STRUCTURAL ANALYSIS AND DESIGN OF INDUSTRIAL BUILDING USING PEB AND TUBE SECTION

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Abstract

The present study focuses on the structural analysis and design of an industrial building using Pre-Engineered Building (PEB) and Conventional Steel Building (CSB) configurations, with an emphasis on the application of tube sections to enhance structural performance. Industrial structures demand cost-effective, lightweight, and sustainable solutions that ensure both safety and efficiency. The comparative analysis was conducted using STAAD.Pro software, considering dead load, live load, wind load, and accidental load combinations as per IS 875 (1987) and IS 800 (2007). Six different models were developed, including variations in bay numbers and structural systems, to evaluate parameters such as axial force, bending moment, shear force, and deflection. The study revealed that PEB structures, particularly those with tubular members, exhibited reduced deflection, superior stiffness, and improved load distribution compared to conventional truss systems. Additionally, PEB systems demonstrated significant material and cost savings without compromising safety and stability. The analysis of accidental loads further confirmed the resilience of PEB designs under extreme conditions. This research concludes that the integration of tube sections within PEB frameworks provides an optimal solution for modern industrial buildings, combining efficiency, economy, and sustainability.

Keywords: *Pre-Engineered Building (PEB), Conventional Steel Building (CSB), STAAD.Pro Analysis, Tube Section, Structural Efficiency, Industrial Shed Design*

1. INTRODUCTION

The industrial sector today demands structural systems that are not only efficient and cost-effective but also flexible, sustainable, and quick to construct. Conventional steel buildings (CSB) often fall short in meeting these requirements due to their heavier sections, longer construction timelines, and increased fabrication costs. In contrast, Pre-Engineered Buildings (PEB) have emerged as a modern solution that optimizes material usage, enhances strength-to-weight ratio, and accelerates the construction process. PEBs are designed and fabricated in a controlled environment using advanced software and are assembled on-site with bolted connections, significantly reducing erection time and project cost. The introduction of tubular sections in industrial structures further enhances the efficiency of PEB systems by offering improved load distribution, torsional rigidity, and resistance to buckling. In industrial applications such as warehouses, workshops, and manufacturing units, large column-free spaces are essential for operational flexibility. PEB technology, combined with tubular steel sections, facilitates the creation of such open spans with minimum material consumption. Tube sections, being hollow and lightweight, provide high flexural strength and stiffness with reduced self-weight compared to solid or conventional rolled sections. This results in a more economical and sustainable design without compromising structural safety or performance. Moreover, tubular sections exhibit aesthetic appeal and corrosion resistance, making them suitable for long-span industrial roofs and portal frames. The increasing adoption of software-based structural design tools such as STAAD.Pro, ETABS, and Tekla Structures has enabled engineers to perform precise modeling, load simulations, and optimization for PEB structures. These tools help analyze complex load combinations, including dead, live, wind, and accidental loads, as per relevant IS codes (IS 800:2007, IS 875, and IS 1893). The integration of tube sections within PEB frameworks provides an innovative approach to reducing deflection and improving stability under lateral and vertical loading conditions.

This study aims to carry out a comprehensive analysis and design of an industrial building using PEB and tubular sections, highlighting their structural performance, cost efficiency, and sustainability compared to conventional steel systems. The research focuses on evaluating parameters such as axial force, bending moment, shear force, and deflection to determine the most effective structural conFigure uration for industrial applications.

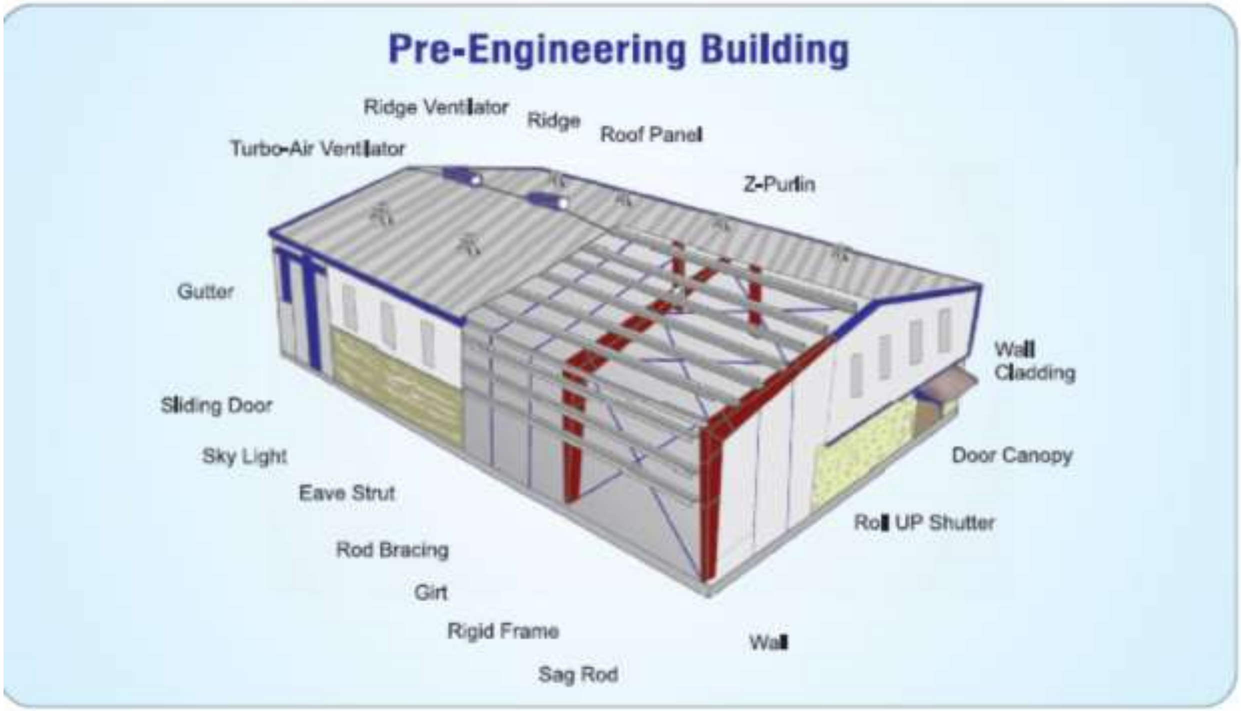

Figure 1: Conceptual schematic of a pre-engineered industrial building using tubular/tapered steel members

The figure 1 illustrates the structural configuration of a pre-engineered industrial building comprising tubular and tapered steel members. It highlights the efficient use of steel in rafters and columns, optimized for strength and weight reduction, ensuring stability, faster construction, and improved load transfer in industrial applications.

