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Comparative Study of an Industrial Pre-Engineered Building with Conventional Steel Building

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Abstract: **In recent years, the introduction of Pre Engineered Building (PEB) concept in the design of structures has helped in optimizing design. The adoptability of PEB in the place of Conventional Steel Building (CSB) design concept resulted in many advantages, including economy and easier fabrication. Long Span, Column free structures are the most essential in any type of industrial structures and Pre Engineered Buildings (PEB) fulfils this requirement along with reduced time and cost as compared to conventional structures. PEB methodology is versatile not only due to its quality pre-designing and prefabrication, but also due to its light weight and economical construction. In this study, an industrial structure (Ware House) is analyzed and designed according to the Indian standard, IS 800-2007 and American code, MBMA-96 by using the structural analysis and design software STAAD-pro. The economy of the structure is discussed in terms of its weight comparison, between Indian code (IS800-2007) & American code (MBMA-96). A comparative study has also been carried out between cold formed sections as purlins with traditional used hot rolled sections for industrial structures.**

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

1. INTRODUCTION

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. Steel is a material which has high strength per unit mass. Hence it is used in construction of structures with large column-free space. The scientific-sounding term pre-engineered buildings came into being in the 1960s. The buildings were pre-engineered because they rely upon standard engineering designs for limited number configurations. These buildings are mostly custom designed metal building to fill the particular needs of customer.

Steel structures also have much better strength-to-weight ratios than RCC and they also can be easily dismantled. Pre Engineered Buildings have bolted connections and hence can also be reused after dismantling. One of the great advantages of cold-formed steel (CFS) is the immense flexibility that the material affords in forming cross-sections. This flexibility would seem to readily lend itself to optimization of member cross-section shapes. Cold formed sections also having the great flexibility of cross-sectional profiles and sizes available to structural steel designers. Whereas, the low strength-to-weight ratio of hot rolled steel members leads to increase in overall load on structure as compared with cold-formed steel sections which is having high strength-to-weight ratio. Advantages of pre-engineered building over conventional steel building are

a) Optimized design of steel reducing weight
b) Reduce construction Time
c) Lower Cost
d) Construction efficiency increases
e) High energy efficient
f) Cost effective
g) Seismic and wind pressure resistant
h) Easy integration of all construction material
i) Easy future expansion/modification
j) Weather proof and fire hazard

This paper study of various papers published related to comparative study of conventional and pre engineered building. The main objective of this literature is to explore related studies of analysis and design of conventional steel building and pre-engineered building and study of economic aspects of cold formed steel over hot rolled steel for purlins.

2. 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.

2.1. Pre-engineered building

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. 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.

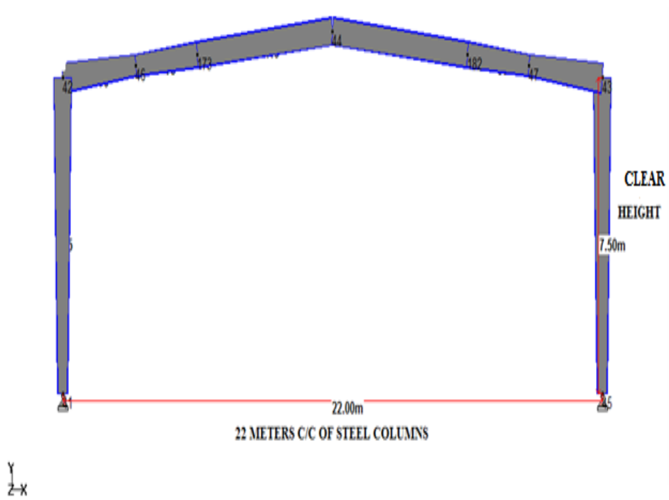

Fig. 1. PEB Frame

2.2. 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.

