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Analytical Study of Pre- Engineered Building

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ABSTRACT: Steel is the most common and smart choice for construction of industrial structure. This has resulted in use of Pre-Engineered Building in India as it has a number of benefits over conventional steel building. It is important to study the PEB using IS code and American code so as to understand the difference between the standards. This study focuses on the analytical study of PEB using Indian Codes (IS 800 and IS 875) and American Code (AISC 360 and AISC 7). A PEB having length 43.26 m, width 32.46 m, eave height 5.82 for Pune location was modeled in STAAD Pro software using IS code as well as American code and the comparison of results obtained was performed. The present work is related to effectiveness of PEB structure using IS code. The results reveal that shear force and bending moment values are higher using IS code. While the displacement values are higher using American code.

KEYWORDS: Steel structure, PEB, CSB, IS code, AISC, STAAD Pro.

I. INTRODUCTION

Steel is one of the most excellent materials, which man has invented. It has numerous advantages as it can be converted into any desired shape as per the needs of the end users. The modern construction methodology for buildings requires best aesthetic look, good quality, cost effective, fast construction and innovative touch. So, structural steel is one of best material as it provides design flexibility, strength, durability, adaptability, ductility and recyclability. Steel is extensively used in the construction of industrial and commercial buildings having large spans, with or without cranes where the construction using concrete is not feasible. Pre-Engineered Building (PEB) is a necessity that satisfies the rising construction demands for increasing urbanization occurring in any region. The prefabricated structures help in keeping construction costs low. Prefabrication accrues for end-to-end fast and hassle-free operations. Having been manufactured from supreme quality materials, these are built to set industry standards. These steel structures are widely preferred for qualities like minimal maintenance, insulation from heat and a wide range of other factors that suit industrial needs. Contrary to the popular belief, these buildings are durable. They are quick to install and are built to last longer. The steel industry is expanding rapidly in almost every part of the world. The use of steel structures at a time when global warming is a concern is not only cost-effective, but also environmentally friendly. If we use standard steel structures, the time frame will be longer, as will be the cost, and both of these factors, will make it expensive. The entire construction is completed in the factory as pre-engineered structures. The members are prefabricated and then transported to the site where they are erected in less than 6 to 8 weeks. Technological advancements over the past years have made a significant contribution to the improvement of quality of life through the introduction of numerous new products and services.

II. RELATED WORK

Thorat and Patil [1] reviewed the design of PEB structure and its study in accordance with Kerby Technical Specification which is based on ASCE 07. Two models i.e. PEB structure with bracing and other Technical bracing are analyzed, designed and compared. Analysis is done on STAAD Pro which includes static, seismic, secondary and El. Centro data for time history analysis. The readings were taken from graphs of acceleration, displacement and velocity. The work concluded the comparison between two models of PEB of 21 meter span based on El-Centro data using Time History Analysis. It showed that the displacement along X, Y and Z direction for PEB structure with bracings is 34%, 13% and 23% respectively less than the PEB structure without bracings.

In their study work **Wakchaure and Dubey [2]** analyzed and designed an industrial structure PEB Frame & CSB Frame according to the Indian standards (IS 800-1998 and IS 800-2007). A structure with length 80 m, width 60 m and clear height 11.4 m having R-Slope 5.71⁰ for PEB & 18⁰ for CSB was considered for analysis and design of 2D frames using STAAD Pro They discussed the economy of the structure in terms of its weight comparison between PEB & CSB



building structure using Indian codes (IS800-1984 and IS800-2007). They also checked the PEB structure and CSB structure for deflection as per the serviceability criteria of the IS codes.

This study concluded that PEB was 30% lighter than the CSB structure and also founded that the deflection limits were higher according to IS 800-1984 when compared with IS 800-2007. From this study we can conclude that PEB structures reduce the dead load and also give an aesthetic view to it.

Lande and Kucheriya [3] considered an industrial structure for analysis and design according Indian Standard IS 800:2007 and American code MBMA-1996 using software STAAD Pro. The study included the design of an Industrial warehouse structure located at Nagpur. They also review the study and comparison between the cold formed sections as purlins with the traditionally used hot rolled sections for industrial structures. The results were discussed in terms of weight comparison between IS code and MBMA. It explores the related studies of analysis and design of Conventional Steel building and Pre Engineered building and study of economic aspects of cold formed steel over hot rolled steel for purlins. The study concluded that use of MBMA gives lesser weight for PEB structure due to its limiting ratio of the section. The loading and deflection limit by IS code are higher than that by MBMA. It was also noticed that PEB roof structure with Z purlins is 30% lighter than the traditional hot rolled section.

