

Comparative Analysis and Design of Pre-Engineered Buildings and Conventional Steel Buildings Under Seismic and Wind Loads

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Abstract - Steel is a dominant material in industrial shed construction due to its high strength, rapid erection capabilities, and suitability for large-spans structures; however, conventional steel building (CSB) designs are often less optimised, leading to excessive material consumption and high costs. This study presents a comparative analysis and design of Pre-Engineered Buildings (PEB) and Conventional Steel Buildings, specifically evaluating their performance under seismic zone II and wind loads for an industrial warehouse building. The research methodology involved the use of STAAD.Pro V8i for the analysis and design of both systems, adhering to relevant Indian Standards. The investigation focused on key structural parameters, including displacement, internal force distribution, and overall steel requirements. The analysis reveals that PEB systems, which utilise tapered built-up sections for primary members and cold-formed sections for secondary members, achieve significantly better material utilisation by matching the bending moment distribution along the span. The findings demonstrate that the PEB system saves 26.40% of the steel compared to CSB while maintaining the necessary safety and serviceability standards as per IS:800-2007. Furthermore, the study concludes that wind load combinations are often more critical than seismic loads for this type of single-storey industrial structure. Ultimately, PEB provides a more cost-effective, rapid, and sustainable solution for modern industrial construction needs, offering reduced construction time and lower foundation demands due to their lighter self-weight.

Keywords - Pre-Engineered Buildings, Conventional Steel Buildings, STAAD.Pro V8i, Seismic Loads, Wind Loads, Structural Optimisation.

I. INTRODUCTION

The rapid industrialisation and urbanisation witnessed across the globe, particularly in developing economies such as India, have necessitated the development of efficient, cost-effective, and sustainable infrastructure solutions [1][2]. Among the various types of industrial structures, single-storey steel buildings remain the preferred choice for warehouses, manufacturing facilities, and logistics centers due to their

high strength-to-weight ratio, ease of construction, and ability to span large distances without intermediate supports [3][4]. Steel as a construction material offers distinct advantages including ductility, recyclability, and predictable performance under diverse loading conditions, making it particularly suitable for regions prone to seismic and wind hazards [5].

Traditionally, Conventional Steel Buildings (CSB) have been designed using hot-rolled sections such as ISWB and ISHB profiles, which are manufactured with uniform cross-sections along their entire length [6]. While these sections are readily available and conform to standardised specifications, they often lead to inefficient material utilisation because the bending moment distribution along a frame member is typically non-uniform, with maximum moments occurring at the supports or ridge locations [7][8]. Consequently, CSB designs frequently result in either over-designed sections in low-moment regions or require additional stiffening elements, leading to excessive steel consumption and higher overall project costs [9][10].

In response to these limitations, Pre-Engineered Buildings (PEB) have emerged as a technologically advanced alternative that optimises material utilisation through the use of tapered built-up sections [11][12]. Unlike conventional hot-rolled sections, PEB members are fabricated by welding together steel plates to create I-sections that vary in depth along the member length, precisely matching the structural demand curve defined by the bending moment diagram [13][14]. This concept, often summarised as "providing the required strength exactly where it is needed," enables significant reductions in steel weight without compromising structural integrity [15]. Additionally, PEB systems incorporate cold-formed secondary members (purlins, girts, and eave struts), factory-controlled prefabrication, and standardised connection details, which collectively reduce on-site labour requirements and accelerate project completion by 30–40% compared to conventional construction methods [16][17].

The structural superiority of PEB systems over CSB has been extensively documented in the technical literature. Zende et al. [18] demonstrated that PEB designs can be 25% lighter than conventional steel frames in multi-storey configurations, while enabling clear spans up to 90 meters that remain uneconomical for standard frames. Lande and Kucheriya [19] reported that three-dimensional PEB structures achieved approximately 35% weight reduction compared to conventional systems, with roof structures alone showing nearly 30% savings. Similarly, Shipa Kewate and Neha Kolate [20] found CSB to be approximately 26% heavier than PEB for identical industrial warehouse configurations. More recent investigations by Londhe et al. [21] indicated that material optimisation in PEB reduces steel consumption by nearly 40.67%, with construction time reduced by 30–40% due to prefabrication techniques. Tagade and Shah [22] confirmed a 26% reduction in steel weight for PEB compared to CSB, concluding that PEB offers a more cost-effective, flexible, and sustainable alternative for modern industrial structures.

Despite the evident advantages of PEB technology, the adoption of these systems in India and other developing nations has been gradual, primarily due to higher initial fabrication costs, limited availability of specialised design expertise, and the entrenched practice of using conventional steel sections [23][24]. Furthermore, while numerous comparative studies have examined PEB and CSB performance under either seismic or wind loads, relatively few investigations have systematically evaluated both lateral load types simultaneously, particularly for structures located in low-to-moderate seismic zones such as Zone II of the Indian seismic classification [25][26]. This gap is significant because the relative criticality of wind versus seismic loads varies substantially with geographic location, building geometry, and local climatic conditions [27].

The present study addresses this knowledge gap by conducting a comprehensive comparative analysis of Pre-Engineered Buildings and Conventional Steel Buildings designed for an industrial warehouse located in Jagdalpur, Chhattisgarh, India. The specific objectives of this research are: (1) to model, analyse, and design both PEB and CSB systems using STAAD.Pro V8i software in accordance with relevant Indian Standards (IS:800-2007 for steel design, IS:875 Parts 1–3 for loads, and IS:1893-2016 for seismic analysis); (2) to compare the structural performance of both systems in terms of displacement behavior, internal force distribution, and member stresses under various load combinations; (3) to quantify the steel consumption and material efficiency of each system; (4) to determine whether wind or seismic load combinations govern the design for this specific building typology and location; and (5) to evaluate

the effect of column flange thickness variations on the overall stiffness and displacement response of the PEB system.

The novelty of this work lies in its systematic comparison of PEB and CSB under both seismic (Zone II) and wind loads (basic wind speed of 39 m/s) for a building configuration with 15 m width, 45 m length, 8.5 m eave height, and 7.5 m bay spacing. Additionally, this study presents a validated methodology through manual calculation verification of software results, ensuring the reliability and applicability of findings for practical engineering design. The outcomes of this research are expected to provide valuable guidance for structural engineers, project planners, and policymakers in selecting appropriate steel framing systems for industrial construction, with particular emphasis on balancing structural safety, material efficiency, and economic viability.

II. LITERATURE REVIEW

This literature review has been carried out by various books, research papers, journals, and reliable online sources to understand the concepts of PEB and CSB.

Zende et al. (2013) define Pre-Engineered Buildings (PEB) as factory-fabricated structures using tapered sections to optimise material according to bending moments. Research shows PEB systems reduce construction time by 40% and offer superior strength-to-weight ratios compared to conventional steel. STAAD Pro analysis indicates PEB designs can be 25% lighter than conventional counterparts in multi-storey contexts. Furthermore, PEB enables clear spans of 90m, which is generally uneconomical for standard frames. The study concludes PEB is the most efficient, sustainable solution for industrial spaces requiring vast column-free areas

D.V.Swathi (2014) found that the pre-engineered steel structures provides high strength, low construction cost, flexibility and durability in design. Their paper explains the design comparison between the 2D plane frame of PEB structures and the CSB structures. The plane frame has a length of 50 m, width of 38.1m, eave height of 7.2 m, roof slope 1 in 10 and bay spacing of 6.25 m. On the basis of analysis and design results, the pre-engineered buildings depends on the bay Spacing. With a certain amount of increase in bay spacing the weight decreases compared to CSB and any subsequent increase leads to a heavier weight.

Shipa Kewate and Neha R. Kolate (2015) examined the need for long-span industrial structures. They investigated the benefits of PEB as a solution. The authors designed an example of a PEB using a Triangular Pratt Truss for a steel frame with a span of 60m and 30m bay spacing. Three different bay spacings were designed (i.e., 4m, 5m, and 6m), each with a length of 60 m. The eave height for all designs was 10m. An EOT crane was also designed to be supported

at an elevation of 8m from the ground. All designs were generated and analysed with the help of STAAD.Pro V8i. The authors compared the analyses and designs of PEB with conventional steel buildings. Their research showed that CSB are approximately 26% heavier than PEB.

