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Comparison of Design Procedures for Pre Engineering Buildings (PEB): A Case Study

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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. In this study, an industrial structure (Ware House) is analyzed and designed according to the Indian standards, IS 800-1984, IS 800-2007 and also by referring MBMA-96 and AISC-89. In this study, a structure with length 187m,width 40m,with clear height 8m and having R-Slope 1:10,isconsidered to carry out analysis& design for 2D frames (End frame, frame without crane and frame with 3 module cranes). The economy of the structure is discussed in terms of its weight comparison, between Indian codes (IS800-1984, IS800-2007) & American code (MBMA-96), & between Indian codes (IS800-1984, IS800-2007).

***Keywords*—**AISC, Crane Beam, MBMA, Pre-Engineered-Buildings, Staad Pro, Utilization Ratio.

I. Introduction

STEEL is the material of choice for design because it is inherently ductile and flexible. In structural engineering, a pre-engineered building (PEB) is designed by a manufacturer, to be fabricated using a pre-determined inventory of raw materials and manufacturing methods that can efficiently satisfy a wide range of structural and aesthetic design requirements. PEB can be fitted with different structural accessories including mezzanine floors, canopies, fasciae, interior partitions, etc. 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. The complete designing is done at the factory and the building components are brought to the site in knock down condition. These components are then fixed/ jointed at the site and raised with the help of cranes.

II. Structure Configuration

Selected structure is located in Rajasthan, India. Structure having the dimensions length 187m, width 40m, eave height 8m(clear), &roof slope 1:10.Structure suited in seismic zone IV with wind speed 47 m/sec considered life span of structure as 5 years. Complete structure configuration details can be found in Table I as follows [1]-[2], [10]-[11]:

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TABLE I
STRUCTURE CONFIGURATION DETAILS

Location	:	Rajasthan, India.
Length	:	187 m
Width	:	40 m
Eave height	:	8m (clear)
Seismic zone	:	IV
Wind speed	:	47 m/sec
Wind terrain category	:	2
Wind Class	:	C
Life Span	:	5 years
Slope of roof	:	1:10
Crane Capacity	:	10 t (for all 3- cranes)
Soil type	:	Medium
Importance factor	:	1
Response reduction factor	:	5
Purlin spacing	:	1800 mm
Girt spacing	:	2200 mm

III. Dead Load Calculation

Dead load calculation includes the weight calculation of sheeting, sag angles, purlins and insulation material as follows in Table II [2].

TABLE II
CALCULATION OF DEAD LOAD

Sheeting unit weight	: 4.78 kg/m^2(5mm thick galvanized sheet)
Purlin wt.	: 4.71 kg/m(spacing of purlin = 1.8m) : 4.71/1.8 : 2.61 kg/m^2
Sag rods wt.	: 1.2 kg/m : 1.2/1.8 :0.667 kg/m^2
Insulation material wt.	: 2 kg/m2
Dead load	: 4.78 + 2.61 + 0.667 + 2 : 10kg/m^2 : 0.1 KN/m^2

IV. Live Load Calculation

Calculation of live loads includes consideration of live loads according to different codes (Indian, American) as follows in Table III [2].

TABLE III
CALCULATION OF LIVE LOAD

As per IS: 875(part-2) -1987-Table-II (Imposed loads on various types of roofs).	
Angle of roof truss (α)	: tan-1(1/10) : 5.71° (<10°)
As per Indian- LL	: 0.75 KN/m^2
As per MBMA-96, Cl-1.3.2.	
As per AISC - LL	: 0.57 KN/m^2

V. Wind Load Calculation

Wind load calculation is done according to Indian code IS: 875(part-2)-1987-Cl.5.3, as follows in Table IV [2].

TABLE IV
CALCULATION OF WIND LOAD

Wind speed	(Vb)	: 47 m/sec
Risk coefficient	(K1)	: 0.71
Probability factor	(K2)	: 0.93
Topography factor	(K3)	: 1.0
Design wind speed	(VZ)	: K1*K2*K3*Vb : 0.71*0.93*1*47 : 31.03 m/sec
Design wind pressure	(PZ)	:0.6*$(Vz)^2$: 0.6*31.03^2 : 578 N/m^2 : 0.578 KN/m^2

VI. Pre-Engineered Buildings by STAAD.Pro

The power tool for computerized structural engineering STAAD Pro is the most popular structural engineering software product for 2D, 3D model generation, analysis and multi-material design. It has an intuitive, user-friendly, visualization tools, powerful analysis and design facilities and seamless integration to several other modeling and design software products. The software is fully compatible with all Windows operating systems. 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, STAAD Pro has been the choice of design professionals around the world for their specific analysis needs [1]-[9].

