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A Comparative Study of Pre-Engineered Building Using Cold-Form Sections with Conventional Building

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Abstract:

In current times, the construction sector has seen a sudden change from traditional building techniques to more advanced and cost-effective solutions. Among these, Pre-Engineered Buildings (PEBs) using cold-formed steel sections have emerged as a highly efficient alternative to conventional construction methods involving hot-rolled steel or reinforced concrete. Cold-formed sections, known for their lightweight and high strength-to-weight ratio, offer significant advantages. In the study, a comparative analysis of the industrial warehouse structure located at Nagpur was performed by using STAAD-Pro software. Also, conventional steel structure with the same dimensions and configuration was analyzed and designed using STAAD-Pro software. Dead load, Live load, and Wind load were adopted for the structures by using Indian codes.

1. INTRODUCTION

The construction industry has witnessed a dramatic change from traditional building methods to advanced pre-engineered systems, driven by the need for faster construction, cost efficiency, and sustainable practices. Steel, as a primary construction material, has been utilized in two distinct forms:

- Pre-Engineered Buildings (PEB) – Utilizing cold-formed steel (CFS) sections.
- Conventional Steel Buildings (CSB) – Using hot-rolled steel (HRS) sections.

While conventional steel construction has been the backbone of industrial and commercial structures for decades, PEBs have emerged as a revolutionary alternative, particularly for warehouses, factories, aircraft hangars, and low-rise commercial buildings.

As construction budgets tighten and sustainability concerns escalate, the choice between PEB and conventional steel construction has become increasingly consequential. The fundamental differences between these approaches extend far beyond mere material selection, encompassing every aspect from conceptual design to final erection and long-term maintenance.

1.1 Conventional Steel Building

The use of steel in construction began during the Industrial Revolution, and conventional steel building methods became popular in the mid-20th century. CSBs were the dominant approach for all major steel structures before the introduction of Pre-Engineered Buildings in the 1980s and 1990s. A Conventional Steel Building (CSB) refers to a structurally engineered steel-framed building that is custom designed and fabricated using hot-rolled steel sections, typically constructed by fabricators and builders using standard civil engineering practices. Unlike Pre-Engineered Buildings (PEBs), which are factory-optimized and modular, CSBs follow traditional design processes and site fabrication.

Conventional steel buildings (CSBs) represent the traditional approach to steel construction, characterized by

- Custom designed structural system specifically made to meet the requirements of the project.
- Hot-Rolled steel sections (I-beam, H-columns, Channels and Angles)
- Field welding and bolting for component assembly.
- On site fabrication of different structural elements.

Conventional steel buildings offer numerous benefits that make them a preferred choice for complex and high-performance structures. Suitable for heavy loads they can support high loads such as cranes, heavy machinery, and equipment

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platforms, making them ideal for industrial and infrastructure projects.

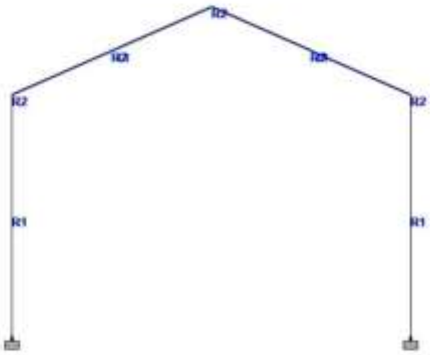
1.2 Pre-Engineered Building

Pre-engineered buildings (PEBs) emerged in the 1960s as an innovative construction solution, revolutionizing how industrial and commercial structures were designed and erected. Originally developed in the United States to meet the growing demand for rapid, cost-effective construction of warehouses and factory buildings, PEBs introduced a paradigm shift from traditional custom-built steel structures to standardized, factory-engineered systems. The fundamental innovation of PEBs lies in their system-based approach, replacing custom-designed structures with pre-engineered solutions featuring predesigned structural frames, standardized connection details, optimized steel sections, and mass-produced cladding systems. This approach transformed the construction industry by dramatically reducing project timelines by 40-60% while cutting steel usage by 20-30% through material optimization.