Sai Kiran Gone et al. [4] observed that in recent years, the introduction of Pre-Engineered Building concept in the design of structures has helped in optimizing the design. In this study, a Ware House is analyzed and designed according to the Indian Standards, IS 800:1984, IS 800:2007 and also by referring American codes, MBMA-96 and AISC-89. The study considered IS 875 Part-3 (1987) for wind load application and design was done according to the AISC 1989, IS 800:1984, IS 800:2007 for built up members. Load combinations and serviceability were applied according to MBMA-1996, IS 800:1984, IS 800:2007. This study concluded that deflection limits by IS codes are higher than the MBMA-1996 and loading is also higher in IS code as compared to MBMA. The use of American code is preferred over IS code because IS code do not consider slender sections and that do not reduce

III. METHODOLOGY

The study of various literatures is carried out and based on that the further work is divided into various steps. The following steps are carried out for this work -

1. Review of papers to understand the practical aspect of PEB design.
2. Identifying the problem and research gap.
3. To study the PEB structure, background and current scenario.
4. To decide the problem statement for modeling of a PEB structure.
5. Selection of code and method.
6. To model and implement PEB in software.
7. Result and discussion.
8. Conclusion.

In this study, software is used to assess and create a pre-engineered building using IS code (IS 800) and American code (AISC-LRFD). A problem statement of a PEB structure is considered for study. A model of same structure is designed and analyzed using STAAD Pro software. Properties for various components of structure are assigned, loads are applied on structure and analysis of model is performed. To compare the difference between two codes i.e. IS code and American code, the same structure is analyzed by two codes and the results are interpreted. Comparison of the results by both the methods is done and the conclusion is made by the same.

Table 1- Problem statement for structure

Sr. No.	Parameter	Detail
1.	Location	Pune, Maharashtra
2.	Length of the building	43.26 m
3.	Width of the building	32.46 m
4.	Eave height	5.82 m
5.	Maximum height	7.44 m
6.	Bay spacing	7.21 m
7.	No. Of bays	6
8.	Slope of roof for PEB	6.33°

9.	Purlin spacing	1.50 m
10.	Soil permeability	Medium- 5 % to 20 %
11.	Basic wind speed of Pune	39 m/s
12.	Wind terrain category	2

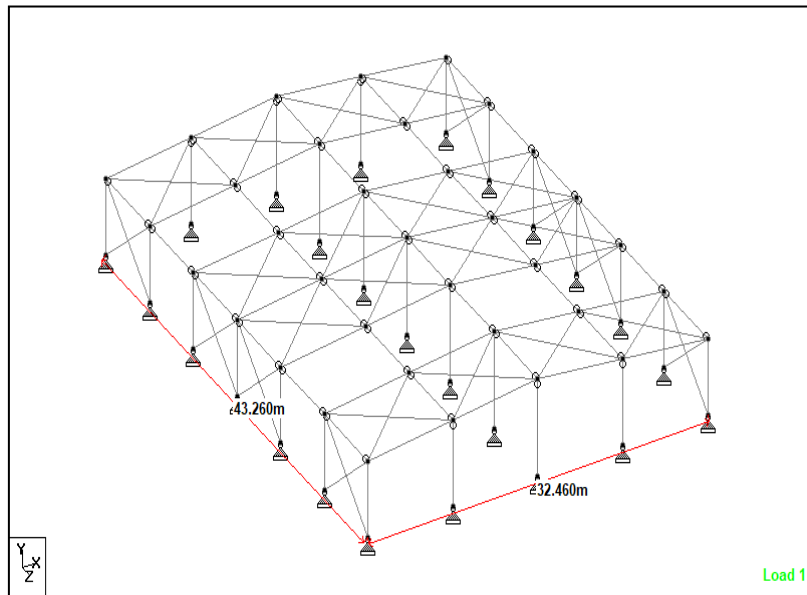


Fig. 1 3-D view of the structure modeled in STAAD PRO Software

Loads applied on the PEB structure-

The loads applied on the above modeled PEB structure are the dead load (IS 875- Part 1, 1987), live load (IS 875- Part 2, 1987), and wind load (IS 875- Part 3, 2015). These loads are calculated as per the IS code. The manually calculated loads are further assigned on the PEB structure.

