International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 5, Issue 07, July-2019

Comparative Study on Conventional Steel Building with Pre-engineered Building and Open Web Frame Building

Rajesh Chaturvedi[1], Rahul Sharma[2]

[1]Professor, Department of Civil Engineering, IPS Academy, Indore,
[2] PG Scholar, Department of Civil Engineering, IPS Academy, Indore,

Abstract— The demand of industrial and warehouse building construction was increasing day by day with development of the industrial areas. Conventional practice of construction for industrial steel buildings was no sufficient to fulfil the demands. There was a requirement of speedy construction practice with economy. Pre-engineered buildings concept was fulfilling all the requirements against demand because of it offers fast construction (erection) with low cost as compare to conventional steel buildings.
In the present study total 72 steel frames are analyzed and designed as per the guidelines of Indian standards. There are three types of steel structures frames (conventional steel building frame, pre-engineered building frame and open web building frame) are selected for the study. To obtain the best optimized section number of frames are analyzed for varying span of (15m, 20m, 25m and 30m.) and varying height (6m, 7.5m, and 9.14m) for wind speed 39m/s and 50m/s. On the basis of analysis results a comparison is established between all the study frames.

Keywords— Conventional steel building, Pre-engineered building, Open web PEB building, Wind analysis, Seismic analysis, Vertical deflection, Lateral deflection, Steel frame weight.

Introduction

In the last decades the construction field of industrial and warehouse buildings has developed very speedily in all reasons of India. The demand of industrial and warehouse building construction was increasing day by day with development of the industrial areas in all over the India. Conventional practice of construction for industrial steel buildings was no sufficient to fulfill the demands. There was a requirement of speedy construction practice with economy. Pre-engineered buildings concept was fulfilling all the requirements against demand because of it offers fast construction (erection) with low cost as compare to conventional steel buildings. While constructing foundation and plinth slab on site at the same time columns and rafters are fabricated in the factory. This procedure saves lots of construction time because after completion of foundation work erection work can be start by the next day. Pre-engineered building system is assembly of the tapered section columns and rafters (beams) as primary structural members and purlins and girts (C and Z section) made up from cold formed steel, roofing and wall cladding of GI sheets as secondary members. The columns and rafters bolt together by attaching end plate to form a primary rigid frame which support all the roofing and cladding system. The foundation system for pre-engineered building is same as the conventional concrete system but it should be confirmed that foundation should be firmly anchor the super structure because large dimension of PEB attract huge amount of wind forces which increase the upward force on a building.
The focus of present study is to design the solid web and open web pre-engineered structure and compare their results to evaluate the performance with economy for both solid web and open web PEB structures at various loading conditions and at multiple span width and bay spacing. The open web sections are fabricated by connecting angles and hollow sections (circular or rectangular) by welding or bolting at top and bottom with plate. Open web section offers more economy for long span with heavy loads compare to solid web and conventional steel sections. Also open web sections allow installing duct and mechanical accessories without compromising the strength of sections.

Type of Steel structure

Pre-Engineered Building: Pre-Engineered Building (PEB) could be a combination of-precast- & -prefabricated-structures. Pre- designed buildings are usually low rise buildings that are ideal for offices, houses, showrooms, etc. The application of pre-engineered buildings conception to low-rise buildings is extremely economical and speedy. Buildings may be made in but in less than half the normal time. Although PEB systems are extensively utilized in industrial and plenty of alternative non-residential constructions worldwide, it is relatively a new concept in India. 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 development 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 totally made-up within the industrial plant once planning, then transported to the site in completely knocked down condition and all components are assembled and erected with nut-bolts, thereby reducing the time of completion.

