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COMPARATIVE STUDY OF PRE-ENGINEERED BUILDING WITH CONVENTIONAL STEEL BUILDING

PROF. P. S. LANDE[1], VIVEK. V. KUCHERIYA[2]

1. Associate professor, Applied Mechanics Department, Government College of Engineering, Amravati, Maharashtra, India.
2. PG Student Applied Mechanics Department, Government College of Engineering, Amravati, Maharashtra, India.

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Abstract: Cost of steel is increasing day by day and use of steel has become inevitable in the construction industry in general and in industrial building in particular. Hence to achieve economic sustainability it is necessary to use steel to its optimum quantity. Pre-Engineered Building (PEB) Concepts are introduced to the Indian market lately in the 1990's with the opening up of the Indian economy and a number of multi-nationals settings up their green-field projects.PEB methodology is versatile not only due to its quality pre-designing and prefabrication, but also due to its light weight and economical construction. The present work presents the comparative study of PEB and Conventional Steel Building (CSB).The study is achieved by designing 3D frame of a Industrial Warehouse building using both the concepts and analyzing the frames u sing the STAAD Pro.v8i Software. The economy of structure is discussed in terms of its weight comparison.

Keywords: Pre-Engineered Building, Conventional Steel Building, Tapered I Section, STAAD Pro

Corresponding Author: PROF. P. S. LANDE

Co Author: MR. VIVEK. V. KUCHERIYA

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INTRODUCTION

The philosophy of lean construction is well applicable to steel construction. The possibilities to reach increased efficiency concerning time, cost, material and resources are already enable through the material property and accuracy, and the established industrial construction concept. Lean construction is one way towards sustainability. Steel is a material which has high strength per unit mass. Hence it is used in construction of structures with large column-free space. India has the second fastest growing economy in the world and a lot of it, is attributed to its construction industry which figures just next to agriculture in its economic contribution to the nation. In its steadfast development, the construction industry has discovered, invented and developed a number of technologies, systems and products, one of them being the concept of Pre-engineered Buildings (PEBs), as in [2]. A combination of standard hot-rolled sections, cold-formed sections, profiled sheets, steel rods, etc. are used for the construction of industrial steel structures. Industrial buildings can be categorized as Pre-Engineered Buildings (PEB) and Conventional Steel Buildings (CSB), according to the design concepts. A section depicting the importance of the software used and the software procedure followed is included. Final portion explains the results obtained from the software analysis of the case study and the inferences from the literature studies. The paper aims at developing a perception of the design concepts of PEB structures and its advantages over CSB structures.

II. METHODOLOGY

The present study is included in the design of an Industrial Warehouse structure located at Nagpur. The structure is proposed as a Pre-Engineered Building of 22 meters width, 10 bays each of 7.5 meters length and an eave height of 8 meters. In this study, a PEB frame of 22 meter width is taken into account and the design is carried out by considering wind load as the critical load for the structure. CSB frame is also designed for the same span considering an economical roof truss configuration. Both the designs are then compared to find out the economical output. The designs are carried out in accordance with the Indian Standards and by the help of the structural analysis and design software STAAD pro v8i.

A. PRE ENGINEERED BUILDINGS

Pre-Engineered Building concept involves the steel building systems which are predesigned and prefabricated. The basis of the PEB concept lies in providing the section at a location only according to the requirement at that spot. The sections can be varying throughout the length according to the bending moment diagram. This leads to the utilization of non-prismatic rigid frames with slender elements. Tapered I sections made with built-up thin plates are used to achieve this configuration. Standard hot-rolled sections, cold-formed sections, profiled roofing sheets, etc. is also used along with the tapered sections, as in [3]. The use of optimal least section leads to effective saving of steel and cost reduction. The concept of PEB is the frame geometry which matches the shape of the internal stress (bending moment) diagram thus optimizing material usage and reducing the total weight of the structure.

