Comparative analysis of Pre Engineered and Conventional Steel Building

[1]Humanaaz Arif Qureshi, [2]Dr. Kuldeep R. Dabhekar, [3]Amol Shahakar,[4]Dr. Isha P. Khedikar

[1]M. Tech Student, [2]Assistant Professor, [3]Director, [4] Professor
[1]Department of Civil Engineering,
[1] G. H. Raisoni College of Engineering, Nagpur, India.

Abstract : In steel structure design the Pre-engineering building (PEB) system is a modern technology that provides economical, eco-friendly and sustainable structures. Whereas before the establishment of the PEB system in steel structure construction conventional steel building (CSB) system is used which is provide time-consuming, costly design. The CSB is costly due to more consumption of steel because of using a uniform cross-section of the hot-rolled section throughout the member length. However, based on the loading effect built-up section used in PEB and only bolted connections are provided at the construction site. PEB consuming less time and provides lightweight design and it is advantageous over CSB when the span is large and column-free space required. The design and manufacturing of structure members are done at plant and later its conveyed to the construction site and the erection process will take place. In this paper, a G+3 industrial warehouse is designed and analyzed as per Indian standard code IS 800-2007 (LSM).The analysis of warehouse building was carryout by using STADD-pro software. In this paper, the comparison is also made between Pre-engineered building (PEB) and Conventional steel building (CSB). The CSB is design and analysis by IS 800:2007 (LSM). The objective of this paper is to discuss the most economical frame in terms of tonnage and the possible reason for the variation of results. The comparative study is also done for the hot-rolled section used in CSB and cold-formed purlins used in PEB.

***Index Terms* - STADD-Pro, Tapered Section, pre-engineered, sustainable, conventional steel building, built-up sections, hot rolled sections, optimizations, minimum weight.**

I. INTRODUCTION

The large part of the Indian economy is contributed by the construction industry. The researcher makes an effort not only to make a structure economical but also to make it eco-friendly. As compared to other construction materials steel is a very expensive material. With the help of paints making steel rustproof. In recent, PEB is modern technology is introduced in steel structure.

In steel structure design the Pre-engineering building system a modern technology that provides economical, Sustainable and eco-friendly structures. Whereas before the introduction of the PEB system in steel structure construction conventional steel building system is used this is to provide time-consuming, costly design. The pre-engineering building is costly due to more consumption of steel because of using a uniform cross-section of the hot-rolled section throughout the member length. However, based on the loading effect built-up section used in PEB and only bolted connections are provided at the construction site. PEB provides lightweight, less time consuming, and it is advantageous over CSB when the span is large and column-free space required. The design and manufacturing of structure members are done at plant and later it's transported to the construction site and the erection process will take place

1.1Concept of Conventional Steel Building

Nowadays, steel used worldwide due to ductility and flexibility properties. Steel bend when it's subjected to heavy loading rather than crushing. Steel is recyclable flexible so that is also eco-friendly due to less wastage are generated. In CSB hot rolled steel section is used. Where members are manufactured in factories and later transported to the site. For connections of different members welding process are used.

1.2Concept of Pre Engineered Building

Pre-Engineering Building is a combination of the tapered built-up section, hot roll section, and cold-formed section material. The structural engineer designs the primary and secondary members of the PEB. For primary components, i.e. column and rafter built-up tapered sections are used instead of hot-rolled sections. The girts and purlins which are supporting to sheeting are the secondary members. These members are made up of a cold-formed section. The sections sizes depend on the bending moment diagram. PEB provides lightweight, less time consuming, and it is advantageous over CSB when the span is large and column-free space required. The design and manufacturing of structure members are done at plant and later it's transported to the construction site and the erection process will take place.