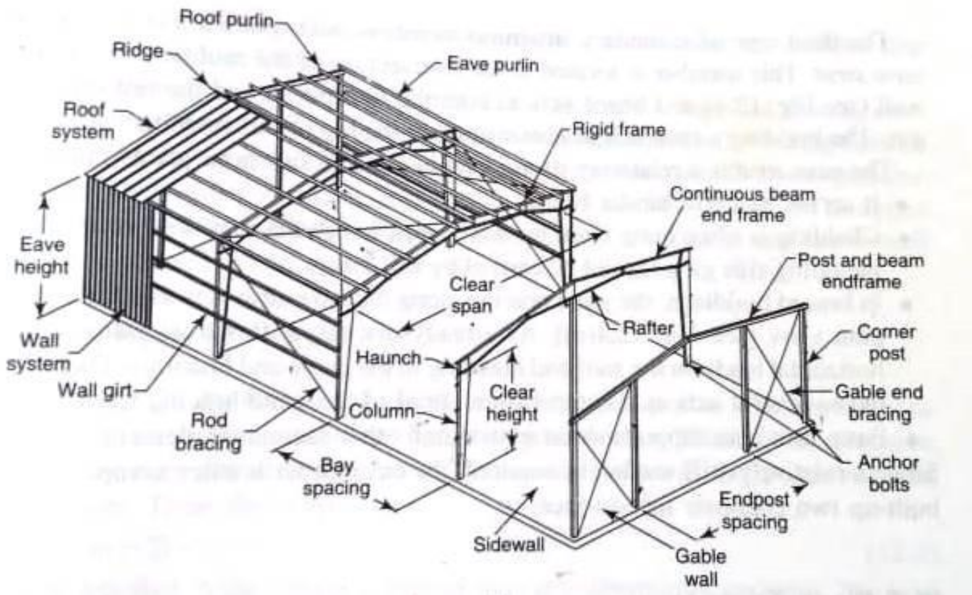

Fig 1: Typical pre-engineered buiding and their components

Conventional Steel Building: Conventional steel buildings are traditional metal structures constructed by rolled steel sections .Most steel construction is done with a type of steel called mild steel. Mild steel could be a material that's vastly sturdy. Which are designed individually and fabricated at site using welding and cutting. Conventional buildings require different skills to construct than pre-manufactured, with the need for metal cutting and punching onsite. Each building is meant one by one, not like a pre-manufactured structure wherever each hole and fastener has been planned and enclosed. Conventional steel construction may well be thought-about the parent to pre-engineered steel buildings; each are measure still employed in the business to develop everything from tiny steel sheds to skyscrapers and wide, open-span facilities.

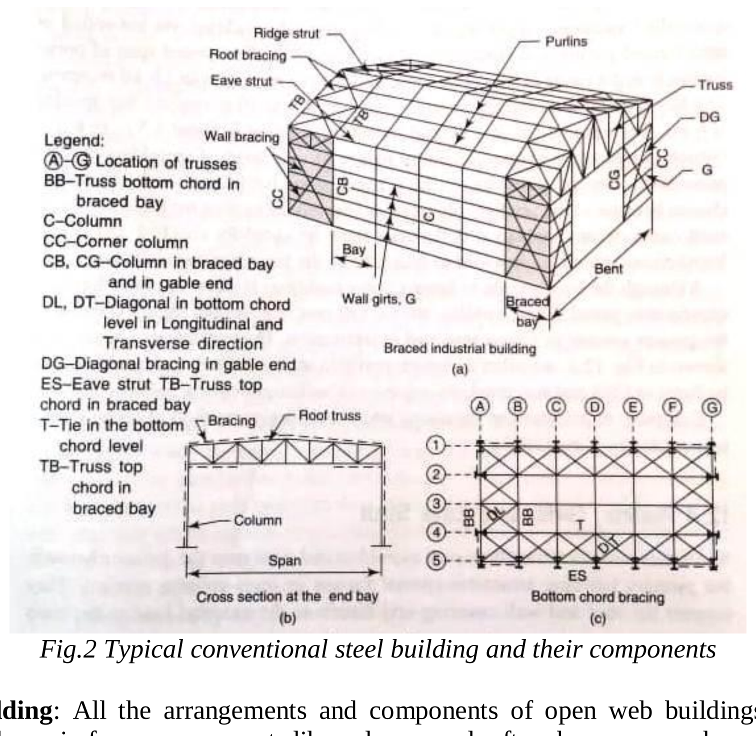

Fig.2 Typical conventional steel building and their components

Open Web Frame Building: All the arrangements and components of open web buildings are similar to the pre-engineered building but the main frame components like columns and rafters have open web arrangement instead of solid plate web. Open web arrangement is made up of hollow pipe section.

Building Modelling

In the present study total 72 cases with different configurations (different loading condition, varying height and width) of conventional building, pre-engineered building and open web type structure are studied. A Centre frame of warehouse building is considered with varying width (15m, 20m, 25m and 30m) and varying eave height (6m, 7.5m and 9m). Each frame is analyzed and designed as per the guidelines of Indian standards. The guidelines of IS 875 (part I) and IS 875 (part II) are used to calculate dead load and live load on the structure respectively. IS 875 (part III) and IS 1893 are used to calculate the designed wind force and designed seismic force on the study frames respectively. Each frame is designed for Wind zone having basic wind speed of 39 and 50m/s. The design of study frames are done as per the IS 800:2007 guidelines. Fe-345 grade of steel having tensile strength of 345 N/mm2 and unit weight of 78.5 KN/m3 has been used in analysis and design for all the study frames. Self-weight of the structure and live load of 0.75 kN/m2 is considered for the analysis. For the presentation of the study frames, a naming standard has been assigned to each frame which. For example 15S6HCSB, 15S6HPEB and 5S6HOWF where S represents span, H represent height and CSB, PEB, OWF represents conventional steel building frame, pre-engineered building frame, open web frame respectively. Figure 3.1 to 3.12 showing the considered study frames of the CSB, PEB and open web frame having span 15m, 20m, 25m and 30m.