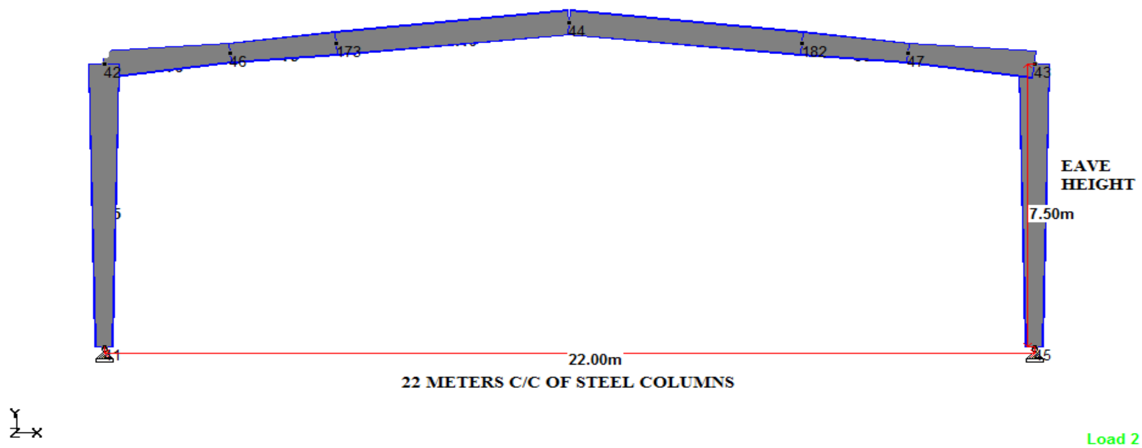

Figure 1: PEB Frame

B. CONVENTIONAL STEEL BUILDINGS

Conventional steel buildings (CSB) are low rise steel structures with roofing systems of truss with roof coverings. Various types of roof trusses can be used for these structures depending upon the pitch of the truss.

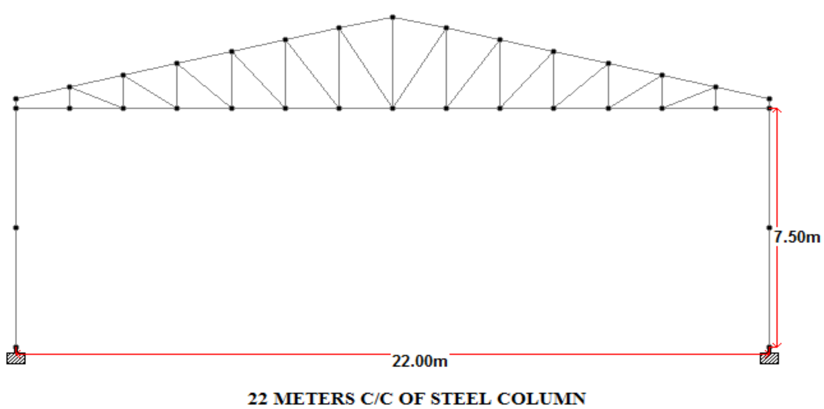

Figure 2: CSB Frame

C.COLD FORM STEEL SECTION

The high strength-to-weight ratio of cold-formed steel members provide substantial savings. As a result, they have become very popular in industrial structures, where usually heavy and bulky structures are required. In such structure utilization of high strength-to-weight ratio will leads to help in reduction of the total load on structure and saving of construction time & cost, as in [10].The easy availability of required shapes and sizes will help us in choosing the most economical cold-formed shape in design of structures. There are various shapes and cross section which can be formed easily and there is no limitation in forming the cross section of any type for column/portal, truss members, purlins / side girts & decking profiles /roofing sheet. Following are some of the typical cold formed section profiles readily available.

