VOL. 19, NO. 3, FEBRUARY 2024 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

ANALYSIS AND DESIGN OF PRE-ENGINEERED INDUSTRIAL WAREHOUSE USING IS: 800 AND AISC

Venkateswara Rao J., Ramana K. V. and Narasimha Rao B.
Department of Civil Engineering, Lakireddy Bali Reddy College of Engineering, India
E-Mail: jampanivenkat8@gmail.com

ABSTRACT

Pre-engineered construction is one of the new trend-setting technology globally, because of its suitability to the current era demands of fast and flexible construction, economical, sustainable, and ecofriendly construction. The analysis and design of pre-engineering buildings are also attracting the attention of design engineers. In this context, the design of an efficient and economical design is of prime concern. The present paper is an analytical study on the design and analysis of Industrial warehouses as per IS: 800-2007, and AISC design specifications. The analysis is executed under two different cases, out of which in one case optimal cross-sectional details are provided based on critical loading combinations of each code of practice. In other case, similar cross-sections were considered for both codes of practice. The critical load combinations and the locations of the maximum design forces in each case and the relative comparison of these between the two codal practices of IS:800 and AISC are discussed.

Keywords: pre-engineered building, Industrial warehouse, analysis, design, deflection.

Manuscript Received 16 December 2023; Revised 1 March 2024; Published 30 March 2024

INTRODUCTION

The prime objective of PEB lies in optimal material usage as the internal moments will be effectively mapped with the frame geometry there by a reduction in the weight of whole the structure is achieved. In the present scenario, Pre-engineered buildings (PEB) globally attracting attention in the construction industry as they serve as one of the best alternatives to conventional steel buildings. Pre-engineered buildings are preferred because of their versatile benefits such as cost-effectiveness, ease of construction as well as flexibility in expansion, reduction in construction time, availability of a wide variety of architectural options, low maintenance, durable and energy-efficient wall, and roofing systems. Typical applications of pre-engineering buildings can be found from small parking sheds to wide aircraft hangers. In industrial sectors for structures like warehouses, and workshops, for commercial purposes like supermarkets, showrooms, and service stations, in the agricultural sector for poultry sheds, dairy farms, etc., PEBs are currently used. Nowadays PEBs are in use even in the case of institutional buildings for structures like university buildings, hospitals, malls, exhibition halls, auditoriums, etc.

Studies also reveal that the reduction in weight of steel used and cost savings of PEB are about 50 and 30% compared to the conventional buildings respectively [1-4]. A lighter roof structure and, the possibility of a better choice of roof connections and foundation is possible in PEB construction compared to conventional steel building [5,6]. Better performance and considerable weight reduction of PEB structure when compared to conventional steel structure with appropriate bracing systems are reported in recent studies [7-10]. Better wind and earthquake resistance of pre-engineered steel buildings when compared to conventional buildings is proved in the earlier conducted modelling and analysis works [11-13].

Analysis and design of PEB are carried out using IS:800-1984, IS:800-2007, AISC-89/MBMA-86, and AISC-2005. Most of the Industrial projects are designed using AISC/MBMA codal provisions due to more conservative loads and less range of allowable limits of deflections as per Indian codes. As a consequence, AISC design provisions resulted in lighter sections [14-18]. The present work depicts an analytical study of the analysis and design of a warehouse considered as per Indian and American codes of practices, under two different criteria to identify the differences in design forces under each criterion.

INDUSTRIAL WAREHOUSE CONFIGURATION

The proposed industrial warehouse location is in Rajam, Srikakulam district, Andhra Pradesh. Warehouse configuration is represented as shown in Figure 1. The warehouse has having length and width of 135 m and 45 m width respectively. The eave height of the building is 9.8 m. The slope of the truss roof is 1V:10H. Purlins are spaced at 1.58 m centre to centre.

Dead Loads

In dead load calculation unit weight of sheeting, self-weight of purlin, sag rods, and the weight insulation are considered and the corresponding values assumed for this analysis are shown in Table-2.