2. LITERATURE REVIEW

The concept of Pre-Engineered Buildings (PEB) has gained increasing attention due to its structural efficiency, cost-effectiveness, and suitability for industrial applications. Several studies have been conducted to evaluate and compare the performance of PEB systems with Conventional Steel Buildings (CSB), highlighting their advantages in material optimization, strength, and construction economy. Gilbile and Mane (2020) conducted a comparative review between PEB and CSB, emphasizing that PEB structures significantly reduce material consumption, fabrication time, and project cost while maintaining structural integrity. The study found that the use of tapered I-sections and lightweight cold-formed members leads to a 30–40% reduction in steel weight compared to conventional designs. Similarly, Vishwakarma and Tayal (2018) optimized an industrial building using both PEB and CSB through the fully stressed design method. Their analysis concluded that the PEB conFigure uration demonstrated better load-carrying capacity and reduced stress concentration under critical load conditions. A comparative analysis by Shujat and Desai (2018) incorporated tubular sections within PEB and CSB frameworks to assess performance variations in industrial warehouses. The study revealed that tubular sections improve torsional rigidity and reduce deflection, making them a superior alternative to conventional rolled sections. This was further supported by Hulwane, Patil, and Joshi (2017), who analyzed the behavior of industrial buildings using tubular sections and demonstrated improved strength-to-weight ratios and aesthetic appeal compared to traditional structural elements. The research by Tagade et al. (2023) in *JETIR* reviewed the practical applications of PEBs, noting their growing adoption in industrial and commercial projects owing to their speed of construction and environmental sustainability. Their subsequent work in *IJCRT* (2023) reinforced that PEBs offer superior performance in terms of bending strength, lateral stability, and seismic resistance when compared with CSBs. Complementary findings were reported by Li, Lee, and Cai (2023), who investigated the material behavior of high-performance tubular steel members and found that hollow sections enhance buckling resistance and flexural strength under combined loading conditions.

Pradeepa, Raj, and Divya (2016) evaluated the cost implications of using tubular sections through a force-coefficient method and concluded that such sections yield significant savings in both material and maintenance costs. Meanwhile, Thakre and Vairagade (2016) conducted a cost-comparative study of PEB and CSB structures, reporting that PEBs reduce project timelines by nearly 40% with minimal structural compromise. Other researchers have focused on specialized contexts and environmental conditions. Meera (2013) analyzed the design of a PEB industrial warehouse and found improved performance under varied load combinations. Similarly, ResearchGate (2025) reported on the seismic design of PEB warehouses across different zones, emphasizing enhanced ductility and stability. The IJSREM (2022) study on steel trusses reinforced the advantages of tube sections in minimizing deformation under heavy roof loads. Recent advancements presented by AIP (2025) in their comparative analysis of pre-engineered structures further demonstrate the increasing integration of computational tools such as *STAAD.Pro* and *ETABS* for modeling complex geometries and optimizing member sizes. These studies collectively underline that PEBs, when combined with tubular sections, offer an optimal balance between strength, economy, and sustainability for modern industrial building applications.

3. METHODOLOGY

3.1 Overview

The methodology adopted for this study focuses on the comparative structural analysis and design of an industrial building using Pre-Engineered Building (PEB) and Conventional Steel Building (CSB) conFigure urations. The primary objective is to evaluate the structural efficiency, weight optimization, and stability of both systems under various loading conditions including dead load, live load, wind load, and accidental load. The analysis is carried out using the STAAD.Pro software package, following relevant Indian Standard codes for design and loading.

This section describes the modeling approach, parameters considered, loading combinations, and validation process used to compare the mechanical and economic performance of the proposed building models.

Figure ure 2: *Flowchart*

Figure ure 2 shows the sequential methodology adopted in this study, starting from the literature review and data collection to modeling, design as per IS 875 Part V (1987), and final result interpretation.

3.2 Model Development

To assess the structural performance, six models of industrial sheds were developed and analyzed. Each model was designed with identical geometric parameters span of 12 m, bay length of 8 m, and eave height of 14 m — to ensure uniformity in comparison. The key distinction among the models lies in their structural system type (PEB or CSB) and number of bays (3 or 9). The details are as follows:

Model No.	Structural System	No. of Bays	Special Feature
1	Conventional Steel Truss (CST)	3	Basic frame
2	Conventional Steel Truss (CST)	9	Extended span
3	Pre-Engineered Building (PEB)	3	Tapered section frame
4	Pre-Engineered Building (PEB)	9	Extended span
5	PEB	3	Tube section rafters
6	PEB	3	Tube section with cross bracing

All models were conFigure ured as single-storey, gable-roofed industrial sheds with pinned supports at the base. The roof slopes considered were 15° for CSB and 5° for PEB systems. Tube sections were introduced in Models 5 and 6 to evaluate their impact on member efficiency and lateral stiffness.

3.3 Software and Design Codes

The modeling and analysis were performed using STAAD.Pro Connect Edition, which allows three-dimensional finite element analysis for steel structures. The design adhered to the following Indian Standard (IS) Codes:

- IS 800: 2007 — General Construction in Steel (Limit State Design)
- IS 875 (Part 1–5): 1987 — Dead, Live, Wind, and Special Loads
- IS 1893 (Part 4): 2015 — Seismic Design of Industrial Structures

All material properties, load intensities, and connection details were modeled according to the above standards.