Dead load (DL) for central portal frames = 4.33 kN/m

Dead load (DL) for gable end frame = 2.16 kN/m

Live load (LL) for central portal frames = 5.41 kN /m

Live load (LL) for gable end frames= 2.71 kN /m

Wind load calculations-

Basic Wind Speed (V_b) = 39 m/s

Probability factor (50 years design life), $K_1 = 1$ (Cl. 6.3.1, T-1)

Terrain category, 2 (Cl. 6.3.2.1)

Terrain, height and structure size factor, $K_2 = 1$ (Cl. 6.3.2.2, T-2)

Topography factor, $K_3 = 1.0$ (Cl. 6.3.3)

Importance factor for the cyclonic region, $K_4 = 1.0$ (Cl. 6.3.4)

Design wind speed, $V_z = V_b \times K_1 \times K_2 \times K_3 \times K_4$ (Cl. 6.3) = $39 \times 1 \times 1 \times 1 \times 1 = 39 \text{ N/m}^2$

Wind pressure, $P_z = 0.6 \times (V_z)^2 = 0.6 \times 39^2 = 912.6 \text{ N/m}^2 = 0.913 \text{ kN/m}^2$

Design Wind pressure, $P_d = K_a \times K_d \times K_c \times P_z$

Area averaging factor, $K_a = 0.8$ (Cl. 7.2.2)

Directionality factor, $K_d = 0.9$ (Cl. 7.2.1)

Combination factor for pressure and suction, $K_c = 0.9$ (Cl. 7.3.3.13)

Design wind pressure, $P_d = 0.8 \times 0.9 \times 0.9 \times 0.913 = 0.592 = 0.60 \text{ kN/m}^2$

Then the wind load F, acting in a direction normal to the individual structural element or cladding unit is found using formula, $F = (C_{pe} - C_{pi}) \times A \times P_d$

The wind load is calculated for 0 degrees & 90 degrees separately. The wind loads are applied from left to right as well as right to left for each case and 8 cases of wind load are applied on the structure.



Load Combinations and Design parameters

For load combination, IS 800:2007 and AISC LRFD codes are used. The load combinations are considered by STAAD Pro software for analysis of PEB structure using Indian code and American code. As two models are created in STAAD Pro software, one is analyzed and design using IS code and other by American code. The design parameters are assigned separately for both the models depending on the codes. The design parameters are defined and assigned as per IS code for one model and as per American code on other model. For the PEB structure, design parameters have been applied in STAAD Pro model under different sections like serviceability parameters and collapse parameters. The PEB models are further analyzed and checked. The results obtained are represented in the form of graph.

IV. RESULTS AND DISCUSSIONS

This part includes the results obtained from the analysis of the PEB models using IS code and American code represented in the graphical form. Further the discussions based on the comparison of the results obtained are presented.

1. Results for Portal frame

The results obtained are maximum shear force, maximum bending moment and displacements. The figures below give graphical representation of the various results obtained using Indian code (IS 800- 2007) and American code (AISC- LRFD).

a. Shear force

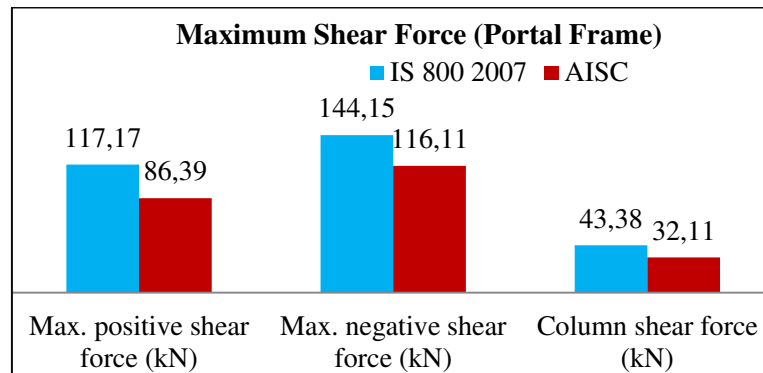


Fig 2- Shear force

The values of shear force using IS code are greater because the sizes of sections used are more when compared to AISC code. The load combinations for PEB structure using IS code are more as compared to American code, so greater values are obtained in case of IS code.