Live Loads

As per IS 875 (Part-2)-1987 for a slope of 1:10, the imposed load may be assumed as 0.75 kN/m^2, also as per AISC it may be assumed as 0.57 kN/m^2.

VOL. 19, NO. 3, FEBRUARY 2024 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Table-1. Industrial warehouse configuration.

Location	**Visakhapatnam, Andhra Pradesh, India.**
Width (mm)	45000
Length(mm)	135000
Eave height (mm)	9800
Bay spacing (mm)	18@7500
Basic wind speed (m/s)	50
Wind terrain category	II
Seismic zone	III
Soil type	Medium
Importance factor	1
Response reduction factor	5.5
Purlin spacing (mm)	1580
Girt Spacing (mm)	1800
Slope(V:H)	1:10

Table-2. Dead loads.

Unit weight of roof cover (GI sheets- 5mm thick)	**4.85 kg/m^2**
Self-weight of purlin @1.8m spacing	2.60 kg/m^2
Weight of sag rods @1.8m spacing	0.7 kg/m^2
Weight of Insulation	1.8 kg/m^2
Total Dead load	95 kg/m^2 ≈ 100 kg/m^2 =0.1 kN/m^2

Wind Loads

As per IS 875 (part 3) wind loads are computed. The basic wind speed for the Zone-III is assumed as 40 m/s. The Risk coefficient (k_1), Probability factor (k_2), and Topography factor (k_3) are taken as 1.0, 0.93, and 1.1 respectively. Design wind pressure is calculated as 1 kN/m^2. Based on internal pressure coefficient (C_{pi}) variations, six different wind load cases are considered. These load cases are designated as WINDL1, WINDR1, WINDL2, WINDR2, LWIND1 and LWIND2.

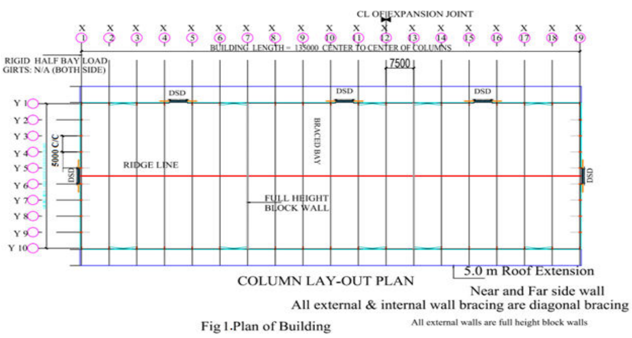

Figure-1. Plan of industrial warehouse.

LOAD COMBINATIONS

As per IS 800-2007, to satisfy serviceability and strength criteria, the load combinations as given in Table-3 are considered.

Table-3. Load combinations considered under IS:800 and AISC.

IS 800:2007	**AISC**
Strength Criteria	
1.5*(DL+LL) +1.05*CL	1.2DL+1.6LL
1.5*(DL+WL/EL)	1.2DL+0.5LL+1.6WL
0.9*DL+1.5* WL/EL	0.9DL+1.6WL
1.2*(DL+LL) +1.05*CL +0.6*WL/EL	
1.2*(DL+LL +WL/EL)+0.53*CL	
Serviceability Criteria	
DL+LL+CL	DL+LL
DL+WL/EL	DL+0.75WL
DL+0.8*(LL+CL +WL/EL)	DL+WL
	0.6DL+WL

ANALYSIS AND DESIGN OF MODELLED PEB INDUSTRIAL WAREHOUSE:

The typical rigid frame cross-section of the PEB warehouse and its perspective view is shown in Figures 2 and 3. The columns and purlin members are modelled as tapered members. The analysis and design of the PEB industrial warehouse are performed using IS:800-2007 and AISC codes of practice.