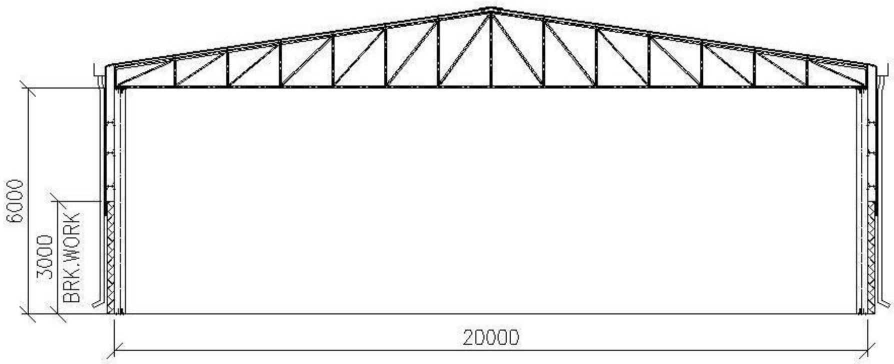

Fig. 3 Conventional steel frame section

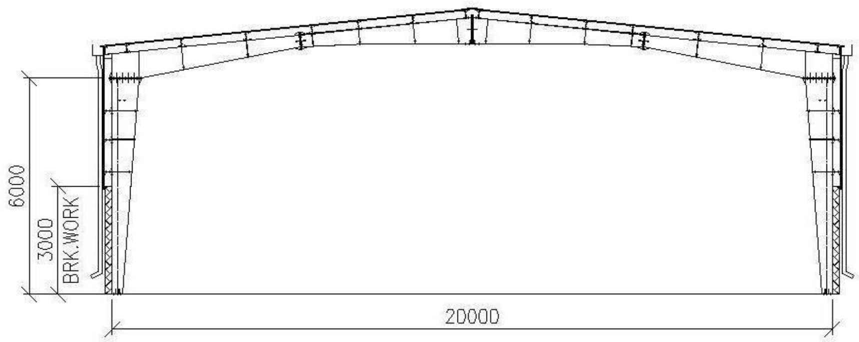

Fig. 4 Pre-engineered building frame section

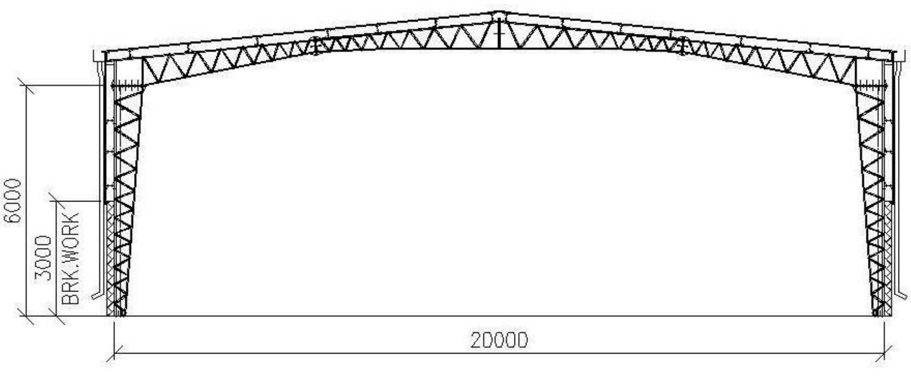

Fig. 4 Open web building frame section

Table 1: Wind force for wind speed 39 m/s

Wind Dir.	A Phase (Kn/m)	B Phase (Kn/m)	E Phase (Kn/m)	F Phase (Kn/m)
WLL (IP)	2.54	2.29	-5.81	-3.05
WLL (IS)	4.57	-0.25	-3.78	-1.02
WLR (IP)	-2.29	2.54	-3.05	-5.81
WLR (IS)	-0.25	4.57	-1.02	-3.78
WL 90 (IP)	-3.56	-3.56	-5.08	-5.08

Table 2: Wind force for wind speed 50 m/s

ind Dir.	A Phase (Kn/m)	B Phase (Kn/m)	E Phase (Kn/m)	F Phase (Kn/m)
WLL (IP)	4.18	-3.76	-9.55	-5.01
WLL (IS)	7.52	-0.42	-6.21	-1.67
WLR (IP)	-3.76	4.18	-5.01	-9.55
WLR (IS)	-0.42	7.52	1.67	-6.21
WL 90 (IP)	-5.85	-5.85	-8.35	-8.35

Where
WLL = wind load at left side
WLR = wind load at right side
IP = internal pressure
IS = internal suction

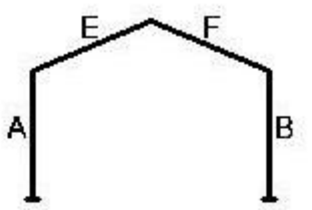

Fig. 5 Position of phase A,B,E and F

Results

Comparison of the study models in terms of various parameters like weight, vertical deflection and horizontal deflection is done in this chapter. The warehouse building having different span width and height situated in the wind zone having wind speed 39 and 50 m/s observed. The results are shown below
.