Subashini and Valentina (2015) evaluates the structural efficiency of Pre-Engineered Buildings (PEB) against Conventional Steel Buildings (CSB). Utilising STAAD Pro V8i for comparative analysis, the study highlights that PEBs employ tapered I-sections optimised for specific bending moments. Results demonstrate that PEB roof structures are 26% lighter and 30% more cost-effective than CSBs, facilitating 30% faster project completion. Furthermore, PEBs offer superior earthquake resistance and enable clear spans up to 90m. The study concludes that reduced support reactions in PEBs allow for economical foundation designs

Lande and Kucheriya (2015) carried out a comparative study between Pre-Engineered Buildings (PEB) and Conventional Steel Buildings (CSB) for an industrial warehouse using STAAD.Pro. Their research focused on structural efficiency, economy, and weight optimisation in accordance with Indian Standards and MBMA provisions. The study found that PEB systems, with tapered built-up sections and cold-formed members, achieved significant steel savings compared to CSB. Results indicated that 3D PEB structures were approximately 35% lighter than conventional systems, while PEB roof structures were nearly 30% lighter. The authors also highlighted the advantages of reduced construction time, improved fabrication efficiency, and adaptability for long-span industrial applications. Their findings established PEB as a more economical and practical solution for modern industrial construction when compared to conventional steel systems.

Meena Sai Lakshmi et al. (2015) conducted a comparative study on Pre-Engineered Buildings (PEB) and Conventional Steel Buildings (CSB) for industrial applications under static and dynamic loading conditions. Using STAAD Pro V8i, the authors analysed structures with varying roof slopes and evaluated their performance under dead, live, wind, and seismic loads. The study reported that PEB systems required significantly less steel than CSB, with steel consumption reduced to nearly 62% for a 5.71° roof slope and 59.35% for a 7.125° roof slope. The research concluded that PEB offers improved structural efficiency, reduced weight, faster construction, and better resistance to seismic forces, making it a practical alternative for industrial buildings.

N.C. Dubey and Swati Wakachaure (2016) revealed many benefits of the PEB system compared to the CSB system. For instance, The tapered sections of PEBs can reduce the amount of steel used to build them. Using IS 800-1984 and IS:800-

2007, they analysed and designed the building. They chose to look at an 80m length by 60m width building that was 11.4 m in height with a 18° slope for the CSB and 5.76° slope for the PEB to conduct their analysis and design of the 2D frames. The authors measured the amount of steel in PEBs and CSBs independently for both IS:800-1984 and IS:800-2007. They find that the CSB was approximately 30% heavier than the PEB.

Sudhir and Yash (2017) carried out a comparative analysis of Pre-Engineered Buildings (PEB) and Conventional Steel Buildings (CSB) for industrial warehouse applications using STAAD Pro. Their findings showed that PEB reduced steel consumption by an average of 30% compared to CSB, with savings of 28.6% for 10 m span, 33.34% for 20 m span, and 29.62% for 30 m span structures. Cost analysis further indicated that PEB systems were approximately 30% more economical due to reduced material usage and lighter foundations. However, for spans beyond 40 m, the percentage savings decreased significantly to 1.17%–2.7%, suggesting that PEB is most beneficial for small to medium spans.

Shashank and Sachin (2017) compares pre-engineered buildings (PEB) with conventional steel structures (CSB) for an industrial warehouse. Using STAAD Pro, the analysis found that PEBs achieved a 33% reduction in structural weight compared to CSB. Cold-formed Z-sections in PEB contributed only 38.4% of dead load versus 55.22% for hot-rolled sections. Consequently, the total cost of PEB was 20.26% lower than that of CSB. The study concludes that optimising member sections based on load magnitude significantly enhances economy, recommending PEB as a lighter, more efficient alternative to conventional steel construction.

Hemant Sharma (2017) conducted an analysis and design comparison of PEB and CSB using STAAD.Pro V8i. Their study compares industrial buildings for bending moments at various locations of members, and the outcomes are contrasted for construction time and cost savings. Following analysis and design report concludes that PEB saves 37% more material than CSB.

Shalu Assis (2019) compares pre-engineered buildings (PEB) with conventional steel buildings (CSB) for industrial structures. Using STAAD Pro, the analysis showed that PEB resulted in a 30% reduction in steel take-off compared to CSB. For varying spans (50m, 60m, 70m), PEB consistently achieved lower gross weight; for example, at 50m span, PEB weighed 104.63 tonnes versus CSB at 172.42 tonnes (approx. 39% lighter). For multi-storied models (G+1 to G+3), PEB also proved lighter. The study concludes PEB is highly suitable for large spans and multi-storied buildings, offering significant material savings.

Chhajed and Mulay (2020) analysed pre-engineered buildings (PEB) using Indian (IS 800:2007) and American (AISC) codes, highlighting efficiency and cost benefits. Their study showed that AISC-based designs reduce structural weight by approximately 10–15% compared to IS codes, mainly due to relaxed serviceability and deflection criteria. Additionally, cost analysis indicated nearly 8–12% savings when using AISC provisions. The authors emphasised that PEB systems improve construction speed by about 30% and material efficiency by 20%, making them a preferred choice for long-span industrial structures. Overall, the literature supports PEB as an economical and sustainable alternative

Patil and Choudhary (2021) performed a structural and cost comparative analysis between Pre-Engineered Buildings (PEB) and Conventional Steel Buildings (CSB) situated in high seismic and cyclonic zones. Utilising STAAD.Pro V8i, the researchers modelled a 48m length and 16m width industrial shed to evaluate steel consumption and structural performance. Their findings demonstrate that CSB systems are approximately 50% less economical than PEB in both substructure and superstructure. Additionally, the PEB structure exhibited a 70% reduction in base shear because its superstructure members efficiently carry horizontal loads, thereby reducing the need for heavy substructures. The study concludes that PEB technology offers superior rigidity, faster construction through factory pre-fabrication, and significant cost savings, with total steel weight and costs reaching only 40% of conventional standards.

Swetha Pantheeradi and Susan Abraham (2022) Recent evaluated Pre-engineered Buildings (PEB) vs Conventional Steel Buildings (CSB), emphasising a shift toward more efficient industrial construction. Research indicates that PEB methodology, which utilises tapered built-up sections and factory-controlled prefabrication, significantly reduces material consumption. A comparative analysis of a warehouse designed via STAAD.Pro demonstrated that PEB structures can achieve a 45% reduction in total steel weight compared to CSB. Structurally, however, PEB frames often experience higher bending moments and shear forces at ridges and haunches because forces are concentrated in the frame rather than distributed through a traditional truss system. While PEB offers advantages in faster construction, better quality, and architectural flexibility, CSB remains preferred for smaller spans or projects with limited initial funding where local materials are accessible. Consequently, while PEB is gaining dominance in the Indian market, both systems remain relevant depending on specific project constraints.

Chetan Tagade and Jigar Shah (2023) Their research paper explores the structural and economic differences between PEB against CSB. By using STAAD.Pro for analysis and

design, the authors compare industrial frames of various dimensions while adhering to IS:800 - 2007 and AISC design codes. This study evaluates the critical factors such as dead load, live load, and wind loads to determine the performance of both systems. Findings indicate that PEB construction is significantly more efficient, offering a 26% reduction in steel weight compared to CSB. Ultimately, the source concludes that PEB structures provide a more cost-effective, flexible, and sustainable alternative for modern industrial structures.

Bharmal and Kumbhar (2023) conducted a comparative analysis and design of PEB and CSB, with varying bracing types (Diagonal, V, X, and K types) and considering Medium soil type and seismic zone II for determining displacement and natural time period. Findings showed that the natural time period and the displacement of the pre-engineered buildings with diagonal bracing decreased by 28.02% and 17.39%, respectively, compared with the corresponding results of the conventional steel buildings.

