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Analysis and Design of Pre Engineering Building by Using STAAD Pro

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Abstract

This thesis presents the structural modelling, analysis, and assessment of a Pre-Engineered Building (PEB) system. The objective of the study is to evaluate the performance of the structure under various loading conditions and to verify its compliance with codal provisions. The analysis was carried out using a 3D model, and results were extracted for critical parameters such as deflection, bending moment, shear force, axial force, utilization ratio, and column end reactions. Deflection checks were performed as per IS 800 limits, and it was found that both vertical and lateral deflections of rafters, purlins, and the overall building frame were within permissible values, ensuring adequate serviceability. The bending moment analysis revealed that the structure is primarily governed by the major axis, with a maximum moment of approximately 317 kNm under gravity load, while the minor axis bending was found to be negligible. Shear force distribution indicated maximum values at supports, with a peak of about 110 kN, whereas axial forces were observed to be safe with a maximum of 189 kN. The utilization ratios of all members were below unity, confirming sufficient strength and structural stability. Column end reactions were extracted to facilitate foundation design, which can be carried out efficiently using standard spreadsheets. Overall, the study concludes that the PEB system is safe, economical, and optimized, demonstrating its effectiveness in providing lightweight, cost-efficient, and structurally reliable solutions for industrial and commercial applications.

1. Introduction

The demand for efficient, economical, and quickly constructed buildings has surged in recent decades, driven by industrial growth, urbanization, and the modernization of infrastructure. While conventional steel structures are widely utilized, they often entail heavier sections, extended fabrication timelines, and higher costs. To address these challenges, Pre-Engineered Buildings (PEBs) have emerged as a leading-edge solution in the construction industry. Originating in the United States during the 1960s, the concept of PEBs has gained global traction. In India, their popularity surged in the early 2000s, attributed to their cost-effectiveness, reduced construction times, and versatility for various applications, including warehouses, factories, showrooms, aircraft hangars, sports complexes, and commercial buildings. A Pre-Engineered Building is a steel structure meticulously designed and fabricated in a controlled factory environment, then shipped to the site in components for assembly using bolted connections. Unlike traditional structures, PEBs employ tapered built-up sections instead of conventional hot-rolled sections, allowing for a lighter, more cost-effective solution without compromising strength or safety. Secondary components such as purlins, girts, and eave struts provide essential stability and support for roofing and wall systems, with the entire structure clad in profiled steel sheets or sandwich panels [1]

- **Literature:** It is essential for developing a comprehensive understanding of the existing knowledge, methods, and codes, while also identifying significant research gaps that could impact our work. A thorough literature review not only provides the necessary background and justification for our study by examining past theories, tools, and practices, but it also helps to frame our research contribution.

Pratik A. Raut and Prof. S. V. Shelar (2022) in their study "Analysis and Design of Pre-Engineered Building for Industrial Shed in Chakan" analysed the structural efficiency of PEBs using STAAD-Pro, AutoCAD, and Bo-CAD software. They emphasized that PEBs save time and cost compared to conventional steel structures by optimizing tapered sections and reducing steel consumption. The study highlighted the use of IS codes (IS 800:2007, IS 875 Parts 1–3, and IS 1893) for accurate design under dead, live, wind, and seismic loads. Their findings confirmed that PEBs are sustainable, economical, and flexible for future modifications or relocation [2].

Ankush Kumar and Pukhraj Sahu (2024) in their paper "Analysis and Design of Pre-Engineering Building" analysed PEBs using STAAD Pro v8i with IS 800, IS 875, AISC-2011, and MBMA-96 codes. They concluded that PEBs are 64% lighter than conventional steel buildings, with reduced axial forces and bending moments. Their findings highlight that PEBs provide economical, energy-efficient, and quick-to-construct solutions for large-span industrial structures [3].

1.1. Pros and Cons of PEB structure

Advantages (Pros):

- **Cost-Effective Construction** PEBs optimize the use of steel with tapered sections, significantly reducing material consumption. This results in lighter structures that are more economical than traditional steel buildings.
- **Faster Construction** with components fabricated in a factory setting, PEBs require only bolting and assembly on-site, which can cut construction time by up to 50% compared to conventional methods.
- **Flexibility and Versatility** These structures can be easily adapted for a variety of applications, including warehouses, factories, aircraft hangars, commercial spaces, showrooms, and even residential needs [4].
- **Quality Control** The controlled factory fabrication process ensures superior quality, accuracy, and durability in the final product.
- **Low Maintenance** Utilizing galvanized steel and weather-resistant paints minimizes corrosion, thereby reducing long-term maintenance requirements.
- **Future Expansion Possibility** PEBs can be easily expanded in length or width by adding bays, making them a flexible choice for future growth.
- **Lightweight Structure** The reduced dead load on foundations lowers foundation costs, enhancing overall project efficiency.
- **Sustainability** PEBs are constructed from recyclable steel, making them a more environmentally friendly alternative to concrete structures.

