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Comparative Study of Multi-Storey Multi-Span G+4 Building by PEB and CSB Concept

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Abstract: *Time being the most important aspect, steel structures (Pre fabricated) is built in very short period and one such example is Pre Engineered Buildings (PEB)..Though it is known to have its origin in 1960's it has been in practice widely only during the recent years. Steel industry is growing rapidly in almost all the parts of the world. Conventional steel buildings and Pre Engineered Buildings can be used extensively for the construction of Industrial , Commercial and Residential Buildings .These buildings can be multistoried (4-6 floors).The adoptability of PEB in the place of Conventional Steel Building (CSB) design concept resulted in many advantages, including economy and easier fabrication. Construction of conventional steel buildings (CSB) incorporates the use of hot rolled sections, which have uniform cross-section throughout the length. However, pre-engineered steel buildings (PEB) utilize steel sections, which are tailored and profiled based on the required loading effects. The concept includes the technique of providing the best possible section according to the optimum requirement. Due to lack of awareness and confidence in design and execution of PEB buildings, still it is not the first choice of owner and designer in India. This paper gives a comparative study of PEB and CSB Concept for multi-storey building .This is achieved by analyzing and designing G+4 commercial building with length 140m ,width 40m,eave height 18m, R slope 1/10 using STADD PRO and IS 800-2007 Design code ,by both concepts*.

Key Words: Pre-Engineered Building, Conventional Steel Building, Staad Pro , IS 800-2007

1. INTRODUCTION

Steel industry is growing rapidly in almost all the parts of the world. The use of steel structures is not only economical but also Eco-friendly at the time when there is a threat of global warming. Here, "economical" word is stated considering time and cost. Time being the most important aspect, steel structures (Pre-fabricated) is built in very short period and one such example is Pre Engineered Buildings (PEB). Pre-engineered buildings are nothing but steel buildings in which excess steel is avoided by tapering the sections as per the bending moment's requirement. One may think about its possibility, but it's a fact many people are not aware about Pre Engineered Buildings. If we go for regular steel structures, time frame will be more, and also cost will be more, and both together i.e. time and cost, makes it uneconomical. Thus in pre-engineered buildings, the total design is done in the factory, and as per the design, members are pre-fabricated and then transported to the site where they are erected in a time less than 6 to 8 weeks. The structural performance of these buildings is well understood and, for the most part, adequate code provisions are currently in place to ensure satisfactory behavior in high winds. 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. Thus, pre-engineered buildings can be shifted and/or expanded as per the requirements in future. Presently, large column free area is the utmost requirement for any type of industry and with the advent of computer software's it is now easily possible. With the improvement in technology, computer software's have contributed immensely to the enhancement of quality of life through new researches. Pre-engineered building (PEB) is one of such revolution. "Pre-engineered buildings" are fully fabricated in the factory after designing, then transported to the site in completely knocked down (CKD) condition and all components are assembled and erected with nut-bolts, thereby reducing the time of completion.

2. METHODOLOGY

The present paper includes the design of an (G+4)Commercial building considered to be located at Pune. The structure is proposed as a Pre- Engineered Building with 140 meter length and 40 meter width with an eave height of 18 meter. 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. Both the designs are then compared to find out the economic output and steel consumption. The designs are carried out in accordance with the Indian Standards and by the help of the structural analysis and design software Staad.pro.

2.1 Concept Of Pre Engineered Buildings

These are produced in the plant itself. Here, according to the requirements of the customer the manufacturing of the members is done. The components are made in completely ready condition for transportation. These are then sent to the site and then the erection process starts. The manufacturing process doesn't takes place at the site. The PEBs are normally constructed for office, shop fronts, ware houses, etc. Here, the extra amount of steel is avoided because the sections are tapered according to the bending moment diagram. Pre-Engineered Building concept involves the steel building structural systems which are predesigned and prefabricated .

In today's 21st century, it is very important to find an alternate resource for civil construction technology, seeing through the depleting natural resources. In India, the concept of PEB construction started in 1999-2000. The growth rate of PEB construction is 20 percent annually. PEB concept has been very successful and well established in North America, Australia and is presently expanding in U.K and European countries.

Fig-1: G+4 PEB Frame

2.2 Concept Of Conventional Steel Buildings

Today's world, steel is bringing elegance, artistry and is functioning in endless ways contributing to new solutions for the construction of formidable structures, which were once unthinkable. Steel offers speedy construction right from the start . Due to its important characteristics like ductility, flexibility etc. steel is been widely used in the construction industry. It bends under the application of heavy loads rather than undergoing crushing and crumbling .