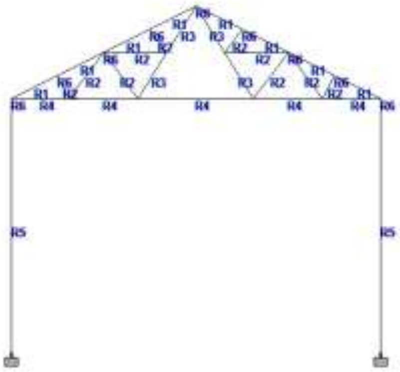
Faster project completion : the prefabricated nature of PEB allows concurrent site preparation and component manufacturing, cutting construction time by 50 to 70 percent. All structural elements arrive pre-cut, pre-drilled, and ready for quick bolted assembly, enabling projects to complete in weeks.

Design Flexibility : Engineers can customize PEB to achieve column-free spans upto 60m, with adjustable building lengths and heights. Various roof styles and wall options accommodate diverse functional and aesthetic requirements.

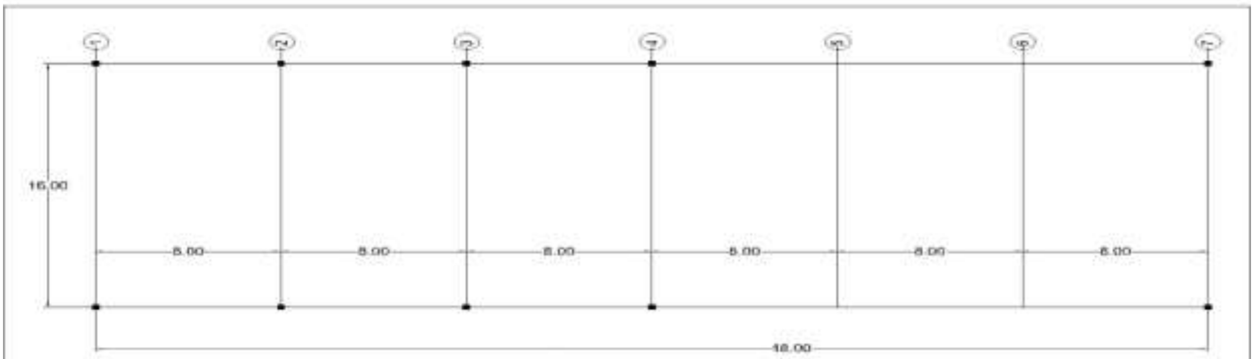
Structural efficiency : advanced software designs PEB using the minimum material needed for required strength, creating lightweight yet robust structures. The precision of computer-modelled components ensures consistent quality and perfect fit during assembly.



Front view of Pre-Engineered Structure



Front view of Conventional Steel Structure



PLAN OF THE BUILDING

2.OBJECTIVES AND METHODOLOGY

- To compare pre-engineered building with conventional building
- To study the design philosophy of pre-engineered building.
- To analyze pre-engineered building using FEM based software (STAAD-Pro)
- To compare cost effectiveness of pre-engineered building.
- To check the feasibility of pre-engineered building as compared to conventional steel building.

PHASE 1 : Technical Aspects

In present study the main aim was to perform a comparative analysis between pre-engineered building and conventional steel building. The comparative analysis with same building configurations and parameters between pre-engineered building and conventional building was conducted. In this study the data generally includes properties and dimensions of the members required to design structures. Dead load, Live load and Wind load were adopted to design and analyze using IS codes.

Table 1 : Building Parameters

Sr No	Parameters	Description
1	Type of structure	Industrial Warehouse
2	Location	Nagpur
3	Zone	Zone 3
4	Wind Speed	44m/sec
5	Overall Length	48 m
6	Overall Width	16 m
7	Height of Column	11 m
8	Height of Truss	4 m
9	Length of Rafter	8.94 m
10	Length of Purlin	16 m
11	Support Conditions	For PEB - Fixed For CSB - Fixed
12	Bay Spacing	8 m c/c
13	No of Bays	6

PHASE 2 : Load Calculation

1. Dead Load

Self-weight of structure = -1

(Self-weight is inclusive of the weight of members and the connections like bolted, welded and weight of gusset plate).

- Load on the intermediate panel points = 7.4 kN

- Load on the end panel points = 3.7 kN

2. Live Load

Live loads are those which may change in position and magnitude. Refers to non-permanent loads imposed on building during its use such as people, furniture, equipment's and movable objects.

- Live load on the intermediate points = 6.7 kN
- Live load on end panel points = 3.35 kN

3. Wind Load

Refers to the force exerted on a structure by the wind, either from direct pressure (windward side) or suction (leeward side).

