Effect of Harp and Perimeter Bracing on PEB Subjected to Wind Loading

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Abstract *- Lateral (i.e. wind) loads are unreliable loads that cause production, overturning moments, plane changes, etc., leading to structural failure. A PEB consists of a series of 2D frames that repeat at regular distances. These frames are stabilized longitudinally by bracing. Cross frames support in-plane loads without longitudinal struts, so the columns act as bending supports, requiring large columns and large foundations. Unlike this arrangement, special roof support arrangements such as perimeter arrangements and harps can be used instead. In current work, STAAD Pro is used to perform dynamic analysis of 3D industrial structures with different support placement configurations to determine the suitability of support placement types and provide insight into the study of different types, media placement.*

Three PEB hangars were simulated in this study: a bare-frame PEB hangar (without supports), a PEB hangar with perimeter supports and a PEB hangar with harp supports. The framework is analyzed in terms of shear forces, bending moments, displacements, normal forces and steel mass. The results show that the perimeter reinforcement is relatively more effective than the bare reinforcement and the harp reinforcement.

Keywords*: PEB, Harp Bracing, Perimeter Bracing, Bare Frame, Steel Structure*

1. INTRODUCTION

India has the second fastest growing economy in the world and a lot of it is due to its construction industry, which is right next to agriculture in its economic contribution to the region. In its continuous development, the construction industry has discovered, invented and developed a number of technologies, systems and products, one of which is the design of pre-engineered buildings (PEBs). In comparison to being assembled on site, PEBs are shipped to the site from a single supplier with a simple structural steel structure with attached factory finished cladding and roofing components as a full finished product. By bolting the different building components together as per requirements, the structure is erected on the ground. Potential design software is used to build PEBs. Conventional building design has been revolutionized by the onset of technological development that enables 3D modeling and detailing of the planned structure and coordination. Pre-Engineered Buildings (PEB) are India's future. The advantages of PEBs have just started to be understood by most of the Indian business community.

1.1 Pre-Engineering Building

In the 1960s, the word Pre-engineering building Scientific Sounding came into being. The idea of pre-engineered buildings requires steel construction systems that are pre-designed and prefabricated. The foundation of the definition of the PEB lies in providing the section at a location only as needed at that location. These buildings were pre-designed into standard sizes, spans, bays and heights and used standard details for repairing cladding, roofing, gutters, flashing, windows, doors, etc. to economically take advantage of industrial mass manufacturing practices of components.

1.2 Crane System

For various material and equipment handling activities within, "these pre-engineered buildings can be fitted with overhead cranes, semi-gentry cranes, wall-mounted cranes, mono rails and under- slung cranes. These structures are built for crane capacities from 1MT to 250MT. The crane runway beams (Gantry Girders) are simply supported by formed parts with and without cap channels and platforms and ladders for maintenance".

1.3 Mezzanine Systems

For crane capacities ranging from 1megatonne to 250 megatonne, these buildings are planned. The crane runway beams (Gantry Girders) are protected by built-up sections with/without cap channels and platforms and ladders for maintenance. A concrete slab is cast as a finished surface on the metal deck. It is also possible to use steel checkered plates as the top surface. Such mezzanines are used in companies for office space, storage or equipment support.

1.4 Fascias

Various structural accessories can be fitted with pre-engineering steel buildings, including mezzanine floors, canopies, fascias, internal partitions, etc. Fascia is used to cover the building's gable roof slop Pre-engineering steel building can be fitted with various structural accessories. The steel building where various components of the building are built in detail and assembled in the plant is shipped to the end erected at the site.

1.5 Harp Bracing

As a result, new perimetral bracing system with a higher level of efficacy is required. A suspended bridge, or "harp bridge," is used as a metaphor for the solution to the problem (Fig. 6). The large bending moment resisted by the deck is controlled by various parts working under axial tensile tension in a harp bridge. When it comes to dimensioning, this is the most conservative step.

1.6 Perimetral Bracing

Others, in contrast to the previous design, demonstrate better overall structure behavior. Some authors, such as Monfort (1991) and Garcimartn (1998), advocated the use of so-called bracing beams. These beams, along with typical bracing, form an on-roof perimetral bracing system linked to a bracing end wall frame. The goal is to produce zero eave deflection in the column, resulting in a reduction in column section and foundation size. The bracing beam is then connected at its extremes to the bracing end wall frame, which thus directs all horizontal loads to the foundations.

