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Analysis and Design of Pre-Engineered Building Structure Using Staad.Pro

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Abstract – This paper presents a comprehensive analysis and design study of a Pre-Engineered Building (PEB) structure using STAAD.Pro, a structural analysis and design software widely used in civil engineering. PEBs have gained significant traction in modern construction due to their modularity, faster erection time, and cost-effectiveness compared to conventional steel structures. The objective of this study is to evaluate the feasibility, material optimization, and structural performance of a PEB industrial shed located in Chennai, India. The structure was modeled and analyzed under various loading conditions including dead load, live load, wind load, seismic load, and collateral load, following IS 800:2007, IS 875 (Parts 1–3), and IS 1893:2016. The design incorporated tapered sections for the primary frames and cold-formed members for purlins and girts. Seismic and wind loads were particularly critical due to the site's location in Zone III and a basic wind speed of 50 m/s. The final STAAD.Pro output confirmed that the structure remains within permissible deflection limits and achieves material economy through optimization. This paper demonstrates that PEBs provide a viable, efficient, and sustainable alternative for industrial infrastructure development.

***Key words**: Pre-Engineered Building, Deflection, Optimization, STAAD PRO, etc.*

1. INTRODUCTION

In the evolving landscape of structural engineering, the demand for efficient, cost-effective, and rapid construction methods has led to the increasing adoption of Pre-Engineered Buildings (PEBs). These structures, which are fabricated in controlled factory settings and assembled on-site using bolted connections, offer superior speed and accuracy over traditional construction techniques. PEBs are especially well-suited for applications such as warehouses, industrial sheds, and commercial spaces where large, unobstructed spans are needed.

Unlike conventional steel structures, where each component is custom-designed and fabricated at the site, PEBs employ standardized components and design templates optimized for load conditions. This modular approach minimizes material wastage, shortens construction timelines, and lowers labor costs. Additionally, PEBs integrate architectural, structural, and MEP elements into a unified system that enhances performance and simplifies project execution. The use of advanced structural analysis tools such as STAAD.Pro further enhances the viability of PEBs. By modeling real-world load scenarios—including wind, seismic, live, dead, and collateral loads—STAAD.Pro enables engineers to refine structural design,

check serviceability, and verify code. compliance. In this project, a PEB located in Chennai was designed to comply with Indian Standard codes such as IS 800:2007, IS 875 (Parts 1–3), and IS 1893:2016. The building is exposed to high wind conditions ~~(50 m/s) and lies within Seismic Zone III, which demands~~ rigorous structural stability checks. This study showcases the benefits of PEB systems in terms of speed, safety, and sustainability. The results validate the effectiveness of the STAAD.Pro-based design methodology and support the broader application of PEBs in industrial infrastructure development.

2. LITERATURE REVIEW

S.K. Duggal – Limit State Design of Steel Structures. This textbook provides the foundational concepts of limit state design as applied to steel structures. It elaborates on design philosophies, member strength calculations, and structural safety as per IS 800:2007. The book played a crucial role in defining the load-carrying capacity and performance criteria used in this study, especially for designing tapered built-up sections and cold-formed members within STAAD.Pro.

Zamil Steel Research and Case Studies, Zamil Steel is one of the world's leading manufacturers of Pre-Engineered Steel Buildings and has executed thousands of projects across industrial, commercial, and infrastructure sectors. Their technical papers and case studies emphasize the use of tapered sections, cold-formed profiles, and optimized structural design tailored to site-specific wind and seismic zones. Zamil's PEB systems are known for efficient fabrication, modular expansion capability, and high-speed erection. Their work supports the global viability of PEBs and was used in this study as a benchmark for comparing Indian practices. The project modeled in this paper follows similar design philosophies used by Zamil — including modular bay spacing, purlin optimization, and load-specific structural detailing.