4. RESULTS AND DISCUSSION

This section presents the analytical outcomes of the structural models developed for PEB and conventional steel structures. The results include comparisons of axial forces, bending moments, deflections, and total steel weight, highlighting the efficiency, stability, and economy of PEB and tubular section conFigure urations under various loading conditions:

Model No.1	CST industrial sheds with 3 bays (each bay of 8m and span 12m)
Model No.2	CST industrial sheds with 9 bays (each bay of 8m and span 12m)
Model No.3	PEB industrial sheds with 3 bays (each bay of 8m and span 12m)
Model No.4	PEB industrial sheds with 9 bays (each bay of 8m and span 12m)
Model No.5	PEB industrial sheds with 3 bays (each bay of 8m and span 12m)
Model No.6	PEB industrial sheds with 3 bays (each bay of 8m and span 12m) with cross bracing

4.1 Analysis, design and validation of an industrial truss

All dead loads, live loads, wind load, accidental load will be confirming to IS:
875-1987. Earthquake loads will be confirming to IS: 1893-2002 part-IV Load combinations considered:

- Dead load + Impose Load.
- Dead load + Impose Load + Wind or Earthquake load with accidental load 3) Dead load + Wind or Earthquake load with accidental load

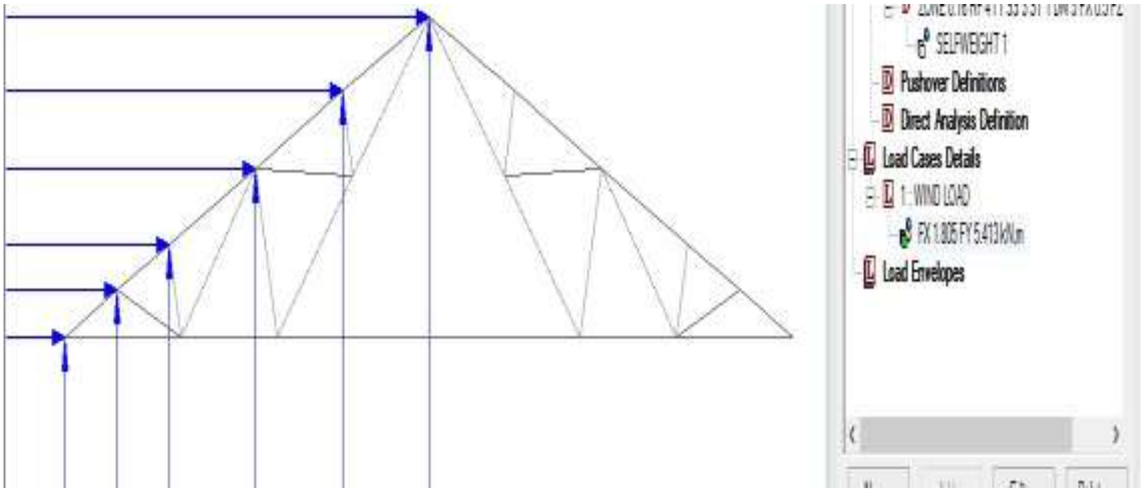

Figure 3: Windward Side Load Distribution on Truss Structure

Figure 3 illustrates the windward side analysis of the truss structure subjected to lateral wind load as defined in STAAD.Pro. The arrows represent the distribution of wind pressure acting perpendicular to the building surface, with intensity increasing toward the roof ridge. This load induces compressive and tensile forces in the truss members, primarily affecting top chords under compression and bottom chords under tension. The analysis shows uniform application of wind pressure (5.413 kN/m²) in the X-direction, conforming to IS 875 (Part 3: 1987). This evaluation helps assess the structure's stability, lateral resistance, and deflection behavior under wind effects.

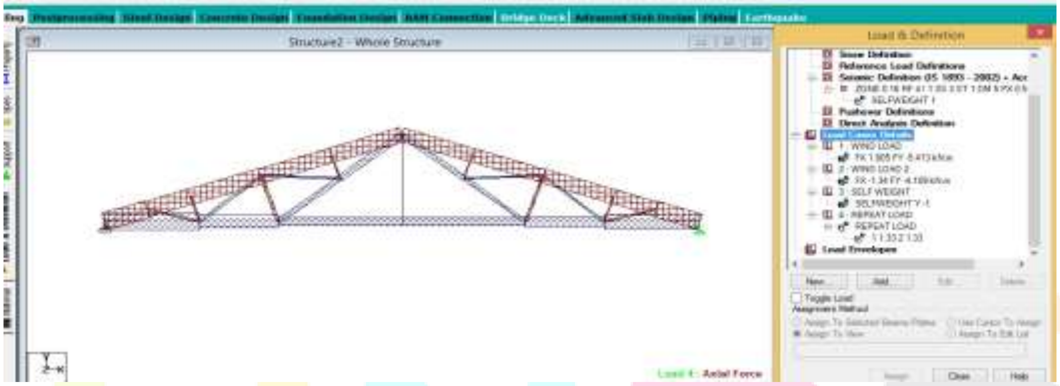

Figure 4: Axial Force Distribution in Truss Structure under Combined Loading

Figure 4 shows the axial force distribution in the truss structure under combined loading conditions. The red zones indicate compression in top chords, while blue zones represent tension in bottom members. The axial forces are uniformly distributed, confirming proper load transfer and structural stability as per the design standards.

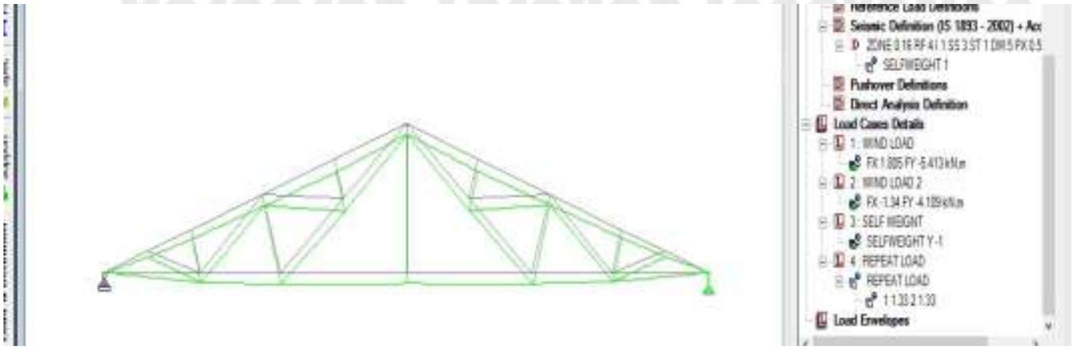

Figure 5: Deflection of Truss Structure under Combined Loading

The Figure 5 illustrates the deflection behavior of the truss under applied loads. Maximum deflection occurs at the mid-span due to combined dead, live, and wind loads, while minimal displacement is observed near the supports. The deformation remains within permissible limits, confirming structural adequacy and effective load distribution.

