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Comparative study of multi-storey multi-span buildings by PEB and CSB concept

Md Shahid Wasim Chaudhary
chaudhary.shahid83@gmail.com
Dr. D. Y. Patil School of Engineering and Technology, Pune, Maharashtra

Dr. Nagesh Shelke
nagesh.shelke@dypic.in
Dr. D. Y. Patil School of Engineering and Technology, Pune, Maharashtra

Vishwajeet Kadlag
kadlagvishwajeet@gmail.com
Dr. D. Y. Patil School of Engineering and Technology, Pune, Maharashtra

ABSTRACT

Pre Engineered Buildings (PEB) are steel structures which are prefabricated and build in a very short period of time. PEB has its origin in the 1960s, but these are widely in practice in almost all parts of the world during recent years. Construction of steel buildings and the steel industries are rapidly growing in India as well as other parts of the world. For the construction of the industrial shed, residential buildings and commercial complex, Conventional steel building concept are commonly in practice. PEB concept is also simple and can be easily adopted and used extensively for the construction of Industrial, Residential and Commercial Buildings. The adoptability of PEB in the place of CSB design concept resulted in many advantages, including light weight structures, economical and easier fabrication process. For the construction of CSB, hot rolled sections are used which have uniform cross-section throughout the length, whereas in the construction of PEB steel sections, which are tailored and profiled based on the required loading effects are used. The concept includes the technique of providing the best possible section according to the optimum requirement. Due to lack of awareness and confidence in the design and execution of PEB buildings, still, it is not the first choice of owner and designer in India. The present work involves the comparative study of PEB and CSB Concept for a multi-story building. This is achieved by analyzing and designing G+4, G+2 and G+1 commercial building with length 140m, width 40m, eave height 18m,12m, and 9m respectively R slope 1/10 using STADD PRO and IS 800-2007 Design code, by both concepts.

Keywords*— Pre-engineered building, Conventional steel building, STAAD PRO, IS 800-2007*

1. INTRODUCTION

The steel industry is growing rapidly in almost all 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 is the most important aspect, steel structures (Pre-fabricated) is built in a 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 of Pre Engineered Buildings. If we go for regular steel structures, the 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 a (G+4), (G+2) and (G+1) 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 18m, 12m, and 9m respectively. 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 take 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 per cent annually. PEB concept has been very successful and well established in North America, Australia and is presently expanding in the UK and European countries.

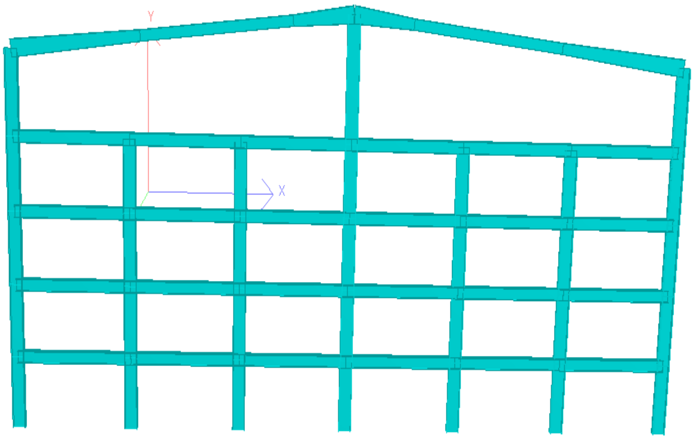


Fig. 1: G+4 PEB Frame

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.