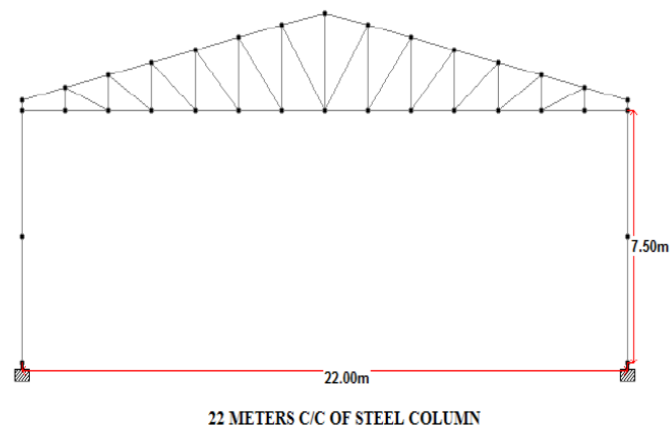

Fig. 2. CSB frame

2.3. 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.

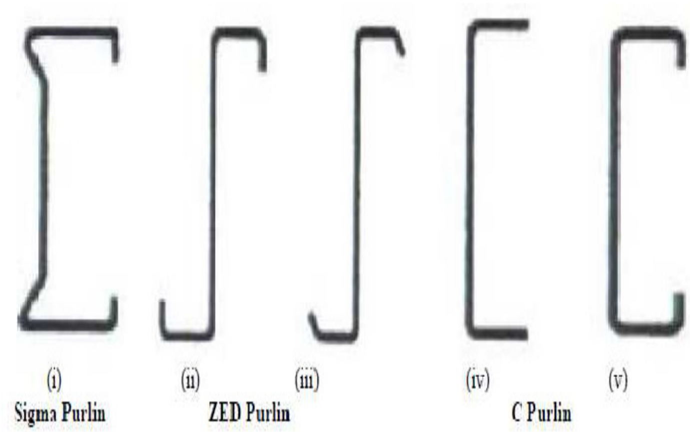

Fig. 3. Typical Cold Formed Section Profiles used for purlin members

3. STRUCTURE CONFIGURATION DETAILS

3.1. Problem statement

The conventional steel building and pre-engineered building is analyzed and designed using STAAD pro v8i software.

TABLE 1: Structural Parameters

Type Of Building	**Industrial Building**
Type Of Structure	Single storey industrial structure
Location	Amravati, 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 design has been done taking into consideration the primary shape of the members. The dimension of I- Section at the two extreme corners of each members have been decided on the basis of the required section modulus to carry the pre-requisite bending moment. The flexural formula forms on the basis in deciding the dimension of the members.