Wind load calculations as per I.S : 875-2015 (Part 3) (Table 1 of IS : 875- 2015)

Basic wind speed ($\boldsymbol{V_b}$) = 44 m/sec

Design wind speed ($\boldsymbol{V_z}$) = $\boldsymbol{K_1} \times \boldsymbol{K_2} \times \boldsymbol{K_3} \times \boldsymbol{V_b}$ (clause 6.3)

where,

$\boldsymbol{K_1}$ = 1.0 (Probability factor)

$\boldsymbol{K_2}$ = 0.89 (Terrain category and roughness)

$\boldsymbol{K_3}$ = 1.0 (Topography factor)

$\boldsymbol{V_b}$ = 44 m/sec (Basic wind speed)

Design wind speed ($\boldsymbol{V_z}$) = 1.0$\times$ $\mathbf{0.89} \times \mathbf{1.0} \times \mathbf{44}$

= 41.83 m/sec

Design wind pressure, ($\boldsymbol{p_d}$) = 0.6 $\times$ $\boldsymbol{V_z}$

= 0.6 × 41.83

= 1.05 kN/$\boldsymbol{m^2}$

4. Load Combinations

Following load combinations were adopted

1.5 DL + 1.5 LL

1 DL + 1 LL

1.2 DL + 1.2 LL + 0.6 WL

1.2 DL + 1.2 LL – 0.6 WL

1 DL + 0.8 LL + 0.8 WL

1 DL + 0.8 LL – 0.8 WL

1.5 DL + 1.5 WL

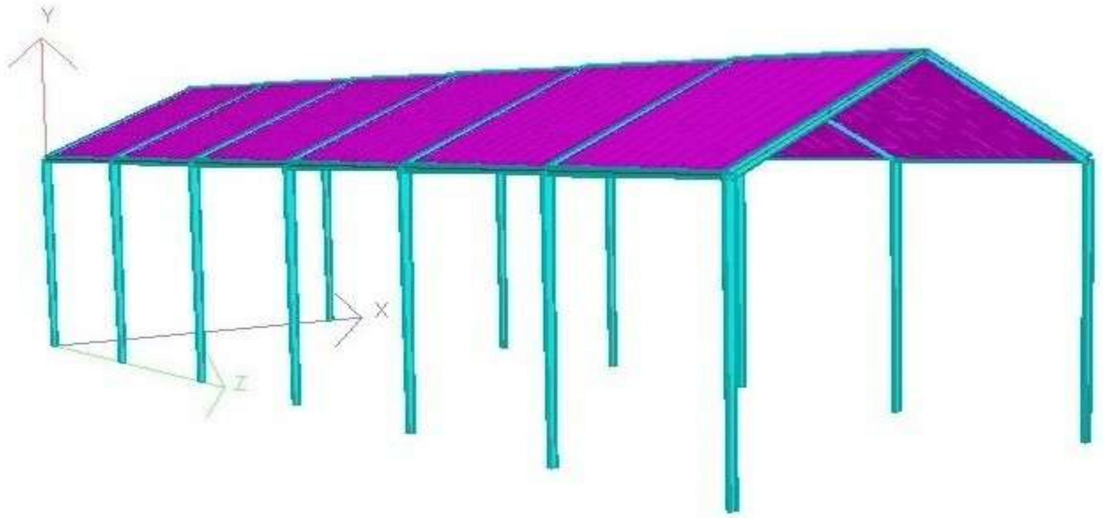
1.5 DL – 1.5 WL

1 DL + 1 WL

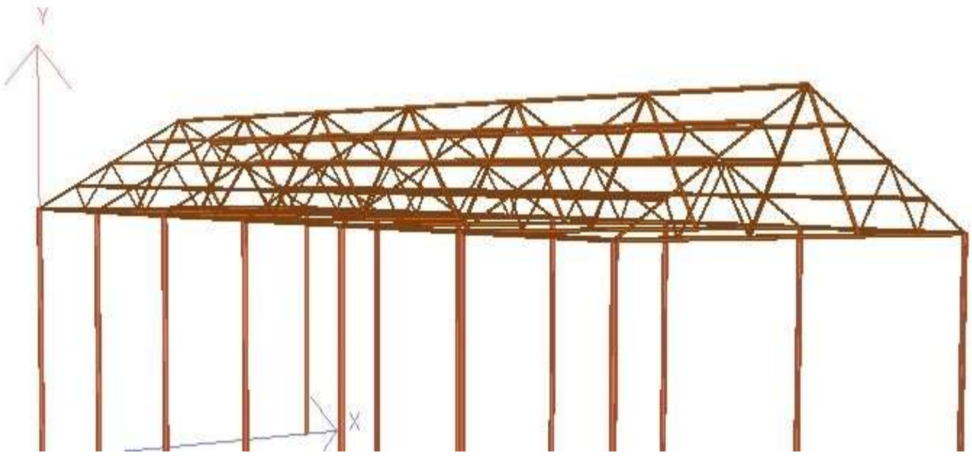
1 DL – 1 WL

PHASE 3 : Modelling Approach

The STAAD-Pro V8i SS6 has been used for analysis and design. In this study industrial warehouse is modeled as a 3D model. In this study two structures are modelled with same building configuration. One industrial warehouse was modelled using beam sections and channel, angle sections with the use of hot rolled steel sections. Another one was modelled by using tapered sections with the use of cold formed sections. Wind load is considered acting on X and Z directions.



STAAD Model of PEB Structure



STAAD Model of Conventional Steel Structure

PHASE 4 : Design and Analysis

In this phase of work, the pre-engineered building and conventional building were designed and then analyzed as per defined parameters and configurations. Two software STAAD-Pro 8Vi and Autodesk Auto-CAD were used for designing of structures.

These designed structures were properly and completely analyzed using STAAD-Pro 8Vi software.