Figure 3: Typical Cold Formed Section Profiles used for purlin members

III.STRUCTURE CONFIGURATION DETAILS

Table 1: Structural Parameters

Type Of Building	Industrial Building
Type Of Structure	Single storey industrial structure
Location	Nagpur, India
Total bay length	75 m
Single bay length for CSB	3.75 m
Single bay length for PEB	7.5 m
Span Width	22 m
Clear height	7.5 m
Wind speed	44 m/sec
Wind terrain category	2
Wind class	C
PEB roof slope	5.71^0
CSB roof slope	13.3^0

The building plan of the proposed industrial warehouse structure considered for the study is as shown in Figure

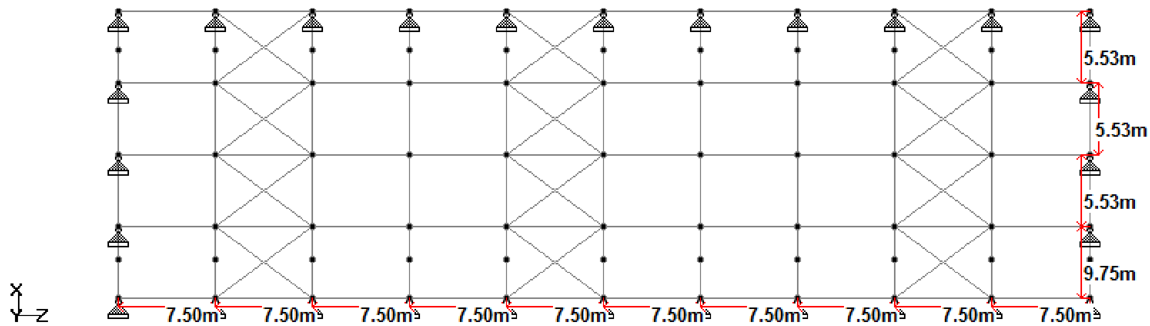

Figure 4: Building Plan

IV.LOAD CALCULATIONS

The loads acting on the structure includes dead load, live load, wind load, as in [4].The load calculation for the structure can be carried out in accordance with IS : 875 – 1987 .For this structure wind load is critical than earthquake load Hence, load combinations of dead load, live load, and wind load are incorporated for design.

4.1. DEAD LOAD

Dead load comprises of self-weight of the structure, weights of roofing, steel sheets, purlins, sag rods, bracings and other accessories, in passing [5]. The dead load distributed over the roof is found to be 1.125 kN/m excluding the self weight. This load is applied as uniformly distributed load over the rafter while designing the structure by PEB concept. For CSB concept the load is applied as equivalent point load of 0.884 kN at intermediate panel points and half the value at end panel points over the roof truss. Reference [5] shows the procedure for dead load calculation.

4.2. LIVE LOAD

According to IS : 875 (Part 2) – 1987, for roof with no access provided, the live load can be taken as 0.75 KN/m^2 with a reduction of 0.02 KN/m^2 for every one degree above 10 degrees of roof slope, explicitly as in [6]. Total uniformly live load acting on the rafter of the PEB structure is found to be 5.625 kN/m. Similar to dead load, live load is also applied as point loads at panel points for CSB structure and is found to be 4.03 kN at intermediate panel points and half this value at end points. Reference [6] shows the procedure for live load calculation.

4.3. WIND LOAD

Wind load is calculated as per IS : 875 (Part 3) – 1987. The basic wind speed for the location of the building is found to be 44 m/s from the code, in passing [7]. The wind load over the roof can be provided as uniformly distributed load acting outward over the PEB rafter and as point loads acting outward over the CSB panel points. For side walls, the wind load is applied as uniformly distributed loads acting inward or outward to the walls according to the wind case. The wind loads over the roof and side walls comes in six different combinations as in Table 2.