VII. Drawings

Following drawings includes drawings of frames which are selected for analysis [11], [12].

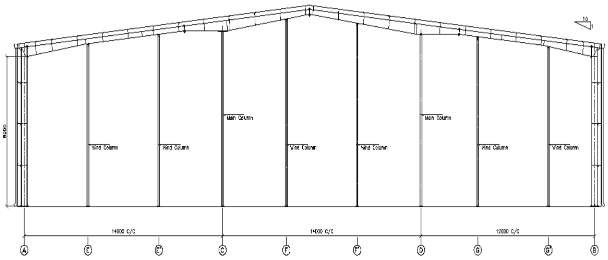

Fig. 1 End frame with wind columns

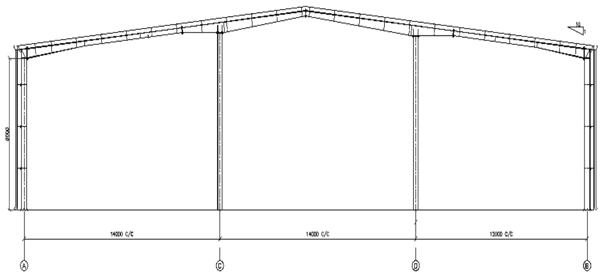

Fig. 2 Internal frame without crane

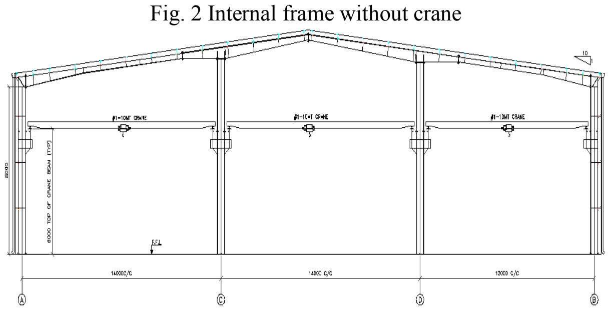

Fig. 3Internal main frame with cranes

VIII. Load Combinations

Load combinations include different combinations of loads according to different codes (AISC-89/MBMA-86, IS800-1984, IS800-2007) by considering serviceability and strength criteria as follows in Table V [4]-[7].

TABLE V
LOAD COMBINATIONS ACCORDING TO DIFFERENT CODES

AISC-89/MBMA-86	IS 800-1984	IS 800-2007
Limit State of Serviceability:	(DL+LL)	Limit State of Serviceability:
(DL+LL)	(DL+WL/EL)	(DL+LL)
(DL+WL/EL)	(DL+LL+WL/EL)	(DL+WL/EL)
(DL+CL)	(DL+LL+CL)	(DL+LL+CL)
(DL+ 0.5*WL/EL+CL)	(DL+ LL + CL+ WL/EL)	(DL+0.8*LL+0.8*WL/EL+0.8*CL)
Limit State of Strength:	Limit State of Strength:	Limit State of Strength:
(DL+LL)	(DL+LL)	1.5*(DL+LL)
(DL+ CL)	(DL+WL/EL)	1.5*(DL+WL/EL)
0.75*(DL+WL/EL)	(DL+ LL+ CL)	(0.9*DL+1.5 WL/EL)
0.75*(DL+WLRL-P)	0.75* (DL+LL+WL/EL)	(1.5*DL+1.5*LL+1.05*CL)
0.75(DL+ 0.58*WL/EL+CL)	0.75*(DL+ LL + CL+ WL/EL)	(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)
		(1.2*DL+1.2*LL+1.2 *WL/EL+0.53*CL)
		(1.2*DL+1.2*LL+1.2*WL/EL+0.53*CL)

IX. Design Specifications

Design specifications include limiting ratios of cross sections and deflection limits according to different codes (AISC-89/MBMA-86, IS800-1984, IS800-2007) as follows in Tables VI & VII [4]-[7].