Kirby Building Systems (KIEBY) – PEB Innovations and Case Studies, Kirby Building Systems is a leading manufacturer of Pre-Engineered Buildings with a strong presence across Asia, including India. Their research and case studies focus on the structural efficiency of PEBs, sustainable materials, and tailored designs for diverse climatic conditions. Kirby has introduced advanced fabrication techniques and integration of energy-efficient solutions such as solar roofing and insulation. Their technical catalog and design approach have inspired widespread use of cold-formed secondary members, tapered primary frames, and optimized bay spacing — all of which were used in this study. Kirby's design standards and construction practices provided valuable industry benchmarks that reinforced the technical validity and real-world applicability of the modeled structure in this paper.

3. METHODOLY

The methodology adopted for this study involves systematic planning, structural modeling, and analysis of a Pre-Engineered Building (PEB) industrial shed using STAAD.Pro. The objective was to ensure structural safety, cost-effectiveness, and

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compliance with relevant Indian Standards.
Material Used

3.1 .Site and Structural Overview
-Location: Chennai, Tamil Nadu
-Wind Zone: Vb = 50 m/s
-Seismic Zone: Zone III
-Structure Type: Industrial warehouse
-Dimensions: 72.2 m (length) × 36 m (span)
- Bay Spacing: End bays @ 8.1 m; intermediate @ 8.0
-Roof Type: Pitched (4.26° slope)
- Collateral Load: 10 kg/m^2 (solar panels)

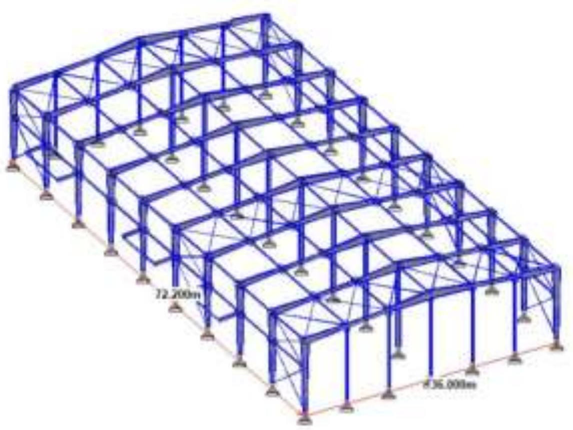

Figure 1. Dimension of PEB

3.2 Design Codes Used
- IS 800:2007 – Steel construction
- IS 875 (Parts 1–3) – Dead, live, and wind loads
- IS 1893:2016 – Seismic design
- IS 811:1987 – Cold-formed sections

3.3 STAAD.Pro Modeling Workflow
- Assignment of tapered I-sections and Z-purlins
- Material definition: hot-rolled and cold-formed steel
- Pinned base support conditions
- Member releases and bracing settings
- Application of load cases and combinations

3.4 Load Cases Considered
- Dead Load (DL)
- Live Load (LL) – 0.75 kN/m^2
- Wind Load (WL) – 50 m/s wind speed
- Seismic Load (EL) – Static method (Z = 0.16)
- Collateral Load (CLL) – Solar panels

3.5 Load Calculations
Dead Load Calculations

a) Side Wall Load on Columns

• Weight of Side Wall Sheet = 5 kg/m^2
• Weight of Sag Rods, Flange Braces, etc. = 5 kg/m^2
• Total = 0.1 × 8.1 = 0.81 KN/m
• Girts (270×75×20×2.55 mm) @ 8.1 m bay spacing
= 8.77 kg/m
• Converted to KN/m = (6 × 8.77 × 8.1) / 7
= 0.608 KN/m

Total Load on Column @ 8.1 m spacing = 0.81 + 0.608 = 1.41 KN/m
Gable Column Load = 0.705 KN/m• Girts (230×75×20×2 mm) @ 6 m spacing = 6.32 kg/m
• Converted = (7 × 6.32 × 6) / 7 = 0.38 KN/m
Total Load on Column @ 6 m spacing = 0.6 + 0.38
= **0.98 KN/m**
Gable Column Load= **0.49 KN/m**

