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Design and Comparative Study of Pre-Engineered Building

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***Abstract* - In recent years, the introduction of Pre Engineered Building (PEB) design of structures has helped in optimizing design. The construction of PEB in the place of Conventional Steel Building (CSB) design concept resulted in many advantages as the members are design as per bending moment diagram and thus reducing the steel requirement. In this study, an industrial structure PEB Frame & CSB Frame is analyzed and designed according to the Indian standards, IS 800-1984, IS 800-2007 .In this study, a structure with length 80m, width 60m,with clear height 11.4m and having R-Slope 5.71 Degree for PEB & 18 Degree for CSB is considered to carry out analysis& design for 2D frames . The economy of the structure is discussed in terms of its weight comparison, between Indian codes (IS800-1984, IS800-2007) & in between PEB & CSB building structure.**

***Index terms*- Tapered I Section, Pre-Engineered Buildings, Staad Pro, Utilization Ratio, IS code**

I. INTRODUCTION

Steel is the material of choice for design because it is ductile and flexible. Steel members have high strength per unit weight and the properties of the steel members mostly do not change with time. Also addition and alteration can be made easily steel structures.

Historically, the primary framing structure of a pre-engineered building is an assembly of I-shaped members, often referred as I-beams. In pre-engineered buildings, the I beams used are usually formed by welding together steel plates to form the I section. The I beams are then field-assembled (e.g. bolted connections) to form the entire frame of the pre-engineered building. Some manufacturers taper the framing members (varying in web depth) according to the local loading effects. Larger plate dimensions are used in areas of higher load effects. In conventional steel building, hot rolled sections are used. The size of each section is selected on the basis of maximum internal stress in the member.

Frames of pre-engineered building are according to bending moment diagram. Thus the BM is maximum at mid span and at fixed support. Thus at maximum BM the depth of section is large and depth is reduced depending on BM. Cold formed Z and C-shaped members as secondary structural elements to fasten and support the external cladding.

II. STRUCTURAL CONFIGURATION

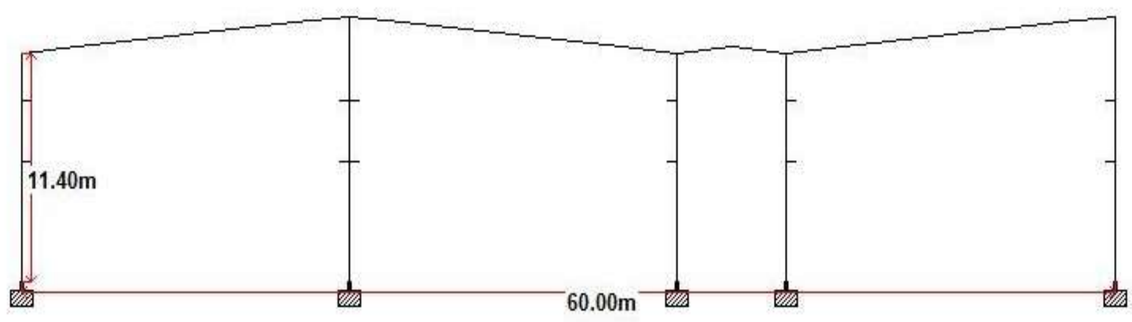

Fig.1 Model of multi-span PEB Frame

STRUCTURAL CONFIGURATION DETAILS

Location	:	Pune, India.
Length of building	:	80 m
Width of building	:	60 m
Eave height of building	:	11.4m (clear)
Seismic zone for Pune	:	III
Wind speed for Pune	:	39 m/sec
Wind terrain category	:	2
Wind Class	:	C
Slope of roof for CSB	:	18 Degree
Slope of roof for PEB	:	5.71 Degree

Soil type : Medium
Importance factor : 1
Response reduction factor : 5
Bay spacing : 7.5 m