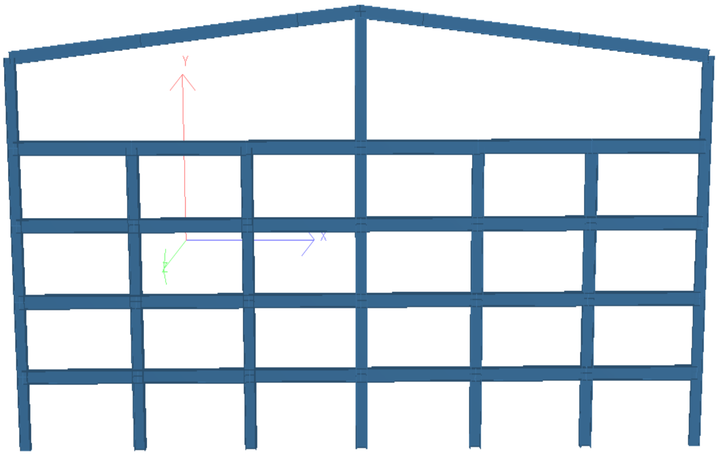


Fig. 2: G+4 CSB Frame

3. STRUCTURE CONFIGURATION

The structure which I considered now is a G+4,(G+2) and (G+1) Commercial Building located in Pune having its dimensions as 140m length and 40m width having a clear height of 20m,14m and 11m respectively 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 the parameters are provided in table 1.

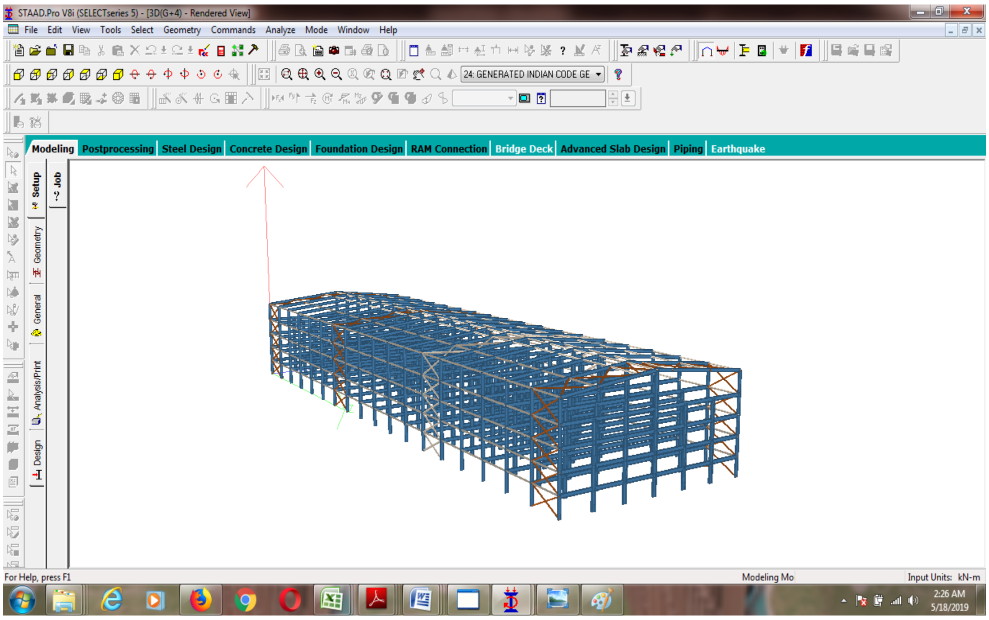


Fig. 3: 3D Frame STAAD Mode

Table 1: Structure configuration details

Structure configuration details	
Building Type	Multi-span Multi Floor
Location	Pune, India
Length	140mtrs
No. of Bays along the length	18Nos (1@7.84+16@7.77+1@7.84)
Width	40mtrs
No. of Bays along the width	6Nos(1@6.8+4@6.6+1@6.8)
Eave Height	18m,12m and 9m respectively
Clear Height	20m,14m and 11m respectively
Seismic Zone	III
Wind Speed	39 m/sec
Wind Terrain Category	2
Wind Class	C
Slope Of Roof	1:10(5.71 degrees)
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 2, table 3 and table 4.

Table 2: 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 3: Live 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 4: Wind load (As per IS 875-Part 3, 1987)

Wind load	
Location	Pune, India
Wind Speed	39 m/sec
Building Height	20m,14m and 11m
The design life of the 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 = 0.98, 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.