b) Point Load Due to Eave Gutter and Eave Strut

• Eave Strut (CS270×75×20×3.15 mm) = 10.7 kg/m
• Eave Gutter (0.25×0.25×0.001 m) = 5.89 kg/m
• Total = 16.59 kg/m
Point Load on main column = 16.59 × 8.1 = 134.37 kg
= 1.344 KN
Point Load on Gable Column = 0.672 KN

c) Roof Load on Rafters

• Weight of Roofing Sheet (0.47 mm thick) = 5 kg/m^2
• Sag Rods, Flange Braces, etc. = 5 kg/m^2
• Collateral Load = 10 kg/m^2
• Total Load = 20 kg/m^2 = 0.2 KN/m^2
UDL on Main Rafter = 0.2 × 8.1 = 1.62 KN/m
• Purlins (270×75×20×2.55 mm) = 8.77 kg/m
• No. of Purlins = Round off (18.062 / 1.5) + 1 = 14
• UDL from purlins = (14 × 8.1 × 8.77) / 18.062
= 55.06 kg/m = 0.551 KN/m
Total UDL on Main Rafter = 1.62 + 0.551 = 2.171 KN/m
Total UDL on Gable Rafter = 2.171 / 2 = 1.086 KN/m

Live Load Calculations

a) Roof Live Load

As per IS 875 Part II, for a flat, sloping, or curved roof with a slope up to and including 10°, and access not provided except for maintenance, the uniformly distributed live load (UDL) is taken as: 0.75 KN/m^2
Given:
• Span (Width of building) = 8.1 m
• UDL on Main Rafter = 0.75 × 8.1 = 6.075 KN/m
• UDL on End Rafter = 0.5 × 6.075 = 3.0375 KN/m

b) Live Load Due to Water Accumulation in Eave Gutter

Weight of water accumulated in the gutter during rainfall is also considered as live load.
Assuming the gutter dimension: 250mm x 250mm x 1mm thick
• Live load on main column due to rainfall water
= 0.25 × 0.25 × 10 × 8.1 = 5.063 KN
• Live load on gable end column
= 0.5 × (0.25 × 0.25 × 10 × 8.1) = 2.532 KN

Seismic Load Calculation

Ah = (Z/2) x (I/R) x (Sa/g)
Where ,

• Z = Zone factor (for Chennai , Z=0.16)
• I = Importance factor (for industrial buildings, I=1.2)
• R = Response reduction factor (for steel moment-resisting frames, R=4)
• (Sa/g) = Spectral acceleration coefficient=2.5
Ah = (0.16/2) x (1.2/4) x 2.5
= 0.08 x 0.3 x 2.5
=**0.06**

Seismic Base Shear **(Vb)=Ah·W**
Assume seismic weight = 1000kn
Vb=0.06×1000= **60kn**

Wind Load Calculation

Calculate Design Wind Speed (Vz)
Vz=Vb×K1×K2×K3×K4
=50×1×1×1×1.15=57.5m/s Vz= **57.5m/s**

Calculate Design Wind Pressure (Pz)
Pz=0.6 x Vz x Vz
= 0.6 x 57.5 x 57.5
Pz= 1.984kN/m2

Design Wind Pressure (Pd)
Pd=Kd×Ka×Kc×Pz

Where:
Kd = 1.0 (Wind Directionality Factor – Clause 7.2.1, for cyclone-prone areas)
Ka = 0.83 (Area Averaging Factor – Clause 7.2.2, Table 4 for tributary area)
Kc = 0.9 (Combination Factor – Clause 7.3.3.13)
Pz= 1.984 kN/m² (from Step 2)
Pd=1.0×0.83×0.9×1.984
Pd=**1.482kN/m2**

Pressure Coefficients

- **Internal Pressure Coefficient (Cpi):** ±0.5 for openings between 5% and 20% as **per Clause 7.3.2.**
- **External Pressure Coefficients (Cpe)** were taken from IS 875 (Part 3), Tables 5 & 6:

Roof (Slope = 4.76°, Windward and Leeward Zones)