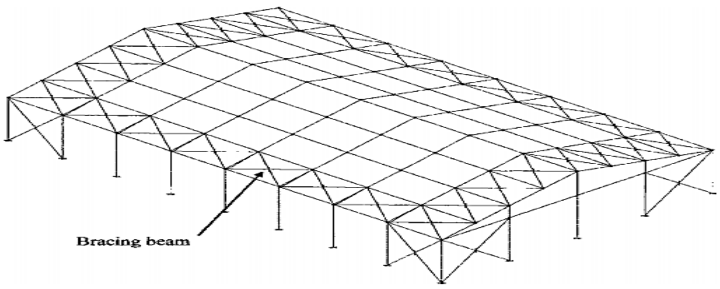

Fig. 1.1 Roof Perimetral Bracing (Martínez et al., 2004)

2. METHODOLOGY

Industrial ware house is majorly constructed in steel and are used for storage units or as workshops. It consists are columns, rafters, tie beams, purlins and cladding. The column and rafter connection are moment resisting connection in the shed and all other connections are usually shear connections. Claddings acts as a covering material for the roof. The present industrial ware house is a pre-engineered building where the sections used are built up sections. There are 3 types of sheds considered for the analysis in STAAD PRO, first one being, bare frame shed with no bracings. Second is PEB shed with perimeter bracing where bracing is in the perimeter of the building. Third is PEB shed with harp bracing.

2.1 Section Size and Support Condition

Built up sections are used for the columns and rafters. For tie beams and bracings pipe sections is considered. Sections properties for are tabulated in the below table. Fixed support is applied to the structure.'

Table 2.1 Built Up Section

Description	Dimension of column and Rafter-2(m)	Dimension of Rafter-1(m)
Depth of section at start node	0.45	0.6
Depth of section at end node	0.6	0.45
Thickness of web	0.008	0.008
Width of top flange	0.35	0.35
Thickness of top flange	0.008	0.008

Properties

Table 2.2 Section Properties

Description	**Section property**
Bracings	**PIP889M**
	PIP1016H
	PIP1397H

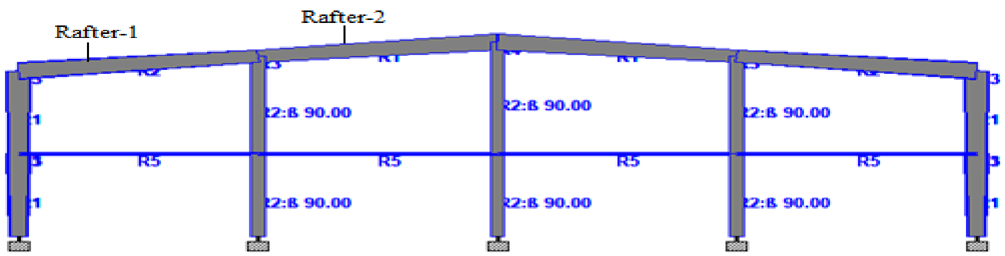

Figure 2.1 PEB Shed With Tapered Sections

3. MODELING AND ANALYSIS

3.1 Loads

The different types of loads that are applied on the structure are dead loads, live loads and wind load. All the three models present in our study are applied with these loads and they are analysed.