Due to its strength, less rate, stability, flexibility and recyclability, it makes a great choice to use steel in construction. It is also seen that steel has some reserve strength in them. The CSBs are stable . Usually hot rolled structural members are used in these buildings. Here the members are fabricated in factories and then transported to the site. The changes can be made during the erection by welding and cutting process. Normally trusses are used in this system.

Fig-2: G+4 CSB Frame

3. Structure Configuration

The structure which I considered now is a G+4 Commercial Building located in Pune having its dimensions as 140m length and 40m width having a eave height of 18m with 5 no. of internal column which is at a distance of 1 @ 6.8m C/C + 1 @ 6.6m C/C + 1 @ 6.6m C/C+6.8m C/C + 1 @ 6.6m C/C + 1 @ 6.6m C/C. As the building in Pune is falls under seismic zone-III with a wind speed of 39m/s i.e. 140Kmph. As the structure is having regular intermediate column spacing the structure be symmetric to its ridge. The details of parameters are provided in table 1

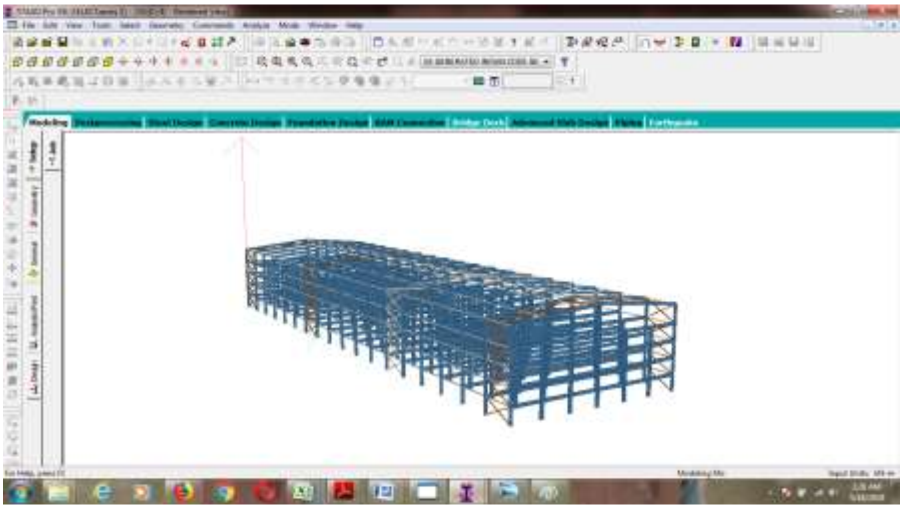


Fig-3: 3D Frame Staad Model

Table -I:

STRUCTURE CONFIGURATION DETAILS	
Building Type	Multi span Multi Floor
Location	Pune ,India
Length	140mtrs
No. of Bays along length	18Nos (1@7.84+16@7.77+1@7.84)
Width	40mtrs
No. of Bays along width	6Nos(1@6.8+4@6.6+1@6.8)
Eave Height	18mtrs
Clear Height	20mtrs
Seismic Zone	III
Wind Speed	39 m/sec
Wind Terrain Category	2
Wind Class	C
Slope Of Roof	1:10(5.71 degree)
Soil Type	Medium

Importance Factor	1
Roof Purlins	Span 7.77m continuous spaced @1.5m c/c.
Wall Girts	Span 7.77m continuous spaced @1.5m c/c.

4. Load Data

IS 800:2007-Clause 3.2 states that the various forces and loads must be considered while performing the design of steel structures . Loading details are given in below Tables II, III & IV.

Table II

Dead load (As per IS 875-Part 1, 1987)

DEAD LOAD	
Self-weight	
Deck Sheeting	0.1 kN/m2
Horizontal slope	5.71 degree

Table III

Dead load (As per IS 875-Part 2, 1987)

LIVE LOAD	
Roof	0.75kN/m2
Mezzanine Floor	5 kN/m2
Horizontal slope	5.71 degree

Table IV

Wind load (As per IS 875-Part 3, 1987)

WIND LOAD	
Location	PUNE,INDIA
Wind Speed	39 m/sec
Building Height	20mtr
Design life of structure	50 years

Wind load is calculated as per IS:875 (Part 3)-1987. The wind load over the roof can be provided as uniformly distributed load acting outward over the rafter. For side walls, the wind load is applied as uniformly distributed loads acting inward or outward to the walls according to the wind case.