N. S. Raman and Ketki V. Meshram (2023) Described that the design methodology of steel structures, the pre-engineered building is a modern technology that provides economical, safe and sustainable structures. The pre-engineered buildings is a modern concept of single-story industrial buildings construction. This type of structure can be highly versatile. They suggested it is effectively pre-designing, pre-fabrication, lightweight, as well as its low construction cost. Light construction implies that PEB has many advantages over the CSB concept of trussed roof buildings. This study was conducted by designing a warehouse building as PEB and as CSB with the help of STAAD.Pro V8i. The CSB is designed and analysed by IS:800-2007 (LSM) and PEB is designed and analysed by AISC 360:10.

Awais Iqbal and Dr. B.H. Shinde (2023) Their research paper represents a technical comparison between PEB and CSBs, focusing on their structural efficiency and economic viability. By analysing an industrial structure in Amravati (MAHARASHTRA) using STAAD.Pro V8i, the authors examine how off-site fabrication and tapered sections in PEBs differ from the on-site assembly of the traditional steel frame systems. The findings demonstrate that PEB frame systems are significantly more advantageous over CSB, requiring 40% less steel and reducing overall construction costs by the same margin. While PEBs exhibit higher bending moments due to their unique geometry, they result in lower support reactions, allowing for more affordable foundation designs. Ultimately, PEB offer a more sustainable alternative for modern industrial applications due to their fast construction and material efficiency.

Pratik M. Londhe and Priyanka R. Dhumal (2024) Their research paper presents a comparative study between PEB and CSB within the context of the Indian construction industry. The authors point out that PEB systems offer a vital alternative to traditional steel structure construction methods by utilising factory-prefabricated components that allow for quicker assembly, faster construction and more efficient material use. Through a detailed industrial case study, the study examines specific variables such as the material weight, transportation expenses and labour costs for both structural types. The findings demonstrate that while PEB structures require significant initial investment, they can achieve approximately 40.67% cost savings compared to CSB. Ultimately, the source advocates for the adoption of pre-engineered technology to address the rising demand for modern, sustainable, and high-quality infrastructure in remote and urban areas.

III. RESEARCH METHODOLOGY

The research methodology involves a comparative analysis of a hypothetical single-storey industrial warehouse model, developed with plan dimensions of 45 m × 15 m and a bay spacing of 7.5 m. The structure is analysed considering the environmental and loading conditions of Jagdalpur. The study contrasts a Pre-Engineered Buildings (PEB) system utilising tapered built-up sections against a Conventional Steel Building (CSB) using standard hot-rolled sections like ISWB and ISHB. Structural modelling, analysis and design are performed by using STAAD.Pro V8i. The design process adheres to Indian Standards, specifically IS:800-2007 for general steel construction, IS:875 (Parts 1-3) for dead load, live load, wind loads, and IS:1893-2016 for seismic analysis. An iterative process of workflow is employed, involving the creation of geometry, material assignment, and refined member design to ensure structural adequacy. Both structures are subjected to various load combinations to evaluate parameters such as displacement, internal forces, and total steel consumption. To ensure accuracy, software results for column reactions are validated through manual calculations, with differences found to be within acceptable limits. Furthermore, two specific trials were conducted for the PEB model, varying the column flange thickness to optimise stiffness and material utilisation.