5.1 Sign conventions

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

Table 5: Final wind loads for G+4 model (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

Table 6: Final wind loads for G+2 model (kN/m)

	Windward	Leeward	Leeward	Windward
WL1	3.1	7.2	4.1	2.9
WL2	6.1	5.1	1.17	.29
WL3	-3.1	7.2	4.1	-2.9
WL4	-6.1	5.1	1.17	-0.29
WL5	-4.2	6.98	6.98	4.2
WL6	-2	4.19	4.19	2
WL7	-4.2	6.98	6.98	4.2
WL8	-2	4.19	4.19	2

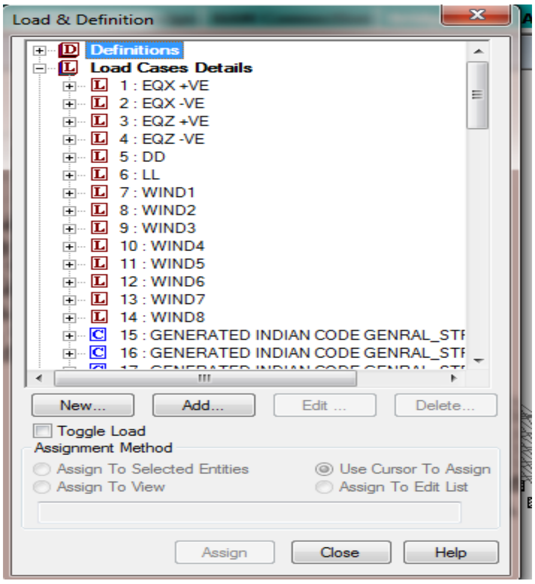
Table 7: Final wind loads for G+1 model (kN/m)

	Windward	Leeward	Leeward	Windward
WL1	3.1	7.2	4.1	2.9
WL2	6.1	5.1	1.17	.29
WL3	-3.1	7.2	4.1	-2.9
WL4	-6.1	5.1	1.17	-0.29
WL5	-4.2	6.98	6.98	4.2
WL6	-2	4.19	4.19	2
WL7	-4.2	6.98	6.98	4.2
WL8	-2	4.19	4.19	2

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



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)