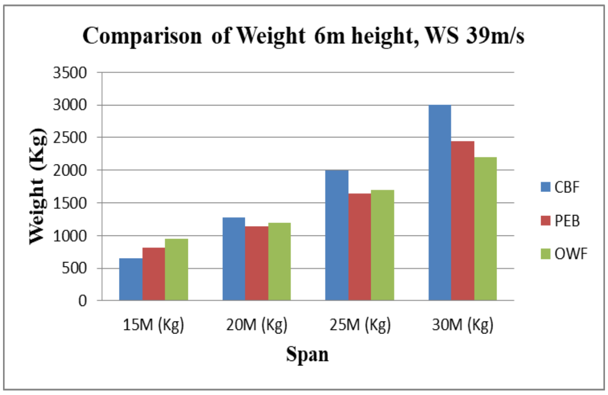

Fig.6 Comparison of weight for 6m height and wind speed of 39 m/s

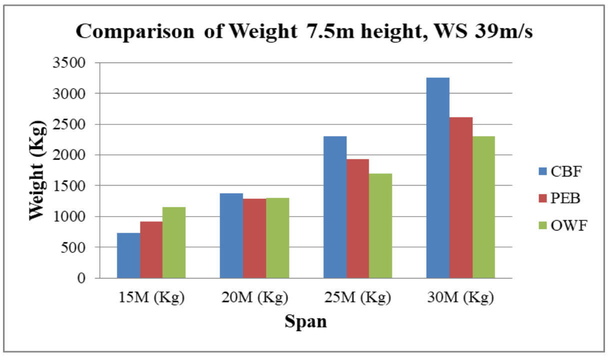

Fig.7 Comparison of weight for 7.5m height and wind speed of 39 m/s

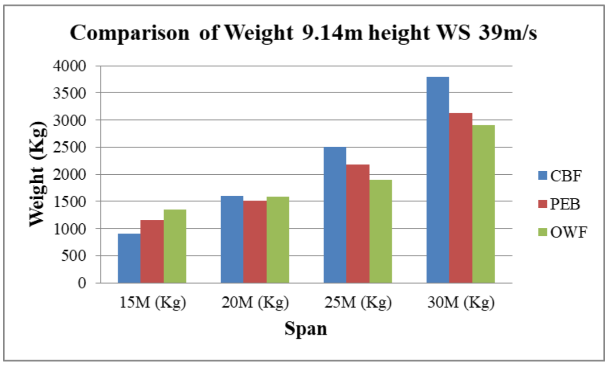

Fig.8 Comparison of weight for 9.14m height and wind speed of 39 m/s

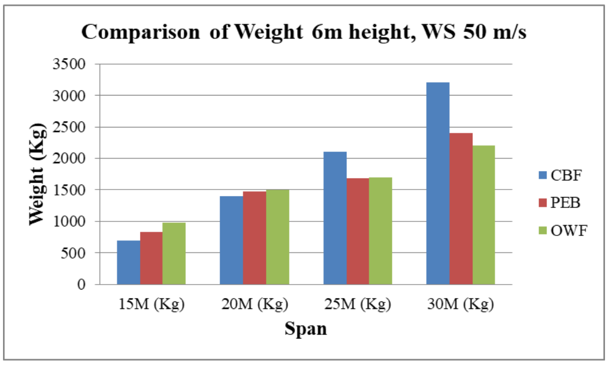

Fig.9 Comparison of weight for 6m height and wind speed of 50 m/s

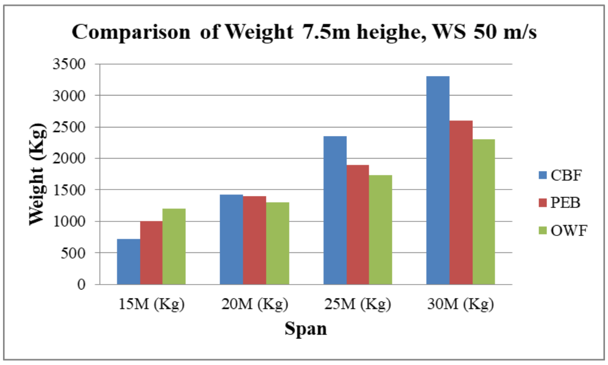

Fig.10 Comparison of weight for 7.5m height and wind speed of 50 m/s

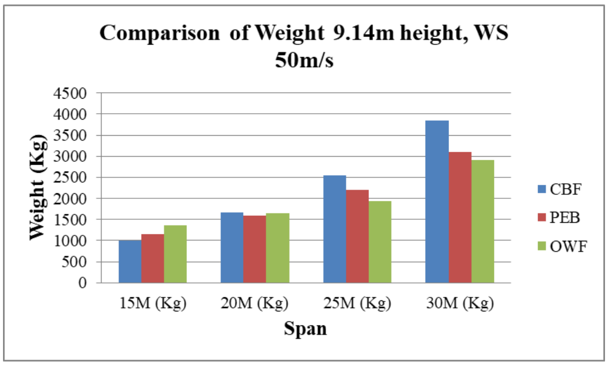

Fig.11 Comparison of weight for 9.14m height and wind speed of 50 m/s

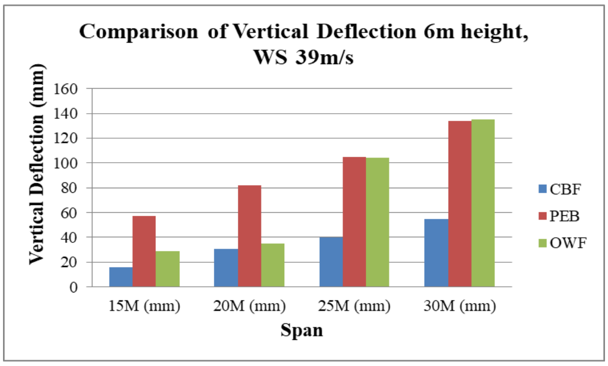