Design wind speed as per Clause 5.3, IS:875 (Part 3) – 1987 is given by,

Vz = Vb * k1 * k2 * k3 For Pune, Vb = 39 m/s, from appendix A as per IS: 875 (Part 3) – 1987
k1 = 1.00, from table 1 as per IS: 875 (Part 3) – 1987
k2 = 0.99, from table 2 for terrain category 2- Class C buildings
k3 = 1,

Therefore Design wind speed (Vz) = Vb * k1 * k2 * k3
= 39 * 1.0 * 0.99* 1.0
= 38.61 m/s

5. Design wind loads:

Depending on the internal and external pressure coefficients, eight different wind load cases are considered in this study. For Internal pressure co-efficient, two design conditions shall be examined in the case of the buildings where the claddings permit the flow of air with openings not more than about 5 percent of the wall area but where there are no large openings.

SIGN CONVENTIONS
+ve sign indicates wind flows towards frame
-ve sign indicates wind flows away from frame.

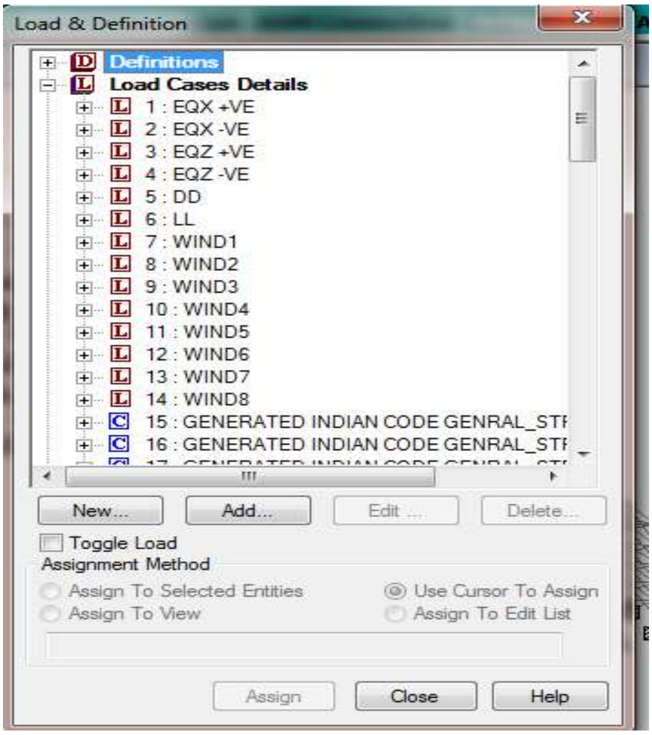
Table V: Final wind loads (kN/m)

	WINDWARD	LEEWARD	LEEWARD	WINDWARD
WL1	3.49	-7.98	-4.19	-3.14
WL2	6.28	-5.19	-1.40	-0.35
WL3	3.49	-7.98	-4.19	-3.14
WL4	6.28	-5.19	-1.40	-0.35
WL5	-4.89	-6.98	-6.98	-4.89
WL6	-2.09	-4.19	-4.19	-2.09
WL7	-4.89	-6.98	-6.98	-4.89
WL8	-2.09	-4.19	-4.19	-2.09

6. Load combinations:

For the present study, various primary loads are considered as given below.

1.EQX +VE	2.EQX –VE	3.EQZ+VE	4.EQZ-VE	5.DL	6.LL	7.WL1
8.WL2	9.WL3	10.WL4	11.WL5	12.WL6	13.WL7	14.WL8



For these primary loads, following are the combinations adopted for the analysis in both the concepts according to IS 800: 2007

Serviceability Combinations:

(DL+LL)

(DL+WL/EL)
(DL+LL+CL)
(DL+0.8*LL+0.8*WL/EL+0.8*CL)

Design combinations:

1.5*(DL+LL)
1.5*(DL+WL/EL)
(0.9*DL+1.5 WL/EL)
(1.5*DL+1.5*LL+1.05*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)
(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)

Table VI: Deflection Limits According to IS 800-2007

Sr.No	Description		Vertical	Lateral
1	Main frame		L/180	H/150
	Main frame with crane (pendent)		L/180	H/200
	Main frame with crane (cab operated)		L/180	H/400
2	Crane Beam	Electric<50t	L/750	
		Electric>50t	L/1000	
3	Wind column			H/150
4	Mezzanine beam		L/240	
5	Under slung crane		L/750	
6	Purlin		L/150	
7	Girt		L/150	
8	Primary Minimum thickness		5mm	
9	Secondary Minimum thickness		2mm	