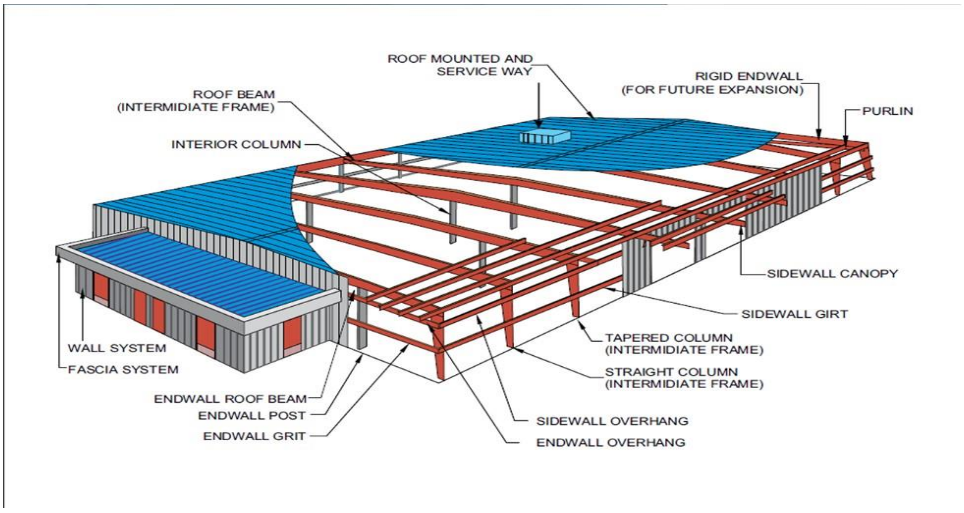


Figure1. Pre-Engineered Building

II. METHODOLOGY

In the present paper comparative analysis of the G+3 Industrial warehouse structure located at Nagpur is performed by using STADD-pro. The structure is clear span framed of 30 meters wide and 75 meters long with 10 bays and sidewall bay spacing 7.5 m and end wall bay spacing 6 meters and each story height 3 meters. In this report, the analysis and design performed on the 3D PEB structure of 30-meter width are by adopting wind load as the critical load for the structure by using Indian code I.S 800:2007 Limit state method (LSM).

Also, the CSB structure 3D frame having the same dimension is an analysis and designed by adopting an economical roof truss by using Indian standard code. All the above three structures are designs then compared to determine the economic output. The comparative analysis is also done for the hot-rolled section used in CSB and cold-formed purlins used in PEB. The designs are performed by the Indian Standards and American Standard and by using STADD-Pro.

III. OBJECTIVES

. Following are the objective of the work

- Comparative analysis of Pre-Engineering Building (PEB) and Conventional Steel Building by using STADD-pro software.
- To analyze and design the building as per Indian standard code I.S 800:2007 (LSM).
- Evaluate the steel consumption in both the design system.
- Reduce the steel consumption and compare the results for both the design procedure
- Find out which design procedure is more effective.

IV. BUILDING PARAMETER

Table 1 Table Building parameter

Sr No.	Description	
1	Type of structure	Multi-Span industrial structure
2	Location	Nagpur
3	Area	2250 m2
4	Length	75 m c/c
5	Width	30 m c/c
7	Height	12 m c/c
6	Each storey Height	3 m c/c
7	Bay Spacing	10@7.5 m c/c
8	Slope for PEB	5.71 degree
9	Slope for PEB	15 degree
10	Support Condition	PEB – Fixed, CSB – Fixed
11	Wind Speed	44 m/s
12	Seismic Zone	II