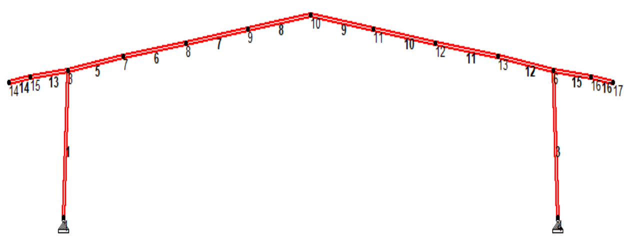

Figure-2. 2-D modelling of industrial PEB warehouse.

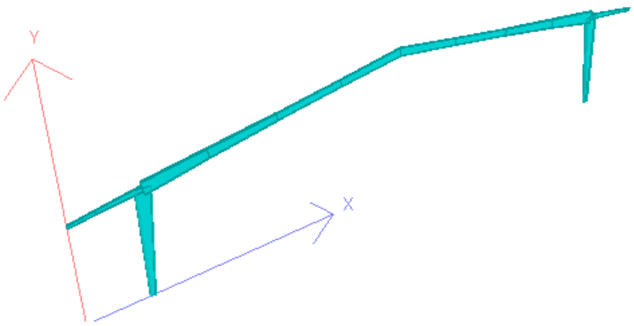

Figure-3. 3-D Rendered view of industrial warehouse.

Two different load cases are discussed herein. In case-1, the optimum cross-sectional details are provided by the requirements of load combinations specified for each of the codes as specified in Table-3. In case-2 compared the analysis results of the PEB when similar cross-sectional details are provided irrespective of critical load combinations of each codal specification requirement.

CASE-I: ANALYSIS AND DESIGN RESULTS OF PEB WAREHOUSE WHEN OPTIMUM CROSS SECTIONS ARE PROVIDED

In this section, the differences in weight of members, displacements, and end forces of members as well as the associated load combinations under the respective codal practices are discussed.

Comparison of the Weight of Tapered Members in IS 800 and AISC

Optimum tapered cross-sections are provided based on the critical load combination for the respective code of practices such that the stresses under serviceability and strength criteria are within allowable limits. The relative weight ratios of the members selected are shown in Table-4. From Table-4 shown below it is clear that the weight of all the members is relatively higher when the design is performed as per IS 800: 2007 compared to AISC. For various members, the percentage saving in the material lies in the range of 0.8% to 124% when the design is considered as per the load combinations of the AISC code, except for members 5, 8, and 13.

Table-4. Relative weights of PEB members obtained as per IS: 800 and AISC designs.

Member No.	Length(m)	Weight required for IS:800 design (kg)	Weight required for AISC design (kg)
1	18.17	4878.7	2168.4
5	10.21	1443.4	1509.6
6	11.5	1237.8	1006.0
7	11.5	764.2	757.9
8	11.5	547.3	831.48
13	6.86	214.07	228.3
14	4.04	111.11	104.1

Overall for the entire cross section, the percentage saving in the material is about 40% when analysis and design are performed according to the AISC specifications.

Comparison of the Nodal Displacements and Associated Load Combination as per IS 800 and AISC: (Case-I)

The upper and lower limits of nodal displacement results of the PEB warehouse under various load combinations of IS and AISC specifications are presented in Table-5. and 6. As per IS :800 and AISC, maximum horizontal deflection is obtained when a combination of dead and wind loads at 0^0 and 180^0(C_{pi} is positive). Vertical deflection in both cases is maximum when the dead and live loads combination is acting as well as when a combination of dead and wind loads acts at 90^0 (C_{pi} is positive). The maximum horizontal and vertical deflections obtained here exceed the allowable limits of respective codal specifications. However, can be minimized by adopting suitable bracing systems such as diagonal, cross (or) K- shaped systems.

Table-5. Nodal displacements of PEB according to AISC design.