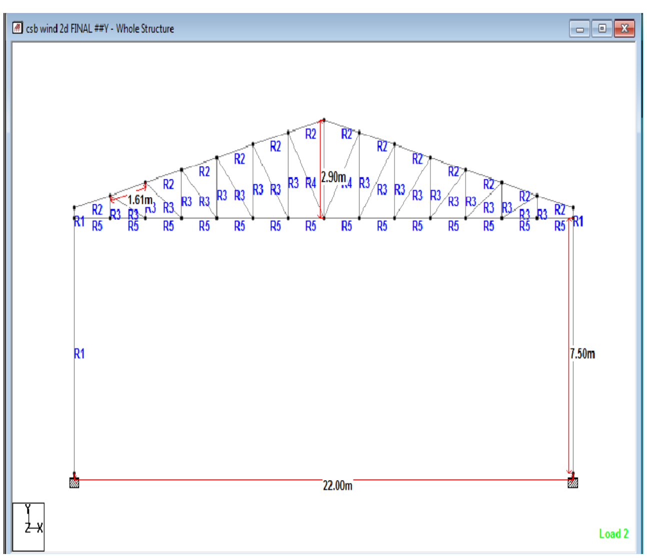

Fig. 4. Elevation of Conventional steel building

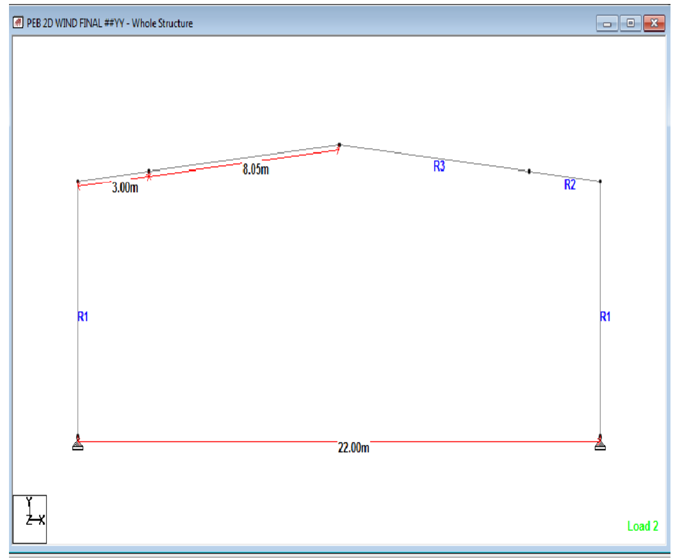

Fig. 5. Elevation of Pre engineered building

4. 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 and MBMA-1996 .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 3D PEB structure by Indian code (IS 800-2007) and American code (AISC-ASD). For 3D 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/m2 with a reduction of 0.02 KN/m2 for every one degree above 10 degrees of roof slope, explicitly as in [6]. Total uniformly live load acting on the rafter of the 3D PEB structure by Indian code (IS 800-2007) is 5.625 kN/m and by American code (AISC-ASD) is 4.275 KN/m .Similar to dead load, live load is also applied as point 25 loads at panel points for 3D 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.

TABLE 2. Dead load and live load on PEB and CSB Structure

Loads	PEB Structure		CSB Structure	
	Load on rafter		Load on top chord members as per IS-875	
	As per IS 875	As per MBMA-1996	At intermediate panel point	At end panel point
Dead load	1.125 KN/m	1.125 KN/m	0.884 KN	0.442 KN
Live load	5.625 KN/m	4.275 KN/m	4.03 KN	2.015 KN

4.3. Wind load

Wind load is calculated as per IS: 875 (Part 3) – 1987 and MBMA (1996). The basic wind speed for the location of the building is 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 3 and table 4.

TABLE 3. Wind Load Cases as per IS: 875 (Part 3) for 3D CSB and PEB

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

TABLE 4. Wind load cases as per MBMA-1996 for 3D PEB

Case	Side wall (KN/m)		PEB Rafter (KN/m)	
	Left	Right	Windward	Leeward
WLP	1.271	8.051	11.865	8.89
WLS	6.356	0.423	4.237	1.271
WRP	8.051	1.271	8.89	11.865
WRS	0.423	6.356	1.271	4.237
WLEP	9.32	9.32	11.865	8.89
WLES	1.69	1.69	4.23	1.271

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 Loads combinations can be adopted according to AISC-ASD. Twenty five different load combinations adopted for the analysis of the frame, as in [10].

5. 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.

In STAAD Pro utilization ratio is the critical value that indicates the suitability of the member as per codes. Normally, a value higher than 1.0 indicates the extent to which the member is over-stressed, and a value below 1.0 tells us the reserve capacity available. Critical conditions used as criteria to determine Pass/Fail status are slenderness limits, Axial Compression and Bending, Axial Tension and Bending, Maximum w/t ratios and Shear. For static or dynamic analysis of Pre-engineered building