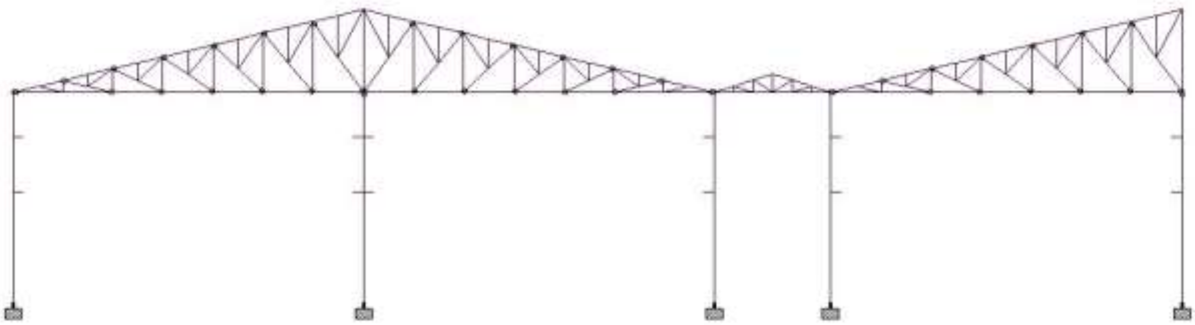

Fig.2 Model of multi-span CSB Frame

III. LOADING CALCULATION

i) Dead load calculation –

Dead load calculation includes Purlins, sheeting, sag rod and insulation material. The total load transferring from these components is 0.150 KN/m².Total Dead load = 0.15*7.5(Bay Spacing) = 1.125 KN/m

ii) Live Load Calculations

Live Load is considered as 0.75 KN/m² according to IS 875(part 2) – 1987 Table II for roof where access is not provided except for maintenance and for a roof where slope is greater than 10 degree then there is reduction of 0.02 KN/m² for every degree in increase above 10 degree

Live Load = 0.75*7.5= 5.625 KN/m² For PEB frame

Live Load = 0.75-((18-10)*0.02) =0.59 KN/m² for CSB frame

iii) Wind Load calculation

Basic wind speed = 39 m/sec

Risk coefficient (K_1) = 1

Terrain height & size factor = 0.98, Topography factor = 1

Design wind speed (V_z) = Vb x K_1 x K_2 x K_3

= 38.22 m/s

Design wind pressure (P_z) = 0.6x $(V_z)^2$

(P_z) = 0.876 KN/m²

Wind load is calculated as per IS 873(Part II).The wind load over the roof can be provided as uniformly distributed load acting outward over the roof and which is calculated as per table 16 given in IS-875 part III . For side walls, the wind load is applied as uniformly distributed load acting inward or outward to the walls according to the wind cases.