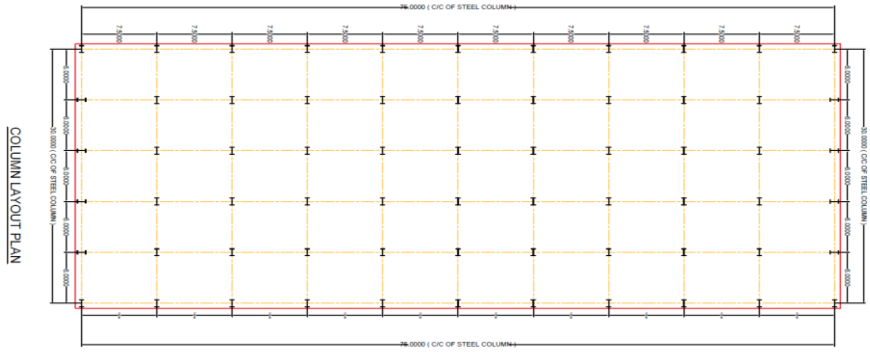


Fig.2. Plan of Industrial Warehouse

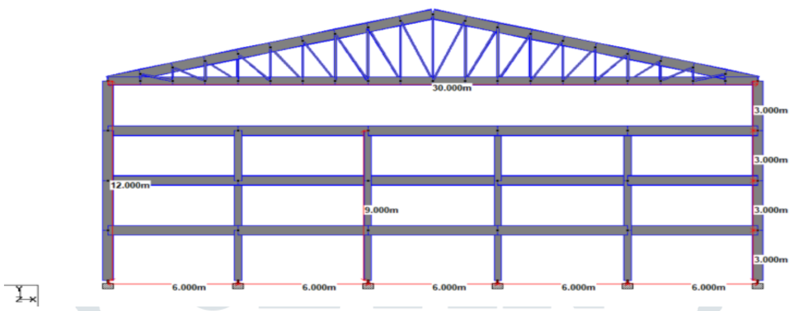


Fig.3. Section of Conventional Steel Building as per IS 800:2007 (LSM)

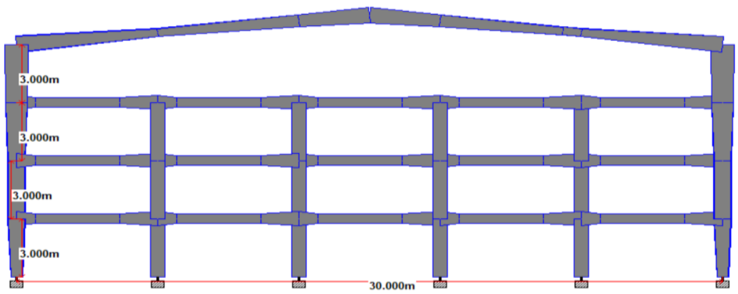


Fig.4. Section of Pre-Engineered Building as per IS 800:2007 (LSM).

V. Load Calculation

In the design of any structure, the load acting during the entire life of structure plays an important role. It should ensure that the structure should be properly designed otherwise failure of structure will take place. The load acting on a structure can be calculated as per IS: 875-1987. For this warehouse structure frame wind load is considered as a critical load.

5.1 Dead load

Dead load acting on the roof consists of self-weight and component of the structure like a dead load of G.I roof sheeting, purlin, sag rod, bracing and insulation, etc. The dead acting on a 2D and 3D frame of PEB is calculated as per Indian code (IS 875-1987 part 1).The dead load acting on a roof excluding self-weight is to be finding out 1.687kN/m. In PEB the load is applied as uniformly distributed per meter rafter length. And 3D and 2D PEB frames are designed by Indian code IS 800:2007 (LSM). In the case of 3D CSB frame, the dead load in the form of equivalent point load applied on the truss i.e. 2.581 KN applied at intermediate panel point and half of this load 1.29 KN is applied at an end panel point. The dead load acting on each mezzanine beam is 23.437kN/m.

5.2 Live load

Live load acting on the not accessible roof is carryout from the Indian standard code IS 875 (Part 2) – 1987. For the structure, it's taken as 0.75 KN/m2 with a reduction of 0.02 KN/m2 for each increase one degree above 10 degrees of the roof slope. The total uniformly distributed live load per running meter of rafter on PEB 3D frame as per Indian code is 5.625 KN/m and on CSB 3Dstructure live load acts as a point and is taken to be 7.57kN at intermediate panel points and half this 3.785 KN at endpoints. The live load acting on each mezzanine beam is 22.5kN/m.