Fig.12 Comparison of vertical deflection for 6m height and wind speed of 39 m/s

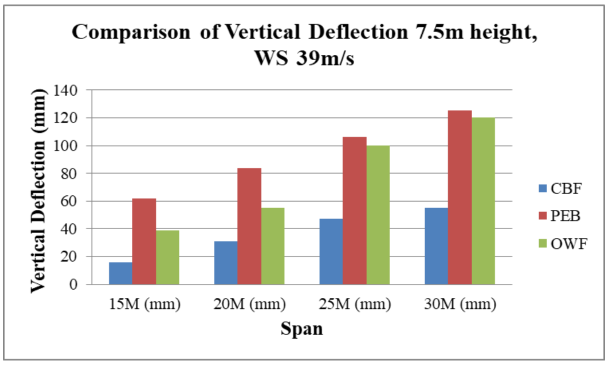

Fig.13 Comparison of vertical deflection for 7.5m height and wind speed of 39 m/s

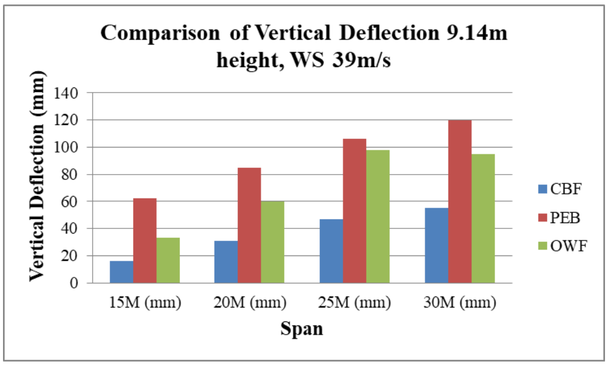

Fig.14 Comparison of vertical deflection for 9.14m height and wind speed of 39 m/s

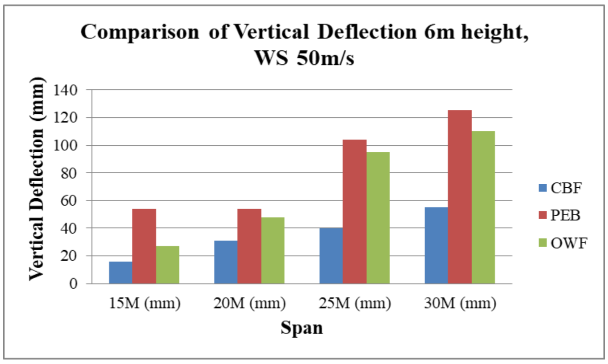

Fig.15 Comparison of vertical deflection for 7.5m height and wind speed of 50 m/s

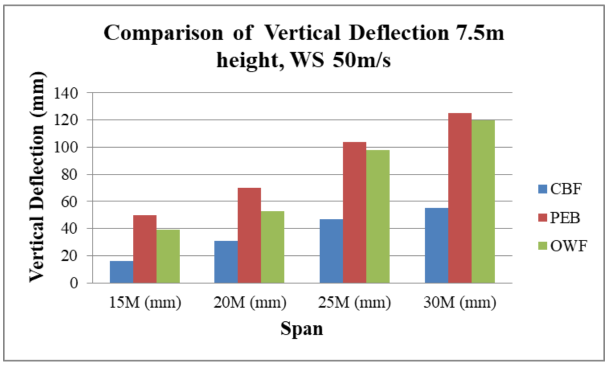

Fig.16 Comparison of vertical deflection for 7.5m height and wind speed of 50 m/s

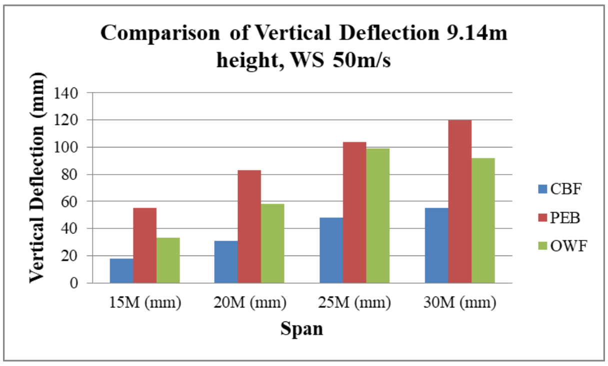

Fig.17 Comparison of vertical deflection for 9.14m height and wind speed of 50m/s