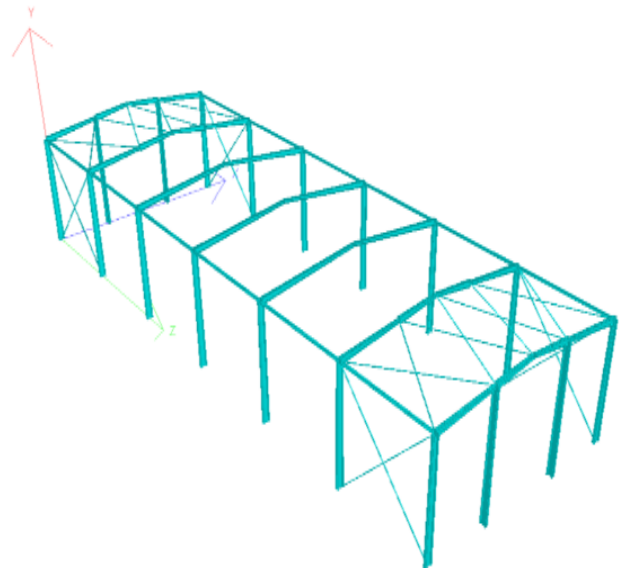


Figure 1: PEB 3D Mode

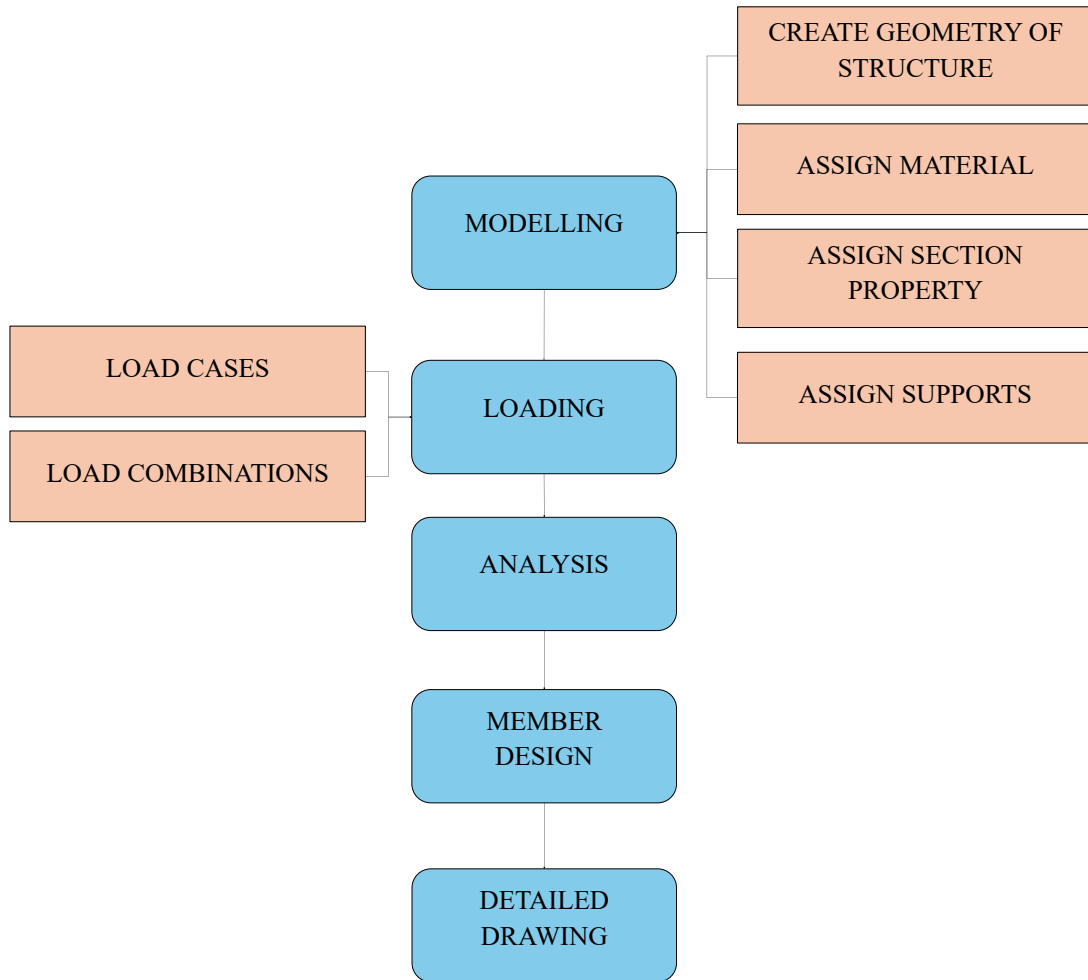


Figure 2: Process of Design

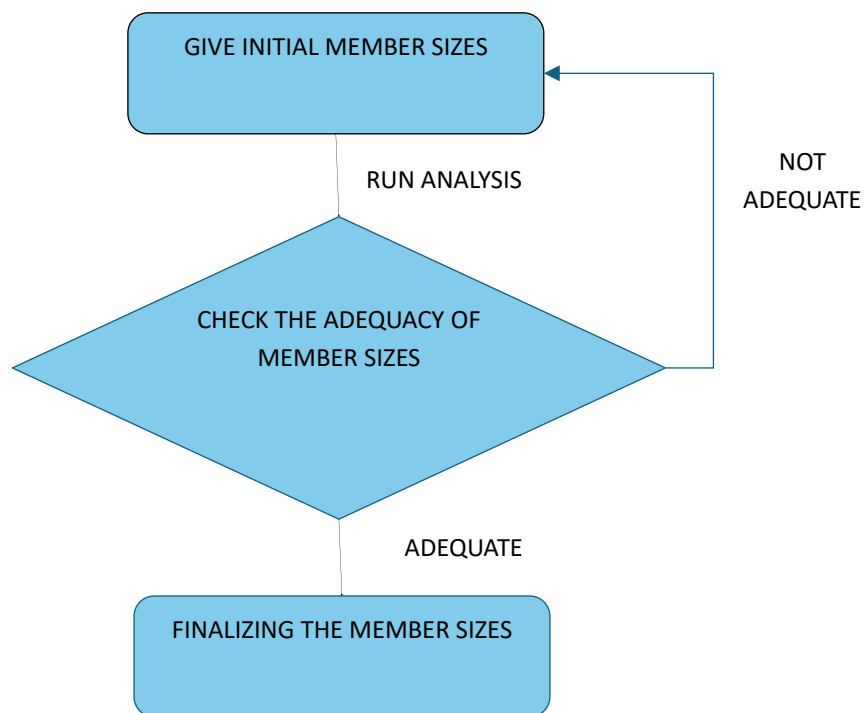


Figure 3: Iterative Process of Member Design

IV. STRUCTURAL PARAMETERS

Table 1: Structural Parameters

S.NO.	PARAMETERS	DETAILS
1	Building type	Industrial building
2	Structure type	Single-story industrial building
3	Location	Jagdalpur
4	Total length	45m
5	Width	15m
6	Bay spacing	6@7.5m
7	Eave height	8.5m
8	Story height	9.5m
9	Support condition	PEB - Fixed, CSB - Fixed
10	Slope	1:7.5
11	Wind speed	39m/s

S.NO.	COMPONENTS	DEAD LOAD (kN/m ²)
1	G.I. roof sheet	0.055
2	Purlin & Girt	0.055
3	Accessories	0.040

Dead Load on Structural Members

- Dead load on internal rafter = $0.15 \times 7.5 = 1.125 \text{ kN/m}^2$
- Dead load one end rafter = $0.15 \times (7.5/2) = 0.562 \text{ kN/m}^2$
- Dead load on internal column = $0.15 \times 7.5 = 1.125 \text{ kN/m}^2$

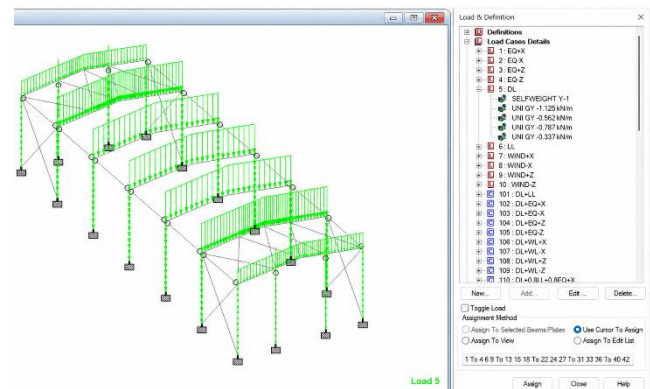


Figure 5: Dead Load Assigned

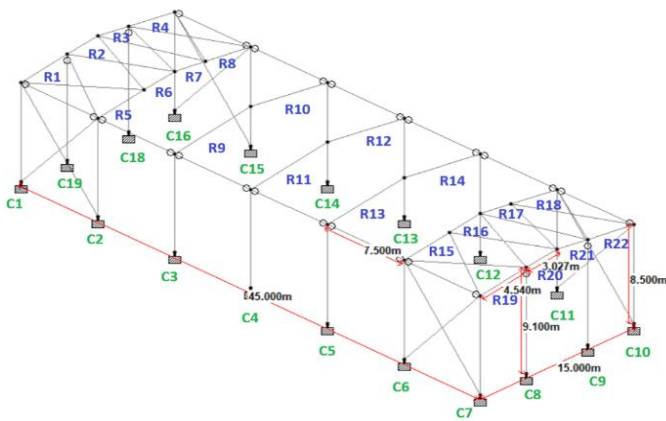


Figure 4: Model of Structure

V. LOAD CALCULATION

A. Dead Load

Dead load is a permanent static load that acts on a structure throughout its service life. Dead load is applied to primary structural members such as columns and rafters in the form of uniformly distributed loads. This includes the self-weight of steel members, purlins, roof sheeting, bracing, and thin fibreglass sheets.

Dead load is computed in accordance with IS: 875 (Part 1)-1987

Table 2: Dead Load Of Components

B. Live Load

Live load is a temporary load acting on a structure. Intensity and direction of this load change with time. Repair workers and movable equipment are examples of live loads. As per IS 875 (Part 2):1987, for a roof slope up to 10 degrees, the minimum roof live load is 0.75 kN/m^2 .

Live load is calculated in accordance with IS 875 (Part 2):1987

- Live load on internal rafter = $0.75 \times 7.5 = 5.625 \text{ kN/m}^2$
- Live load on end rafter = $0.75 \times (7.5/2) = 2.812 \text{ kN/m}^2$

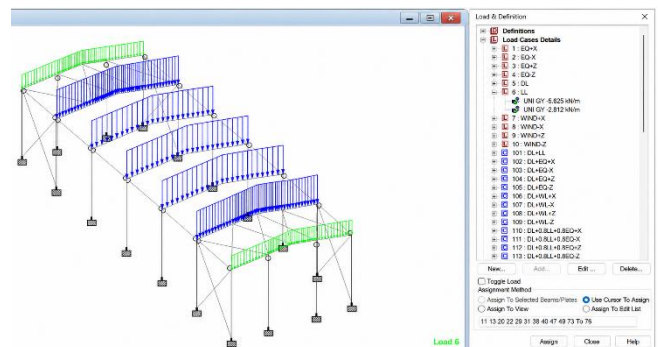


Figure 6: Live Load Assigned

C. Wind Load

Wind loads are forces that act horizontally and vertically on a structure by wind due to air pressure. Wind load generally represents the suction and pressure effects on the structure produced by wind acting on it. Wind load depends on many factors such as building height, shape and size of building, terrain categories and pressure coefficients.

Wind load is computed in accordance with IS: 875 (Part 3)-1987

- Basic Wind speed(V_b) = 39m/s
- Probability factor(K_1) = 1
- Terrain category(K_2) = 1
- Topography factor (K_3) = 1
- Importance factor(K_4) = 1.15
- Design wind speed(V_z)

$$= V_b \times K_1 \times K_2 \times K_3 \times K_4$$

$$= 44.85 \text{ m/s}$$

- Wind pressure(P_z) = $0.6(V_b)^2$
- $$= 0.6(44.85)^2 = 1.206 \text{ kN/m}^2$$

- Wind directionality factor (K_d) = 0.9
- Area averaging factor(K_a) = 0.848
- Combination factor(K_c) = 0.9

- Design wind pressure(P_d)
- $$= K_d \times K_a \times K_c \times P_z$$
- $$= 1 \times 0.848 \times 1 \times 1.206$$
- $$= 0.828 \text{ kN/m}^2$$

[Reduce 20 % as per IS 875(Part – 3):2015 Clause 6.3]

$$= 0.662 \text{ kN/ m}^2$$

$$\therefore P_d \leq 0.7P_z \Rightarrow P_d = 0.85 \text{ kN/ m}^2$$

- Internal Pressure Coefficient (C_{pi}) = ± 0.2
- External Pressure Coefficient(C_{pe})
- Ratio of H/W = 0.63
- Ratio of L/W = 3
- Wind Load (F) = $(C_{pe} - C_{pi}) \times A \times P$

Where A =surface area of structural element or cladding unit

• Wind load on surface with positive C_{pi} and negative C_{pi}

When wind flows inside the building through openings, such as windows and doorways, a positive internal pressure coefficient(C_{pi}) occurs. The trapped air enhances the internal pressure, which acts outward on the roof and wall surfaces. The positive internal pressure coefficient(C_{pi}) adds with external pressure (C_{pe}), generally increases the uplift on roof elements and outward force acts on cladding.