I. Dead load.
II. Live load.
III. Wind load.

3.1.1 Dead load:

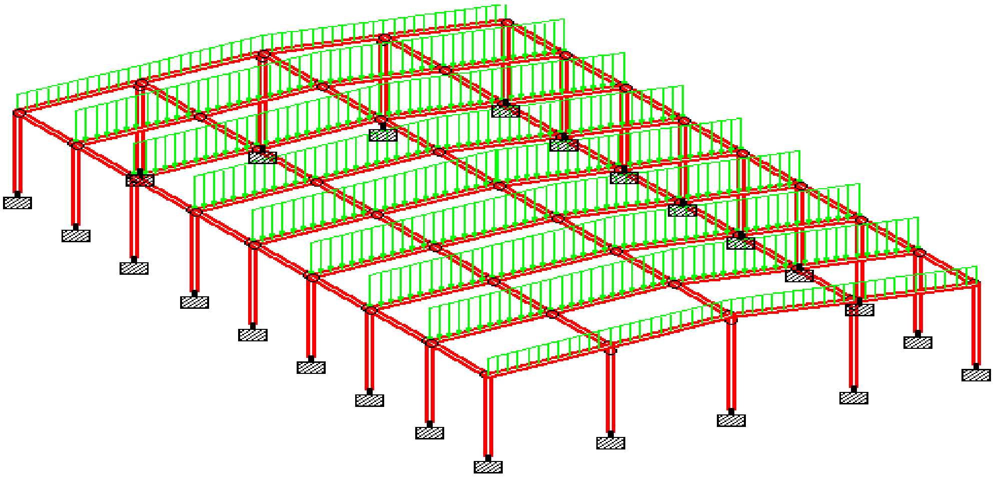

Figure 3.1 Self Weight of the PEB

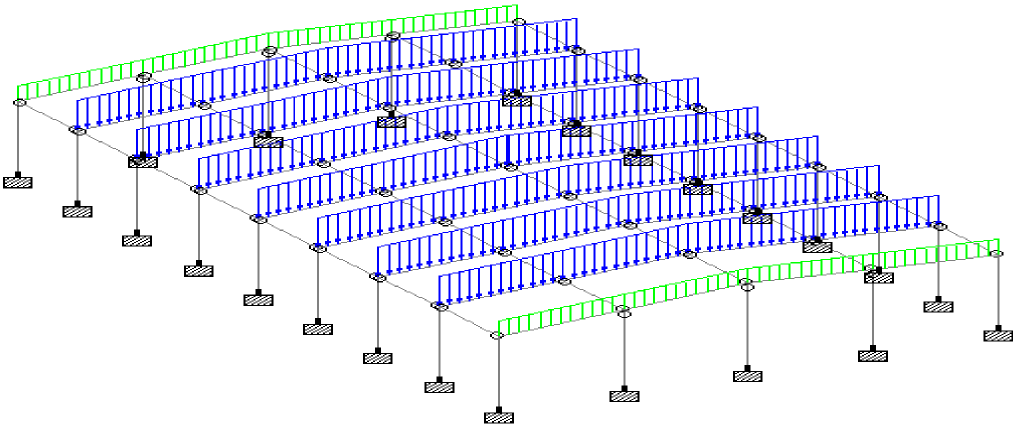

Figure 3.2 Sheeting Load on PEB

3.1.2 Live load:

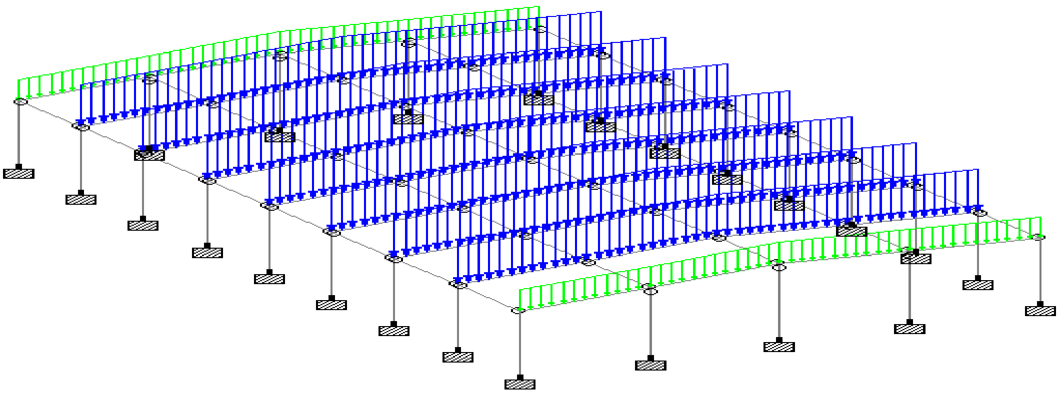

Figure 3.3 Live Load on PEB

3.1.3Wind load:

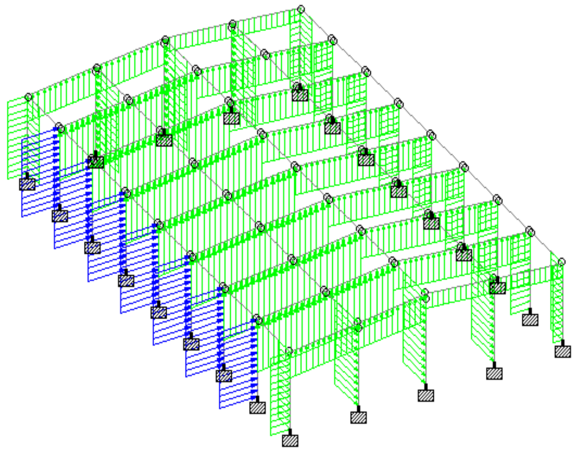

Figure 3.4 Wind Load in +X Direction

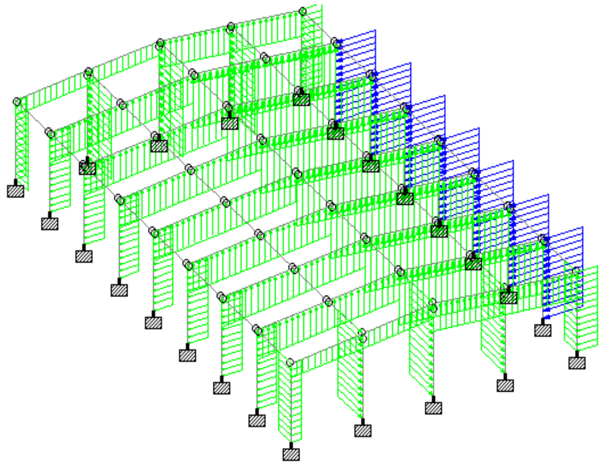

Figure 3.5 Wind Load in -X Direction

4. RESULTS AND DISCUSSION

4.1 PEB with Bare Frame: In this model, there are no bracings modelled. The second bay of the model is selected to tabulate the results.