4.2 Performance analysis of Industrial Warehouse

Type of building: Industrial Warehouse.
Type of structure: Single Storey Industrial Structure
Area of site: 8636.25 m^2 (92957.56 sq.ft.)
Eave height: 14m
Total span width: 12m
Number of bays: 9
Single bay length: 8.00 m
Total bay length: 72m
Support condition: Pinned
PEB roof slope: 5 degrees
CSB roof slope: 15 degrees

The building view of the Industrial Warehouse structure considered for the study is as shown in Figure

4.3 Staad Pro Generated Frames

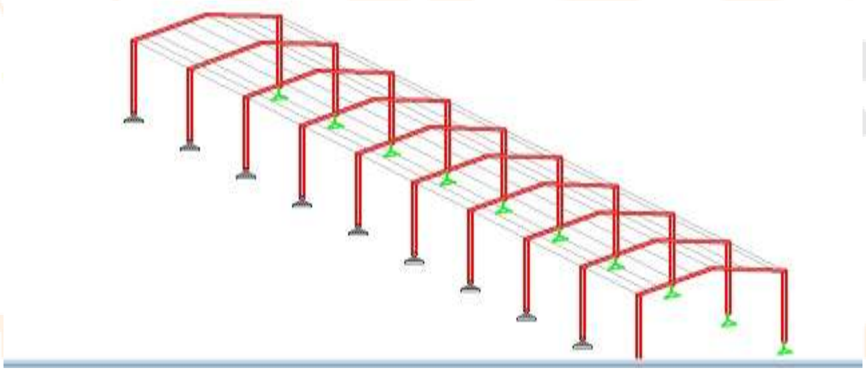

Figure 6: STAAD.Pro Generated Pre-Engineered Building (PEB) with 9 Bays

The Figure 6 presents a 3D model of a pre-engineered building (PEB) generated in STAAD.Pro, consisting of nine bays. The structure uses tapered steel portal frames with pinned base supports. This conFigure uration demonstrates optimal spacing, lightweight design, and efficient load transfer across the entire span for industrial applications.

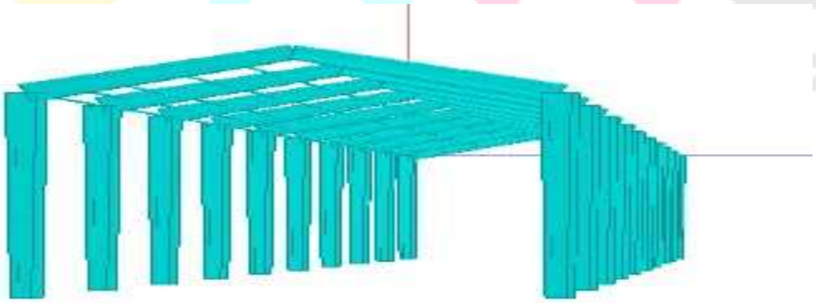

Figure 7: STAAD.Pro Rendered View of Pre-Engineered Building (PEB)

The Figure 7 shows a rendered 3D visualization of a pre-engineered building (PEB) model in STAAD.Pro. The turquoise-colored frames represent the tapered steel members forming the structural skeleton. This visualization helps in evaluating geometry, frame alignment, and overall conFigure uration before detailed analysis and design implementation.

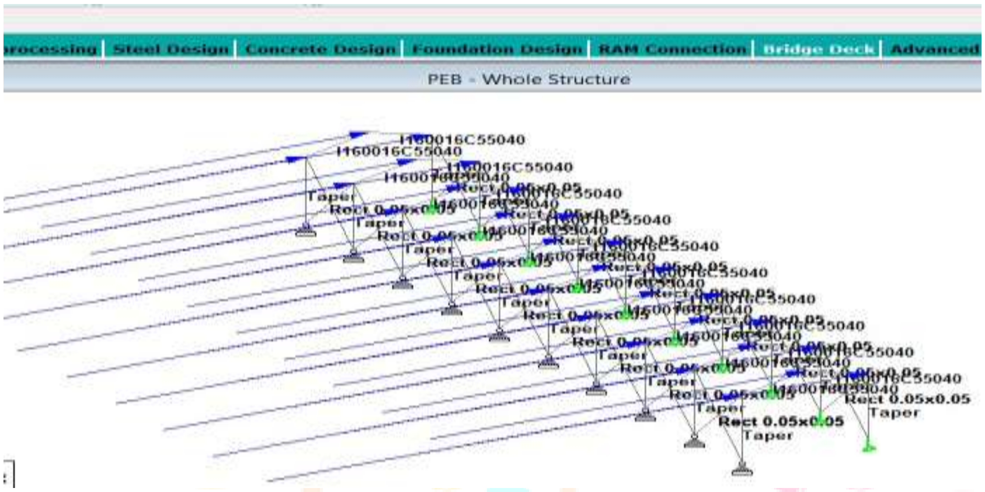

Figure 8: STAAD. Ro Generated Conventional Steel Building (CSB)

The Figure 8 depicts the STAAD. Ro model of a conventional steel building (CSB) showing detailed member labeling and load application. Rectangular and tapered sections are used for columns and rafters, respectively. The blue arrows represent applied loads, illustrating the structure's behavior and load transfer under wind and gravity effects.