TABLE VI
LIMITING WIDTH TO THICKNESS RATIO ACCORDING TO IS 800 -2007-TABLE-2

Compression		Ratio	Class of section		
			Class 1 (Plastic)	Class 2 (Compact)	Class 3 (Semi-Compact)
Outstanding element of compression flange	Rolled section	b/t_f	9.4ε	10.5ε	15.7ε
	Welded section	b/t_f	8.4ε	9.4ε	13.6ε
Internal element of compression flange	Compression due to bending	b/t_f	29.3ε	33.5ε	42ε
	Axial compression	b/t_f	Not applicable		
Web of an I,H or box section	Neutral axis at mid-depth	d/t_w	84ε	105ε	126ε
	Generally If r_1 is negative	d/t_w	$(84\varepsilon)/(1+r_1)$ but ≤ 42ε	$(105\varepsilon)/(1+r_1)$	$(126\varepsilon)/(1+2r_2)$ but ≤ 42ε
	If r_1 is positive	d/t_w		$(105\varepsilon)/(1+1.5r_1)$ but ≤ 42ε	
	Axial compression	d/t_w	Not applicable		42ε
Web of a channel		d/t_w	42ε	42ε	42ε
Angle, compression due to bending (Both criteria should be satisfied)		b/t	9.4ε	10.5ε	15.7ε
		d/t	9.4ε	10.5ε	15.7ε
Single angle, or double angles with the components separated, axial compression (All three criteria should be satisfied)		b/t d/t (b+d)/t	Not applicable		15.7ε 15.7ε 25ε
Outstanding leg of an angle in contact back-to-back in a double angle member		d/t	9.4ε	10.5ε	15.7ε
outstanding leg of an angle with its back in continuous contact with another component		d/t	9.4ε	10.5ε	15.7ε
Stem of a T-section, rolled or cut from a rolled I-or H- section		D/t_f	8.4ε	9.4ε	18.9ε
Circular hollow tube, including welded tube subjected to:					
a) Moment		D/t	$42\varepsilon^2$	$52\varepsilon^2$	$146\varepsilon^2$
b) Axial compression		D/t	Not applicable		$88\varepsilon^2$

NOTES
1. Elements which exceed semi-compact limits are to be taken as of slender cross-section.
2. $\varepsilon = (250/f_y)^{1/2}$.
3. The stress ratio r_1 and r_2 are defined as:
r_1 = (Actual average axial stress(negative if tensile)/(Design compressive stress of web alone)
r_2 = (Actual average axial stress(negative if tensile)/(Design compressive stress of overall section)

TABLE VII
DEFLECTION LIMITS ACCORDING TO DIFFERENT CODES

S.No	Description		Limiting Deflections					
			AISC-89/MBMA-86		IS 800:1984		IS 800:2007	
			Vertical	Lateral	Vertical	Lateral	Vertical	Lateral
1	Main frame		L/180	H/60	L/325	H/325	L/180	H/150
	Main frame with crane (pendent)			H/100	L/325	H/325	L/180	H/200
	Main frame with crane (cab operated)			H/240	L/325	H/325	L/180	H/400
2	Crane beam	Electric<50t	L/600	L/400	L/750		L/750	
		Electric>50t	L/800		L/1000		L/1000	
3	Wind column			H/120		H/325		H/150
4	Mezzanine beam		L/240		L/325		L/240	
5	Under slung crane		L/450		L/750		L/750	
6	Purlin		L/180		L/180		L/150	
7	Girt		L/120		L/180		L/150	
8	Minimum thickness	Primary	4 mm		6 mm		4 mm	
		Secondary	1.6 mm		2 mm		1.6 mm	

X. Comparison Between IS 800-1984, IS 800-2007, MBMA

Comparison includes comparison of frame weights from STAAD.Pro and its variation of weight percentage according to different codes (AISC-89/MBMA-86, IS800-1984, IS800-2007) as follows in Table VIII [9]:

TABLE VIII
FRAME WEIGHTS FROM STAAD.PRO & ITS PERCENTAGE VARIATION ACCORDING TO DIFFERENT CODES

Description	MBMA/AISC (Kg's)	IS 800-2007 (Kg's)	IS 800-1984 (Kg's)	Comparison (% of increase in Wt.)		
				In IS 800-2007 compared to MBMA	In IS 800-1984 compared to MBMA (%)	In IS 800-1984 compared to IS 800-1984(%)
GL-1	2934	3334	3738	13.7	27.5	12.2
GL-2-3	1908	2411	2538	26.4	33.1	5.3
GL-4-25	2863	3599	3898	25.8	36.2	8.4
Total	7705	9344	10174	21	32	9

XI. RESULTS

Following graph shows the % increase in wt. in IS800-1984, 2007 compared to MBMA/AISC.