7. STAAD PRO ANALYSIS

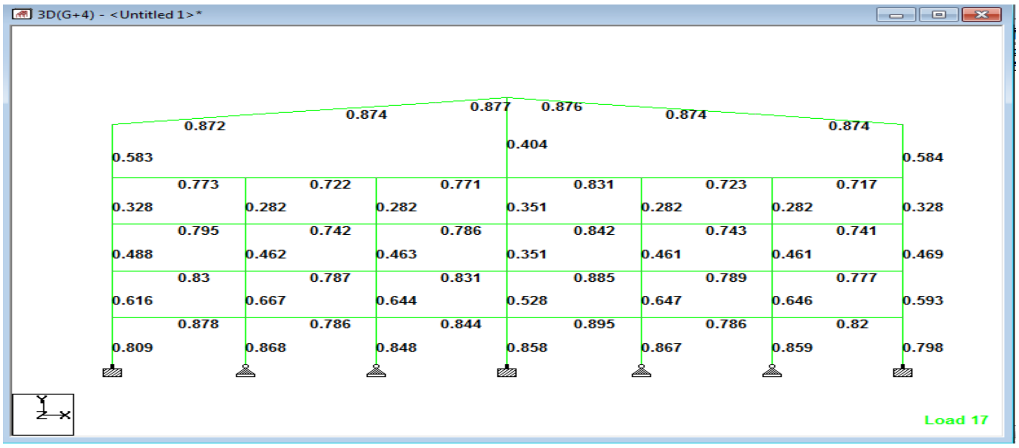


Fig. 4: Unity Ratio for PEB Model

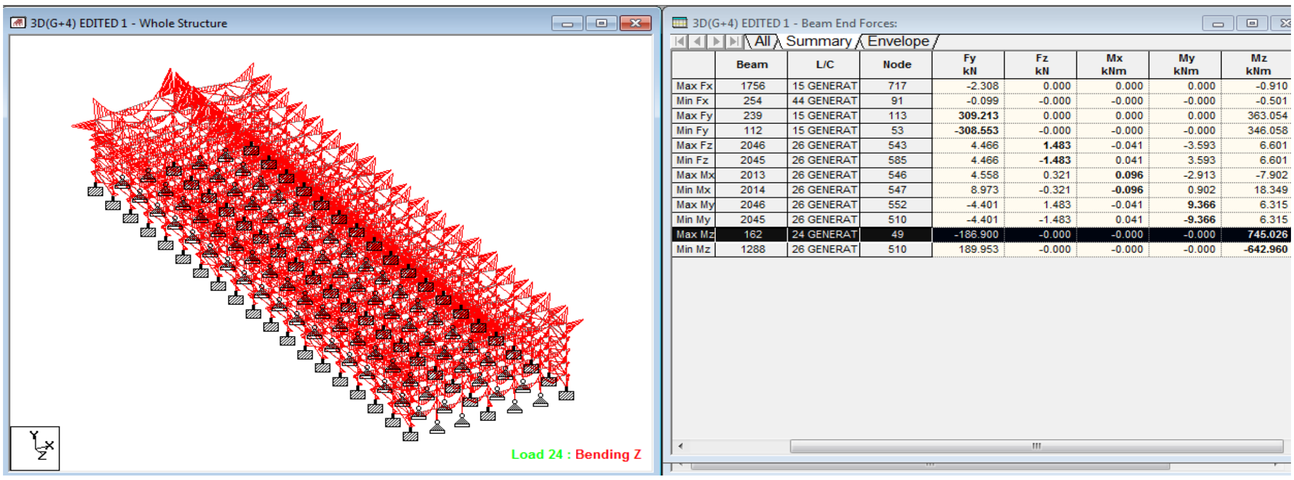
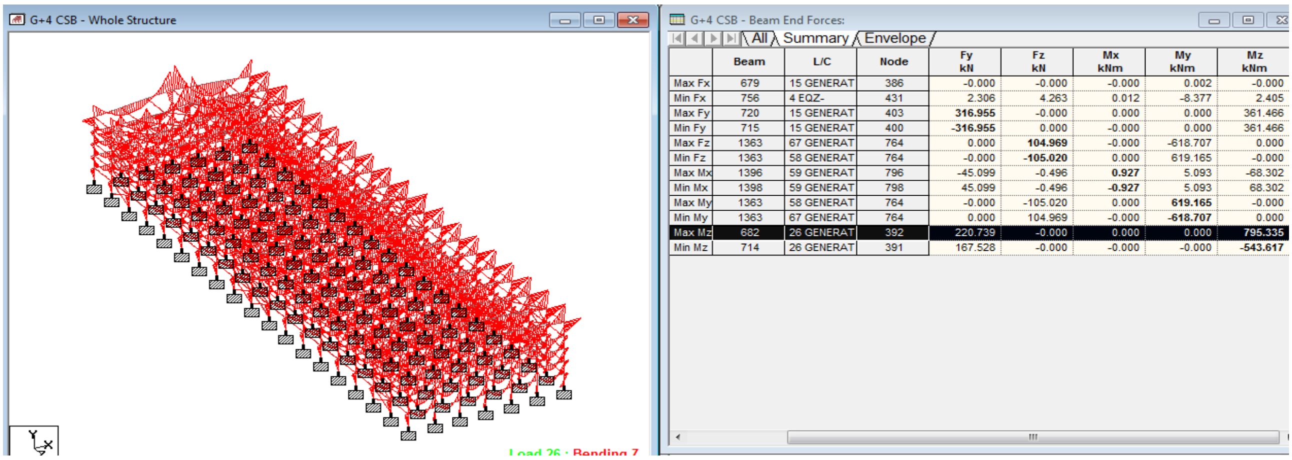
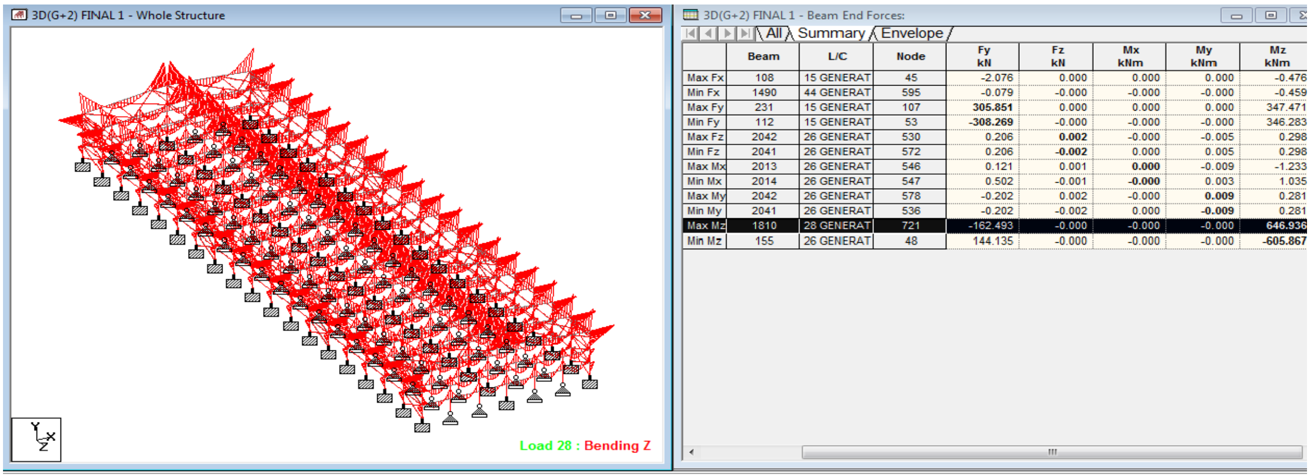