Table 2 Dead load and Live load calculation

Loads	PEB Structure	CSB Structure	
	Load on rafter	Load on top chord as per IS-875	
	As per IS 875:1987	At Intermediate panel point	At end panel point
Dead load	1.687 KN/m	2.581 KN	1.29 KN
Live load	5.625 KN/m	7.57 KN	3.785 KN
	Load on mezzanine Beam	Load on mezzanine Beam	
Dead load	23.437 KN/m	23.437 KN/m	23.437 KN/m
Live load	22.5 KN/m	22.5 KN/m	22.5 KN/m

5.3 Wind load

Wind load is calculated according to IS: 875 (Part3) –2015. The structure located at Nagpur and the basic wind speed for the location of the building is 44 m/s from the code. On a PEB rafter and sidewall, wind load is applied as U.D.L. In the case of CSB, the point load applied on the panel point but the sidewall, it's applied as U.D.L. Six different wind combinations acting on rafter and sidewall are shown in tables 3and 4.

Table 3 wind load calculation for CSB as per IS 875-2015 part3

Case	**Column (KN/m)**		**CSB panel points (KN)**			
	Left	Right	Windward		Lee ward	
			Intermediate	End	Intermediate	End
WL1	5.71	-0.32	-7.29	-3.64	-1.97	-0.98
WL2	-0.32	5.71	-1.97	-0.98	-7.29	-3.64
WL3	3.17	-2.85	-11.23	-5.61	-5.91	-2.96
WL4	-2.85	3.17	-5.91	-2.96	-11.23	-5.61
WL5	-1.9	-1.9	-5.91	-2.96	-2.26	-1.13
WL6	-1.9	-1.9	-2.26	-1.13	-5.91	-2.96
WL7	-4.44	-4.44	-9.85	-4.92	-6.208	-3.10
WL8	-4.44	-4.44	-6.2	-3.1	-9.85	-4.92

Table 4 wind load calculation for PEB as per IS 875-2015 part3

Case	**Column (KN/m)**		**PEB Rafter (KN/m)**	
	left	Right	Wind ward	Lee ward
WL1	5.71	-0.32	-4.69	-1.27
WL2	-0.32	5.71	-1.27	-4.69
WL3	3.17	-2.85	-1.14	-3.81
WL4	-2.85	3.17	-3.81	-1.14
WL5	-1.9	-1.9	-3.81	-1.46
WL6	-1.9	-1.9	-1.46	-3.81
WL7	-4.44	-4.44	-6.35	-3.99
WL8	-4.44	-4.44	-3.99	-6.35

5.4 load calculation

Loads combinations can be taken as per IS: 800-2007 (LSM). For both system analyses, thirteen load combinations are considered.

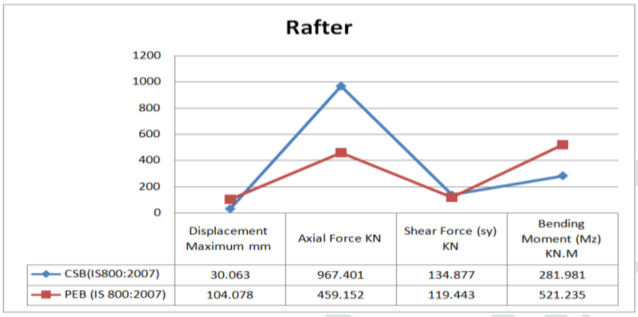
VI. STADD PRO PROCEDURE

For design, analysis and modeling of structure STADD Pro. Software is used. This software support several country standards including Indian standard. In this Software, the Modeling of structure, properties, load and loading combination specification, applied analysis and design are carryout. The utilization ratio in the STADD Pro analysis shows the suitability of the component according to codes. If the value is greater than 1 its shows the component is overstressed, and if less than 1 indicates under stress and means it's suitable for design.

VII. RESULT

Table 5 Calculation for rafter

Sr.No	Description	CSB(IS 800:2007)	PEB (IS 800:2007)
1	Length M	30	30
2	Displacement Maximum mm	30.063	104.078
3	Axial Force KN	967.401	459.152
4	Shear Force (sy) KN	134.877	119.443
5	Bending Moment (Mz) KN.M	281.981	521.235
6	Steel Quantity KN	84.793	19.839