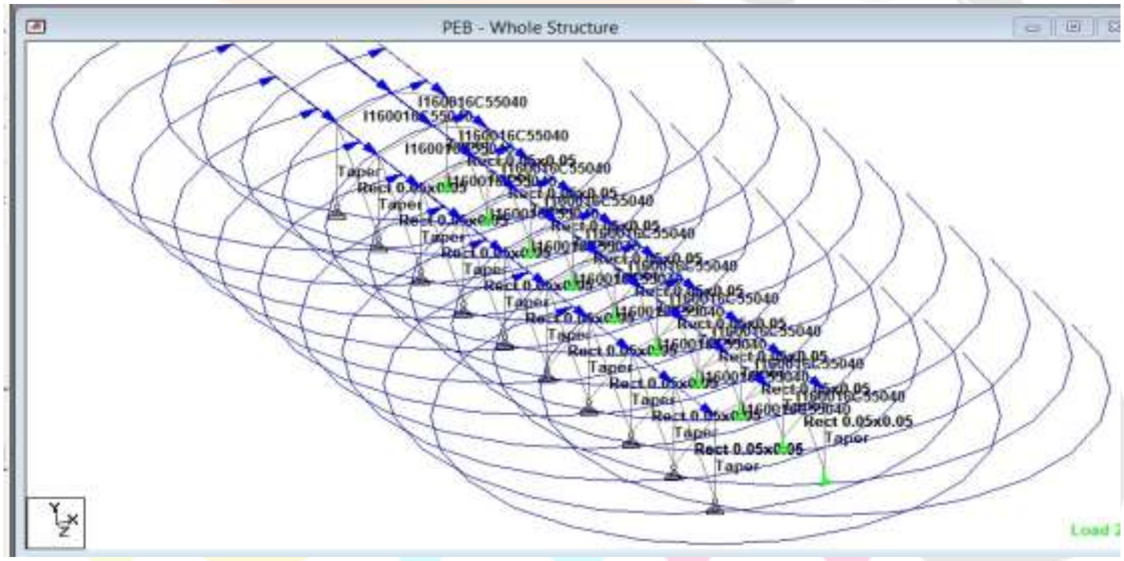

Figure 9: STAAD.Pro Generated PEB Frames under Accidental Load

The Figure 9 shows the pre-engineered building (PEB) frames analyzed under accidental load conditions. The curved contours represent the deformation pattern, while arrows indicate the applied load directions. The analysis highlights how PEB structures effectively resist lateral and vertical forces, maintaining structural stability and integrity even under unexpected load scenarios.

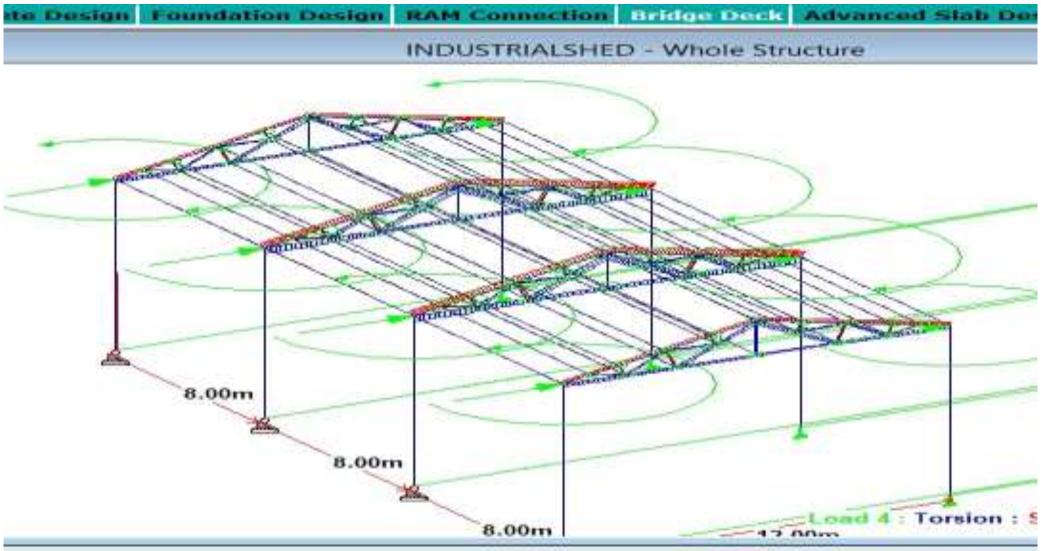

Figure 10: Torsional Stresses in Joints due to Accidental Load

The Figure 10 illustrates the distribution of torsional stresses in the joints of an industrial shed subjected to accidental loading. The green circular arrows indicate torsional effects on truss joints and beam intersections. These stresses are concentrated at ridge and eave joints, showing rotational deformation and highlighting the need for joint reinforcement to maintain stability under extreme loading conditions.

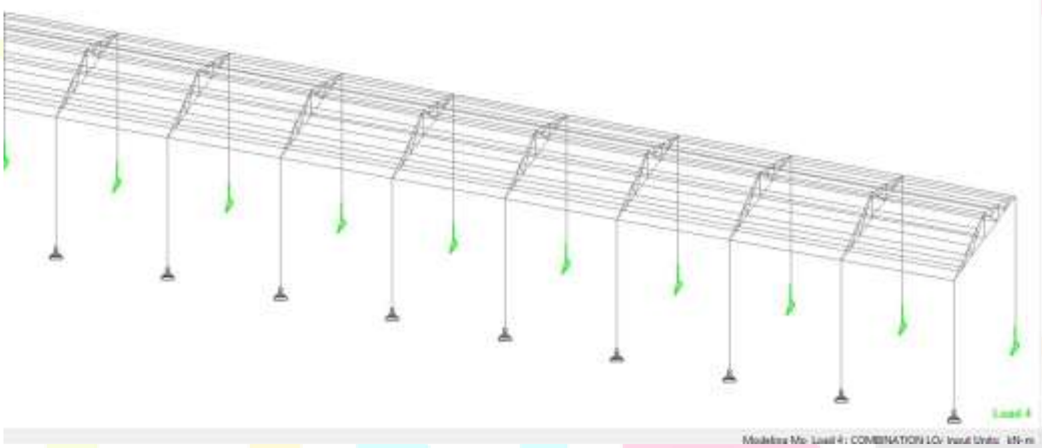

Figure 11: Conventional Steel Truss (CST) Industrial Shed with 9 Bays (8m Each, 12m Span)

The Figure ure shows the STAAD.Pro model of a conventional steel truss (CST) industrial shed consisting of nine bays, each 8 meters long with a total span of 12 meters. The green arrows indicate applied loads on roof members. This conFigure uration demonstrates the structural behavior of traditional truss systems under uniform loading conditions, emphasizing their stiffness and member connectivity.