Fig. 5: Max. Moment of G+4 PEB frame



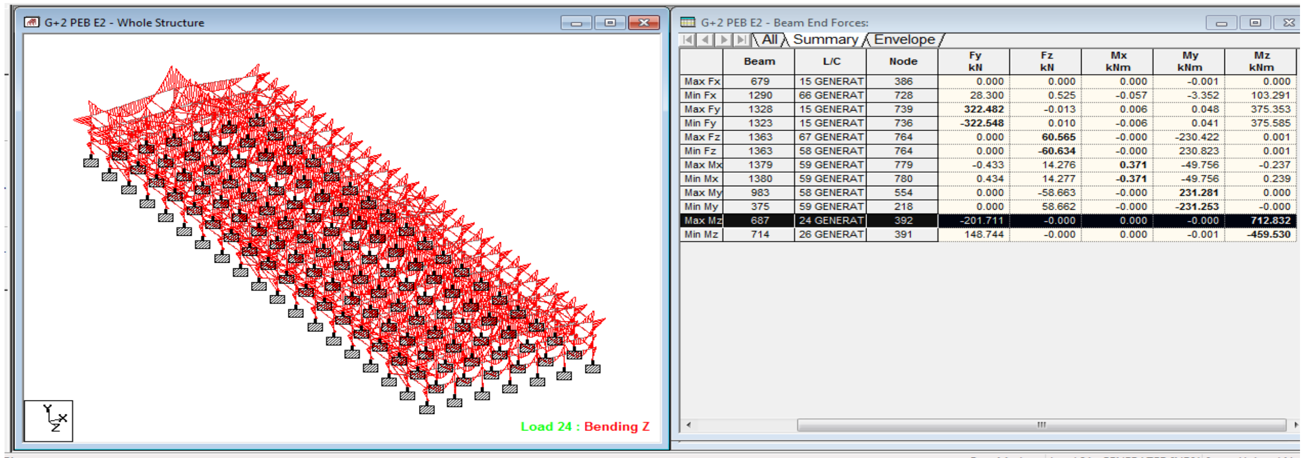
	Beam	L/C	Node	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
Max Fx	679	15 GENERAT	386	-0.000	-0.000	-0.000	0.002	-0.000
Min Fx	756	4 EQZ-	431	2.306	4.263	0.012	-8.377	2.405
Max Fy	720	15 GENERAT	403	316.955	-0.000	0.000	0.000	361.466
Min Fy	715	15 GENERAT	400	-316.955	0.000	-0.000	0.000	361.466
Max Fz	1363	67 GENERAT	764	0.000	104.969	-0.000	-618.707	0.000
Min Fz	1363	58 GENERAT	764	-0.000	-105.020	0.000	619.165	-0.000
Max Mx	1396	59 GENERAT	796	-45.099	-0.496	0.927	5.093	-68.302
Min Mx	1398	59 GENERAT	798	45.099	-0.496	-0.927	5.093	68.302
Max My	1363	58 GENERAT	764	-0.000	-105.020	0.000	619.165	-0.000
Min My	1363	67 GENERAT	764	0.000	104.969	-0.000	-618.707	0.000
Max Mz	682	26 GENERAT	392	220.739	-0.000	0.000	0.000	795.335
Min Mz	714	26 GENERAT	391	167.528	-0.000	-0.000	-0.000	-543.617