Disadvantages (Cons):

- **Initial Investment in Fabrication Facilities** The need for specialized design, fabrication, and erection facilities may pose challenges in certain locations [5].
- **Limited Aesthetic Appeal** The standardized shapes and cladding of PEBs

may restrict architectural creativity compared to Reinforced Cement Concrete (RCC) or traditional steel buildings.

- **Transportation Constraints** Large structural components can encounter transportation challenges, particularly to remote or difficult-to-access sites.
- **Thermal Insulation Issues** Metal sheets can result in heat transfer, necessitating additional insulation for comfort in extreme climates.
- **Dependency on Skilled Erection** Successful assembly requires skilled labour and proper equipment; any errors during erection can impact the building's performance [6].
- **Not Always Suitable for Multi-Storey Buildings** PEBs are most cost-effective for single-storey, large-span structures; conventional systems may be more practical.

1.2. Objectives of the Study

The objectives of our current study, which aims to advance our understanding of Pre-Engineered Buildings (PEBs) and their advantages over conventional steel structures:

- To thoroughly examine the concept and structural behaviour of PEBs, highlighting their benefits compared to traditional steel frameworks.
- To effectively model and analyse a PEB structure utilizing advanced structural analysis software such as STAAD.Pro, ETABS, or SAP2000, under diverse loading conditions, including dead load, live load, wind load, and seismic load, in accordance with relevant IS codes.
- To design the primary structural members (rafters and columns) as well as the secondary members (purlins, girts, bracings, etc.) of the PEB, employing limit state design principles as outlined in IS 800:2007.
- To develop robust designs for connections and base plates that meet both strength and serviceability criteria [7].
- To prepare comprehensive drawings and layout plans for the designed PEB, demonstrating its practical applicability.
- To formulate well-founded recommendations for the implementation of PEBs in industrial, commercial, and institutional settings based on our study's findings Shown in Table 1.

2. Method

Table 1 Building Information

Parameter	Pre-Engineered Building (PEB)
Building Width (Span)	**18.2 m**
Building Length	44.36 m
Building Height	6.0 m at eaves (ends), 7.6 m at ridge
Roof Slope	10°
Main Frame	Built-up steel sections (columns & rafters)
Frame / Truss Spacing	5.45 m (portal frame spacing
Roof Purlins	RHS-section purlins @ 1.15 m c/c
Roof Sheeting	1.2 mm thick Galvanized Iron (GI) sheet
Wall Girts	(Assumed) Z-section, spacing 1.5–2.0 m c/c
Cladding	Roof & wall cladding (GI sheet or sandwich panels)
Load Transfer Path	Roof sheet → Purlins → Rafters → Columns → Foundation
Load Types Considered	Dead Load, Live Load, Wind Load (as per IS 875 or relevant design code)
Foundation	RCC isolated footings / pedestals (assumed)
Structural Action	Portal frame action with rigid joints resisting vertical & lateral loads

The methods adopted in the modelling and analysis includes.

- **Literature Review** – Study of PEB concepts, components, and relevant IS codes (IS 800:2007, IS 875, IS 1893).
- **Problem Definition** – Selection of a single-span PEB structure with defined geometry and usage [8].
- **Data Collection** – Gathering material properties, load parameters, and design requirements.
- **Structural Modelling** – Creation of a 3D model of the PEB in STAAD.Pro / ETABS.
- **Load Application** – Application of dead load, live load, wind load, and seismic load as per IS codes.
- **Analysis** – Determination of bending moments, shear forces, axial forces, and deflections.
- **Design** – Designing primary members (rafters, columns), secondary members (purlins, girts, bracings), base plates, and connections Shown in Figure 1 - 7.
- **Drawings & Documentation** – Preparation of structural drawings and final report Shown in Table 2.