b. Bending moment

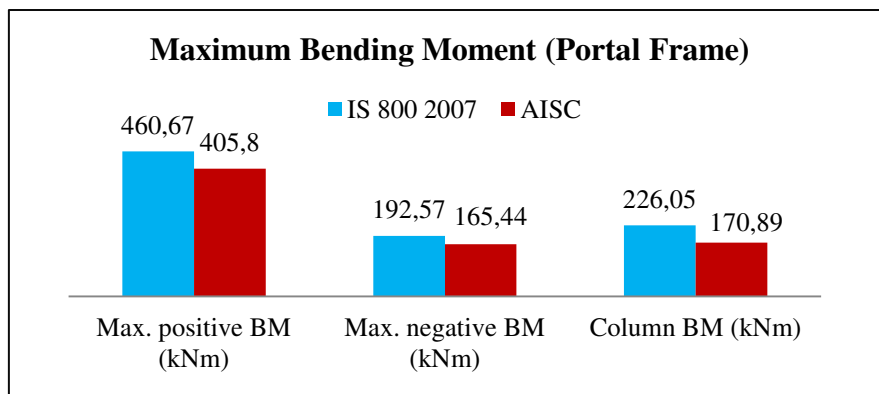


Fig 3- Bending moment



The factor of safety for loads used in IS code is more than American code. The load combinations for PEB structure using IS code are more than AISC code which results in greater bending moment values using IS code. The section sizes for structure IS code are more, so the bending moment values as also greater as compared to AISC code.

c. Displacement

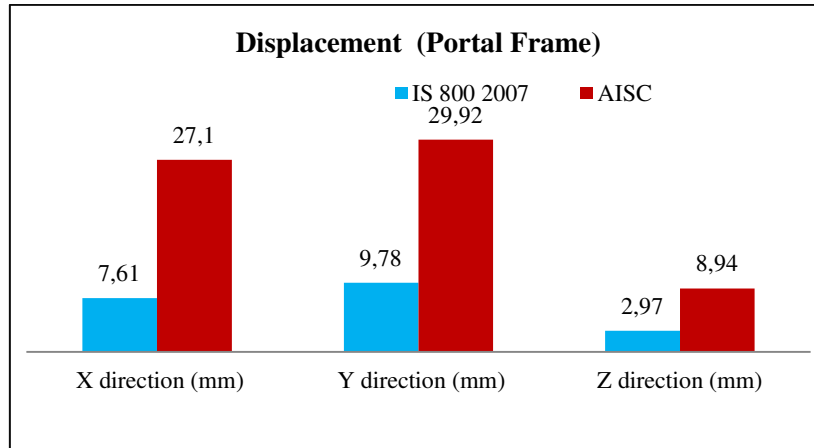


Fig 4- Displacement

The values are greater in case of American is due to its light weight. IS code gives heavier sections so the displacement values obtained are less as compared to that obtained using American code.

2. Results for Gable frame

The results obtained are maximum shear force, maximum bending moment and displacements. The figures below give graphical representation of the various results obtained for IS code and American code.

a. Shear force

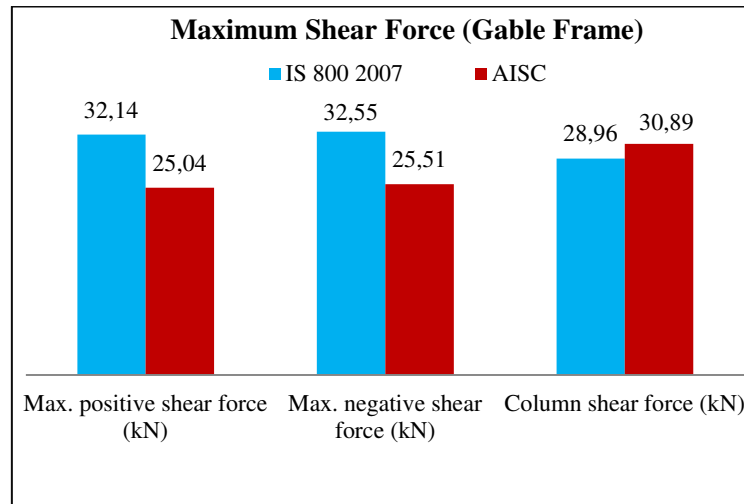


Fig 5- Shear force

The shear force values are greater in case of rafters for structure using IS code as the load combinations are greater. But at the same time the column shear force is less using IS code this may be due to the section size is greater than American code. The wind forces acting on the gable end columns are in two directions but the sections used for American code are small which results in greater values.