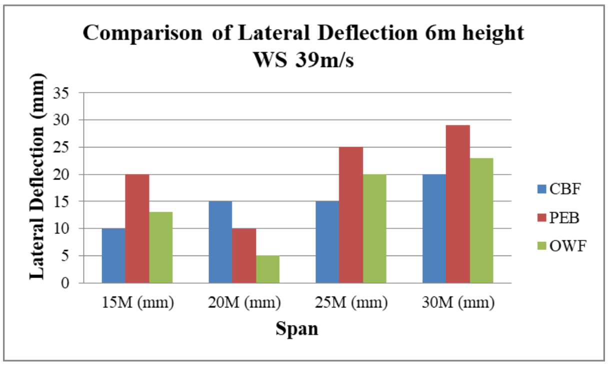

Fig.18 Comparison of lateral deflection for 6m height and wind speed of 39 m/s

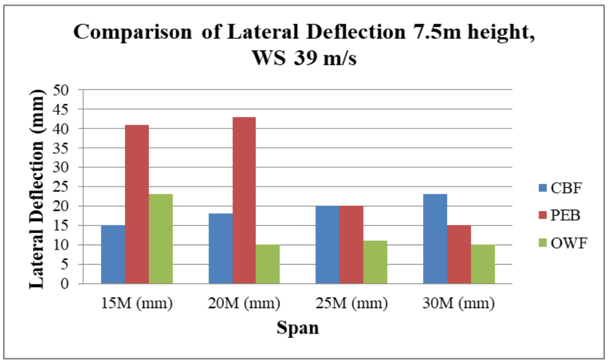

Fig.19 Comparison of lateral deflection for 7.5m height and wind speed of 39 m/s

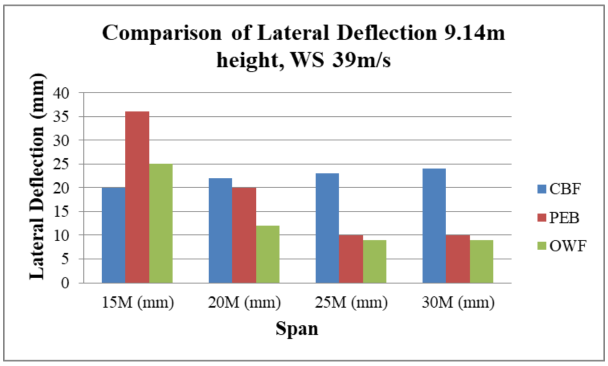

Fig.20 Comparison of lateral deflection for 9.14m height and wind speed of 39 m/s

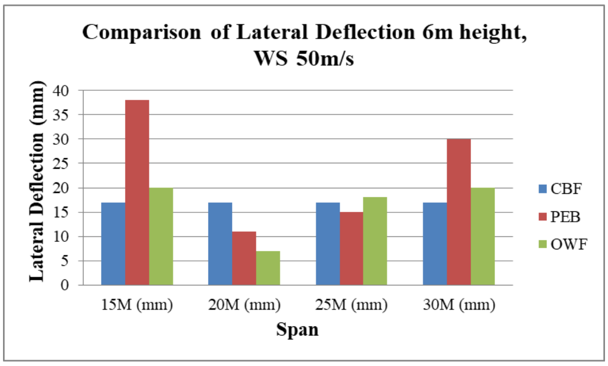

Fig.21 Comparison of lateral deflection for 6m height and wind speed of 50 m/s

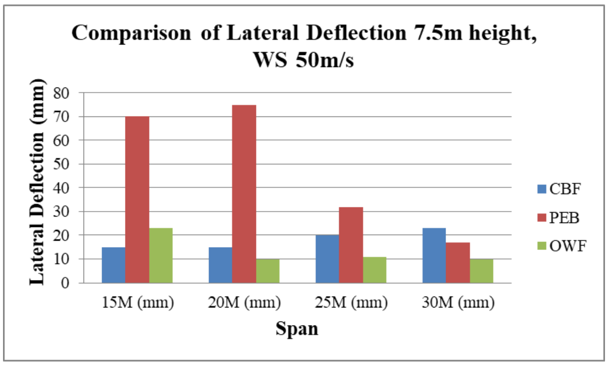

Fig.22 Comparison of lateral deflection for 7.5m height and wind speed of 50 m/s

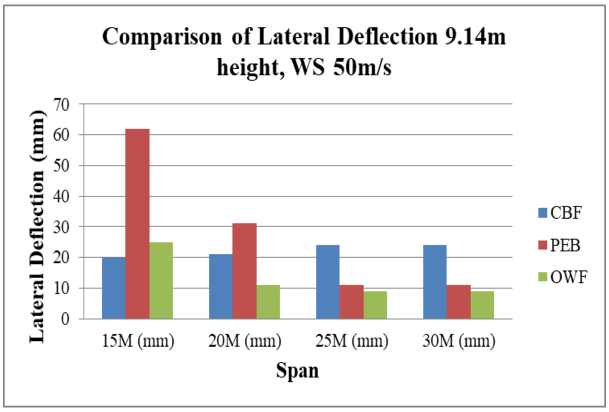

Fig.23 Comparison of lateral deflection for 9.14m height and wind speed of 50 m/s