When wind creates suction inside the building due to openings such as roof vents and the leeward side of a building, a negative internal pressure coefficient (C_{pi}) occurs. In such a situation, there appears to be a reduction in internal air pressure compared to external air pressure, leading to a net force acting on roofs and walls of buildings. Negative internal pressure coefficient (C_{pi}) increases roof uplift and wall suction when combined with external pressure coefficients (C_{pe})

Table 3: Wind Loads

Surface	Wind+X $\theta = 0^\circ$ (kN/m ²)	Wind-X $\theta = 90^\circ$ (kN/m ²)	Wind+Z $\theta = 180^\circ$ (kN/m ²)	Wind-Z $\theta = 270^\circ$ (kN/m ²)
A	5.737	-3.187	-4.462	-4.462
B	3.187	-5.737	4.462	4.462
C	-4.016	-4.016	4.016	-1.338
D	4.016	4.016	1.338	-4.016
EF	7.012	5.100	-	-
GH	5.100	7.650	-	-
EG	-	-	7.012	5.100
FH	-	-	5.100	7.012

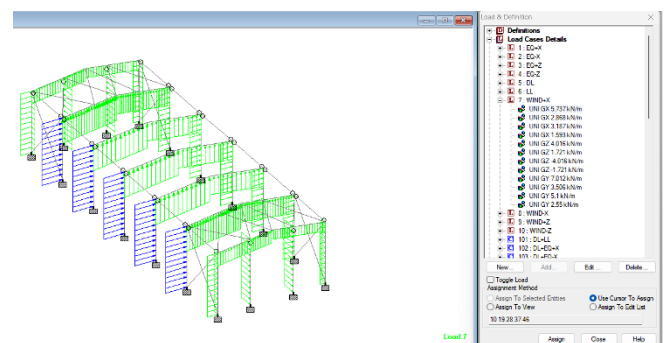


Figure 7: WIND+X Direction

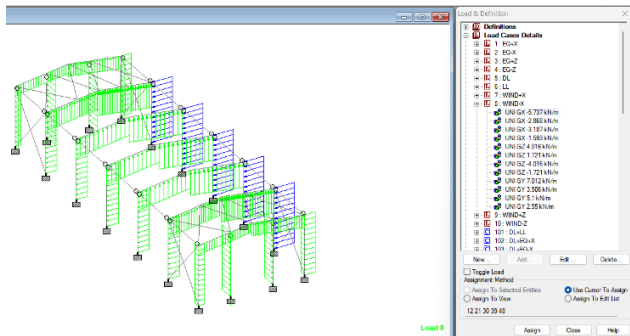


Figure 8: WIND-X Direction

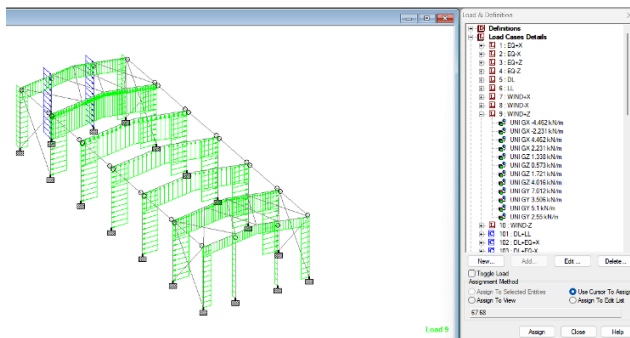


Figure 9: WIND+Z Direction

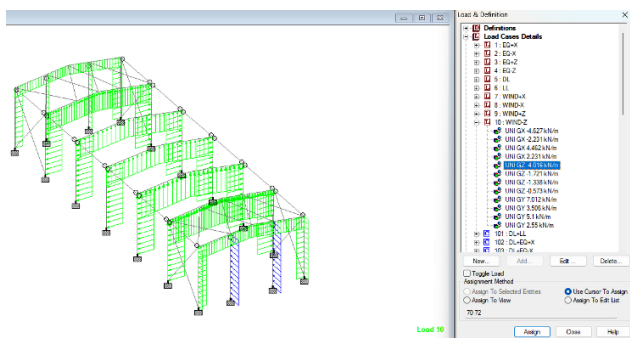


Figure 10: WIND-Z Direction

D. Earthquake Load

Earthquake load is calculated in accordance with IS 1893 (Part 1):2016

Table 4: Earthquake Factor

S.No.	Description	Details
1	Zone(Z)	II
2	Response factor(R)	4
3	Importance factor(I)	1.5
4	Damping Ratio(R)	4
5	Soil category	Medium
6	Sa/g	2.5

- Natural Time Period of the Structure(T_a)

$$T_a = 0.085h^{0.75}$$

$$= 0.085 \times 8.5^{0.75}$$

$$= 0.423 \text{Sec}$$

- Design horizontal seismic coefficient (A_h)

$$A_h = \frac{Z}{2} \times \frac{I}{R} \times \frac{S_a}{g}$$

$$= \frac{0.1}{2} \times \frac{1.5}{4} \times 2.5$$

$$= 0.0469$$

- Design base shear(V_b)

$$v_b = A_h W$$

$$v_b = 0.0469 \times 104.472$$

$$v_b = 4.9 \text{ KN}$$

where,

v_b = Design base shear (kN)

W = Total seismic weight of the structure (kN)

VI. LOAD COMBINATIONS

The load combination ensures the structural safety for different possible combinations of loads when they may act simultaneously on a structure during its service period. This combination accounts for uncertainties in the magnitude of the loads and structural behaviour through the application of suitable load factors.

The load combinations are considered in accordance with IS: 800 - 2007.

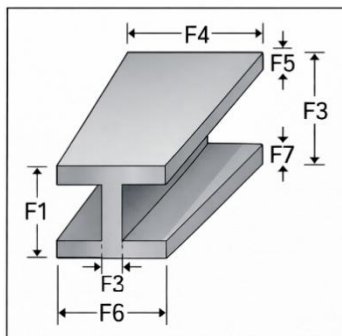
Table 5: Load Combinations

S.NO.	Limit State of Collapse	Limit State of Serviceability
1	1.5DL+1.5LL	DL+LL
2	1.2DL+1.2LL+1.2EQ+X	DL+EQ+X
3	1.2DL+1.2LL+1.2EQ-X	DL+EQ-X
4	1.2DL+1.2LL+1.2EQ+Z	DL+EQ+Z
5	1.2DL+1.2LL+1.2EQ-Z	DL+EQ-Z
6	1.2DL+1.2LL+1.2WL+X	DL+WL+X
7	1.2DL+1.2LL+1.2WL-X	DL+WL-X
8	1.2DL+1.2LL+1.2WL+Z	DL+WL+Z
9	1.2DL+1.2LL+1.2WL-Z	DL+WL-Z
10	1.5DL+1.5EQ+X	DL+0.8LL+0.8EQ+X

