficiency under varying geometrical conditions. The objective of the research was to identify the influence of different structural configurations on load-carrying behavior and overall economy. The researchers developed multiple three-dimensional structural models using STAAD.Pro with varying: Bay spacing: 5 m, 6 m, and 7 m Roof slope: 1:10 and 1:15 Different loading combinations The models were analyzed for: Dead loads Live loads Wind loads Structural displacement Support reactions Beam forces Overall stiffness The analysis indicated that PEB systems showed lower lateral displacement and higher stiffness compared to conventional systems. Because PEB sections are tapered and optimized according to bending moment requirements, material utilization became more efficient. Major findings were: PEB structures had better load transfer efficiency. Larger bay spacing (7 m) increased support reactions and internal beam forces. Smaller bay spacing improved structural balance and stability. Reduction in steel quantity directly reduced foundation load. The study also reviewed previous research and observed that PEB systems generally reduce total structural weight by approximately 30–40%. The authors concluded that selection of optimum bay spacing is critical because excessive spacing can reduce structural economy.

Dashore and Kanojiya "*Analysis and Design of Pre-Engineered Building Warehouse in Different Seismic Zones*"

This paper focused on the seismic response of warehouse structures designed using PEB concepts under different earthquake zones of India. The study followed: IS 800:2007 IS 1893 (Part 1) STAAD.Pro was used for structural modeling and analysis. Parameters studied included Base shear Storey displacement Steel quantity Seismic response Loading conditions considered: Dead load Live load Wind load Seismic load The authors observed that lightweight PEB structures generated lower seismic forces because seismic load is proportional to building mass.Key observations included: PEB structures performed efficiently in higher seismic zones. Tapered built-up sections minimized steel usage. Cold-formed Z and C sections further reduced weight. Flexible framing improved energy dissipation. The researchers also summarized previous literature and found that PEB systems are generally 25–35% lighter than CSB structures. The study concluded that PEB systems provide a balance of: Structural safety Economy Seismic performance for industrial warehouse applications.

Jibhkate and Budhlani "*Comparative Analysis of Industrial Warehouse using PEB and CSB"*

In this paper they performed a comparative analysis of a G+3 industrial warehouse to investigate differences between PEB and conventional steel systems. The warehouse dimensions considered were: Span = 30 m Length = 75 m Codes used: IS 800:2007 IS 875 Part 1–3 The parameters studied included: Steel consumption Dead load Wind load response Structural behavior The study found: PEB systems reduced dead load by approximately 20–25% Structural steel requirement decreased significantly Construction speed improved because of prefabricated bolted systems The researchers found that: Built-up tapered sections reduced unnecessary material use. Cold-formed purlins improved economy. Wind load became the governing factor in roof design. The authors concluded that although PEB requires high precision during design and fabrication, it offers better long-term economic benefits.

Vishnu Sai, et. al "*Structural Performance of Pre-Engineered Building: A Comparative Study"*

The researchers studied the effect of regional environmental loading on PEB structural behavior. Two locations were selected: Vijayawada Hyderabad The study investigated: Wind speed variation Steel quantity variation Structural response Using STAAD.Pro, structures were analyzed under: Dead load Live load Wind load combinations Results indicated: Higher wind zones increased steel requirement by approximately 11% Wind intensity significantly influenced member sizing The researchers concluded that PEB systems are adaptable to varying environmental conditions while maintaining lower structural weight and economy.

Uppal and Kumar "*A Review of Pre-Engineered Steel Building"*

They performed a comprehensive review of previously published studies on PEB systems. The study compared: PEB Conventional steel buildings Reinforced concrete buildings Parameters reviewed included: Cost Construction time Structural efficiency Environmental sustainability Major findings were: PEB structures can reduce structural weight by nearly 30% Construction duration can be reduced by approximately 50% Factory fabrication improves quality control Material wastage decreases considerably Advantages identified: Ease of expansion Recyclability Low maintenance Energy efficiency The authors stated that PEB systems are more suitable for low-rise and medium-span applications.