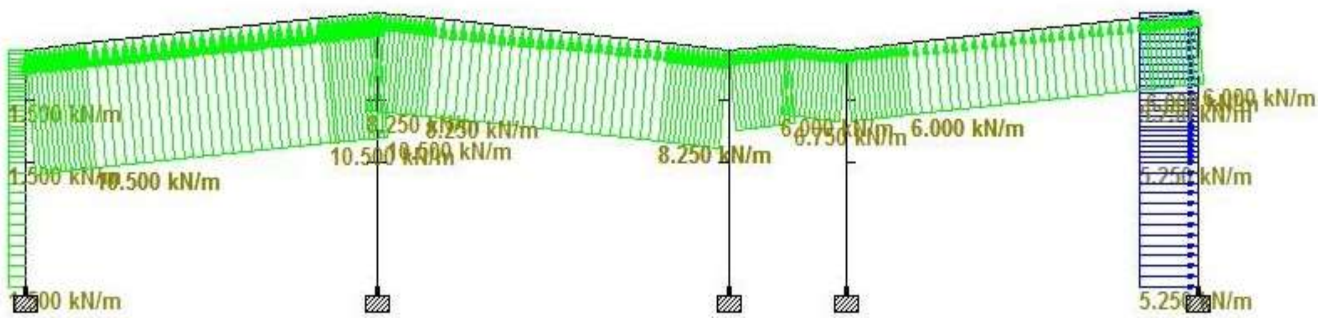

Fig.3 Typical wind load diagram for PEB Frame

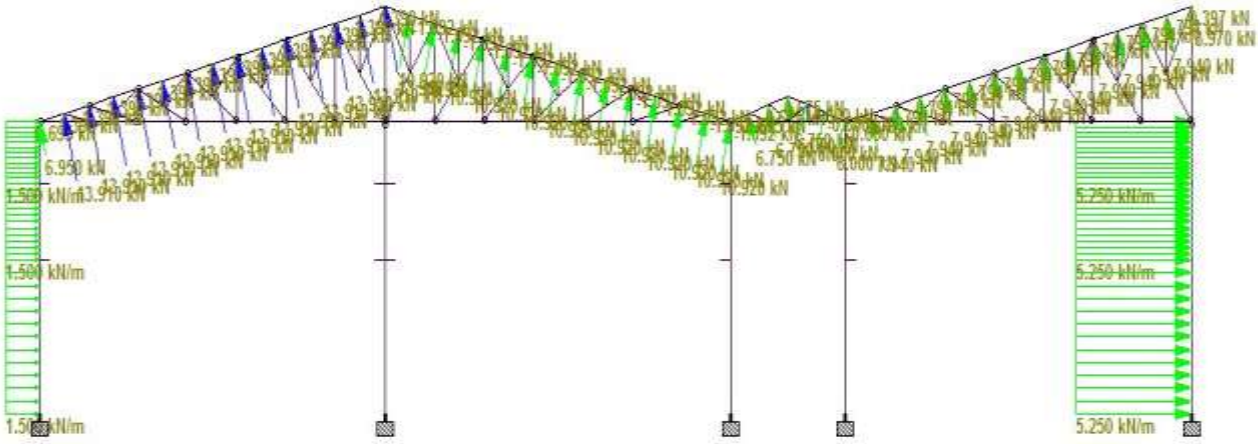

Fig.4 Typical wind load diagram for CSB Frame

iv) Seismic Load calculation –

Earthquake loads affect the design of structures in areas of great seismic activity. The proposed structures in this project shall be analyzed for seismic forces. The seismic zone shall be considered as per IS: 1893-2002 (Part 1). For analysis and design, Zone III shall be considered as Pune region falls under this zone as per IS: 1893-2002 (Part 1).

v) Crane load calculation –

Cranes are used in warehouse for lifting heavy materials from one point to another. The cranes are supported by crane bridge end trucks bearing on rails that are supported on the top of the crane beams. The crane bridge itself moves over the rails on the gantry girder which is in turn supported on the column brackets. The crane load is calculated by positioning the moving load for maximum effects of shear force and bending moment

IV PRE-ENGINEERED BUILDING BY STAAD.PRO

The staad-pro used in structural analysis and design structure. The procedure for design of structure modeling the structure, specification to structure, support, loading and load combination, of analyzing and design of the structure. In staad- pro utilization ratio indicates the suitability of the member as per codes. Normally a value higher than 1 indicates the given member is no suitable for a given loading & load combination, and value below 1.0 indicates the reserve capacity available. The 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.

V LOAD COMBINATION & DEFLECTION LIMITS

Table I - Load combination according to different codes

IS 800-1984	IS 800-2007
Limit state of serviceability	Limit state of serviceability
(DL+LL)	DL+LL)
(DL+WL/EL)	(DL+WL/EL)
(DL+LL+CL)	(DL+LL+CL)
(DL+LL+CL+WL/EL)	(DL+0.8*LL+0.8*CL+0.8*WL/EL)
Limit state of strength	Limit state of strength
(DL+LL)	1.5(DL+LL)
DL+ (WL/EL)	1.5(DL+WL/EL)
(DL+LL+CL)	0.9*DL+ 1.5*WL/EL
DL+0.75*(LL+WL/EL)	(1.5*DL+1.5*LL+1.05*CL)
DL+0.75*(LL+CL+WL/EL)	(1.5*DL+1.05*LL+1.5*CL)
	(1.5*DL+1.05*LL+1.5*CL)
	(1.2*DL+1.2*LL+0.6*WL/EL+1.05*CL)
	(1.2*DL+1.05*LL+0.6*WL/EL+1.2*CL)

Deflection load combinations & Design Load combinations as per the different codes shown in table II & as per above limits the members are checked for deflection & for stress check.

Table II - Deflection limits according to different codes

Sr.no	Description	IS 800-1984		IS 800-2007	
		Vertical	Vertical	Vertical	Vertical
01	Main frame	L/325	H/325	L/180	H/150
02	Main frame with crane(Cab-operated)	L/325	H/325	L/180	H/400
03	Crane beam electric < 50t	L/750		L/750	
04	Crane beam electric >50t	L/1000		L/1000	
05	Wind column		H/325		H/120
06	Mezzanine beam	L/325		L/240	
07	Purlin	L/180		L/150	
08	Girt	L/180		L/150	

VI RESULTS

1. Steel take-off

The multi-span model is designed by code IS 800 -2007 & IS 800 -1984 using the staad-pro. The same geometry is used for conventional steel building and pre-engineering building. Following graph shows the comparison in terms of weight between different codes.