	Node	L/C	Horizontal (mm)	Vertical (mm)
Max X	3	0.6DEAD + WINDL1	67.6	-2.47
Min X	6	0.6DEAD + WINDR1	-67.6	-2.47
Max Y	10	0.6DEAD + LWIND1	0	192.5
Min Y	10	DEAD + LIVE	0	-221.4

Table-6. Nodal displacements of PEB according to IS: 800 design.

	Node	L/C	Horizontal (mm)	Vertical (mm)
Max X	3	DEAD + WINDL1	53.1	-2.1
Min X	6	DEAD + WINDR1	-53.2	-2.1
Max Y	10	DEAD + LWIND1	0	150.9

Min Y	10	DEAD + LIVE	0	-234.7

Comparison of the Beam end Forces and Associated Load Combination as per IS 800 and AISC

The maximum axial (F_x,), shear force (F_y), and bending moment (M_z) in various members and the respective load combinations are presented in Table-7 and 8. Maximum values of end forces are obtained when the combination of dead and live loads is acting. Critical design values of axial forces and moments are obtained when a combination of dead and wind loads acts at 180^0 (C_{pi} is positive). The critical values of shear forces are obtained when a combination of dead and wind loads act at 90^0(C_{pi} is positive). The critical values of these forces are observed in column members (1 and 3) and beams adjacent to columns (5 and 12).

Table-7. Maximum end forces of PEB members according to AISC design.

	Beam	L/C	Node	F_x kN	F_y kN	M_z kN-m
Max Fx	1	DEAD + LIVE	1	176.3	91.5	0.0
Min Fx	3	0.6DEAD + WINDR1	6	-173.3	-63.7	-729.1
Max Fy	5	DEAD + LIVE	3	119.0	114.9	911.1
Min Fy	1	0.6DEAD + LWIND1	3	-123.5	-111.5	-819.4
Max Mz	5	DEAD + LIVE	3	119.0	114.9	911.1
Min Mz	12	0.6DEAD + WINDR1	6	-96.9	-104.2	-872.6

Table-8. Maximum end forces of PEB members according to IS:800 design.

	Beam	L/C	Node	F_x kN	F_y kN	M_z kN-m
Max Fx	1	DEAD + LIVE	1	227.7	115.2	0.0
Min Fx	3	DEAD + WINDR1	6	-156.6	-56.4	-666.8
Max Fy	5	DEAD + LIVE	3	149.4	140.0	1148.9
Min Fy	1	DEAD + LWIND1	3	-106.8	-104.6	-761.5
Max Mz	5	DEAD + LIVE	3	149.4	140.0	1148.9
Min Mz	12	DEAD + WINDR1	6	-86.7	-91.5	-804.3

CASE-II: ANALYSIS AND DESIGN RESULTS OF PEB WAREHOUSE WHEN SIMILAR CROSS SECTIONS ARE PROVIDED FOR BOTH AISC AND IS: 800

Since the same cross-section is provided for both AISC and IS:800, it can be noticed that there is no difference in weight of members of the PEB warehouse. However, displacements and end forces of members differ from each other.

Table-9 and Table-10 show the maximum limits of axial and shear deflections of PEB as per AISC and IS:800 specifications. Axial displacements are found to be maximum at the junction of column and rafter members when wind load loads acting at 0^0 and 180^0 (C_{pi} is positive) combined with dead loads.

Table-9. Nodal displacements of PEB as per AISC design.

	Node	L/C	Horizontal (mm)	Vertical (mm)
Max X	3	0.6DEAD + WINDL1	50.4	-2.0
Min X	6	0.6DEAD + WINDR1	-50.5	-2.0
Max Y	10	0.6DEAD + LWIND1	0	148.3
Min Y	10	DEAD + LIVE	0	-174.3

Table-10. Nodal displacements of PEB as per IS:800 design.