Table 2: Wind Load Cases

Case	Side wall (KN/m)		PEB Rafter (KN/m)		CSB panel points(KN)			
	Left	Right	Windward	Lee ward	Wind ward		Lee ward	
					Intermediate	End	Intermediate	End
WLP	1.506	5.65	3.262	0.753	2.633	1.316	0.608	0.304
WLS	9.401	-1.88	10.796	6.7810	8.714	4.357	5.473	2.736
WRP	-5.65	-1.5069	0.7534	3.2624	0.608	0.304	2.633	1.316
WRS	1.88	-9.04	6.781	10.79	5.473	2.736	8.714	4.357
WLEP	-7.53	7.53	2.004	0.7534	1.617	0.808	0.608	0.304
WLES	0	0	9.538	8.2879	7.69	3.849	6.689	3.344

4.4. LOAD COMBINATION

Loads combinations can be adopted according to IS: 800-2007.Thirteen different load combinations adopted for the analysis of the frame in both the concepts, as in [4] and are listed as follows

1) 1.5DL+1.5LL
2) 1.2DL+1.2LL+0.6WLP
3)1.2DL+1.2LL+0.6WLS
4)1.2DL+1.2LL+0.6WRP

8)1.5DL+1.5WLP
9)1.5DL+1.5WLS
10)1.5DL+1.5WRP
11)1.5DL+1.5WRS

5)1.2DL+1.2LL+0.6WRS

6)1.2DL+1.2LL+0.6WLEP

7)1.2DL+1.2LL+0.6WLES

12)1.5DL+1.5WLEP

13)1.5DL+1.5WLES

Note:

DL – Dead Load

LL – Live Load

WL – Wind Load

WLP – Wind Left Pressure

WLS – Wind Left Suction

WRP – Wind Right Pressure

WRS – Wind Right Suction

WLEP – Wind Longitudinal Pressure

WLES – Wind Longitudinal Suction

V. STAAD.PRO PROCEDURE

The Staad.Pro software package is a structural analysis and design software which helps in modeling, analyzing and designing the structure. The software supports standards of several countries, including Indian standard. The procedure includes modeling the structure, applying properties, specifications, loads and load combinations, analyzing and designing the structure. This software is an effective and user-friendly tool for three dimensional model generation, analysis and multi-material designs, explicitly as in [8].