PHASE 5 : Results and Discussions

The PEB and CSB structures were analyzed for 10 load combinations as per IS codes. The results obtain from analysis are tabulated below with figure.

Table 2 : Software Analysis Result Summary

Sr No	Parameters	PEB	CSB
1	Maximum Bending Moment	168.964	189.259
3	Maximum Support Reaction	2.2967	3.775
4	Maximum Displacement	100.267	104.345

- Following are the designs result on PEB Structure

5.1 Support Reactions

Table 3 : Support Reactions on PEB Structure

	Horizontal		Vertical	Moment kN-m		
	Fx kN	Fz kN	Fy kN	Mx	My	Mz
Max Fx	23.495	0.004	97.986	0.02	0	-89.486
Min Fx	-23.495	0.004	97.986	0.02	0	89.486
Max Fy	23.4	-0.008	100.267	-0.021	0	-89.096
Min Fy	0	0	0	0	0	0
Max Fz	22.711	0.054	73.622	0.203	0	-86.934
Min Fz	22.695	-0.08	73.523	-0.288	0	-86.869
Max Mx	22.711	0.054	73.622	0.203	0	-86.934
Min Mx	22.695	-0.08	73.523	-0.288	0	-86.869
Max My	17.002	-0.079	54.615	-0.286	0	-64.958
Min My	-17.002	-0.079	54.615	-0.286	0	64.959
Max Mz	-23.495	0.004	97.986	0.02	0	89.486

5.2 Beam End Forces

Table 4 : Beam End Forces on PEB Structure

	Horizontal		Vertical	Moment kN-m		
	Fx kN	Fz kN	Fy kN	Mx	My	Mz
Max Fx	100.267	-0.008	-23.4	0	0.021	-89.096
Min Fx	-12.915	0.006	1.697	0	-0.016	2.302
Max Fy	2.469	-0.002	34.589	0	-0.02	154.718
Min Fy	97.986	0.004	-23.495	0	-0.02	-89.486
Max Fz	-7.972	0.072	2.965	0	-0.145	3.732
Min Fz	73.523	-0.08	-22.695	0	0.288	-86.869
Max Mx	2.339	0.003	34.564	0.001	0.015	154.598
Min Mx	2.274	-0.003	34.564	-0.001	-0.014	154.598
Max My	-7.972	0.072	-0.058	0	0.429	-7.434
Min My	69.366	-0.08	-22.695	0	-0.588	162.771
Max Mz	93.828	0.004	-23.495	0	0.028	168.964

5.3 Displacement

Table 5 : Displacement on PEB Structure

	X mm	Z mm	Y mm	mm	rX rad	rY rad	rZ rad
Max Fx	114.026	-0.42	-1.578	114.037	0	0	0.017
Min Fx	-114.025	-0.42	-1.578	114.037	0	0	-0.017
Max Fy	0	0	0	0	0	0	0
Min Fy	0.001	-0.434	-229.735	229.736	0	0	0
Max Fz	0	0.011	-39.024	39.024	0	0	0
Min Fz	0.001	-0.842	-168.314	168.316	-0.001	0	0