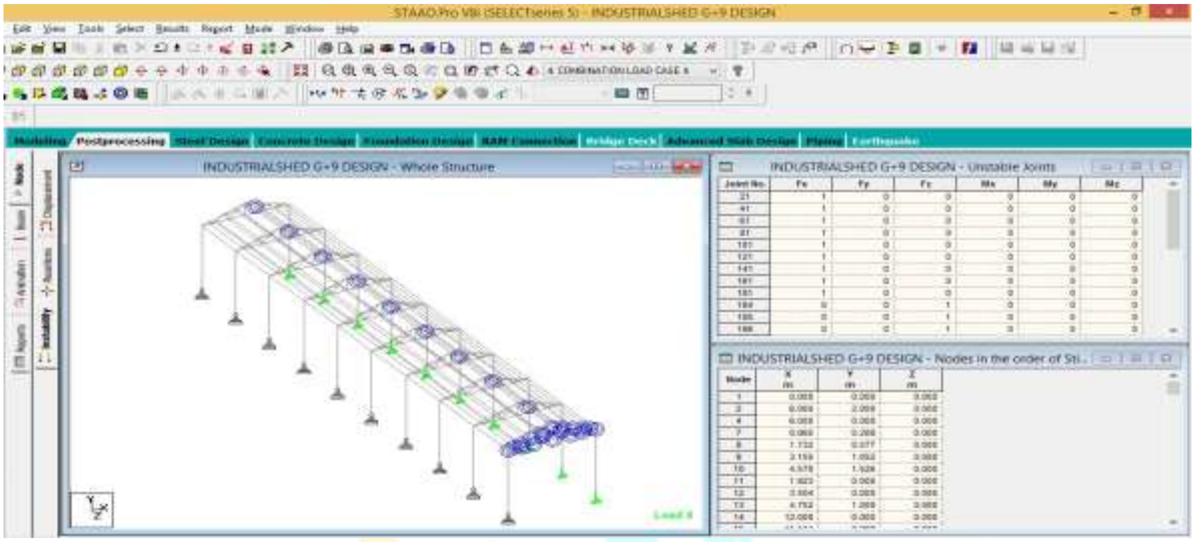

Figure 12: Instability of Joints in Conventional Steel Truss (CST) Structure with 9 Bays

The Figure 12 illustrates the instability of joints in a conventional steel truss (CST) industrial shed modeled with nine bays. The highlighted circular zones indicate unstable joints with unrestrained degrees of freedom. This instability results from inadequate bracing or improper boundary conditions, emphasizing the importance of joint stability for maintaining overall structural integrity.

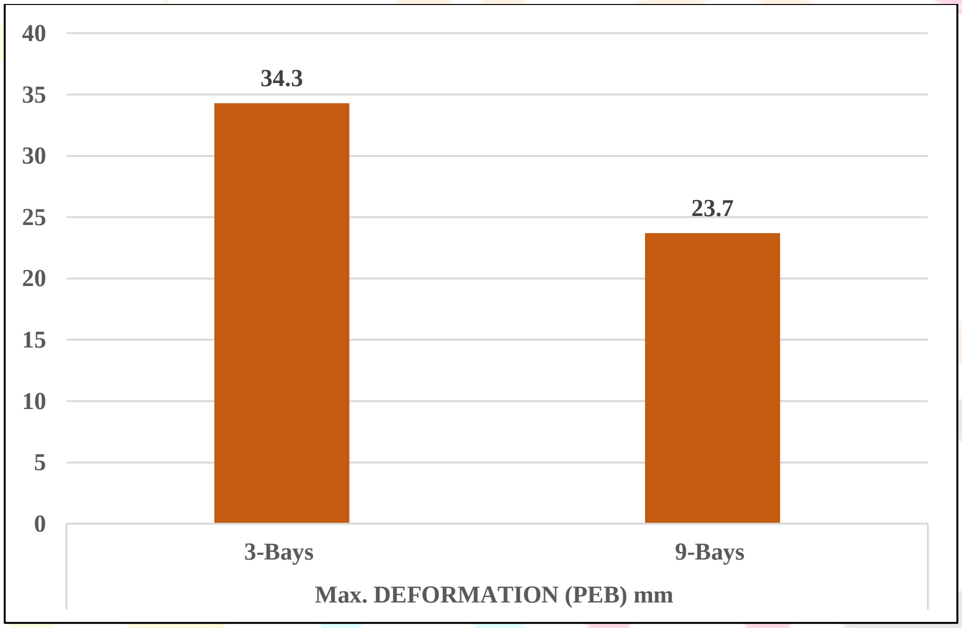

Figure 13: Maximum deformation of PEB 3-Bays and 9-Bays

Figure 13 shows the comparison of maximum deformation in Pre-Engineered Buildings (PEB) with different bay con Figure urations. The 3-bay model shows higher deformation of about 35 mm, while the 9-bay model exhibits around 25 mm. This indicates that increasing the number of bays enhances rigidity and reduces overall structural deflection.