11	1.5DL+1.5EQ-X	DL+0.8LL+0.8EQ-X
12	1.5DL+1.5EQ+Z	DL+0.8LL+0.8EQ+Z
13	1.5DL+1.5EQ-Z	DL+0.8LL+0.8EQ-Z
14	0.9DL+1.5EQ+X	DL+0.8LL+0.8WL+X
15	0.9DL+1.5EQ-X	DL+0.8LL+0.8WL-X
16	0.9DL+1.5EQ+Z	DL+0.8LL+0.8WL+Z
17	0.9DL+1.5EQ-Z	DL+0.8LL+0.8WL-Z
18	1.5DL+1.5WL+X	-
19	1.5DL+1.5WL-X	-
20	1.5DL+1.5WL+Z	-
21	1.5DL+1.5WL-Z	-
22	0.9DL+1.5WL+X	-
23	0.9DL+1.5WL-X	-
24	0.9DL+1.5WL+Z	-
25	0.9DL+1.5WL-Z	-

	F3	320 mm	324 mm	210 mm	112 mm
	F4	200 mm	200 mm	180 mm	180 mm
	F5	10 mm	12 mm	10 mm	6 mm
	F6	200 mm	200 mm	180 mm	180 mm
	F7	10 mm	12 mm	10 mm	6 mm
CSB	-	ISHB350		ISWB300	ISHB300

VII. GEOMETRY OF MEMBERS



- F1 (Depth of Section at Start No)
- F2 (Thickness of Web)
- F3 (Depth of Section at End Noc)
- F4 (Width of Top Flange)
- F5 (Thickness of Top Flange)
- F6 (Width of Bottom Flange)
- F6 (Width of Bottom Flange)
- F7 (Thickness of Bottom Flange)

Material
 STEEL

Table 6: Geometry Of Members

Buildi ng Type	Descri ption	Column	Rafter	Eave Strut
	-	PEB-1	PEB -2	-
PEB	F1	420 mm	424 mm	420 mm
	F2	8 mm	8 mm	6 mm

VIII. VALIDATION OF 1ST TRIAL

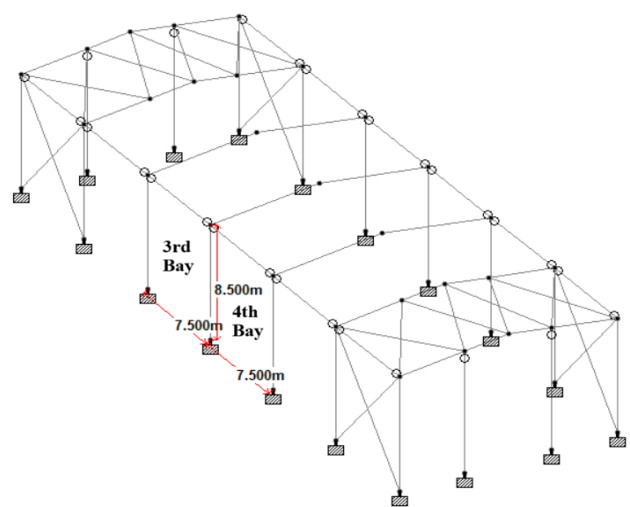


Figure 11: Model of Trial Section

Data

- Width of frame (B) = 15 m
- Bay Spacing (b) = 7.5 m
- Eave Height (h) = 8.5 m
- Dead Load (DL) = 0.15 kN/m²
- Live Load (LL) = 0.75 kN/m²

Step 1: Calculate dead load on rafter

Dead load on rafter (DL₁)

$$\begin{aligned}
 &= \text{Dead load of components} \times \frac{\text{Spacing of 3rd bay}}{2} \times \frac{\text{Spacing of 4th bay}}{2} \times \frac{\text{Width of frame}}{2} \\
 &= 0.15 \times \frac{7.5}{2} \times \frac{7.5}{2} \times \frac{15}{2} \\
 &= 8.437 \text{ kN}
 \end{aligned}$$

Step 2: Calculate dead load on column

Dead load on column (DL₂)

$$= \text{Dead load of components} \times \frac{\text{Spacing of 3rd bay}}{2} \times \frac{\text{Spacing of 4th bay}}{2} \times \text{Eave height}$$

$$= 0.15 \times \frac{7.5}{2} \times \frac{7.5}{2} \times 8.5$$

$$= 9.562 \text{ kN}$$

Step 3: Calculate the total dead load (self-weight) of members

Dead load (Selfweight) of members

$$= \text{Column} + \text{Rafter} + \text{Eave Strut}$$

Dead load (Selfweight) of PEB members (SW_{PEB})

$$= 4.45 + 3.12 + 1.07$$

$$= 8.640 \text{ kN}$$

Dead load (Selfweight) of CSB members (SW_{CSB})

$$= 5.33 + 3.57 + 2.96$$

$$= 11.860 \text{ kN}$$

Step 4: Calculate total dead load (DL)

Total dead load on middle column base in PEB (DL_{PEB})

$$= \text{DL}_1 + \text{DL}_2 + \text{SW}_{\text{PEB}}$$

$$= 8.437 + 9.562 + 8.64$$

$$= 26.639 \text{ kN}$$

Total dead load on middle column base in CSB (DL_{CSB})

$$= \text{DL}_1 + \text{DL}_2 + \text{SW}_{\text{CSB}}$$

$$= 8.437 + 9.562 + 11.86$$

$$= 29.859 \text{ kN}$$

Step 5: Calculate total live load (LL)

Total live load on middle rafter (LL)

$$= \text{live load} \times \frac{\text{Spacing of 3rd bay}}{2} \times \frac{\text{Spacing of 4th bay}}{2} \times \frac{\text{Width of frame}}{2}$$

$$= 0.75 \times \frac{7.5}{2} \times \frac{7.5}{2} \times \frac{15}{2}$$

$$= 42.187 \text{ kN}$$

Step 6: Calculate column reaction due to factored (1.5DL+1.5LL)

Column reaction of PEB

$$= 1.5\text{DL}_{\text{PEB}} + 1.5\text{LL}$$

$$= 1.5 \times 26.639 + 1.5 \times 42.187$$

$$\text{Column reaction of PEB} = 103.239 \text{ kN}$$

Column reaction of CSB

$$= 1.5\text{DL}_{\text{CSB}} + 1.5 \text{ LL}$$

$$= 1.5 \times 29.859 + 1.5 \times 42.187$$

$$\text{Column reaction of CSB} = 108.069 \text{ kN}$$

The analysis results obtained from STAAD.Pro were validated by comparing them with manual calculations based on standard design procedures. Column reaction value given by STAAD.Pro is 104.472 kN (In PEB) and 108.816 kN (In CSB), and by manual calculation, 103.239 kN (In PEB) and 108.069 kN (In CSB) are obtained. The comparison indicates that the variation between software results and manual calculations is within acceptable limits. Minor differences are attributed to modelling assumptions, boundary conditions and numerical methods used in the software. Hence, the analysis was done by using STAAD.Pro is considerably accurate and reliable for the design of PEB and CSB.

IX. RESULTS

1st Trial

Table 7: Column Results Of 1st Trial

Description	Load Combination	PEB - 1		CSB	
		Member	Value	Member	Value
Maximum Displacement (X-Direction)	WIND+X	C4	53.760 mm	C4	49.927 mm
Axial Force/Support Reaction	1.5 DL +1.5 LL	C3, C4, C5, C12, C13, C14	104.472 kN	C3, C4, C5, C12, C13, C14	108.816 kN
Bending Moment (Z-Direction)	0.9 DL+1.5 WL+X	C4	305.900 kNm	C4	278.905 kNm

Trial 1: Column having an I- Section of dimension, at the start node flange 200mm × 10mm, web 400mm × 8mm and at end node flange 200mm × 10mm, web 300mm × 8mm.