Table 2 Loading Information

Structure	**Steel Structure**
Type of building usage	Ware house Building
Location	Bangalore
Seismic zone	Z-2
Wind Speed	33 m/s
Dead Load Intensities	
Self-weight of GI Sheet (Assuming 1.2mm thick Sheet) = 1.2 x 1.15 x 78.5/1000	0.11 KN/m2
Fixtures (Assumed 5 kg/sq.-m)	0.05 KN/m2
Ceiling Overhangs (Assumed 50 kg/sq.-m)	0.50 KN/m2
Live Load Intensities	
Roof	0.75 KN/m2
Wind Loading	Refer Appendix B

2.1. Figures

Plan of PEB structure

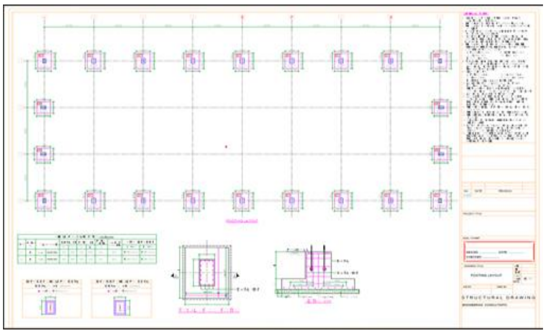

Figure 1 Plan View – Auto cad (1)

PEB structure View

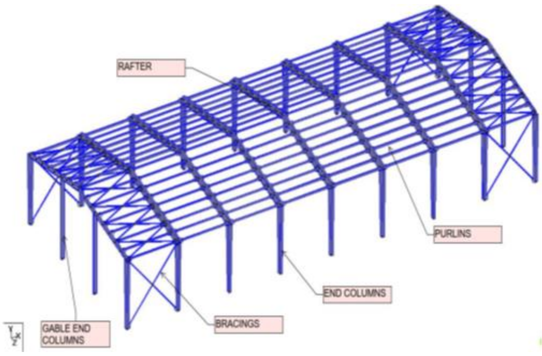

Figure 2 3D View of Building in Staad Pro (1)

Typical section View:

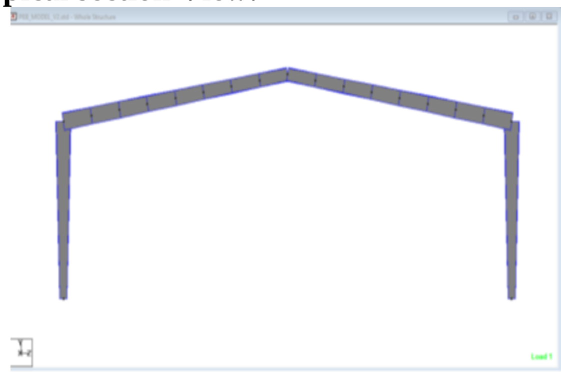

Figure 3 Section View – Staad Pro (2)

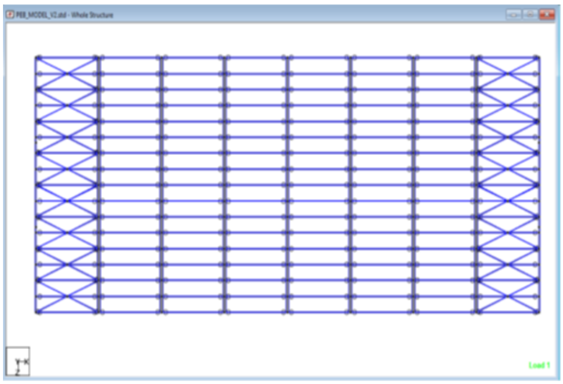

Figure 4 Plan View – Staad Pro (3)