Table 3: Weight comparison for wind speed 39 m/s

Comparison of Weight at Wind Speed 39 m/s					
Height	**Frame Type**	**15M (Kg)**	**20M (Kg)**	**25M (Kg)**	**30M (Kg)**
6	CBF	646	1280	2000	3000
	PEB	819	1140	1640	2450
	OWF	950	1200	1700	2200
7.5	CBF	16	31	47	55
	PEB	62	84	106	125
	OWF	39	55	100	120
9.14	CBF	900	1600	2500	3800
	PEB	1150	1520	2175	3128
	OWF	1350	1590	1900	2900

Table 4: Vertical deflection for wind speed 39 m/s

Comparison of Vertical Deflection 6m at Wind Speed 39 m/s					
Height	**Frame Type**	**15M (mm)**	**20M (mm)**	**25M (mm)**	**30M (mm)**
6	CBF	16	31	40	55
	PEB	57	82	105	134
	OWF	29	35	104	135
7.5	CBF	16	31	47	55
	PEB	62	84	106	125
	OWF	39	55	100	120
9.14	CBF	16	31	47	55
	PEB	62	85	106	120
	OWF	33	60	98	95

Table 5: Lateral deflection for wind speed 39 m/s

Comparison of Lateral Deflection at Wind Speed 39 m/s					
Height	**Frame Type**	**15M (mm)**	**20M (mm)**	**25M (mm)**	**30M (mm)**
6	CBF	10	15	15	20
	PEB	20	10	25	29
	OWF	13	5	20	23
7.5	CBF	15	18	20	23
	PEB	41	43	20	15
	OWF	23	10	11	10
9.14	CBF	20	22	23	24
	PEB	36	20	10	10
	OWF	25	12	9	9

Table 6: Weight comparison force for wind speed 39 m/s

Comparison of Weight at Wind Speed 50 m/s					
Height	**Frame Type**	**15M (Kg)**	**20M (Kg)**	**25M (Kg)**	**30M (Kg)**
6	CBF	700	1400	2100	3200
	PEB	834	1474	1690	2400
	OWF	980	1500	1700	2200
7.5	CBF	720	1420	2350	3300
	PEB	1000	1400	1900	2600
	OWF	1200	1300	1730	2300
9.14	CBF	990	1670	2550	3850
	PEB	1150	1600	2200	3100
	OWF	1360	1650	1930	2900

Table 7: Vertical deflection for wind speed 39 m/s

Comparison of Vertical Deflection 6m at Wind Speed 50 m/s					
Height	**Frame Type**	**15M (mm)**	**20M (mm)**	**25M (mm)**	**30M (mm)**
6	CBF	16	31	40	55
	PEB	54	54	104	125
	OWF	27	48	95	110
7.5	CBF	16	31	47	55
	PEB	50	70	104	125
	OWF	39	53	98	120
9.14	CBF	18	31	48	55
	PEB	55	83	104	120
	OWF	33	58	99	92

Table 8: Lateral deflection for wind speed 39 m/s

Comparison of Lateral Deflection at Wind Speed 50 m/s					
Height	**Frame Type**	**15M (mm)**	**20M (mm)**	**25M (mm)**	**30M (mm)**
6	CBF	20	21	24	24
	PEB	62	31	11	11
	OWF	25	11	9	9
7.5	CBF	15	15	20	23
	PEB	70	75	32	17
	OWF	23	10	11	10
9.14	CBF	20	21	24	24
	PEB	62	31	11	11
	OWF	25	11	9	9

Figure 6 to Figure 23 and Table 3 to Table 8 showing the weight of the all study framed for all span, height and wind speed. The results show that conventional steel building frames exhibits less weight for 15m span for 6m height and wind speed of 39m/s and 50m/s. But in the case of 20m and 25m span pre-engineered building frames have less weight as compare to open web building and conventional steel building frames. Open web building frames are seems to be more economical than pre-engineered building and conventional steel frames for span of 30m. For 7.5m height and 9.14m height same results are obtained as discussed above. There is no such higher difference in weight of frames for wind speed of 39m/s and 50m/s.
Figure 5.79 to Figure 5.90 showing the comparison of vertical and lateral deflection of the all study frames. The vertical deflection of conventional steel building frame is less in compare of pre-engineered building and open web building. Open web building frames has lesser deflection values than pre-engineered building frames for larger spans the lateral deflection for pre-engineered building frames are more when compare to open web building frames. That means open web structures are stiffer in lateral direction in compare of pre-engineered structures.