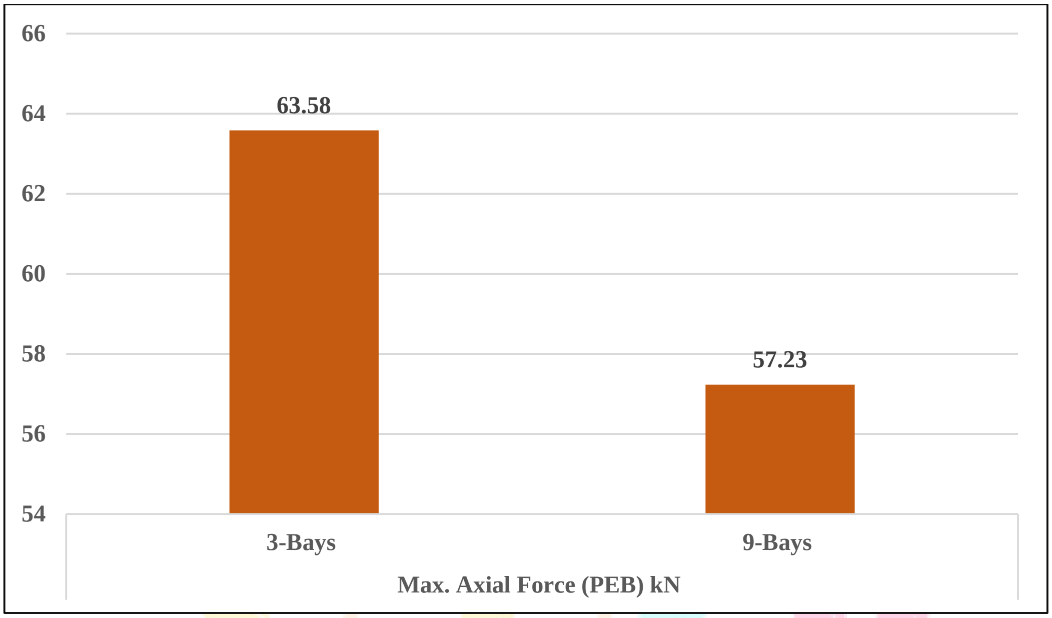

Figure 14: Comparison of Maximum Axial Force in PEB Structures

The Figure 14 compares the maximum axial force in PEB structures for 3-bay and 9-bay configure urations. The 3-bay structure exhibits a higher axial force of 63.58 kN, while the 9-bay model records 57.23 kN, indicating better load distribution in extended bay structures.

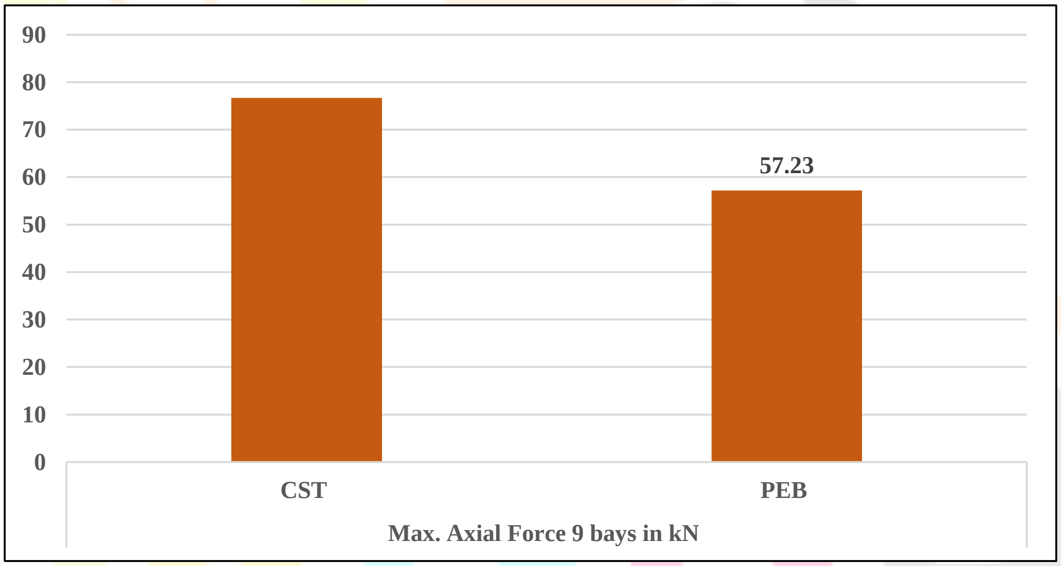

Figure 15. Comparison of Maximum Axial Force for CST and PEB (9 Bays)

The Figure 15 compares axial forces in 9-bay conventional steel truss (CST) and pre-engineered building (PEB) structures. The CST model shows a higher axial force of approximately 77 kN, while the PEB records 57.23 kN, demonstrating that PEB offers better material efficiency and reduced member loading.

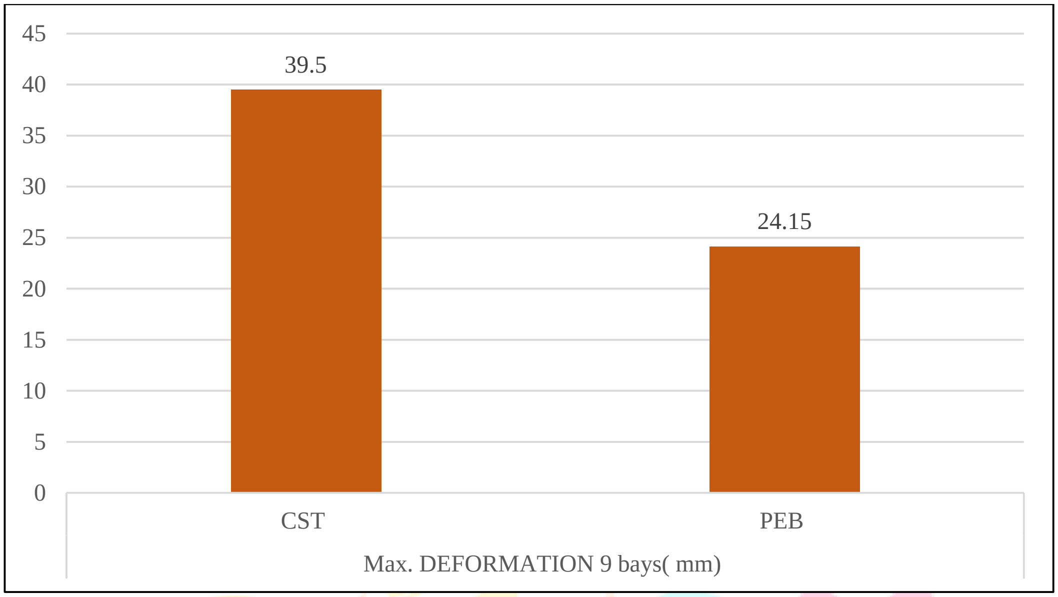

Figure 16: Comparison of Maximum Deformation for CST and PEB (9 Bays)

The Figure 16 illustrates the maximum deformation in 9-bay CST and PEB structures. The CST model exhibits a higher deformation of 39.5 mm, while the PEB structure shows only 24.15 mm. This indicates that PEB systems offer improved stiffness, better load distribution, and enhanced structural stability.