Bending Moment in Rafters

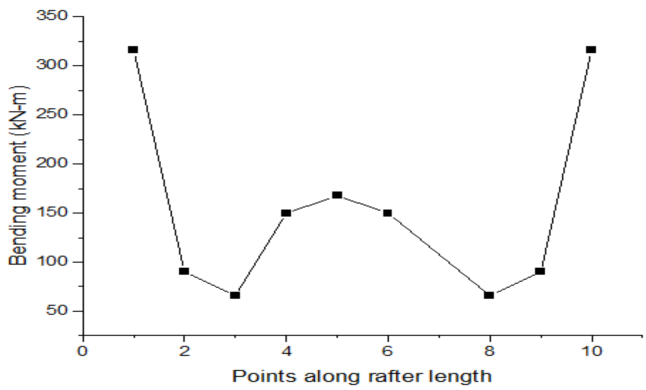

Figure 4.1 Bending Moment Variation along the Rafter in Model -1

Shear Force in Rafters

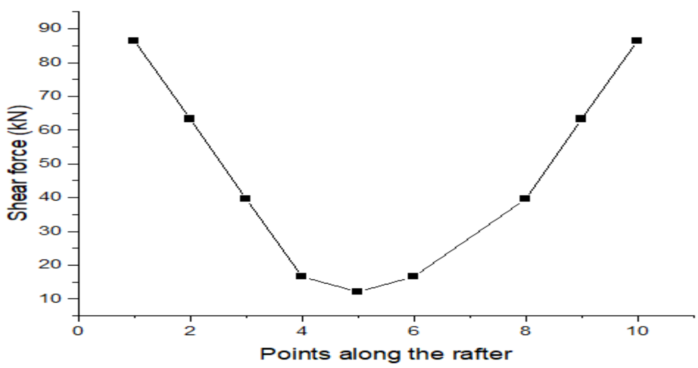

Figure 4.2 Shear Force Variations along the Rafter in Model-1

Bending Moment in Column

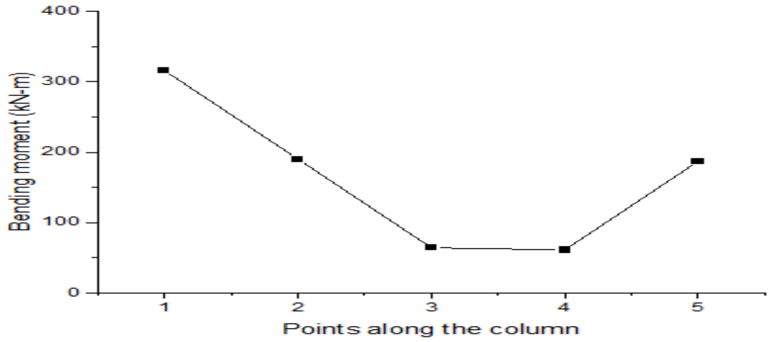

Figure 4.3 Bending Moment Variation along the Column in Model -1

Axial Force in Column

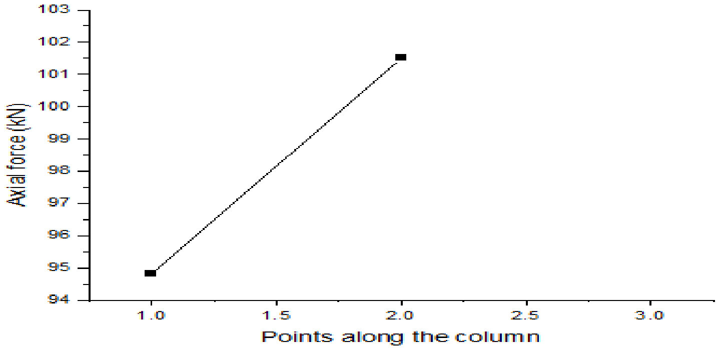

Figure 4.4 Axial Force Variations along the Column in Model-1

4.2 Deflection in PEB Shed Bare Frame

The maximum deflection of the PEB shed with bare frame is tabulated from the envelop load combination. The envelop load combination is found to be 1.5(DL+LL) and the maximum deflection is 72.42 mm and allowable deflection according to the IS is 96 mm for the present study. Hence, PEB shed is safe under deflection criteria. From figure 4.5, highlighted point gives the position of maximum deflection.