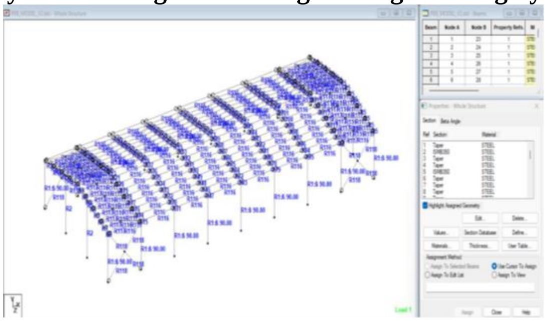

Figure 5 Properties assigned

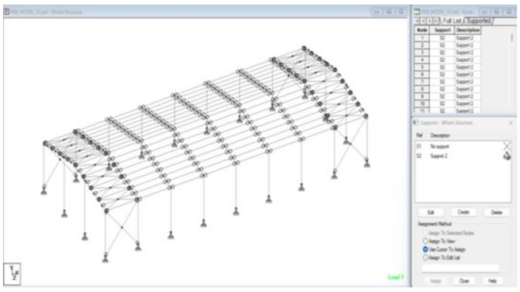

Figure 6 Pinned Support

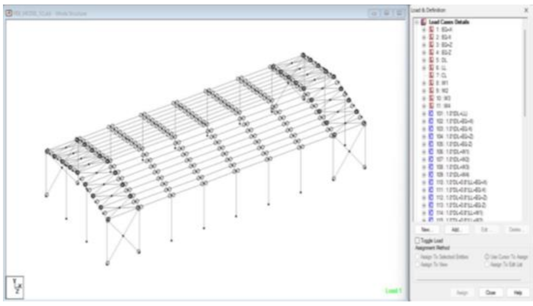

Figure 7 Load Cases and Combinations

3. Results and Discussion

Deflection Check

The deflection limits are checked as per the Table 6 of IS800. The analysis results are extracted from the developed models; the results are compared with their limiting values Shown in Figure 8.

Vertical Deflection – Rafter

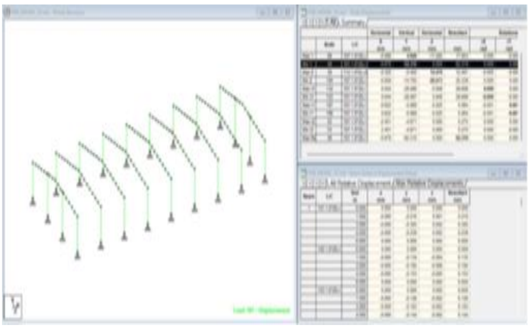

Figure 8 Vertical Deflection – Rafter

The vertical deflection of rafter is Found to be 63mm. However, the limiting value is Span/ 180 = 18200/180 = 101mm. And hence it is safe Shown in Figure 9.

Vertical Deflection – Purlin

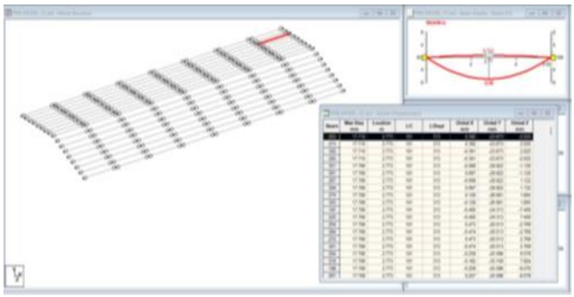

Figure 9 Vertical Deflection – Purlin

The vertical deflection of purlin is Found to be 17.7mm. However, the limiting value is Span/ 180 = 5450/180 = 30mm. And hence it is safe Shown in Figure 10

Lateral Deflection – Building

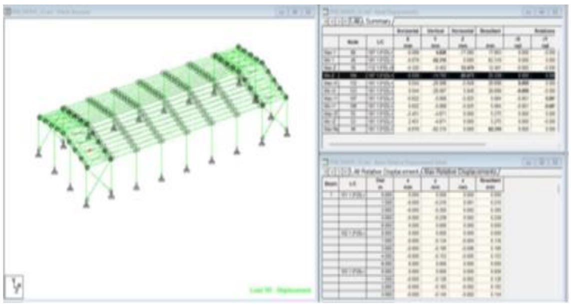

Figure 10 Lateral Deflection – Building

The Max. Lateral deflection of rafter is Found to be 21mm. However, the limiting value is Height/ 150 = 6000/150 = 40mm. And hence it is safe Shown in Figure 11.

Bending Moment Diagram

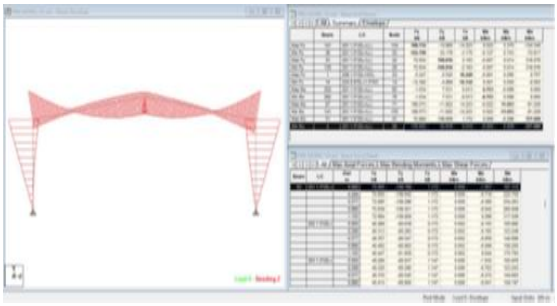

Figure 11 Bending Moment Diagram – Frame

The major bending moment is found along the major axis. It is evident that thickness of the tapered member is maximum at the location of the maximum bending moment. Also, it is found that the max. bending moment is around 317 KN-m for the gravity load case. And hence, in this building, it is found that neither wind nor seismic is affecting the structure Shown in Figure 12.