Chaudhary et al. "*Comparative Study of Multi-Storey Multi-Span Buildings by PEB and CSB Concep*t"

The study analyzed multi-storey buildings using PEB and CSB concepts. Building configurations included: G+1 G+2 G+4 STAAD.Pro analysis considered: Bending moments Shear force Support reactions Steel quantity Results indicated: Nearly 39% reduction in steel quantity Lower support reactions Lower internal forces The authors concluded that optimized tapered sections improved overall structural efficiency. Assis [7] (2019) Analysis of PEB Structures and Comparison with Conventional Steel Buildings with Varying Parameters IRJET Assis studied different building configurations with varying: Span (50–70 m) Heights Structural configurations Parameters investigated: Steel take-off Dead load Structural weight Cost efficiency Major findings: PEB required 30–40% less steel Faster construction due to prefabrication Better performance in low-rise multi-storey structures The research mainly concentrated on quantitative comparison.

Kalantri, et. al "*Comparative Study on the Performance of PEB with CSB Considering Various Parameters"*

The researchers developed PEB and CSB models with similar geometry and loading conditions. Parameters compared: Structural weight Cost Construction time Results: PEB steel quantity ≈ 33.7 t CSB steel quantity ≈ 56 t Therefore: Weight reduction ≈ 39–40% Cost reduction ≈ 35% Construction time reduction ≈ 35% The researchers concluded that PEB systems provide substantial economic advantages.

Lee, et. al "Ultimate Strength of Long-Span Buildings with P.E.B System Steel and Composite Structures"

They carried out one of the earliest advanced investigations on long-span PEB systems. The abstract of the study explains that due to improvements in construction technology, large-scale long-span buildings increasingly adopted PEB systems because tapered members distribute stresses efficiently and improve economy. However, multiple PEB failures occurred in Korea under sudden environmental loading conditions. The researchers investigated two large-span structures through: Finite element analysis Nonlinear analysis Buckling analysisn Ultimate strength analysis using ANSYS The study examined: Uniform snow loading Non-uniform snow loading Wind gust effects Structural stability Data from the investigation showed that snow loads reached approximately: 1.80 kN/m² 1.64 kN/m² which were nearly 2.5 times greater than the original design load of 0.60 kN/m². Major observations: Non-uniform snow loading caused premature yielding. Local buckling occurred in tapered rafters. Lateral torsional buckling became a major collapse mechanism. Connection details and construction quality strongly affected behavior. The researchers recommended: Improved ductile design Better quality control during fabrication More realistic load assumptions The study established the foundation for many later PEB investigations.

2.3 Research gap.

- Optimization of Design Parameters: Research such as points to the importance of bay spacing and roof slope optimization, but more extensive parametric studies are needed to establish design guidelines balancing cost, structural performance, and constructability.
- Regional and Climatic Variations: Studies often focus on specific geographic regions or wind/seismic zones but broader comparative analyses across diverse climates and environmental conditions are limited.
- Economic Analysis Limitations: Some economic comparisons rely on assumed unit costs or single-case scenarios lacking sensitivity analyses or consideration of market fluctuations, labor availability, and supply chain factors.
- Integration of Modern Technologies: There is limited exploration of integrating emerging technologies such as Building Information Modeling (BIM), advanced materials, or smart monitoring systems in PEB and CSB design and construction.
- Limited Scope of Case Studies: Several studies focus on a small number of case studies or single building geometries, which limits the generalizability of their findings across diverse building types and geographic locations.
- Connection and Constructability Details: Research such as highlights structural efficiency but often lacks detailed exploration of connection design, constructability challenges, and erection procedures, especially for taller or more complex PEB structures.
- Serviceability and Long-Term Performance: Many analyse emphasize weight and cost but do not extensively address serviceability criteria such as deflection limits, fatigue, corrosion resistance, or long-term durability of PEB versus CSB systems.
- Seismic and Dynamic Load Performance: While some recent studies consider seismic effects, there remains a need for more comprehensive dynamic analyses under varied seismic intensities and soil conditions, especially for multi-storey PEB applications.
- Environmental Impact and Lifecycle Analysis: Although sustainability is mentioned few studies provide detailed lifecycle assessments comparing environmental footprints, energy consumption, and recyclability of PEB and CSB systems throughout their service lives.
- Multi-Storey and Hybrid Structural Systems: The efficiency of PEBs is often limited to low- to medium-rise buildings. There is a lack of in-depth research on hybrid or reinforced PEB systems suitable for taller or architecturally complex structures.