Conclusion

- For shorter span CBS structures are economical but for large span it becomes uneconomical when compared to PEB and open web structures.
- For shorter span open web structures are uneconomical but with increase in span it becomes more economical then PEB and CSB structures.
- The open web structure and PEB structure offers better resistance to earthquake forces as compared to CSB structure because of their lighter weight.
- The vertical deflection of PEB structure is found to be higher deflection as compared to both CSB and open web structure.
- As compared of vertical deflection conventional steel building structures exhibits less deflection.
- The lateral deflection of PEB structure is found to be higher deflection as compared to both CSB and open web structure.
- As compared of lateral deflection open web structures exhibits less deflection then both PEB and CSB structures. Also exhibits more lateral stiffness as compared to PEB structures.
- The lateral deflection of PEB structure is more in compare of CSB buildings because the base condition is different.
- The fabrication cost and erection cost of open web is less in comparison of PEB structures.
- For large spans of industrial structures open web structure are more suitable than PEB structures and CSB structures.
- The aesthetic look of PEB is more attractive in compare of CSB structures and open web structures.
- In PEB structure for higher span there is no such effect of wind speed.
- The behaviour of the open web and PEB structure for wind speed 39 m/s and 50m/s is same.

REFERENCES

[1] Ahmed, A., Yamal, S. M., Zende, A. J., and Allagi, S. S., (2018). "Performance assessment of pre-engineered building." IJERT, 7(6), 92-96.
[2] Al-Jallad, S. A. A., and Al-Thairy, H. (2016). "Effect of web opening on the axial load capacity of steel columns with cold formed thin walled section (CFS)." Kufa journal of engineering, 7(3), 13-26.
[3] Chavan, V. B., Nimbalkar, V. N., and Jaiswal, A. P. (2014). "Economic evaluation of open and hollow structural sections in industrial trusses." IJIRSET, 3(2), 9554-9565.

[4] Cristutiu, I. M., and Nunes, D. L. “Behaviour of single storey frames with tapered web members accounting for manufacturing and assembling imerfections.” Recent researches in geography, Geology, Energy, environment and Biomedicine, 219-224.
[5] Dharmalingam, G., and Silambarasan, G. (2017). “Design and analysis of pre-engineered building with subjected to seismic loads using E-Tabs.” IJSRD, 5(4), 1628-1631.
[6] Eroz, M., White, D. W., and DesRoches, R. (2008). “Direct analysis and design of steel frames accounting fo partially restrained column base conditions.” Journal of structural engineering, 1508-1517.
[7] Firoz, s., and Kumar, S. C., and Rao, S.K. (2012). “Design concept of pre-engineered building.” IJERA, 2(2), 267-272.
[8] FEMA-356 (Federal Emergency Management Agency 356).(2000).“Prestandards and commentary for the seismic rehabilitation of buildings.”
[9] IS 1893:2002, “Indian Standard Criteria for Earthquake Resistant Design of Structures,” Bureau of Indian standard, New Delhi.
[10] IS 800:2007, “General construction in steel-code of practice.” Bureau of Indian standard, New Delhi.
[11] IS 875:1987, Part 1, “Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures.” Bureau of Indian Standard, New Delhi.
[12] IS 875: 1987, part 2, “Code of Practice for Design Loads (Other than Earthquake) for Building and Structures.” Bureau of Indian Standard, New Delhi.
[13] IS 875: 2015, part 3, “Code of Practice for Design Loads (Other than Earthquake) for Building and Structures.” Bureau of Indian Standard, New Delhi.
[14] Kumar, K. P., and Praksh, D. S. (2018). “Planning analysis and design of industrial building using staad pro.” International journal of pure and applied mathematics, 119(17), 131-137.
[15] Kolate, N. R., and Kewate, S. (2015). “Comparative study of pre-engineered and conventional steel frames for different wind zones.” IRJES, 4(7), 51-59.
[16] Lande, P. S., and Kucheriya, V. V. (2015). “Comparative study of an industrial pre-engineered building with conventional steel building.” Journal of civil engineering and environmental technology, 2(10), 77-82.
[17] Meera, C. M. (2013). “Pre-engineered building design of industrial warehouse.” IJESET, 5(2), 75-82.
[18] Mishra, A. G., and Ahtasham, M., Banday, J.M. (2017). “A comparative study of PEB frames TCCS & TCS1.” IJRSET, 6(7), 13624-13632.
[19] Mythili, P.G. (2017). “An overview of pre-engineered building systems.” IJSER, 8(4), 557-563.
[20] Pawar, S. R., and Magdum, M. M. (2017). “Comparative study of innovative corrugated hollow columns and conventional column.” IJCESR, 4(7), 30-37.