Max Mx	-112.898	-0.81	-1.178	112.908	0.002	0.001	-0.016
Min Mx	-112.814	-0.029	-1.177	112.82	-0.003	-0.001	-0.016
Max My	83.765	-0.044	-0.866	83.769	-0.003	0.001	0.012
Min My	-83.764	-0.043	-0.866	83.769	-0.003	-0.001	-0.012
Max Mz	114.026	-0.42	-1.578	114.037	0	0	0.017

- Following are the design results on CSB Structure

5.4 Support reaction

Table 6 : Support Reaction on CSB Structure

	Horizontal		Vertical	Moment kN-m		
	Fx kN	Fz kN	Fy kN	Mx	My	Mz
Max Fx	0.567	104.324	-0.014	-0.051	0	-2.25
Min Fx	-0.567	104.324	-0.014	-0.051	0	2.25
Max Fy	0.567	104.324	-0.014	-0.051	0	-2.25
Min Fy	0	0	0	0	0	0
Max Fz	0.531	97.126	0.063	0.232	-0.001	-2.107
Min Fz	-0.531	97.126	-0.063	-0.232	-0.001	2.107
Max Mx	0.531	97.126	0.063	0.232	-0.001	-2.107
Min Mx	-0.531	97.126	-0.063	-0.232	-0.001	2.107
Max My	-0.531	97.126	0.063	0.232	0.001	2.107
Min My	0.531	97.126	0.063	0.232	-0.001	-2.107
Max Mz	-0.567	104.324	-0.014	-0.051	0	2.25

5.5 Beam End Forces

Table 7 : Beam End Forces on CSB Structure

	Horizontal		Vertical	Moment kN-m		
	Fx kN	Fz kN	Fy kN	Mx	My	Mz
Max Fx	189.249	-0.378	-0.005	0	-0.015	0.382
Min Fx	-168.477	-2.081	0.015	0	-0.011	-2.289
Max Fy	-168.477	2.632	0.015	0	-0.027	3.603
Min Fy	-168.477	-2.632	0.015	0	0.027	3.603
Max Fz	137.215	-0.012	0.334	0.002	-0.282	-0.09
Min Fz	137.102	0.237	-0.334	-0.002	0.465	0.188
Max Mx	-58.019	1.552	0.022	0.005	-0.11	1.745
Min Mx	-58.019	1.552	-0.022	-0.005	0.11	1.745
Max My	137.102	-0.237	0.334	0.002	0.465	0.188
Min My	137.102	-0.237	-0.334	-0.002	-0.465	0.188
Max Mz	100.711	-0.567	-0.014	0	-0.101	3.985

5.6 Displacement

Table 8 : Displacement on CSB Structure

	X mm	Y mm	Z mm	mm	rX rad	rY rad	rZ rad
Max Fx	3.775	-27.21	1.781	27.528	-0.001	-0.001	0
Min Fx	-3.775	-27.21	1.781	27.528	-0.001	0.001	0
Max Fy	0	0	0	0	0	0	0

Min Fy	-3.481	-27.775	-0.004	27.992	-0.001	0.001	-0.001
Max Fz	-0.592	-23.094	14.175	27.103	-0.004	-0.002	-0.002
Min Fz	0.592	-23.094	-14.175	27.103	0.004	-0.002	0.002
Max Mx	-2.973	-21.634	0.002	21.837	0.006	-0.003	0.002
Min Mx	2.973	-21.634	-0.002	21.837	-0.006	-0.003	-0.002
Max My	-1.645	-18.767	-6.72	20.001	0.005	0.003	-0.005
Min My	1.645	-18.767	-6.72	20.001	0.005	-0.003	0.005
Max Mz	1.756	-20.085	1.713	20.234	-0.001	0.001	0.006

3.CONCLUSION

- Two typical steel buildings, one with PEB sections and the other with CSB sections have been designed for various load combinations using IS codes.
- The present study focuses on comparing the pre-engineered building with conventional steel structures in every aspect.
- Several factors were considered for the comparison which affects the pre-engineered building and conventional steel building in every aspect.
- The quantity of steel required for pre-engineered building is lesser by 6.4 percent compared to conventional steel building (CSB), which is considered to be significant.
- It is observed that the maximum bending moment, support reactions and displacement in PEB and CSB varies by 4.23 percent.
- As the PEB offers various advantages like cost reduction, speedy construction, future expansion, good architectural view over CSB, structural engineers prefer PEB over CSB.
- It is concluded that PEB structure is considerably cost effective compared to a CSB structure.

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