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Study and Analysis of Pre-Engineered Building with Respect to Conventional Steel Building

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ABSTRACT: Rapid industrialization and the growing demand for economical and fast-track construction have increased the use of steel structures in industrial buildings. Pre-Engineered Buildings (PEB) have emerged as an efficient alternative to Conventional Steel Buildings (CSB) due to optimized material utilization, reduced construction time, and lower overall cost. This study presents a comparative analysis of PEB and CSB systems for an industrial shed under identical loading and geometric conditions using STAAD Pro software. Both structures were analyzed under dead load, live load, wind load, and seismic load according to Indian Standards. Structural response parameters such as bending moment, shear force, displacement, support reactions, and steel quantity were evaluated. Results indicate that PEB structures exhibit significantly lower self-weight, reduced foundation reactions, improved serviceability performance, and lower overall project cost compared to CSB systems. The study demonstrates that PEB systems provide approximately 8.37% overall cost savings along with better structural efficiency, making them suitable for modern industrial applications.

KEYWORDS: Pre-Engineered Building, Conventional Steel Building, STAAD Pro, Structural Analysis, Steel Optimization, Industrial Shed.

I. INTRODUCTION

Industrial development and infrastructure expansion have increased the need for lightweight, economical, and rapidly constructed structural systems. Steel structures are widely preferred in industrial applications because of their high strength-to-weight ratio, durability, recyclability, and ease of construction. Traditionally, industrial sheds and warehouses were constructed using Conventional Steel Buildings (CSB) employing hot-rolled standard sections such as ISMB and ISWB sections.

However, Conventional Steel Buildings often utilize uniform sections throughout the structure irrespective of actual force demand, resulting in increased steel consumption and higher dead load. To overcome these limitations, Pre-Engineered Buildings (PEB) were introduced as an optimized steel construction system. In PEB structures, members are fabricated using tapered built-up sections that follow the actual bending moment distribution, leading to efficient utilization of steel.

PEB systems consist of tapered rafters and columns, cold-formed purlins and girts, roof and wall cladding systems, and bracing components fabricated in factory-controlled conditions. These buildings offer advantages such as reduced structural weight, lower foundation cost, improved quality control, and shorter construction duration.

The present study aims to compare the structural and economic performance of PEB and CSB systems under identical loading and geometric conditions using STAAD Pro analysis software.

II. LITERATURE REVIEW

Several researchers have investigated the structural behavior and optimization potential of Pre-Engineered Buildings. Sah et al. (2023) reviewed developments in PEB analysis and concluded that tapered built-up sections significantly improve structural efficiency compared to conventional prismatic sections. Salama et al. (2023) demonstrated that

tapered portal frames achieve lower steel weight while satisfying serviceability criteria. Babaei et al. (2022) emphasized that drift control governs industrial shed design under wind loading and showed that optimized geometry leads to considerable material savings.

Fraser (1983) established the fundamental theory behind tapered portal frames and explained that member depth should vary according to bending moment distribution for efficient steel utilization. Saka (1997) confirmed through optimization studies that non-prismatic members reduce structural weight significantly compared to uniform sections. Studies on connection behavior by Zhang et al. (2024) showed that joint stiffness considerably influences global structural response and lateral drift. Research on cold-formed purlins and cladding interaction indicated that roof diaphragm action contributes to lateral stiffness and improves structural performance under wind loads.

Previous literature confirms that PEB systems generally provide superior material efficiency, lower dead load, and improved economy compared to CSB systems. However, a direct comparative study under identical loading and geometric conditions remains essential for practical industrial applications.

III. OBJECTIVES OF THE STUDY

The objectives of this study are:

1. To model PEB and CSB industrial buildings using STAAD Pro.
2. To analyze both structures under identical loading conditions.
3. To compare bending moment, shear force, and displacement behavior.
4. To evaluate steel quantity and foundation requirements.
5. To determine the most economical structural system.

IV. METHODOLOGY

4.1 Structural Configuration

A representative industrial steel building was selected for analysis. Both PEB and CSB structures were modeled with identical geometry, support conditions, and loading criteria.