	Node	L/C	Horizontal (mm)	Vertical (mm)
Max X	3	DEAD + WINDL1	47.8	-1.9
Min X	6	DEAD + WINDR1	-47.8	-1.9
Max Y	10	DEAD + LWIND1	0	130.0
Min Y	10	DEAD + LIVE	0	-214.9

VOL. 19, NO. 3, FEBRUARY 2024 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

Vertical deflections are found to be maximum at ridge when the combinations of dead and live loads as well wind loads acting at 90^0 (C_{pi} is positive) in combination with dead loads. Although the vertical deflection values exceed the permissible values, they can be minimized by the vertical bracing. It is observed that horizontal deflections in both cases are nearly equal, but the vertical deflections are relatively high in the case of PEB design using IS:800. The maximum downward deflection occurs at the ridge when the dead and live load combination is considered.

Comparison of the Beam End Forces and Associated Load Combination as per IS 800 and AISC

The maximum axial (F_x,), shear force (F_y), and bending moment (M_z) in various members and the respective load combinations are presented in Table-11 and 12. Although similar cross sections are provided the shear and bending moments values are relatively higher in the case of PEB design with IS:800. Beam end forces maximum values are obtained when the combination of dead and live loads is acting. Critical design values of axial forces and moments are obtained when a combination of dead and wind loads at 180^0 (C_{pi} is positive). The critical values of shear forces are obtained when a combination of dead and wind loads are acting at 90^0(C_{pi} is positive). The critical values of these forces are observed in column members (1 and 3) and beams adjacent to columns (5 and 12).

Table-11. Maximum end forces of PEB members according to AISC design.

	Beam	L/C	Node	Fx kN	Fy kN	Mz kN-m
Max Fx	1	DEAD + LIVE	1	194.4	95.0	0.0
Min Fx	3	0.6DEAD + WINDR1	6	-171.2	-64.2	-735.5
Max Fy	5	DEAD + LIVE	3	123.7	116.7	948.1
Min Fy	1	0.6DEAD + LWIND1	3	-121.5	-112.3	-829.4
Max Mz	5	DEAD + LIVE	3	123.7	116.7	948.1
Min Mz	12	0.6DEAD + WINDR1	6	-97.1	-102.7	-877.4

Table-12. Maximum end forces of PEB members according to IS:800 design.

	Beam	L/C	Node	Fx kN	Fy kN	Mz kN-m
Max Fx	1	DEAD + LIVE	1	232.9	116.7	0
Min Fx	3	DEAD + WINDR1	6	-152.3	-53.3	-639.4
Max Fy	5	DEAD + LIVE	3	151.7	142.7	1166
Min Fy	1	DEAD + LWIND1	3	-102.5	-101.5	-733.3
Max Mz	5	DEAD + LIVE	3	151.7	142.7	1166
Min Mz	12	DEAD +WINDR1	6	-83	-88.9	-774.2

CONCLUSIONS

The analysis and design of the pre-engineering building are performed using AISC and IS: 800 codal specifications under two different cases. In one case similar cross-sectional details are provided for PEB, whereas in another case the cross-section details are provided based on optimum design. The following conclusions are made from these cases.

a) PEB design under optimum design considerations using AISC specifications results in 40% saving of the materials when compared to design using IS:800 standards.

b) Maximum horizontal deflection is obtained when a combination of dead and wind loads at 0^0 and 180^0(C_{pi} is positive) for both codal specifications under optimum design requirements.

c) Under optimum design considerations vertical deflections are found to be maximum when wind loads acting at 90^0 (C_{pi} is positive) along with dead and live load combination.

d) For PEB under optimum design considerations using both AISC and IS codes, critical design values of axial, shear forces, and moments are obtained when a combination of dead and wind loads are acting. Also found that the critical values of these forces are observed in columns, and beams next to columns.

e) When the same cross-sectional details are provided the vertical deflections are more in the case of PEB design with IS: 800 design compared to the design as per AISC. The maximum vertical deflections are obtained at the ridge point.

f) Shear and bending moment are on the higher side in the case of PEB design with IS: 800 design compared to design as per AISC, when the same cross-sectional details are provided. These maximum values are obtained in columns and beams next to columns.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the keen interest shown by our students P.N.S. Santosh Kumar, B. Subba Lakshmi, and A. Ashish Kumar during the PEB modelling In Staad Pro.