Minor Axis

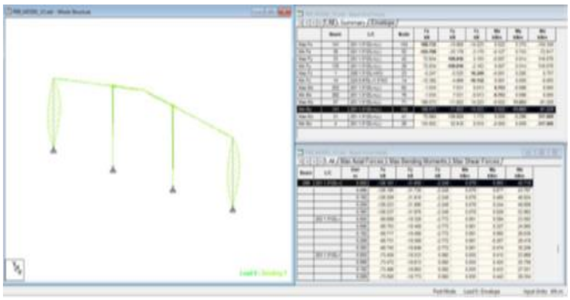

Figure 12 Bending Moment Diagram – Frame

The bending moment along the building length is found to be very minimal compared to the overall span, with a value of around 11 mm, which can be considered negligible [9 - 11]. This result demonstrates that PEB structures are highly economical, as their member sizes can be customized precisely to meet the required structural forces Shown in Figure 13 and 14.

Shear Force Diagram

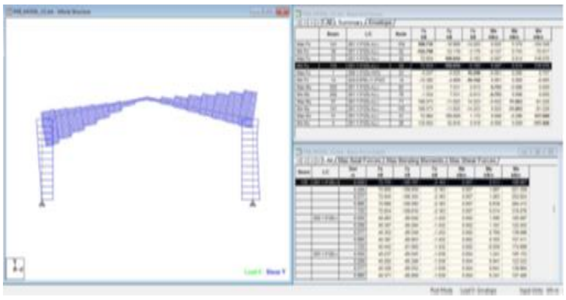

Figure 13 Shear Force Diagram – Frame

Axial Force Diagram

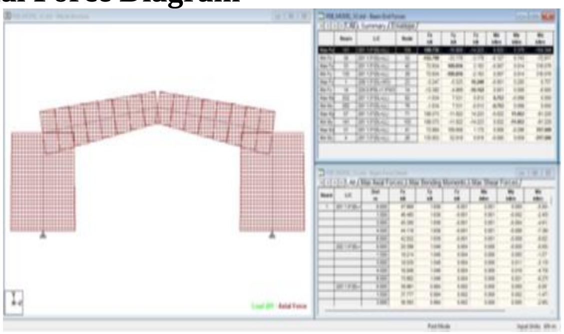

Figure 14 Axial Force Diagram – Frame

The axial force is found to be maximum for gravity load case and load case no. 201. The Maximum value is found to be 189 Kn Shown Figure 15.

Utilization Ratio

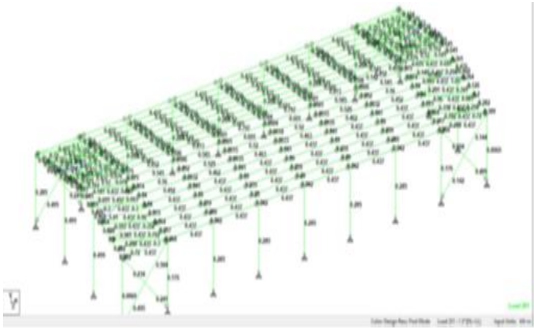

Figure 15 Utilization Ratio

All the members are well within the limit of 1. And hence the structure is safe.

Conclusion

- The structural model was analysed, and results were systematically extracted for assessment.
- All vertical and lateral deflections are within the permissible limits prescribed by IS 800, ensuring serviceability.
- The maximum vertical deflection of rafters (63 mm) and purlins (17.7 mm) are safe compared to their limiting values.
- The maximum lateral deflection of the building (21 mm) is also well within the allowable range.
- Bending moment analysis indicates that the major axis governs the design, with a maximum value of ~317 kNm under gravity loading.
- The minor axis bending is negligible (~11 kNm), validating the efficiency of tapered PEB members.
- Shear forces peak at the supports (~110 kN), as expected, and remain within safe design limits.
- Axial forces are also found to be safe, with a maximum value of ~189 kN under critical load cases.
- The utilization ratios of all members are less than unity, confirming adequate strength and stability.
- Column end reactions are obtained for foundation design, and overall, the structure is found to be safe, economical, and optimized for the applied loads.

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