6. RESULTS

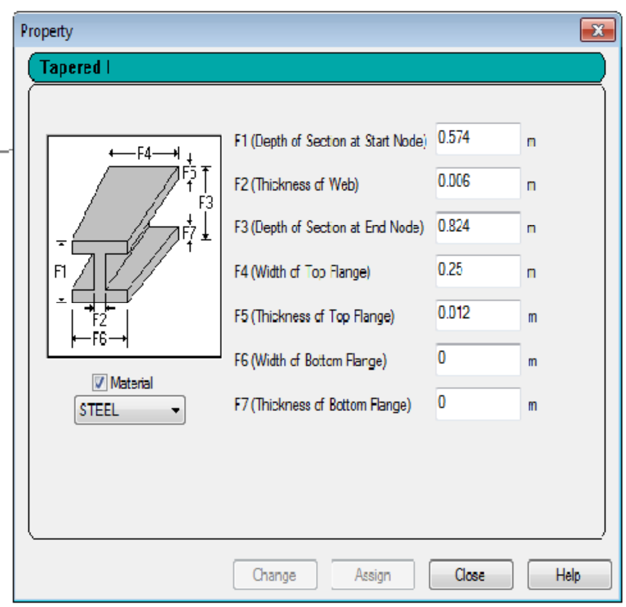

Fig. 6. Assigning dimension to the tapered I section member

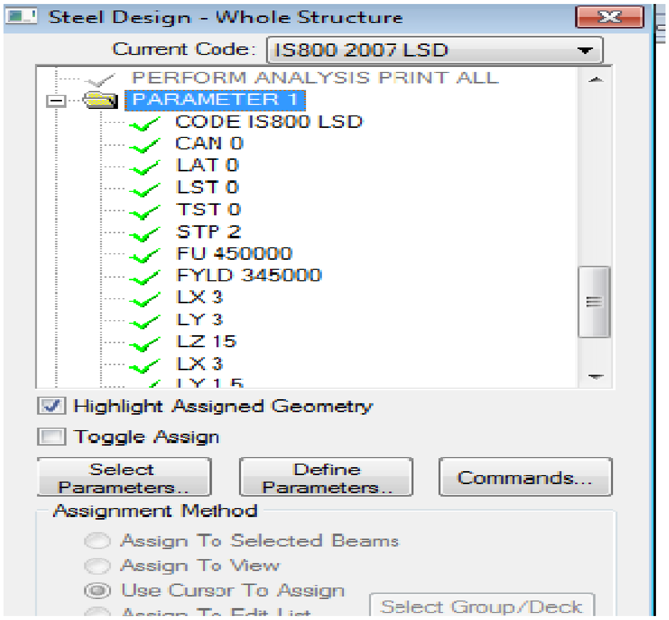

Fig. 7. Defining parameters to members

6.1. Comparison In Terms of Weight of 2D CSB and PEB Frame

Table 5. Total weightage of steel utilized for the 2D structure

Description	For CSB (ton)	For PEB (ton)	
		As per IS 800:2007	As per IS AISC-ASD
Quantity of steel for frame	1.966	2.602	2.41
Steel connection quantity	0.353	0.468	0.4338
Total quantity of steel	2.319	3.07	2.843

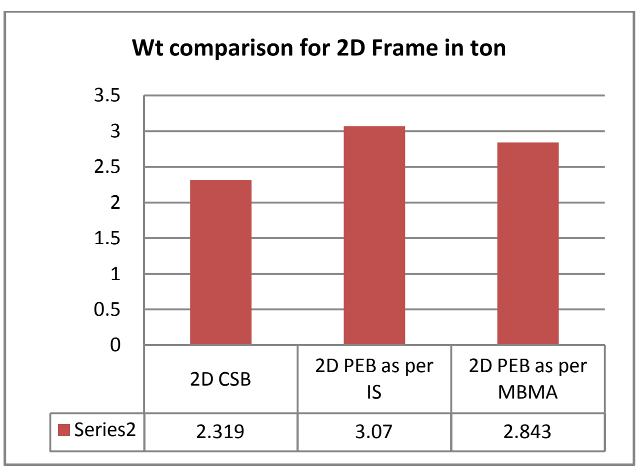

Fig. 8. Weight comparison for single framing system.

6.2. Weight comparison of purlins in 3D building

Economic aspects of cold formed sections as purlins in comparison with traditionally used hot rolled section for industrial structure are measure in terms of weight.

TABLE 6. Comparison of weight of purlins for 3D Building

Type of building	Cross section profile	Total purlin weight (KN)
3D CSB Building	ISMC 75 (HRS)	102 KN
3D PEB Building	200Z20 (CFS)	67 KN

The following graph shows Quantity of steel required for HRS sections and CFS section for purlins for 3D Structure.