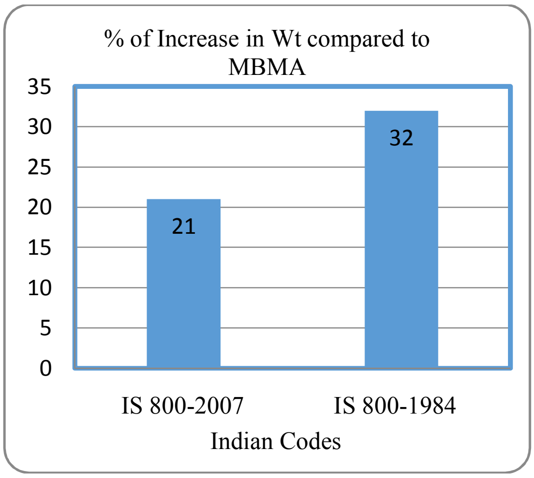

Fig. 4 Comparison between Indian codes (IS800-1984 &IS800-2007) & American code (MBMA)

Following graph shows the % increase in wt. in IS800-1984 compared to IS 800-2007.

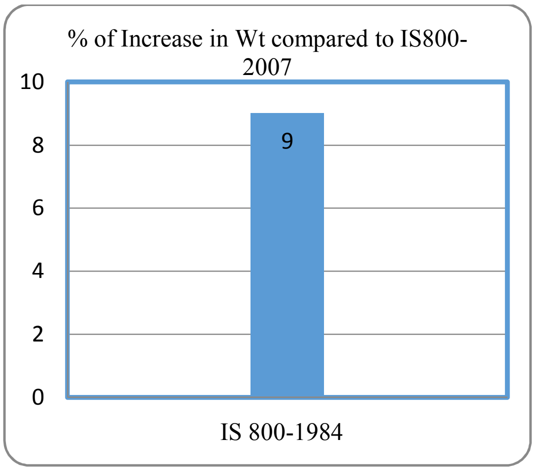

Fig. 5 Comparison between Indian codes(IS800-1984 & IS800-2007)

XII. CONSIDERATIONS

1) Wind Load application as per IS 875 (Part-3) -1987 (reaffirmed 1997), Design According to ASIC -1989, IS800-1984, & IS800-2007 for Built-up Members& Load combinations and Serviceability according to MBMA -1996, IS800-1984, & IS800-2007 [2], [4]-[7].
2) Internal Pressure Coefficient is considered as +/-0.2. (Since %of opening<5%) [2].
3) External column base considered as fixed support. (Sway is not controlling with pinned connection).Internal column base considered as fixed support.
4) Wall cover is full height sheeted all around the building.

XIII.CONCLUSION

Following are the conclusions which are observed:

1) 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 are higher than deflection limits by MBMA.
2) Reason for higher wt. in IS 800-2007 compared to AISC/MBMA is limiting ratios of the sections (Table 2 of IS800-2007).
3) 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.
4) The main difference between the Indian Code (IS800-2007) to the other equivalent American Codes are in the classification of the cross-section of the steel member. 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.
5) It was observed in industries most of the projects done with AISC/MBMA. Reasons to preferring AISC/MBMA Code are IS 800:2007 has not considered slender sections which are often encountered in cold formed thin sections, because there is another code IS 801 for this. Hence people using cold formed sections cannot use IS 800.May be that is the reason people are using AISC code &the main reason to use the AISC code for PEB structures is due the fact that it leads to an economical structural solution as compared to the Indian Code.
6) It is observed that crane Impact load allowance is similar in case of vertical loads whereas in case of horizontal loads (surge, barking loads) the impact allowance is more in MBMA compared to IS codes.

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