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Table VII :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/tf	9.4ε	10.5ε	15.7ε
	Welded section		b/tf	8.4ε	9.4ε	13.6ε
Internal element of compression flange	Compression due to bending		b/tf	29.3ε	33.5ε	42ε
	Axial compression		b/tf	Not applicable		
Web of an I,H or box section	Neutral axis at mid-depth		d/tw	84ε	105ε	126ε
	Generally	If r1 is negative	d/tw	(84ε)/(1+r1) but ≥ 42ε	(105ε)/(1+r1)	(126ε)/(1+2r2) but ≥ 42ε
		If r1 is positive	d/tw		(105ε)/(1+1.5r1) but ≥ 42ε	
	Axial compression		d/tw	Not applicable		42ε
Web of a channel			d/tw	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/tf	8.4ε	9.4ε	18.9ε
Circular hollow tube, including welded tube subjected to:						
a) Moment			D/t	42ε2	52ε2	146ε2
b) Axial compression			D/t	Not applicable		88ε2

1. Elements which exceed semi-compact limits are to be taken as of slender cross-section.

2. ε= (250 /fy) 1/2.

3. The stress ratio r1 and r2are defined as:

r1 = (Actual average axial stress(negative if tensile)/(Design compressive stress of web alone)

r2 = (Actual average axial stress(negative if tensile)/(Design compressive stress of overall section)

7. STAAD PRO Analysis

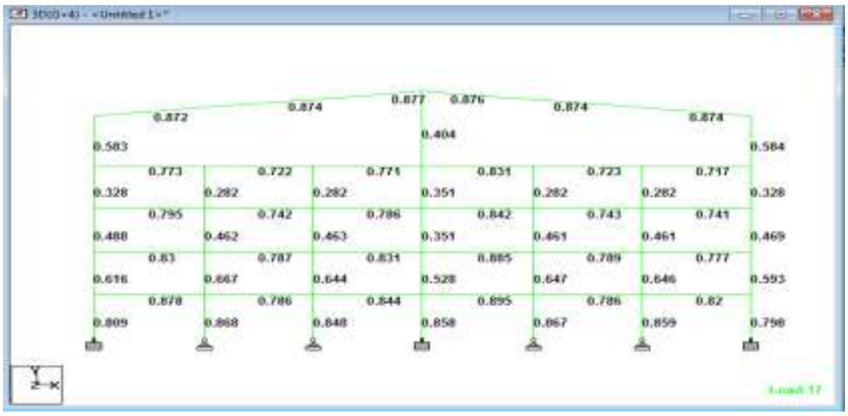

Fig-4: Unity Ratio For PEB Model.

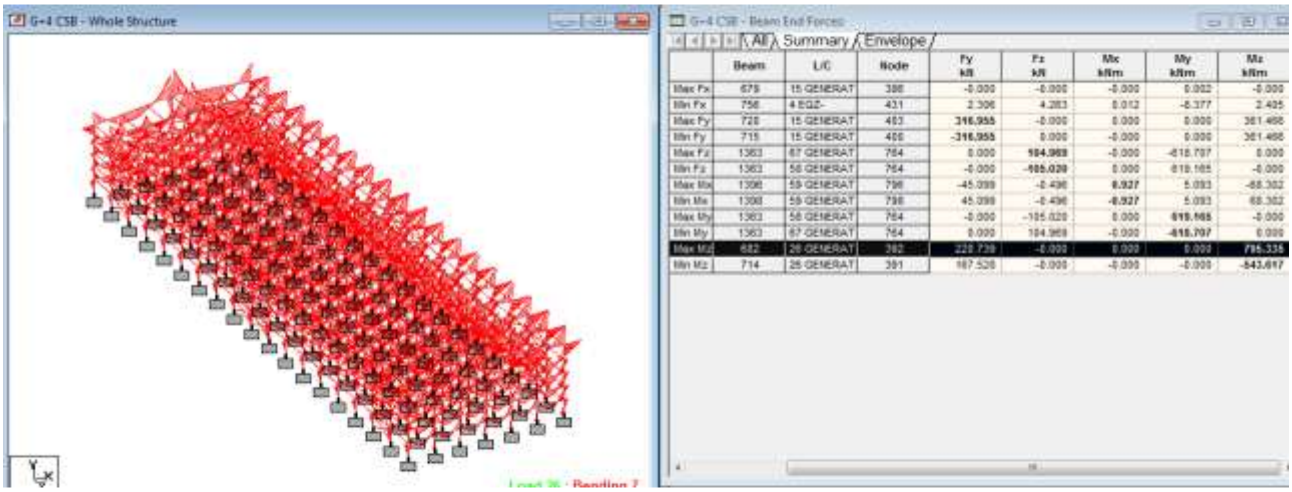

Fig-5: Max Bending Moment For CSB Frame.