REFERENCES

[1] L e, S.-H., Kim, Y.-H. and Choi, S.-M. (2015). Ultimate strength of long-span buildings with P.E.B (Pre-Engineered Building) system. Steel and Composite Structures, 19(6), pp. 1421–1443. https://pure.uos.ac.kr/en/publications/ultimate-strength-of-long-span-buildings-with-peb-pre-engineered

[2] Kalantri, D., Deshpande, S. and Gudi, P. (2017). A Comparative study on the Performance of PEB with CSB considering various parameters. International Research Journal of Engineering and Technology (IRJET), 4(5), pp. 2674–2679. https://www.irjet.net/archives/V4/i5/IRJET-V4I5212.pdf

[3] Assis, S. (2019). Analysis of PEB structures and comparison with conventional steel buildings

with varying parameters. International Research Journal of Engineering and Technology (IRJET), 6(5), pp. 3462–3467. https://www.irjet.net/archives/V6/i5/IRJET-V6I5758.pdf

[4] Chaudhary, M.S.W., et al. (2019). Comparative study of multi-storey multi-span buildings by PEB and CSB concept. International Journal of Advance Research, Ideas and Innovations in Technology (IJARIIT), 5(3), pp. 1791–1798. https://www.ijariit.com/manuscripts/v5i4/V5I4-1167.pdf

[5] Vishnu Sai, V., Poluraju, P. and Venkat Rao, B. (2021). Structural Performance of Pre Engineered Building: A Comparative Study. IOP Conference Series: Materials Science and Engineering, 1197(1), 012086. https://www.scribd.com/document/822454374/Vishnu-Sai-2021-IOP-Conf-Ser-Mater-Sci-Eng-1197-012086

[6] State-of-the-art review on PEB analysis & design (Dec 2022) — A comprehensive review covering PEB components, design practices, common portal-frame configurations, and gaps in seismic/bracing detailing. https://colab.ws/articles/10.1016%2Fj.matpr.2022.11.361

[7] Comparative studies using STAAD/ETABS (2021–2024; multiple conference & journal papers) — Several project reports and peer-reviewed conference papers perform side-by-side STAAD/ETABS modelling of single-storey buildings comparing steel tonnage, deflections and reactions for PEB vs CSB. https://www.ijraset.com

[8] E3S Conference comparative review (2024) — A short review contrasting design, construction, performance and sustainability aspects of PEB and CSB. https://www.e3s-conferences.org/articles/e3sconf/pdf/2024/89/e3sconf_icstce2024_04030.pdf

[9] Peer-reviewed comparative analysis & design paper (AIP / Jan 2025) — Recent engineering journal article presenting side-by-side design of PEB and CSB for a sample structure. https://www.ijnrd.org/papers/IJNRD2511091.pdf

[10] Market & industry reports (2023–2025) — Industry reports and market analyses (Straits Research, Data Mint Intelligence) summarise global PEB market growth, leading suppliers, and reasons for adoption. https://www.datamintelligence.com/research-report/pre-engineered-buildings-market

[11] IRJET / IJRASET / IJIRT comparative reviews (2020–2024) — Multiple open access review papers that summarize comparisons (steel weight, erection time, cost). https://1library.net/document/q7651mvy-comparative-study-performance-peb-csb-considering-various-parameters.html

[12] Technical articles & industry primers (2023–2025) — Trade articles and engineering blogs that explain PEB fabrication, shop QC, and erection advantages. https://www.epcworld.in/beyond-sheds-evolution-of-intelligent-steel-buildings

[13] Recent critical reviews (2024–2025) — Newly published critical reviews note research gaps such as PEB behaviour under extreme seismic demands, fire/blast resistance, and long-span transport/handling constraints. https://www.ijraset.com

[14] "A Comparative Study of the Pre-Engineered Building and Conventional Steel Building" (June 2024, Journal of Physics: Conference Series) — Finds PEB requires about 24.9% less steel than CSB and performs better under wind and seismic loading. https://www.researchgate.net/publication/383019590_A_Comparative_Study_of_the_Pre-Engineered_Building_and_Conventional_Steel_Building

[15] "A state of art review on analysis and design of pre-engineered buildings" (2022, Materials Today: Proceedings) — Reports PEBs are up to 50% lighter, ~35% cheaper, and assemble in half the time compared to CSBs. https://www.sciencedirect.com/science/article/pii/S2214785322072145

[16] "Design Solutions for Sustainable Construction of Pre Engineered Steel Buildings" (2018, Sustainability) — Shows PEB frames are about 32% lighter than CSB frames for a 30m span, with better lateral and vertical performance. https://www.mdpi.com/2071-1050/10/6/1761