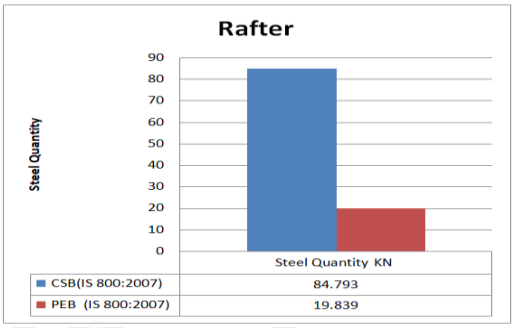
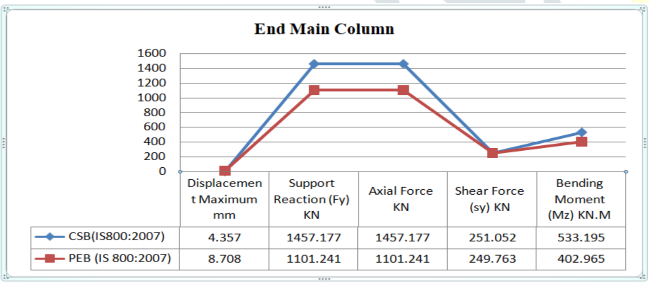


Table 6 Calculation for Main column

Sr.No	Description	CSB(IS 800:2007)	PEB (IS 800:2007)
1	Section size	ISWB600	Web 500~750 x 6 mm Flange 240x12mm
2	Length M	12	12
3	Displacement Maximum mm	4.357	8.708
4	Support Reaction (Fy) KN	1457.177	1101.241
5	Axial Force KN	1457.177	1101.241
6	Shear Force (sy) KN	251.052	249.763
7	Bending Moment (Mz) KN.M	533.195	402.965
8	Steel Quantity KN	15.671	8.636



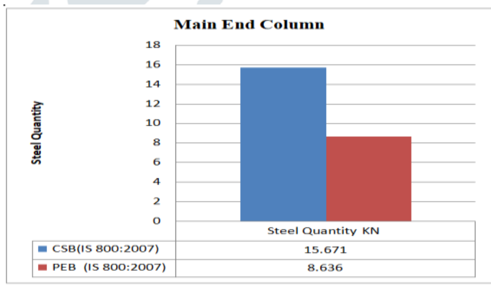
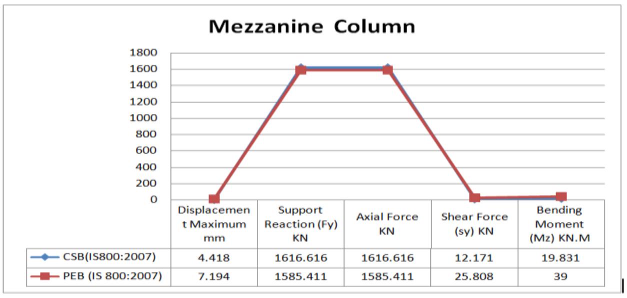


Table 7 Calculation for Mezzanine column

Sr. No	Description	CSB(IS 800:2007)	PEB (IS 800:2007)
1	Section size	2ISMC	Web 550x 6 mm Flange 270x12mm
2	Length M	9	9
3	Displacement Maximum mm	4.418	7.1940
4	Support Reaction (Fy) KN	1616.616	1585.411
5	Axial Force KN	1616.616	1585.411
6	Shear Force (sy) KN	12.171	25.808
7	Bending Moment (Mz) KN.M	19.831	39.0
8	Steel Quantity KN	7.42	6.745



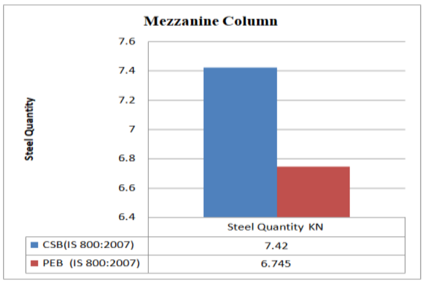
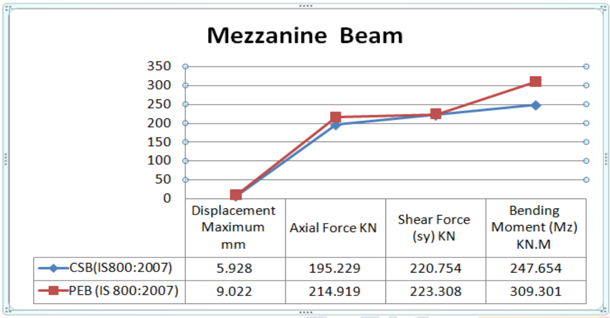