Conclusion

The comparative study between Pre-Engineered Buildings (PEB) and Conventional Steel Buildings (CSB) highlights the structural and economic advantages of PEB systems in industrial construction. The analysis revealed that PEB structures are lighter in weight, consume less steel, and exhibit lower deflection compared to conventional truss buildings. The use of tubular sections further enhanced the stiffness, strength-to-weight ratio, and torsional rigidity of PEB frames. Results obtained from STAAD.Pro analysis indicated that the maximum axial force and deformation in PEB were considerably lower than those observed in CSB structures. For a 9-bay PEB model, the deflection was 24.15 mm compared to 39.5 mm in CSB, confirming improved load distribution and reduced stress concentration. The study also identified that PEB models with tube sections performed better under accidental and wind load conditions, maintaining structural stability and serviceability. Economically, PEB construction proved to be more cost-efficient due to reduced fabrication time and material usage. Thus, it can be concluded that PEBs with tubular sections are highly suitable for large-span industrial buildings, offering sustainability, efficiency, and superior performance compared to traditional systems.

Future Scope

Future research can focus on optimizing PEB designs using advanced computational tools such as Building Information Modeling (BIM) and AI-based design optimization. Studies can also explore the performance of PEB structures under seismic and fatigue loading to enhance safety in critical zones. Integration of smart sensors for structural health monitoring and life-cycle cost analysis may provide insights into long-term performance and maintenance. Additionally, the use of alternative lightweight materials, corrosion-resistant coatings, and hybrid tubular composites can further improve durability and energy efficiency, making PEB systems more sustainable for future industrial applications.

References

[1] Gilbile, M. J., & Mane, S. S. (2020). A review on comparative study on the structural analysis and design of pre-engineered building (PEB) with conventional steel building (CSB). International Journal of Engineering Research & Technology, 9(09). https://www.ijert.org/a-review-on-comparative-study-on-the-structural-analysis-and-design-of-pre-engineered-building-peb-with-conventional-steel-building-csb

[2] Vishwakarma, N., & Tayal, H. (2018). Optimization of industrial building using pre-engineering building and conventional steel building by fully stressed design. International Journal of Applied Engineering Research, 13(20), 14573–14590. https://www.ripublication.com/ijaer18/ijaerv13n20_14.pdf

[3] Shujat, Q. S., & Desai, R. (2018). Comparative study of design of industrial warehouse using CSB, PEB and tubular sections. International Journal of Engineering Research and Applications, 8(5 Part-I), 53–57. https://www.ijera.com/papers/Vol8_issue5/Part-1/J0805015357.pdf

[4] Hulwane, V. T., Patil, R. D., & Joshi, P. K. (2017). Analysis and design of industrial building by using tubular section and its comparison with conventional sections. International Journal for Scientific Research & Development, 5(09). https://www.academia.edu/35629080/Analysis_and_Design_of_Industrial_Building_by_Using_Tubular_Section_and_its_Comparison_with_Conventional_Sections

[5] Tagade, C., Shende, A. D., Ruprai, B. S., & Shah, J. (2023). Study of pre-engineered building (PEB) with respect to conventional steel building: Review paper. Journal of Emerging Technologies and Innovative Research (JETIR), 10(6). https://www.jetir.org/papers/JETIR2306067.pdf

[6] Li, Y., Lee, C.-C., & Cai, Y. (2023). Recent research advances in high-performance steel tubular members: Material properties, stub columns, and beams. Buildings, 13(11), 2713. https://doi.org/10.3390/buildings13112713

[7] Pradeepa, S., Gokul Raj, D., & Divya, M. R. (2016). A review on cost assessment of conventional steel structure and square tubular sections using force-co-efficient method. International Journal of Civil Engineering and Technology (IJCIET), 7(4), 242–245. http://iaeme.com/MasterAdmin/Journal_uploads/IJCIET/VOLUME_7_ISSUE_4/IJCIET_07_04_020.pdf

[8] Tagade, C., Shende, A. D., Ruprai, B. S., & Shah, J. (2023). Study & analysis of pre-engineered building (PEB) with respect to conventional steel building. International Journal of Creative Research Thoughts (IJCRT), 11(6). https://ijcrt.org/papers/IJCRT2306026.pdf

[9] Thakre, V., & Vairagade, L. (2016). Analysis and cost comparative study of conventional industrial building with PEB structure. Journal of Information, Knowledge and Research in Civil Engineering. (ISSN 0975–6744).

[10] Analysis and design of pre-engineered building warehouse in different seismic zones. (2025). ResearchGate. https://www.researchgate.net/publication/380565631_ANALYSIS_AND_DESIGN_OF_PRE-ENGINEERED_BUILDING_WAREHOUSE_IN_DIFFERENT_SEISMIC_ZONES

[11] Meera, C. M. (2013). Pre-engineered building design of an industrial warehouse. International Journal of Engineering Sciences & Emerging Technologies, 5(2), 75–82.

[12] Research paper on analysis and design of steel truss by using angle and tube section. (2022). International Journal of Scientific & Research Engineering & Management (IJSREM). https://ijsrem.com/download/research-paper-on-analysis-and-design-of-steel-truss-by-using-angle-and-tube-section/

[13] Comparative analysis and design of pre-engineered structure. (2025). AIP Conference Proceedings. https://pubs.aip.org/aip/acp/article/3255/1/040003/3333248