Table 8: Rafter Results Of 1st Trial

Description	Load Combination	PEB - 1		CSB	
		Member	Value	Member	Value
Maximum Displacement (Y-Direction)	WIND+X /WIND -X	R9, R10, R13, R14	82.814 mm	R6, R7, R16, R17	72.168 mm
Axial Force	0.9 DL+1.5 WL-Z	R5, R8	59.910 kN	R15, R18	58.522 kN
Bending Moment	0.9 DL+1.5 WL+X	R11	190.300 kNm	R11	175.853 kNm
Shear Force (Y-Direction)	1.5 DL +1.5 LL	R5, R15, R18, R8	76.846 kN	R5, R15, R18, R8	77.951 kN

Table 9: Displacement Variations Of Different Components In 1st Trial

Component	Maximum Displacement Limit (IS:800 – 2007)	PEB - 1		CSB	
		Value	Maximum Displacement in %	Value	Maximum Displacement in %
Column	56.6 mm	52.087 mm	92.02 %	49.927 mm	88.20 %
Rafter	83.33 mm	82.814 mm	99.38 %	72.168 mm	86.60 %

2nd Trial

Table 10: Column Results of 2nd Trial

Description	Load Combination	PEB - 2		CSB	
		Member	Value	Member	Value
Displacement (X- Direction)	WIND+X	C4	45.974 mm	C4	49.927 mm
Axial Force/ Support Reaction	1.5DL+1.5 LL	C3, C4, C5, C12, C13, C14	105.466 kN	C3, C4, C5, C12, C13, C14	108.816 kN
Bending (Z-Direction)	0.9 DL+1.5 WL+X	C4	307.505 kNm	C4	278.905kNm

Trial 2: Column having I- Section of dimension, at the start node flange 200mm × 12mm, web 400mm × 8mm and at end node flange 200mm × 12mm,web 300mm × 8mm.

Table 11: Rafter Results of 2nd Trial

Description	Load Combination	PEB - 2		CSB	
		Member	Value	Member	Value
Displacement	WIND+X /WIND -X	R6, R7, R16, R17	75.712 mm	R6, R7, R16, R17	72.168 mm
Axial Force	0.9 DL+1.5 WL-Z	R15, R18	61.994 kN	R15, R18	58.522 kN
Bending Moment	0.9 DL+1.5 WL+X	R11	191.391 kNm	R11	175.853 kNm
Shear Force (Y- Direction)	1.5DL +1.5LL	R5, R15, R18, R8	76.449 kN	R5, R15, R18, R8	77.951 kN

Table 12: Displacement Variations Of Different Components In 2nd Trial

Component	Maximum Displacement Limit (IS:800 – 2007)	PEB - 2		CSB	
		Value	Maximum Displacement in %	Value	Maximum Displacement in %
Column	56.6 mm	45.972 mm	81.22 %	49.927 mm	88.2 %
Rafter	83.33 mm	75.712 mm	90.85 %	72.168 mm	86.60 %

Table 13: Steel Quantity (kg)

Description	PEB - 1	PEB - 2	CSB
Column	8296	9270	11250
Rafter	4466	4466	5095
Eave Strut	1956	1956	3654

Table 14: % Variation Of Steel Quantity

Building Type	Gross Weight of Steel (kg)	% Variation compared to CSB
CSB	19999	0 %
PEB - 1	14718	26.40 %
PEB - 2	15692	21.5%