Table 1 CPE Value for Roof

Wind Direction	Surface	CPE
0°	EF	-0.9
0°	GH	-0.4
90°	EG	-0.8
90°	FH	-0.4

Walls (Windward and Leeward Zones)

Table 2 CPE Value for Walls

Wall Surface	Cpe (0° Wind)	Cpe (90° Wind)
A (Windward)	+0.7	-0.5
B (Leeward)	-0.25	-0.5
C (Sidewall)	-0.6	+0.7
D (Sidewall)	-0.6	-0.1

Wind Calculation on Rafter: -

EF Side (Wind = 0°)

➤ Case A: Internal Pressure = +0.5
• cpe = −0.9, cpi = +0.5
• (cpe – cpi) = −0.9 − 0.5 = −1.4
• Design Pressure (pd) = −1.4 × 1.482 = −2.07 kN/m²
• UDL = −2.07 × 8.1 = −16.81 kN/m

➤ Case B: Internal Pressure = −0.5
• cpe − (−cpi) = −0.9 + 0.5 = −0.4
• pd = −0.4 × 1.482 = −0.59 kN/m²
• UDL = −0.59 × 8.1 = −4.80 kN/m

Table 3 Wind Calculation on Rafter

Side	Wind Angle	cpe	pd (0+CPI)	UDL (0+CPI)	pd (0−CPI)	UDL (0−CPI)
EF	0°	-0.9	-2.07	-16.81	-0.59	-4.80
GH	0°	-0.4	-1.33	-10.80	+0.15	+1.20
EG	90°	-0.8	-1.927	-15.61	-0.445	-3.60
FH	90°	-0.4	-1.334	-10.80	+0.148	+1.20

Wind Calculation on Column: -

A Side (Wind = 0°)

➤ Case A: Internal Pressure = +0.5
• cpe = +0.7, cpi = +0.5
• cpe − cpi = 0.7 − 0.5 = 0.2
• Design Pressure (pd) = 0.2 × 1.482 = 0.296 kN/m²
• UDL = 0.296 × 8.1 = 2.40 kN/m

➤ Case B: Internal Pressure = −0.5
• cpe − (−cpi) = 0.7 + 0.5 = 1.2
• pd = 1.2 × 1.482 = 1.778 kN/m²
• UDL = 1.778 × 8.1 = 14.41 kN/m

Table 4 Wind Calculation on Column

Surface	Wind Angle	cpe	pd (+CPI) (kN/m²)	UDL (+CPI) (kN/m)	pd (−CPI) (kN/m²)	UDL (−CPI) (kN/m)
A	0°	+0.7	+0.296	+2.40	+1.778	+14.41
B	0°	−0.25	−1.112	−9.00	+0.371	+3.00
C	0°	−0.6	−1.63	−9.78	−0.148	−0.89
D	0°	−0.6	−1.63	−9.78	−0.148	−0.89
A	90°	−0.5	−1.482	−12.00	0.00	0.00
B	90°	−0.5	−1.482	−12.00	0.00	0.00
C	90°	0.7	0.2964	1.78	1.778	10.67
D	90°	−0.1	−0.889	−5.34	0.593	3.56

3.6 Load Combinations(IS 800:2007)

Strength Design

1. 1.5DL + 1.5LL
2. 1.2DL + 1.2LL + 1.2 WL/EL
3. 1.5DL + 1.5WL/EL
4. 0.9DL + 1.5WL/EL

Serviceability Design

1. 1.0DL + 1.0LL
2. 1.0DL + 1.0EL/WL
3. 1.0DL + 0.8LL + 0.8WL
4. 1.0DL + 0.8LL + 0.8EL

4.Result and Discussion

4.1 Deflection Checks in STAAD.Pro

Deflections were checked under service combinations (not ultimate strength combinations). STAAD.Pro calculates nodal displacements and member end deflections, which were compared against the permissible limits:

Rafter Deflection:
Span = 36 m
Limit = 36000 mm / 180 = 200 mm
STAAD Result: Maximum deflection = 135.7 mm → Safe

Purlin Deflection:
Span = approx. 5 m
Limit = 5000 mm / 150 = 33.3 mm
STAAD Result: Max deflection = 23.5 mm → Safe

Column Lateral Displacement:
Height = ~7.5 m
Limit = 7500 mm / 150 = 50 mm
STAAD Result: Max sway = 36.2 mm → Safe

4.2 Structural Behavior Under Load Cases

Load distribution was observed to be balanced and realistic. The structure responded symmetrically under gravity loads and dynamically under lateral and seismic loads.