Fig. 6: Max. Moment of G+4 CSB frame



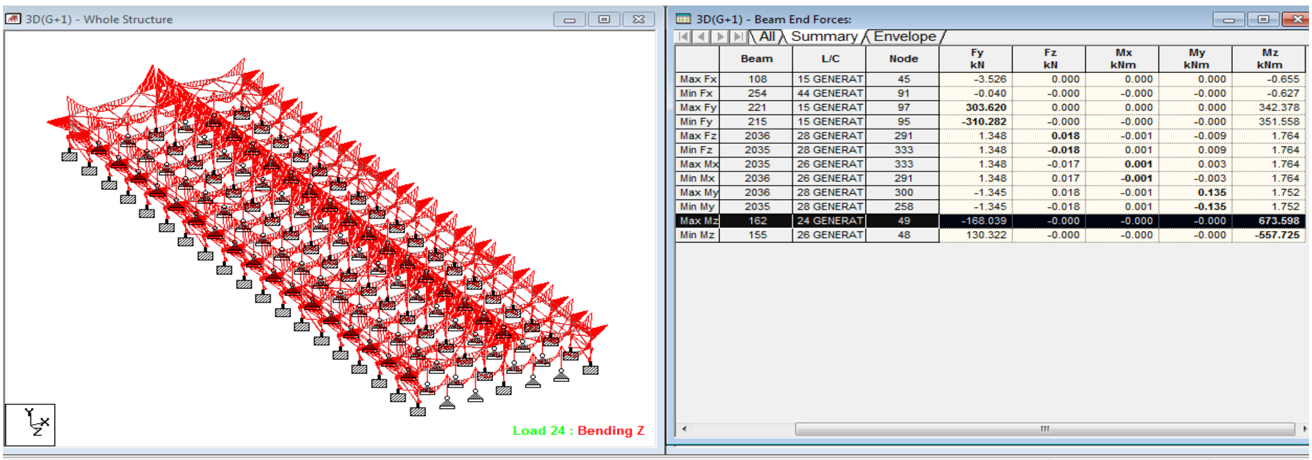
	Beam	L/C	Node	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
Max Fx	108	15 GENERAT	45	-2.076	0.000	0.000	0.000	-0.476
Min Fx	1490	44 GENERAT	595	-0.079	-0.000	-0.000	-0.000	-0.459
Max Fy	231	15 GENERAT	107	305.851	0.000	0.000	0.000	347.471
Min Fy	112	15 GENERAT	53	-308.269	-0.000	-0.000	-0.000	346.283
Max Fz	2042	26 GENERAT	530	0.206	0.002	-0.000	-0.005	0.298
Min Fz	2041	26 GENERAT	572	0.206	-0.002	0.000	0.005	0.298
Max Mx	2013	26 GENERAT	546	0.121	0.001	0.000	-0.009	-1.233
Min Mx	2014	26 GENERAT	547	0.502	-0.001	-0.000	0.003	1.035
Max My	2042	26 GENERAT	578	-0.202	0.002	-0.000	0.009	0.281
Min My	2041	26 GENERAT	536	-0.202	-0.002	0.000	-0.009	0.281
Max Mz	1810	28 GENERAT	721	-162.493	-0.000	-0.000	-0.000	646.936
Min Mz	155	26 GENERAT	48	144.135	-0.000	-0.000	-0.000	-605.867