[17] "A Comparative Study of Conventional Steel Building and Pre-Engineered Building Structure using Staad Pro" (June 2022, ResearchGate) — Analyzes buildings of 10m to 50m spans, showing substantial steel savings with PEB tapered sections vs conventional hot-rolled sections. https://www.researchgate.net/publication/36130

7067_A_Comparative_Study_of_Conventional_Steel_Building_and_Pre-Engineered_Building_Structure_using_Staad_Pro

[18] "A Comparative Analysis of Conventional Steel Building and Pre-Engineered Building Systems: A case study Approach" (2024, E3S Web of Conferences) — Case study of industrial structure showing PEB offers ~40.67% cost savings relative to CSB. https://www.researchgate.net/publication/383018754_A_Comparative_Analysis_of_Conventional_Steel_Building_and_Pre-Engineered_Building_Systems_A_case_study_Approach

[19] "A Comparative Study of the Pre-Engineered Building and Conventional Steel Building" (June 2024, Journal of Physics: Conference Series) — PEB requires approximately 24.9% less steel and achieves around 35% cost savings. https://www.researchgate.net/publication/383019590_A_Comparative_Study_of_the_Pre-Engineered_Building_and_Conventional_Steel_Building

[20] "A Comparative Analysis of Conventional Steel Building and Pre-Engineered Building Systems: A case study Approach" (2024, E3S Web of Conferences) — Case study showing PEB offers ~40.67% cost savings relative to CSB. https://www.researchgate.net/publication/383018754_A_Comparative_Analysis_of_Conventional_Steel_Building_and_Pre-Engineered_Building_Systems_A_case_study_Approac

[21] "Study of Pre-Engineered and Conventional Steel Structure: A Review" (2024, ResearchGate) — Literature review summarizing comparative studies of PEB vs CSB for industrial warehouses under Indian and international standards. https://www.researchgate.net/publication/400291573_Study_of_Pre-Engineered_and_Conventional_Steel_Structure_A_Review

[22] "A state of art review on analysis and design of pre-engineered buildings" (2022, Materials Today: Proceedings) — Peer-reviewed review reporting PEBs are up to 50% lighter, ~35% cheaper, with reduced displacements and half construction time compared to CSBs. https://www.sciencedirect.com/science/article/pii/S2214785322072145

[23] "A state of art review on analysis and design of pre-engineered buildings" (2024, ResearchGate) — Structural performance comparison showing better structural behavior and efficiency for PEB under various load combinations. https://www.researchgate.net/publication/365967401_A_state_of_art_review_on_analysis_and_design_of_pre-engineered_buildings

[24] "Cost and steel savings (PEB vs CSB)" (2024, IRJET) — Reports ~24.9% steel savings and ~35% cost reduction for PEB relative to CSB; also notes about 32.69% lower cost due to faster construction and reduced labor. https://www.irjet.net/archives/V6/i3/IRJET-V6I3238.pdf

[25] "A Comparative Study of Conventional Steel Building and Pre-Engineered Building Structure using Staad Pro" (2022, ResearchGate) — Shows substantial steel savings due to tapered PEB sections versus conventional hot-rolled sections. https://www.researchgate.net/publication/361307067_A_Comparative_Study_of_Conventional_Steel_Building_and_Pre-Engineered_Building_Structure_using_Staad_Pro

[26] "Design Solutions for Sustainable Construction of Pre Engineered Steel Buildings" (2018, Sustainability) — PEB steel frames about 32% lighter than CSB frames for a 30m span with better lateral and vertical performance. https://www.mdpi.com/2071-1050/10/6/1761

[27] "Comparative Study of Pre-Engineered and Conventional Steel Structures" (2023, IJIRSET) — Highlights steel weight reduction, cost benefits, and faster erection times for PEB over CSB. https://www.ijirset.com/upload/2023/july/Comparative_Study_of_Pre-Engineered_and_Conventional_Steel_Structures.pdf

[28] IS 800:2007 – Revised code of practice for general construction in steel.

[29] IS 875(part 1, 2, 3 and 5):1987 – Code for practice for design of loads(other than earthquake) for the building and the structure.

[30] IS 456-2000 –Revised code of practice for general construction in RCC.

[31] Duggal, S.K. :"Design of Steel Structures" , Tata McGraw-Hill Publication Company limited 2000.

[32] Dr. B.C.Punmia , Ashok Kumar Jain, Arun Kumar Jain: "Design of Steel Structure", Lakshmi Publication.
[33] Dr. V.L.Shah and Dr.S.R.Karve. :"Limit State Theory and Design of Reinforced Concrete".