Building Parameters

Parameter	Value
Building Span	20 m
Building Length	77 m
Bay Spacing	7 m
Number of Bays	11
Eave Height	8 m
Ridge Height	9 m
Roof Type	Pitched Roof
Support Condition	Pinned Base
Analysis Type	3D Linear Static Analysis

4.2 Modelling of PEB

In the PEB model, primary members such as columns and rafters were designed as tapered built-up sections. Member depth was varied according to bending moment demand, providing maximum depth near the knee and ridge regions. Cold-formed Z and C sections were used for secondary members such as purlins and girts. Bracing systems were included to ensure lateral stability.

4.3 Modelling of CSB

The Conventional Steel Building model employed standard hot-rolled prismatic sections with constant cross-sectional properties throughout member length. Secondary framing was modeled using conventional rolled sections. Both models were analyzed using identical loading and support conditions to ensure a fair comparison.

V. LOADING AND ANALYSIS

The structures were analyzed according to IS 875 and IS 1893 provisions.

5.1 Loads Considered

- Dead Load (DL)
- Live Load (LL)
- Wind Load (WL)
- Seismic Load (EQ)

5.2 Wind Parameters

Parameter	Value
Wind Zone	IV
Basic Wind Speed	47 m/s
Terrain Category	2
Design Wind Pressure	1.461 kN/m ²

5.3 Load Combinations

The following critical load combinations were considered:

- 1.5(DL + LL)
- 1.2(DL + LL + WL)
- 1.5(DL + WL)
- 1.2(DL + LL + EQ)
- 1.5(DL + EQ)

STAAD Pro software was used for three-dimensional analysis and steel design.

VI. RESULTS AND DISCUSSION

6.1 Structural Response

The analysis results showed considerable differences in structural behavior between PEB and CSB systems.

Deflection Comparison

Structure Type	Actual Horizontal Deflection	Permissible Limit
CSB	146.907 mm	60 mm
PEB	47.984 mm	60 mm
Structure Type	Actual Vertical Deflection	Permissible Limit
CSB	216.963 mm	111.11 mm
PEB	59.644 mm	111.11 mm

The PEB structure satisfied serviceability requirements, whereas the CSB structure exceeded permissible limits.

6.2 Steel Quantity Comparison

Structure	Steel Quantity
CSB	43,606 kg
PEB	38,360 kg

The PEB structure required significantly less steel due to optimized tapered members.

6.3 Foundation Comparison

Due to reduced self-weight, the PEB structure developed lower support reactions and required smaller foundations.

Parameter	CSB	PEB
Footing Size	1.4 m × 1.4 m	1.0 m × 1.0 m
Concrete Quantity	19.0 m ³	7.26 m ³
Reinforcement	1305 kg	781 kg

PEB foundations resulted in considerable savings in concrete and reinforcement.

6.4 Cost Comparison

Total Project Cost

Structure Type	Total Cost (Rs.)
CSB	44,19,616
PEB	40,49,580

Cost Saving

Overall cost saving achieved by PEB:

$$[\text{Saving}] = 44,19,616 - 40,49,580$$

$$[= 3,70,036 \text{ Rs.}]$$

Percentage saving:

$$[= 8.37\%]$$

The reduction in steel weight and foundation size contributed significantly to cost savings.

VII. CONCLUSION

Based on the analytical and economic comparison between Pre-Engineered Buildings and Conventional Steel Buildings, the following conclusions are drawn:

1. PEB structures exhibit superior structural efficiency due to optimized tapered members.
2. Steel consumption in PEB systems is significantly lower compared to CSB systems.
3. PEB structures produce lower support reactions, resulting in smaller and more economical foundations.
4. Serviceability performance of PEB structures is better, with deflections remaining within permissible limits.
5. The total project cost of PEB was approximately 8.37% lower than CSB.
6. PEB systems provide faster construction, reduced dead load, and improved economy.
7. PEB structures are highly suitable for industrial sheds, warehouses, and large-span structures.

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