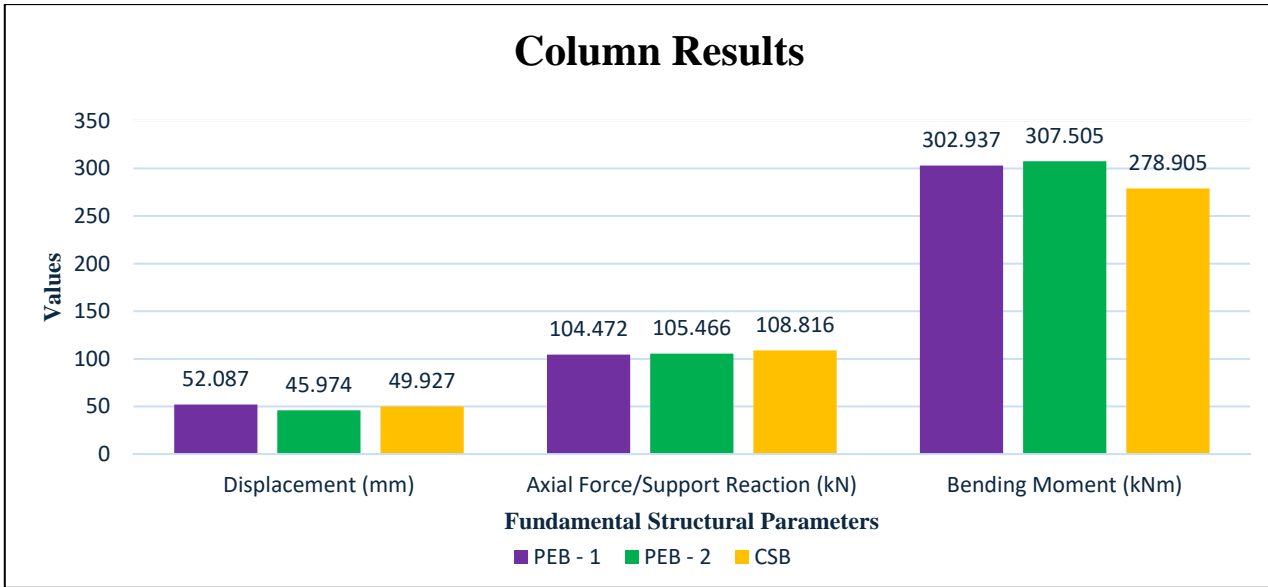


Figure 12: Column Results

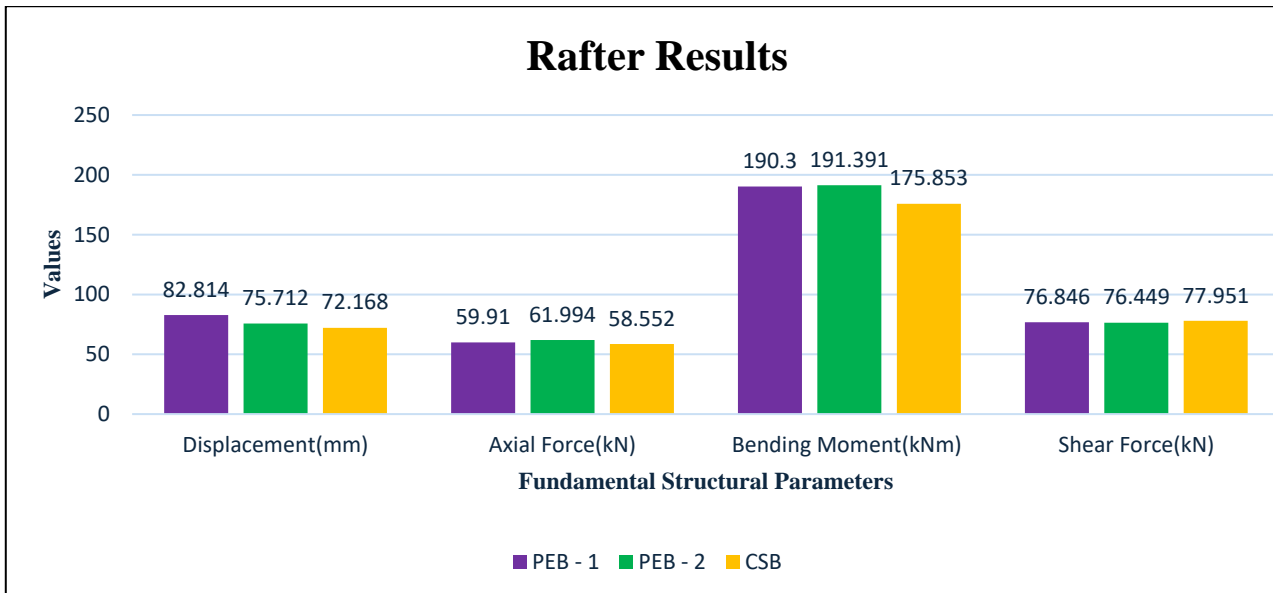


Figure 13: Rafter Results

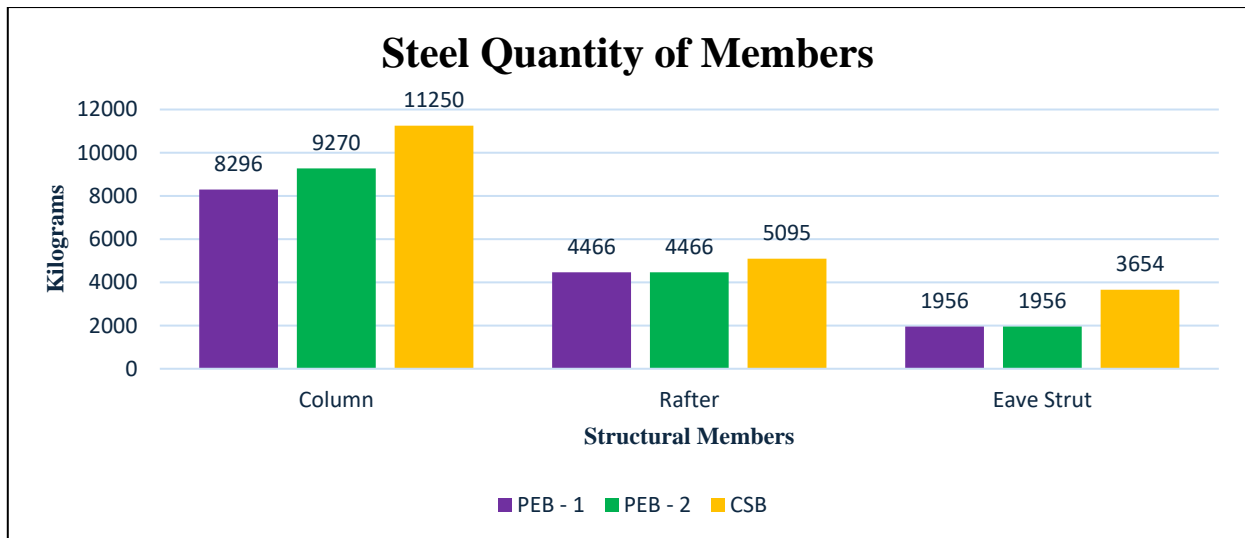


Figure 14: Steel Quantity of Members

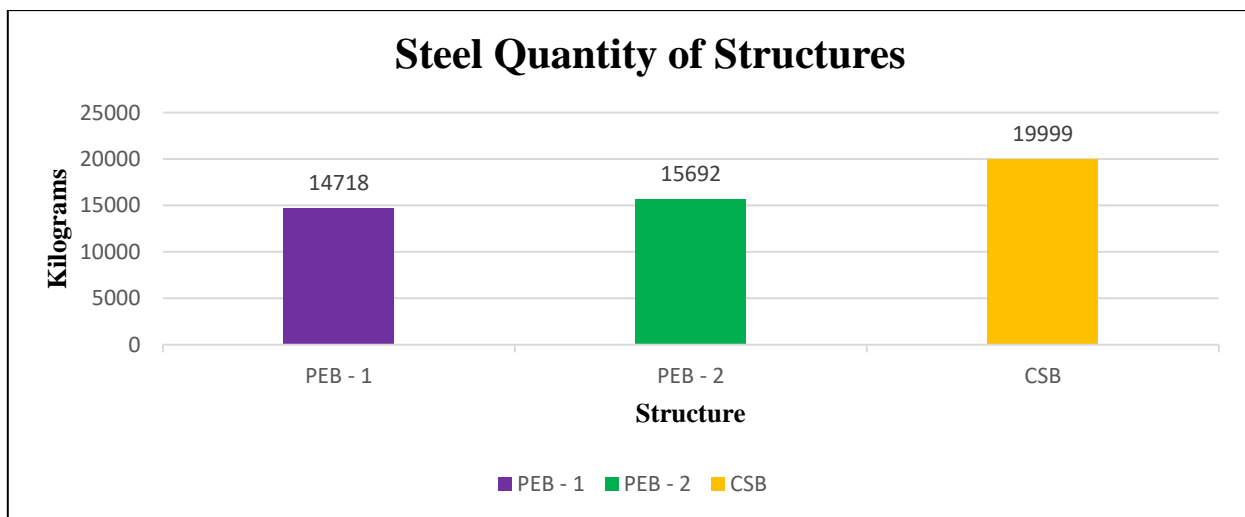


Figure 15: Steel Quantity of Structures

X. DISCUSSIONS

The analysis show that the utilisation ratio of most PEB members is near 0.9, which indicates better material utilisation. In comparison to the CSB, the total steel consumption in PEB-1 and PEB-2 is reduced by 26.4% and 21.50%, respectively.

The use of tapered built-up sections in PEB results in reduces steel quantities, as these members efficiently match the bending moment variation along the member length, whereas the CSB uses hot-rolled section members uniformly over the span.

Although PEB uses less steel, the displacement value do not exceed the permissible limit according to IS 800:2007. It exhibited adequate stiffness and structural stability. The study examines a particular building configuration; therefore, results may differ for varying height, spans and the loading condition.

XI. RESEARCH GAP

- Many studies have compared Pre-Engineered Buildings (PEB) and Conventional Steel Buildings (CSB) in terms of cost and steel quantity; limited research is available on the combined effects of seismic and wind loads.
- Most previous studies focus on single parameters such as weight reduction or economic benefits, but a comprehensive analysis including load combinations is lacking. Additionally, there is insufficient work on the optimisation of member sections in PEB under dynamic loading conditions.
- Further, very few studies consider real-life validation of software results with manual

calculations, especially for industrial buildings. Hence, there is a need for a detailed comparative study considering practical loading conditions, validation, and structural performance, which this research aims to address

XII. CONCLUSION

This study presented a comparative analysis of a pre-engineered buildings (PEB) and a conventional steel building (CSB) for a single-storey industrial structure subjected to seismic and wind loads. The comparison was performed with respect to displacement behaviour, internal force distribution, steel requirement, and the influence of different load combinations. Based on the analytical results obtained from the selected trials section, the following conclusions are drawn:

- From trials 1 and 2, based on the maximum displacement, the following conclusions are drawn. firstly, trial 1 achieved PEB vs CSB the maximum displacement against safe value (as per IS:800 – 2007) for column as 92.02 %, and rafter as 99.38%. Trial 2 achieved PEB vs CSB the maximum displacement against safe value (as per IS:800 – 2007) for column as 81.22%, and rafter as 90.85%.
- The only difference between Trial 1 and Trial 2 was the column flange thickness, which was increased from 10 mm to 12 mm. This increase of 2 mm led to a reduction in displacement of up to 10.78% in the columns and 8.53% in the rafters. This shows that a relatively small increase in flange thickness can significantly improve the stiffness of the structure and reduce lateral deformation in column and rafter.
- The axial force in the rafters of PEB-1 and PEB-2 was found to be 2.30% and 5.60% higher, respectively, than that in the CSB rafter. This increase may be attributed to the sloping geometry of the PEB frame, which introduces additional thrust in the rafter members, as well as to the redistribution of forces within the members of PEB framing system.
- A significant reduction in steel consumption was observed in the PEB system. The steel quantity required for PEB-1 and PEB-2 was 26.4% and 21.50% lower, respectively, than that required for the CSB. This confirms that the PEB structure of tapered built-up sections has better material efficiency than CSB.
- From the application of various load combinations, it is significantly observed that wind load combinations are more critical than seismic load combinations. This clearly indicates that, for this type of single-storey industrial building, wind

effects govern the design of structure more than earthquake effects.

Overall, the comparative study shows that, for the chosen structure geometry and loading conditions, the PEB system is structurally more efficient and economically advantageous in comparison with the CSB system. Both systems satisfy the relevant strength and serviceability requirements. However, the PEB achieves these requirements with lower steel consumption and better material utilisation. In addition, the reduced self-weight of the PEB causes reduced loading on the foundation. The foundation size of PEB structure will be significantly smaller compared to the foundation of CSB under similar soil conditions. Thus, for the specific case considered in this study, the pre-engineered buildings system emerges as a more economical and practical alternative to the conventional steel building system.

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