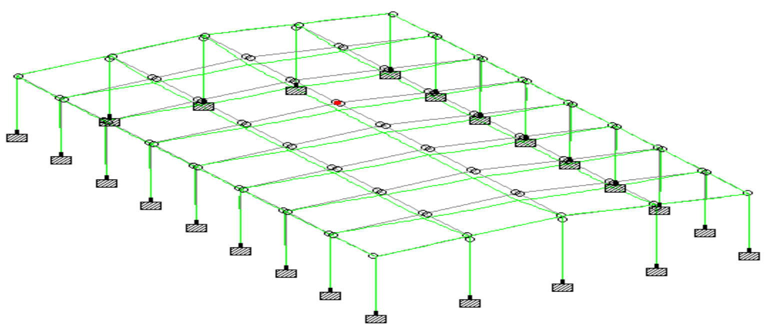

Figure 4.5 Deflections in Model-1

4.3 Utilization Ratio in PEB Shed Bare Frame

The PEB shed was designed according to the IS-800 code standards and the utilization ratio was found to be less than 1 which means all the members of the shed are passing and same can be seen in figure 4.6.

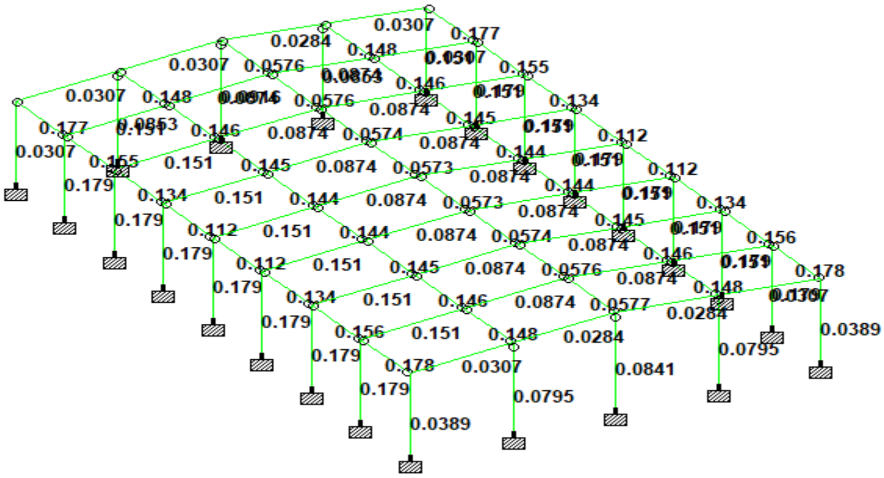

Figure 4.6 Utilization Ratio of Model-1

4.4 Comparison of Bending Moments in Rafter

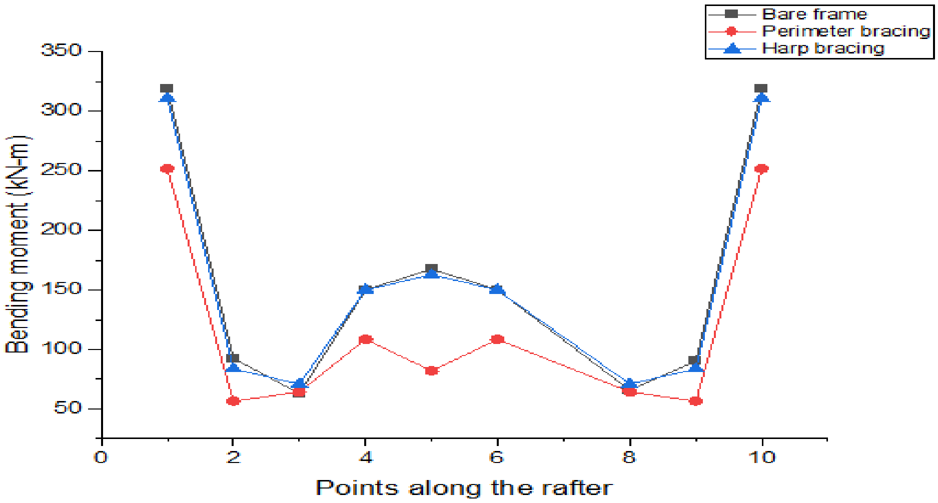

Figure 4.7 Comparison of Bending Moment in Rafter

Figure 4.7 is a graph plotted to show variation of bending moment in rafters among all three models. It is evident from the graph that the bending moment is less for PEB with perimeter bracing and maximum for PEB with bare frame. The bending moment for PEB shed bare frame and PEB with harp bracing doesn't have noticeable difference.

PEB shed with perimeter bracing is found to be efficient out of all three models when parameter like bending moment in rafter is considered.