VI.RESULTS AND DISCUSSION

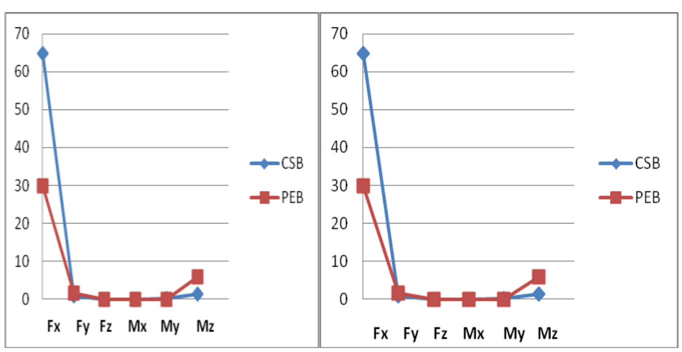

Figure 5: Bending moments and reactions at support and in columns

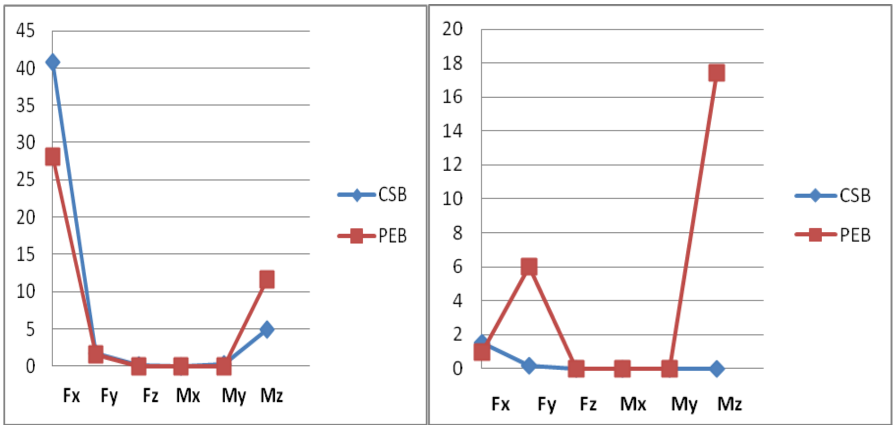

Figure 6: Bending moments and reaction at end of columns and in rafters

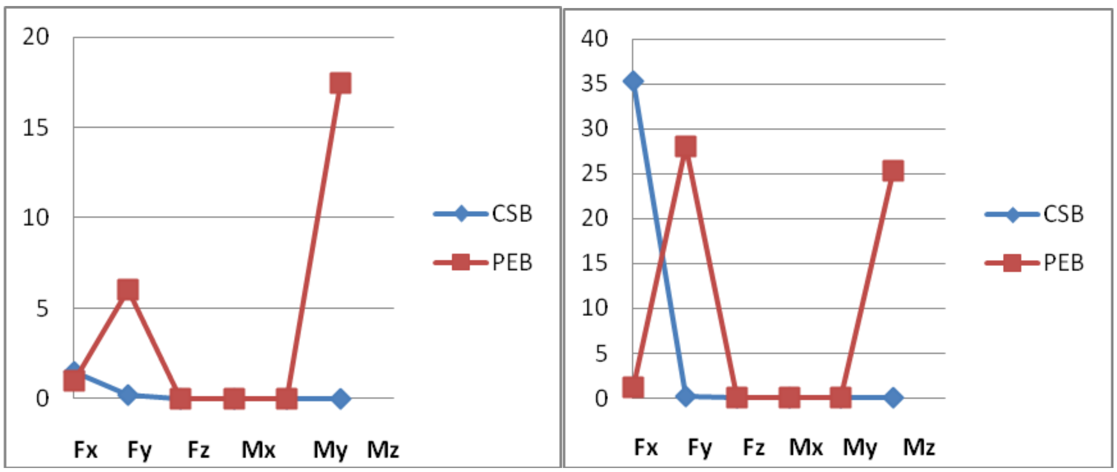

Figure 7: Bending moments and reaction at end of rafters and at ridge portion

Table 3: Tapered member steel take off

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STEEL TAKE-OFF
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   PROFILE                    LENGTH(METE)       WEIGHT(KN   )

270. 120 TO 124 130 TO 135 141 TO 146 152 TO 157 163 TO 168 174 TO 179 275 TO 280
271. 353 TO 356 361 TO 368 371 TO 373 379 TO 429
Tapered   MembNo:     1         42.00            12.986
Tapered   MembNo:    68         10.11             2.874
Tapered   MembNo:    75        135.00            96.447
Tapered   MembNo:    76         54.00            39.823
Tapered   MembNo:    79         45.49            26.980
Tapered   MembNo:   275         32.20             9.400
Tapered   MembNo:   276         17.20             5.285
LD  ISA100X100X10              427.08           125.327
Tapered   MembNo:   408         22.11             6.624
Tapered   MembNo:   410         99.49            64.966
                                     ----------------
                             TOTAL =          390.712
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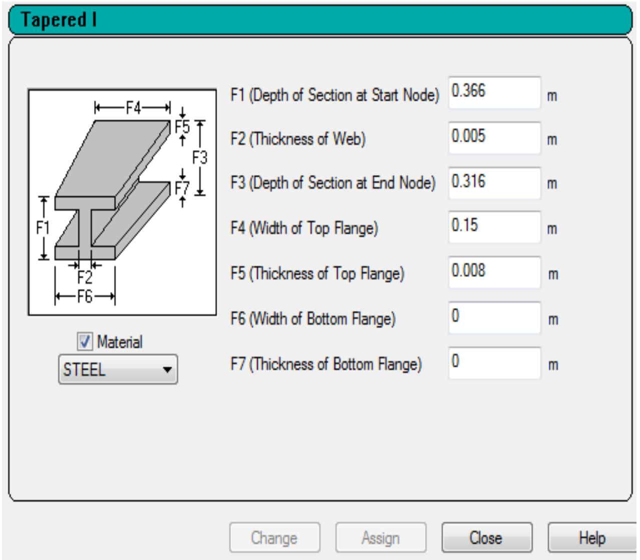