Fig. 7: Max. Moment of G+2 PEB frame



	Beam	L/C	Node	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
Max Fx	679	15 GENERAT	386	0.000	0.000	0.000	-0.001	0.000
Min Fx	1290	66 GENERAT	728	28.300	0.525	-0.057	-3.352	103.291
Max Fy	1328	15 GENERAT	739	322.482	-0.013	0.006	0.048	375.353
Min Fy	1323	15 GENERAT	736	-322.548	0.010	-0.006	0.041	375.585
Max Fz	1363	67 GENERAT	764	0.000	60.565	-0.000	-230.422	0.001
Min Fz	1363	58 GENERAT	764	0.000	-60.634	-0.000	230.823	0.001
Max Mx	1379	59 GENERAT	779	-0.433	14.276	0.371	-49.756	-0.237
Min Mx	1380	59 GENERAT	780	0.434	14.277	-0.371	-49.756	0.239
Max My	983	58 GENERAT	554	0.000	-58.663	-0.000	231.281	0.000
Min My	375	59 GENERAT	218	0.000	58.662	-0.000	-231.253	-0.000
Max Mz	687	24 GENERAT	392	-201.711	-0.000	0.000	-0.000	712.832
Min Mz	714	26 GENERAT	391	148.744	-0.000	0.000	-0.001	-459.530

Fig. 8: Max. Moment of G+2 CSB frame



	Beam	L/C	Node	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
Max Fx	108	15 GENERAT	45	-3.526	0.000	0.000	0.000	-0.655
Min Fx	254	44 GENERAT	91	-0.040	-0.000	-0.000	-0.000	-0.627
Max Fy	221	15 GENERAT	97	303.620	0.000	0.000	0.000	342.378
Min Fy	215	15 GENERAT	95	-310.282	-0.000	-0.000	-0.000	351.558
Max Fz	2036	28 GENERAT	291	1.348	0.018	-0.001	-0.009	1.764
Min Fz	2035	28 GENERAT	333	1.348	-0.018	0.001	0.009	1.764
Max Mx	2035	26 GENERAT	333	1.348	-0.017	0.001	0.003	1.764
Min Mx	2036	26 GENERAT	291	1.348	0.017	-0.001	-0.003	1.764
Max My	2036	28 GENERAT	300	-1.345	0.018	-0.001	0.135	1.752
Min My	2035	28 GENERAT	258	-1.345	-0.018	0.001	-0.135	1.752
Max Mz	162	24 GENERAT	49	-168.039	-0.000	-0.000	-0.000	673.598
Min Mz	155	26 GENERAT	48	130.322	-0.000	-0.000	-0.000	-557.725