REFERENCES

[1] Shaik K., BSS R. R. and Jagarapu D. C. K. 2020. An analytical study on pre-engineered buildings using staad pro. Materials Today: Proceedings. 33, pp. 296-302.

[2] Sharma L., Taak N. and Mishra P. K. 2021. A comparative study between the pre-engineered structures and conventional structures using STAADPRO. Materials Today: Proceedings. 45, pp. 3469-3475.

[3] Kolate N. R. and Kewate S. 2015. Comparative Study of Pre-Engineered and Conventional Steel Frames for different Wind Zones. International Referred Journal of Engineering and Science. 4(7): 51-57.

[4] Kumar G. S. and Varghese K. M. 2020. Comparative analysis on pre-engineered and conventional buildings with diagonal braces. International Research Journal of Engineering and Technology. 7(06): 3668-3671.

[5] Valentina L. M. S. S. 2015. Comparative study of pre-engineered and conventional industrial building. Indian Journal of Science and Technology. 8(32): 1-8.

[6] Subramanian D. N. 2008. Pre-engineered buildings selection of framing system, roofing and wall materials. Master Builder. 48-56.

[7] Bharmal P. P., Kumbhar P. D. and Gumaste K. S. 2023. Comparative study on the behaviour of conventional and pre-engineered buildings provided with different types of bracing. Asian Journal of Civil Engineering. pp. 1-9.

[8] Zende A. A., Kulkarni A. V. and Hutagi A. 2013. Comparative study of analysis and design of pre-engineered-buildings and conventional frames. IOSR Journal of Mechanical and Civil Engineering. pp. 2278-1684.

[9] Kumar A. S., Rao S., Mohan M. and Reddy D. S. 2014. Design and Analysis of Pre-Engineered Industrial Buildings (PEB). Int. J. Appl. Sci., Eng. Manag. 3(06): 2320-3439.

[10] Somasekharan S. and Vasugi K. 2017. Wind load analysis for industrial building with different bracing patterns and its comparison with pre-engineered building. International Journal of Civil Engineering and Technology. 8(4): 1074-85.

[11] Goswami A. and Shende T. 2018. Pre-engineered building design of an industrial warehouse. International Research Journal of Engineering and Technology. 5(6): 1484-1488.

[12] Lakshmi B. M. S., Ratnam M. K. M. V., Krishna Chaitanya M. K. S. S., 2015. Comparative Study of Pre-Engineered and Conventional Steel Building. International Journal of Innovative Research in Technology. 2(3): 124-129.

[13] Sah S. K., Kangda M. Z., Sathe S. and Mate N. 2023. A state of art review on analysis and design of pre-engineered buildings. Materials Today: Proceedings. 77, pp. 704-710.

[14] Kiran G. S. 2015. Comparison of design procedures for pre-engineering buildings (PEB): a case study. The Master Builder. pp. 48-56.

[15] Patil M. 2019. Comparative study of analysis & design of a pre-engineered building using IS 800: 2007 & various international codes. International Journal of Frontier in Civil and Structural Engineering. 1(1): 7-18.

[16] Animesh T., Rituraj, Shezad Meman Patil, N. 2020. Parametric Study on Design of Pre-Engineered building Using IS 800–2007 and AISC 360-10 13th Edition. IOSR Journal of Mechanical and Civil Engineering. 17(4): 7-14.

[17] Shah N. Vanza M. G., Vora P., 2021. Comparative study of PEB by Indian and American Code. International Research Journal of Engineering and Technology. 8(5): 1683-88.

[18] Chhajed D. K. and Mulay S. B. 2020. Design and Analysis of Pre-Engineered Steel Building with Indian Standard Code and International Code. International Research Journal of Engineering and Technology. 7(9): 3246-49.