Figure 8: Properties of tapered member I section

Table 4: Quantity of steel utilized for the purlins

Description	Section	Weight
Cold form steel as PEB	200Z20	102 KN
Hot rolled steel as CSB	ISMC75	67KN

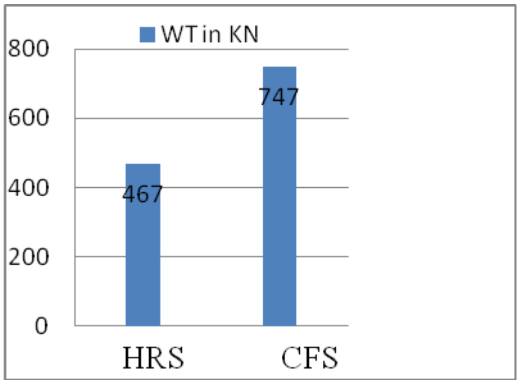

Figure 9: Weight of CFS and HRS

Table 5: Quantity of steel utilized for the structure

Description	Weightage
Conventional steel building	747 KN
Pre-engineered building	467 KN

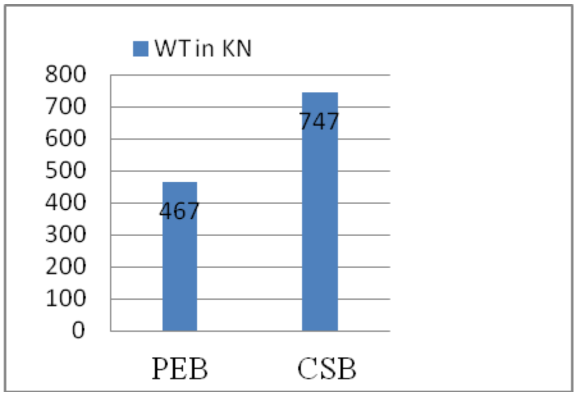

Figure 10: Weightage of PEB and CSB

6.1 DISSCUSSIONS

1. After analyzing at different load cases it is observed that the axial force at supports in PEB (32.62 KN) is less than when compared to that in CSB (67.42 KN).In mid-span of column ,the axial force in PEB (29.88 KN) is less than when compared to that in CSB (64.89 KN).The bending moment in PEB (5.83 KN-m) is more due to its light weight structure (Tapered sections) when compared to that in CSB (1.36 KN-m).

2.At end of column the axial force in PEB (28.144 KN) is less than when compared to that in CSB (40.8 KN).The bending moments in PEB (11.67 KN-m) is more due to its light weight structure (purlins and rafter) when compared to that in CSB (4.94 KN-m).In rafter, the bending moments in PEB (20.23 KN-m) is more due to its light weight structure (purlins and rafter) when compared to that in CSB .

3. In Rafters at Ends, the Axial force in PEB (0.954kN) is less when compared to that in CSB (1.496 kN). The Bending Moments in PEB (17.43 kN-m) is more when compared to that in CSB.

In Rafters at Ridge portion The Bending Moments in PEB (25.336 kN-m) is more when compared to that in CSB.

VII.CONCLUSIONS

In this work, Analysis and design of Conventional Steel Building and Pre-Engineered Building has been carried out and conclude that,

1) PEB structures can be easily designed by simple design procedures in accordance with country standards.

2) Low weight flexible frames of PEB offer higher resistance to wind loads.

3) Cold formed steel section over hot rolled section as purlin is almost lighter than 32%.

4) Pre-engineered building weight is 35% lesser than the weight of conventional steel building.

5) Pre-Engineered Building construction gives end users a much more economical and better solution for long span structures where large column free areas are needed.

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