Fig. 9: Max. Moment of G+1 PEB frame

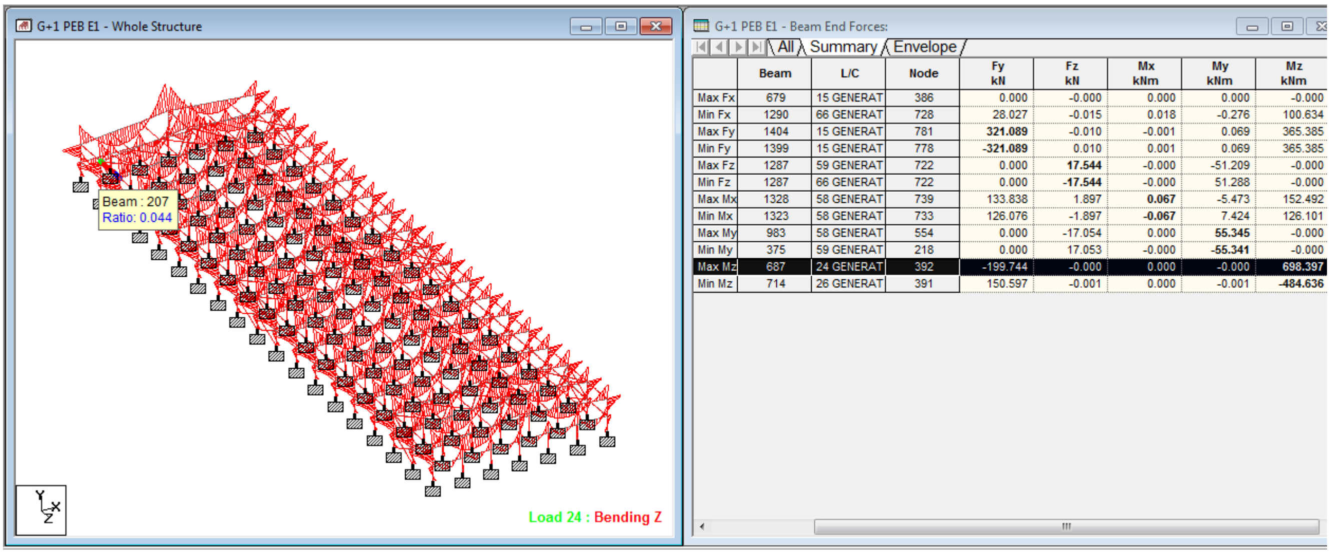


Fig. 10: Max. Moment of G+1 CSB frame

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 8, table 9 and table 10 with reference to figures 5,6,7,8,9 and 10.

Table 8: Outcomes of study (G+4)

S no.	Parameter	PEB	CSB
1	Steel Take Off (kN)	6088.8	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

Table 9: Outcomes of study (G+2)

S no.	Parameter	PEB	CSB
1	Steel Take Off (kN)	4291	7016
2	Maximum Moment (kNm)	646.936	712.832
3	Maximum Shear Force (kN)	1420	1500.261
4	Support Reaction (kN)	305	322.482

Table 10: Outcomes of study (G+1)

S no.	Parameter	PEB	CSB
1	Steel Take Off (kN)	2189	3475.40
2	Maximum Moment (kNm)	673.598	698.397
3	Maximum Shear Force (kN)	807.978	872.150
4	Support Reaction (kN)	303.620	321.89

9. CONCLUSIONS

The paper contains the study for analysis and design of G+4.G+2 and G+1 multistoried multi-span building as per PEB and CSB Concept. The results obtained from the study shows that the multistoried building of PEB is also advantageous over CSB and should be adoptable by the designers and owners in India. The various outcomes from the study are as bellows:

- As per the study, it has been observed that the weight of the PEB model is lesser than that of the CSB model of the same length, width and height. Reduction in weight directly deals with the quantity of steel required, here in these study of G+4, G+2and G+1commercial PEB structure reduces the quantity of steel by about 39%, 39% and 37% respectively than that required by the G+4, G+2 and G+1 commercial CSB structure.
- 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.
- PEB structures are lighter than CSB structures, hence provide good resistance to Seismic forces.
- 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 make the work faster and easier.
- 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.
- PEB technology can be adopted for the bigger sized buildings more effectively than the smaller sized buildings.

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