b. Bending moment

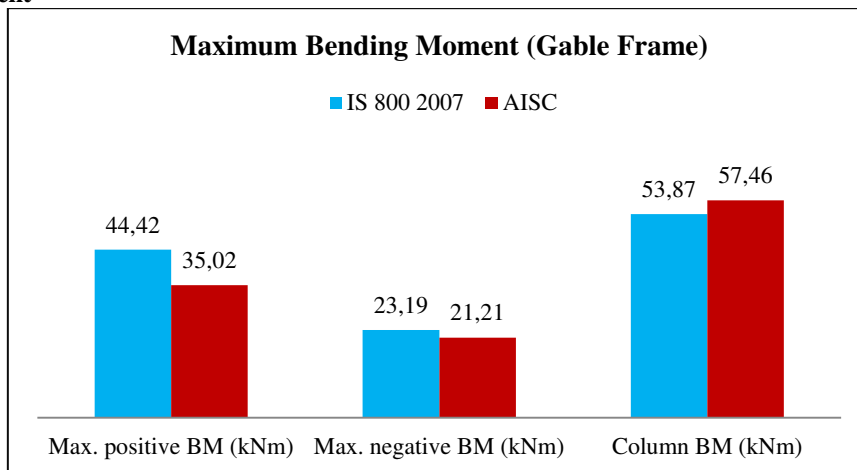


Fig 6- Bending moment

The bending moment values are greater of rafters for structure using IS code as the load combinations used are greater and the sections used are also more when compared to American code. The column bending moment is more in case of structure using AISC code because section size is less as compared to IS code. The load acting on the both the structure is similar but the column section used for AISC code is smaller in size which results in greater bending moment. The section used for column using AISC code is W (400 mm x 5 mm) 2F (200 mm x 10 mm) and that using IS code is W (600 mm x 5 mm) 2F (220 mm x 10 mm).

c. Displacement

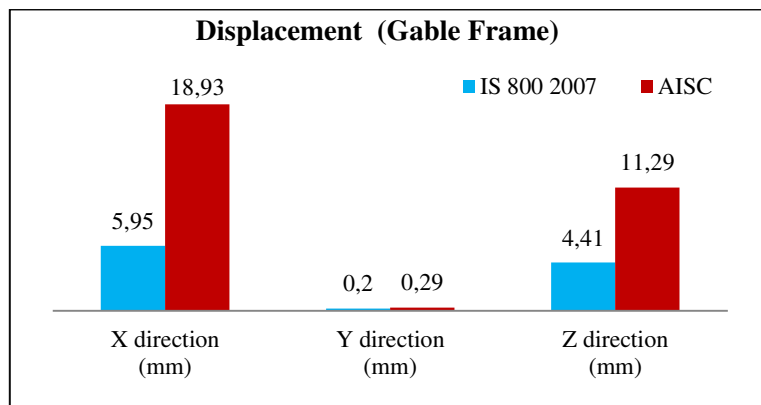


Fig 7- Displacement

The values are greater in case of American is due to its light weight. IS code gives heavier sections so the displacement values obtained are less as compared to that obtained using American code.

V. CONCLUSION

- 1) For portal frame the maximum positive shear force, maximum negative shear and column shear obtained using AISC Code are less by 26.27%, 19.45% and 25.98% respectively as compared to those obtained using IS 800-2007. Similarly, for gable frame the maximum positive shear force and maximum negative shear obtained using AISC Code are less by 22.09% and 21.63% respectively and column shear is more by 6.25% as compared to those obtained using IS 800- 2007.
- 2) For portal frame the maximum positive bending moment, maximum negative bending moment and column bending moment obtained using AISC Code are less by 11.91%, 14.09% and 24.4% respectively as compared to those obtained using IS 800- 2007. Similarly, for gable frame the maximum positive bending moment and maximum negative bending moment values obtained using AISC Code are reduced by 21.16% and 8.54%



respectively while the column bending moment is more by 6.24% as compared to those obtained using IS 800-2007.

- 3) The displacement values for portal frame in X, Y and Z directions using IS code are 71.92%, 67.31% and 66.78% less respectively as compared to American Code. These displacement values for gable frame using IS Code are 68.57%, 31.03% and 60.94% less respectively when compared to AISC Code.

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