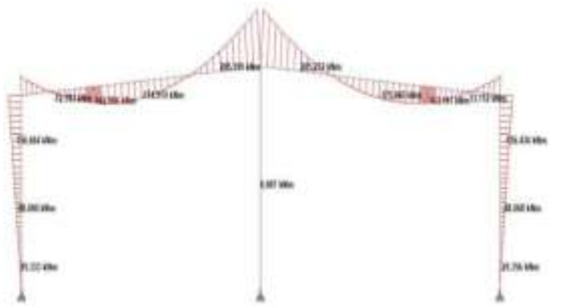

Figure 2 Bending Moment

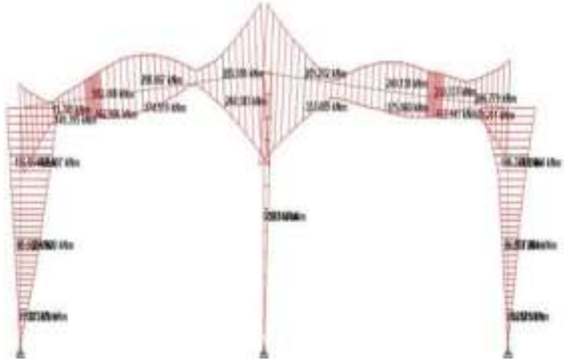

Figure 3 Load Envelope for Strength

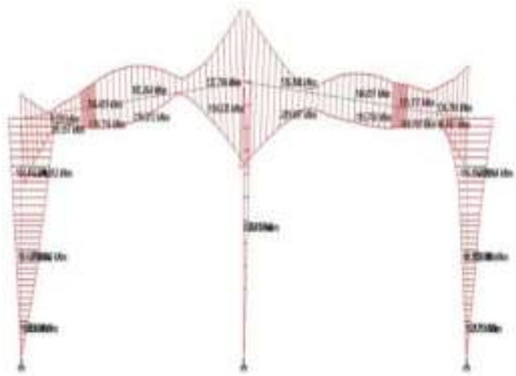

Figure 4 Load Envelope for Serviceability

5. Conclusion

The present study focused on the structural analysis and design of a Pre-Engineered Building (PEB) industrial shed using STAAD.Pro, following relevant Indian Standards such as IS 800:2007, IS 875 (Parts 1 to 3), and IS 1893:2016. The objective was to develop a steel structure that is not only safe and code-compliant but also optimized in terms of material usage and construction efficiency.

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The structure was modeled using tapered sections for rafters and columns, cold-formed Z-purlins for roof support, and tension-only bracings for lateral stability. All critical loads — including dead load, live load, wind load, seismic load, and collateral load from rooftop solar panels — were considered in the design process.

From the earlier results and discussion, it can be concluded that,

- The total structural steel weight was calculated to be 695 kN, which demonstrates the success of the optimization approach.
- All members were remained within the deflection limits as prescribed by the I.S.Code.
- The behavior of the frame under different load combinations was stable and predictable.
- All deflections are well within permissible limits, ensuring that the structural members will not sag, sway, or deflect excessively under regular working conditions.
- No redesign was necessary after final iterations, confirming the accuracy of the methodology.
- Tapered I-Sections: Reduced self-weight in low-stress zones of rafters and columns.
- Cold-Formed Z-Purlins: Light yet effective for carrying roofing loads and collateral weight.
- Tension-Only Bracing: Used to minimize material usage while ensuring lateral stability.
- Iterative Design: Member sizes were refined through multiple design runs to stay within the 0.75–0.95 utilization range.

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