Table 8 Calculation for Mezzanine beam

Sr.No	Description	CSB(IS 800:2007)	PEB (IS 800:2007)
1	Section size	ISMB500	Web 650~300x 6 mm Flange 190x10mm
2	Length M	6	6
3	Displacement Maximum mm	5.928	9.022
4	Axial Force KN	195.229	214.919
5	Shear Force (sy) KN	220.754	223.308
6	Bending Moment (Mz) KN.M	247.654	309.301
7	Steel Quantity KN	5.116	2.779



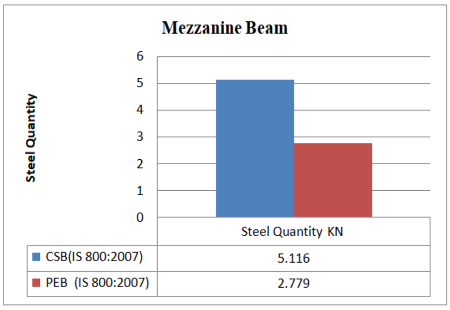
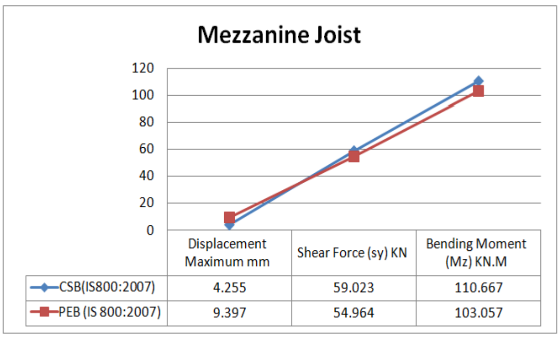


Table 9 Calculation for Mezzanine joist

Sr. No	Description	CSB(IS 800:2007)	PEB (IS 800:2007)
1	Section size	ISWB600	Web 500x 6 mm Flange 230x10mm
2	Length M	7.5	7.5
3	Displacement Maximum mm	4.255	9.397
4	Shear Force (sy) KN	59.023	54.964
5	Bending Moment (Mz) KN.M	110.667	103.057
6	Steel Quantity KN	9.794	4.379



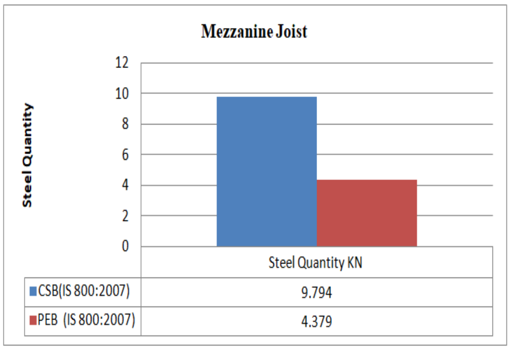
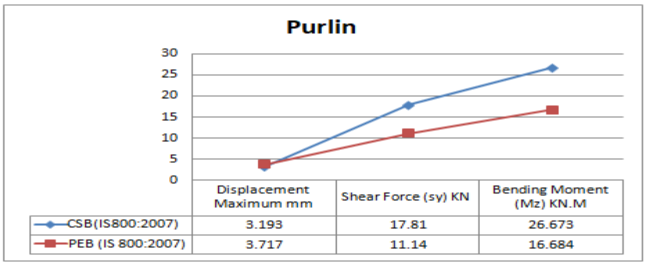
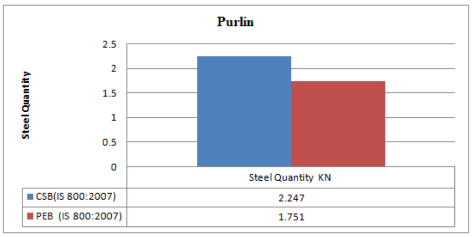