4.5 Comparison of Shear Force in Rafter

Figure 4.8 is a graph plotted to show variation of shear force in rafters among all three models. We can concur from the graph that the shear force is less for PEB with perimeter bracing and maximum for PEB with bare frame. The shear force for PEB shed bare frame and PEB with harp bracing doesn't have noticeable difference and shear force at the ridge is higher for the PEB shed with perimeter bracing.PEB shed with perimeter bracing is found to be efficient out of all three models when parameter like shear force in rafter is considered.

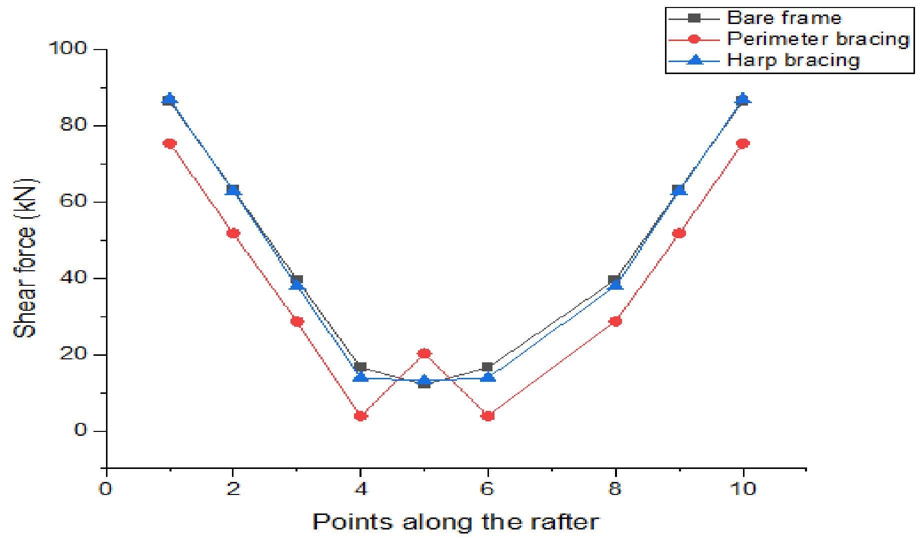

Figure 4.8 Comparison of Shear Force in Rafter

4.6 Comparison of Bending Moments in Column

Figure 4.9 is a graph plotted to show variation of bending moment in column among all three models. It is evident from the graph that the bending moment is less for PEB with perimeter bracing and maximum for PEB with bare frame. The bending moment for PEB shed bare frame and PEB with harp bracing doesn't have noticeable difference.

PEB shed with perimeter bracing is found to be efficient out of all three models when parameter like bending moment in column is considered.