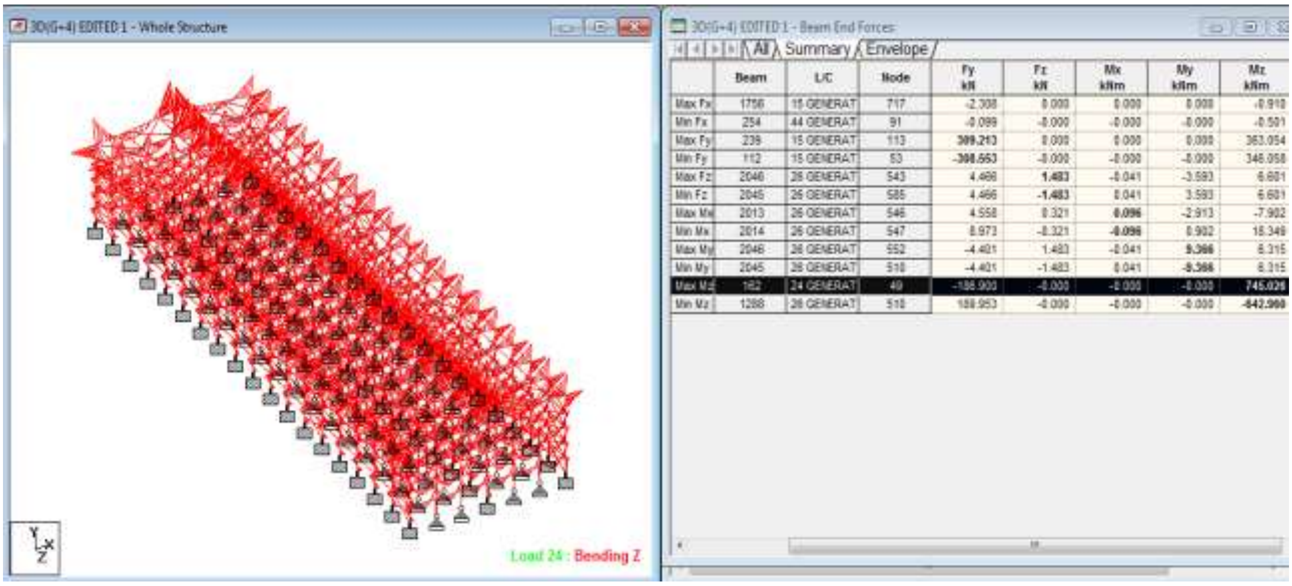

Fig-6: Max Bending Moment For PEB Frame.

8. Results And Discussion

Using the software Staad pro, the structure considered was analyzed and designed using both the PEB and CSB concept and obtained results are summarized as below in table VIII with reference to figure 5 and 6.

Table VIII: Outcomes Of Study

SR.NO	PARAMETER	PEB	CSB
1	STEEL TAKE OFF (kN)	6088.82	10084.4
2	MAXIMUM MOMENT (kNm)	745.026	795.335
3	MAXIMUM SHEAR FORCE (kN)	2683	2852.931
4	SUPPORT REACTION (kN)	309.213	316.955

9. CONCLUSIONS

The paper contain the study for analysis and design of G+4 multistoried multi-span building as per PEB and CSB Concept. The results obtained from study shows that multistoried building of PEB are also advantageous over CSB and should be adoptable by the designers and owners in India.

The various outcomes from the study are as belows

1. As per study it has been observed that the weight of PEB model is lesser than that of the CSB model of same length width and height. Reduction in weight directly deals with the quantity of steel required, here in these study of G+4 commercial PEB structure reduces the quantity of steel by about 39% than that required by the G+4 commercial CSB structure.
2. As of the quantity of steel , also Moment, Shear Forces and Support Reactions are lesser than the CSB which in turn reduces the heavy work, cost saving and also material saving in the structure.
3. PEB structures are lighter than CSB structures , hence provide good resistance to Seismic forces .
4. Delivery and Erection time for PEB is also less as compared to CSB , as they are manufactured in factories and just erected using nut and bolts on site, these makes the work faster and easier.
5. The construction of PEB structure is lighter , faster, cost and material saver than CSB , and has a very wide scope in India but they are still not preferred .
6. PEB technology can be adopted for the bigger sized buildings more effectively than the smaller sized buildings .

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