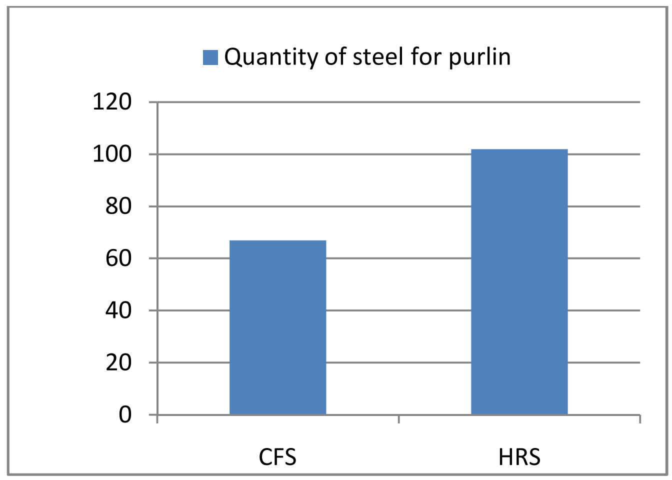

Fig. 9. Quantity of steel required for HRS sections and CFS section for purlins for 3D Structure

6.3. Comparison in terms of weight of 3D CSB and PEB Building according to IS and AISC/MBMA code

TABLE 7: Total weightage of steel utilized for the 3D structure

Description	For CSB (ton)	For PEB (ton)	
		as per IS 800:2007	as per AISC-ASD
Quantity of steel for frame	54.14	31.42	27.79
Quantity of steel for purlin	10.2	6.7	6.7
Steel connection quantity	9.74	5.65	5.36
Total quantity of steel	74.08	43.77	39.85

The following graph shows weight comparison between IS code and AISC/MBMA.

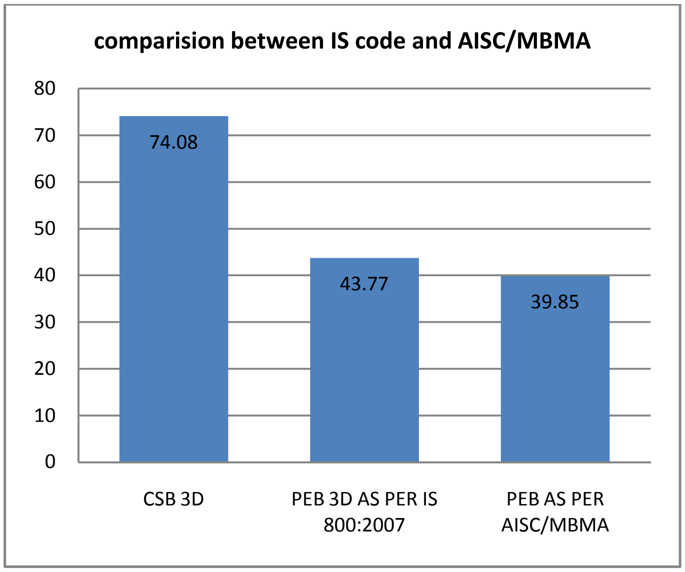

Fig. 10. Weight comparison between IS code and AISC/MBMA

7. CONCLUSIONS

1) As per Indian code, the classes of section considered for design are Plastic, Compact and Semi- compact, slender cross-section. It is well known that many PEB manufacturers use sections with very thin webs in order to reduce the weight of the section and be economical/competitive in their commercial offers, and these thin webs do not satisfy the codal provisions of IS 800: 2007.

2) For 3D PEB structure weight is 35 % lesser than the weight of CSB structure. Reason for higher weight in IS 800:2007 compared to AISC/MBMA is limiting ratio of the section.

3) Weight of PEB depends on the bay spacing with the increase in bay spacing up to certain spacing , the weight reduces and further increase makes weight heavier.

4) Live load is 0.75 KN/m^2 in IS code & whereas it is 0.57 KN/m^2 in MBMA. Thus, concluded that loading as per Indian codes is greater than MBMA code.

5) One of the main reason to increase in weight in IS 800-1984 compared to IS 800-2007 is "Serviceability Criteria". Deflection limits by IS code (H/150) are higher than deflection limits by MBMA (H/60).

6) PEB roof structure is almost 30% lighter than conventional steel building. In Secondary members, light weight " Z" purlins are used for PEB structure.

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