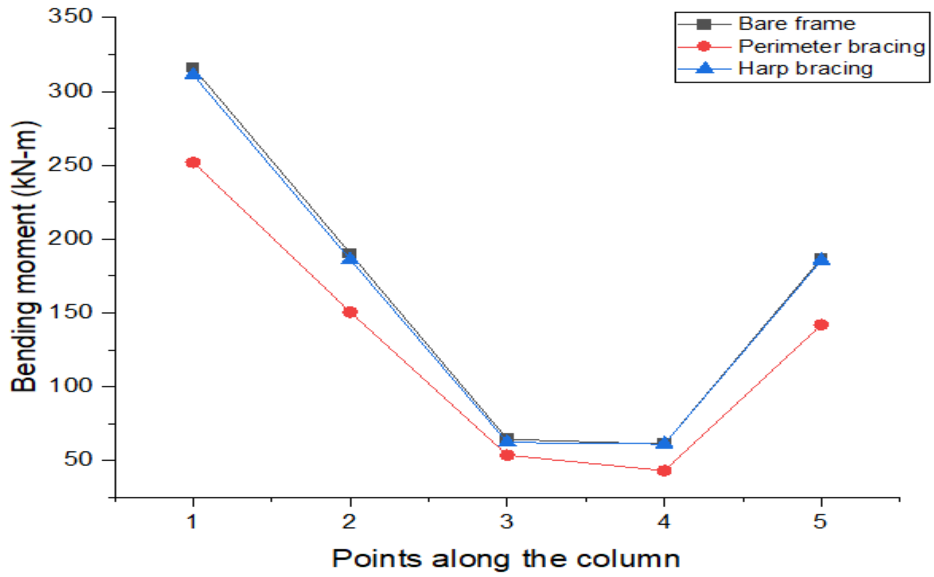

Figure 4.9 Comparison of Bending Moment in Column

4.7 Comparison of Axial Force in Column

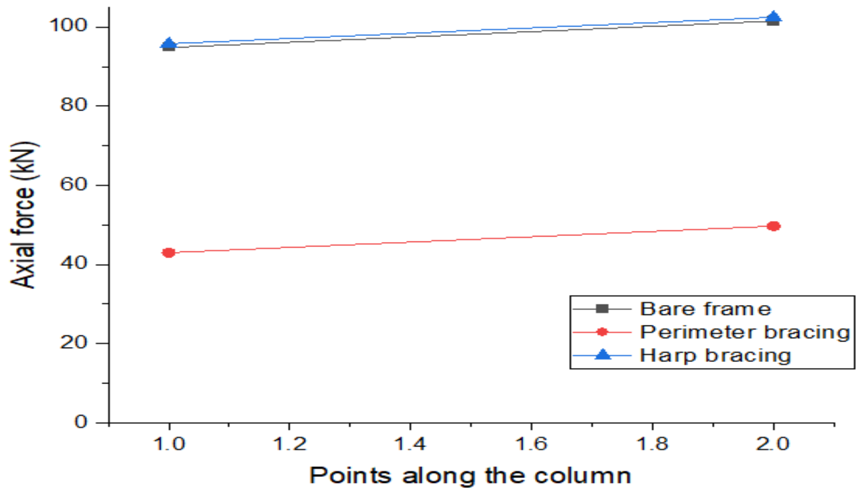

Figure 4.10 Comparison of Axial Force in Column

Figure 4.10 is a graph plotted to show variation of axial force in column among all three models. We can concur from the graph that the axial force is less for PEB with perimeter bracing and maximum for PEB with bare frame. The axial force values of column for PEB shed bare frame and PEB with harp bracing are almost similar.

PEB shed with perimeter bracing is found to be efficient out of all three models when parameter like axial force in column is considered.

4.8 Comparison of Deflection

Deflection of the shed is compared with all the 3 models present in our thesis. Figure 4.11 is a graph plotted to show total deflection of the shed among all three models and the permissible deflection allowed according to the Indian standards.

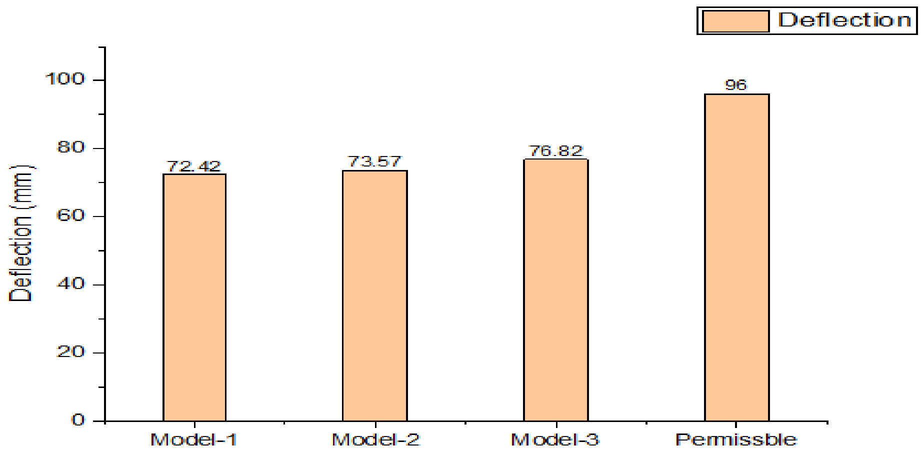

Figure 4.11 Comparison of Deflection

5. CONCLUSION AND FUTURE SCOPE

5.1 Conclusion

On the basis of design and analysis of pre-engineered structure with harp and perimetral bracing subjected to wind loading, many inferences can be seen.

Conclusions of the research work are:

Hence, as per the above-mentioned conclusion on different aspects clearly indicating that the perimeter bracing gives effective and satisfactory results and this can be utilized in field applications of PEB. Further, no significant results are obtained on PEB by using harp bracing so it is advised to avoid such bracing in field application.

5.2 Future Scope

In the present study PEB shed with Perimeter and harp bracing are modeled and analyzed. Various properties like axial force, bending moment, shear force on column and rafter of all sheds are compared. Based on results various important conclusions are drawn which are described above. However, few issues or parameters can be considered in future for research which is detailed as follows:

- As present study suggests that Perimeter bracing is more effective as compare to harp and bare frame in case of wind loading, hence further optimization on cost is still need research.

- A detailed connections design of shed is also considered for further study.

- Further, the effectiveness of Perimeter bracing can also be validating in case of time-history analysis.

6. REFERENCES

6.1 Journal Papers

1. G M, Renuka., S H, S., Patange, R., S P, M., & C K, D. (2020). "The Design and Analysis of Industrial warehouse using STAAD Pro". International Journal of Futures Research and Development, 1(1), 99-113.