Table 10 Calculation for Purlin

SR.NO	Description	CSB(IS 800:2007)	PEB (IS 801:1975)
1	Section size	ISMC250	Z300X75X3.15
2	Length M	7.5	7.5
3	Displacement Maximum mm	3.193	3.717
4	Shear Force (sy) KN	17.810	11.140

5	Bending Moment (Mz) KN.M	26.673	16.684
6	Steel Quantity KN	2.247	1.751





VIII. DISCUSSION

Software analysis results of structure and literature studies suggest that the PEB structure is more economical and advantageous over CSB.

IX. CONCLUSION

The following are the different conclusions of the project.

- **Displacement :-**

The PEB structure model designed by IS 800:2007 has more displacement as compared to CSB structure due to less weight of the structure.

- **Support Reaction :-**

The PEB structure model designed by IS 800:2007 has less support reaction as compared to CSB structure due to less weight of the structure.

- **Axial , shear Force and Bending Moment :-**

The PEB structure model designed by IS 800:2007 has less axial, shear force and Bending Moment as compared to CSB structure.

- **Steel Quantity:-**

The PEB structure model designed by IS 800:2007 lightweight as compared to CSB structure. PEB structure is 64% lighter as compared to CSB Structure.

- **Wind Resistance:-**

The PEB structure model designed by IS 800:2007 higher resistance to wind as compared to CSB structure.

- **Purlin:-**

The cold formed purlin is 32.5% lighter as compared to Hot rolled Purlin.

X. REFERENCE

Codes:

[1] IS 875 (part-1) "Code of practice for design loads (other than earthquake) for building and structures", Dead loads, New Delhi,.

[2] IS 875 (part-2) "Code of practice for design loads (other than earthquake) for building and structures", Imposed loads, New Delhi, .

[3] IS 875 (part-3) "Code of practice for design loads (other than earthquake) for building and structures", Wind loads, New Delhi, .

[4] AISC: American Institute of Steel Construction-2011, Manual of Steel Construction.

[5] MBMA: Metal Building Manufactures Association-1996, Metal Building Systems Manual

Journal Articles:

[6] C.M. Meera (2013). Pre-Engineered Building Design of an Industrial warehouse. International Journal of engineering sciences & Emerging Technologies (2013) 2231-6604.

[7] Milind Bhojkar and Milind Darade (2014).Comparison of Pre Engineering Building and Steel Building with Cost and Time Effectiveness. International Journal of Innovative Science, Engineering & Technology (IJISET), Vol. 1 Issue 10.

[8] G. Sai Kiran, A. Kailasa Rao, R. Pradeep Kumar (August 2014) . "Comparison of Design Procedures for Pre Engineering Buildings (PEB): A Case Study". International Journal of Civil, Architectural, Structural &Construction Engineering (IJCASCE), Volume 8, No. 4.

[9] Vrushali Bahadur, Prof. R.V.R.K.Prasad (January -February 2013) on "Comparison between Design and Analysis of Various Configuration of Industrial Sheds. International Journal of Engineering Research and Applications (IJERA), Vol. 3, Issue 1, pp.1565-1568.

[10] Swati Wakchaure, N.C. Dubey "Design and Comparative Study of Pre-Engineered Building", International Journal of Engineering Development and research- (IJEDR) ISSN: 2321-9939 volume 4, Issue 2, 2016

[11] Bhojkar Milind and Darade Milind (December 2014) on "Comparison of Pre Engineering Building and Steel Building with Cost and Time Effectiveness". International Journal of Innovative Science, Engineering & Technology (IJISET), Vol. 1 Issue 10

[12] Aijaz Ahmad Zende. al, (2013) "Comparative Study of Analysis and Design of Pre-Engineered-Buildings and Conventional Frames", IOSR Journal of Mechanical and Civil Engineering. Volume 5, Issue 1.

Book:

[13] Design of Steel Structures by N. Subramanian, published in India by Oxford University Press in 2011, ISBN 0-19567681-5