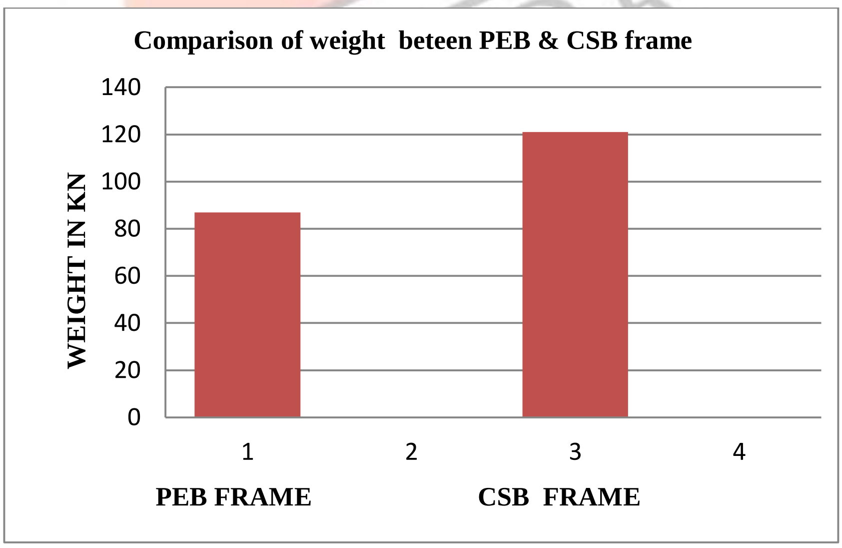

Fig.5 Weight comparison for PEB & CSB Frame by IS 800-2007

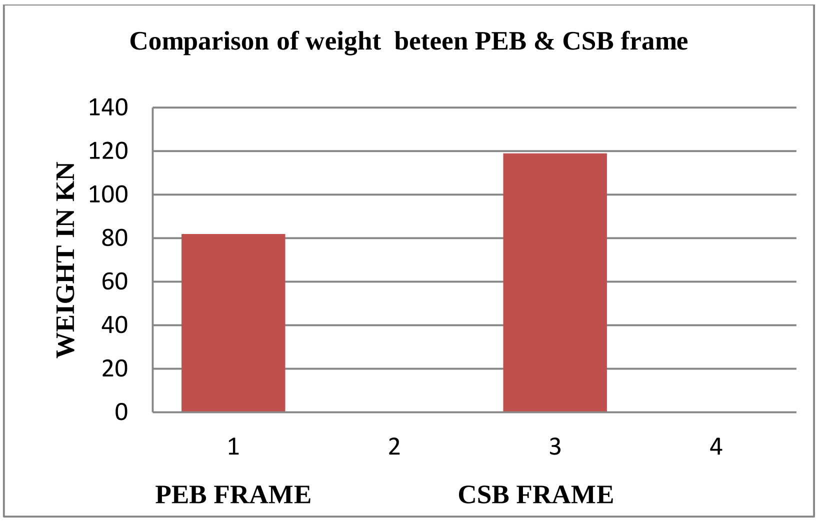

Fig.6 Weight comparison for PEB&CSB Frame by IS 800-1984 Code

Table III Weight Comparison for PEB& CSB frame between different codes

Description	As per IS 800-2007	As per IS 800-1984
PEB Frame (Weight in KN)	87	82
CSB Frame (Weight in KN)	121	119

2. Deflection

The conventional steel frame and conventional building frame is checked for deflection as per the serviceability criteria given in codes. The actual deflection should be less than the permissible deflection. The following table shows the maximum displacement of frame as per calculations.

Table IV-Deflection for PEB& CSB frame between different codes

Description	As per IS 800-2007 (deflection in mm)	As per IS 800-1984 (deflection in mm)
For PEB frame	66.6 mm	51 mm
For CSB frame	46 mm	26.92 mm

VII. CONCLUSION

1. PEB Structure is 30% lighter than the conventional building structure.
2. As per IS Code 800-2007 Table 2, the section is classified as Plastic, Compact and semi-compact, slender cross section. The slender section are not design as per IS 800-2007.So in PEB design the slender section are not design as per IS 800-2007 code and IS 800-1984 code design the slender section and reducing the weight of structure.
3. The deflection limits are higher in IS 800-1984 compared to IS 800-2007.
4. PEB structure reduces the dead load & hence it reduces the size of foundation.
5. Pre-engineering building structure increases the aesthetic view of structure.

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