2. Mitaali Jayant Gilbile , S. S. Mane, (2020), "A Review on Comparative Study on the Structural Analysis and Design of Pre-Engineered Building [PEB] with Conventional Steel Building [CSB]", International Journal of Engineering Research and Technology (IJERT) Volume 09, Issue 09 (September 2020)

3. Harshil Patel, Dhruv Upadhyay , Divyang Patel. Design Optimization of Box Girder in Gantry Crane using Finite Element Analysis Software. International Research Journal of Engineering and Technology (IRJET). 2020.

4.Zhiqiang Zhang, Haibin Jin, Xing Li and Jinjin Tian Rigid Dynamic Load of the Crane Lifting Mechanism When the Series Resistance Starts. Journal of Physics: Conference Series.2020.

5. Sitthipong, S., Meengam, C., Chainarong, S., & Towatana, P. (2018). Design Analysis of Overhead Crane for Maintenance Workshop.

6.Shivani Meher , Ruchita Nar , Sadichha Jagadale , Gautami Kalal , Viren Chandanshive, 2018, "Design of Industrial Warehouse" International Journal of Engineering Research and Technology (IJERT) Volume 07, Issue 02 (February 2018),http://dx.doi.org/10.17577/IJERTV7IS020170

7. Habibur Rahaman, Faiyaz Azam, Mirza Aamir Baig Seismic risk assessment of an industrial steel building. International Journal of Advance Research, Ideas and Innovations in Technology, 2018.

8. Patil, Subodh & Jadhav, Raviraj & Mali, Pritam.A. & Bhanuse, Maheshkumar. (2017). "Analysis and Design Of Pre-Engineed Building Of An Industrial Warehouse". 10.13140/RG.2.2.23069.77282.

9. Venkatesh, A., Vignesh, S., Iyappan, S., Vignesh Kumar, P., Tamilvanan, G. and Vijaya Sarathy, R. DESIGN OF AN OVER HEAD PLATE GANTRY GIRDER. International Journal of Development Research, 2016.

10. Kavita R. Kapadni, Prof. S. G. Ganiger. A Review Paper on Design and Structural Analysis of Simply Supported Gantry Crane Beam for Eccentric Loading. International Research Journal of Engineering and Technology (IRJET) e-IS. 2015

11. Navya P, Dr.Y.M Manjunat. Structural Behavior of Industrial Structure Subjected to Lateral Loads. International Journal of Engineering Research & Technology (IJERT). 2015.

12. Kapadni, K.R., & Ganiger, P.S. (2015). A Review Paper on Design and Structural Analysis of Simply Supported Gantry Crane Beam for Eccentric Loading

13. Sagar gajanan kashid, prof. mr. pandit rangrao sawant, 2014, design and development of material handling crane, international journal of engineering research & technology (ijert) volume 03, issue 10 (october 2014),.

14. Mohamed H. Mabrouk, Sherif M. M. Abdelkhalek, 2014, Design and Implementation of a Light Duty Gantry Crane, INTERNATIONAL JOURNAL OF ENGINEERING RESEARCH & TECHNOLOGY (IJERT) Volume 03, Issue 12 (December 2014),

15.C. Oktay Azeloglu, Ayse Edincliler, Ahmet Sagirli, "Investigation of Seismic Behavior of Container Crane Structures by Shake Table Tests and Mathematical Modeling", Shock and Vibration, vol. 2014, Article ID 682647, 9 pages, 2014. https://doi.org/10.1155/2014/682647

16. Andrea GODOY, Frédéric BARBIER , Charisis CHATZIGOGOS, Nicolas BESSON, Alfred THIBON and Martin RAY. COMPARATIVE SEISMIC ANALYSIS OF OVERHEAD CRANE ON STEEL FRAME CARRYING STRUCTURE: EVALUATION OF ADEQUATE EQUIPMENT-STRUCTURE INTERACTION MODELING. Second Europeon Conference on Earthquake Engineering. 2014.

17. Subhrakant Mohakul, Dr. Shaikh Yajdani, Abhay Dhurde,August 2014 “Design of industrial storage shed and analysis of stresses produced on failure of a joint”. International Journal of Civil Engineering and Technology

18. Saleem, Muhammad Umair, et al. “Minimum Weight Design of Pre Engineered Steel Structures Using Built-up Sections and Cold Formed Sections.” Advanced Materials Research, vol. 684, Trans Tech Publications, Ltd., Apr. 2013, pp. 125–129. Crossref, doi:10.4028/www.scientific.net/amr.684.125.

19.Syed Firoz, Sarath Chandra Kumar B, S.Kanakambara Rao,” Design Concept of Pre Engineered Building”, IJERA Vol. 2, Issue 2,Mar- Apr 2012, pp.267-272

20. C.M. Meera, June 2013 “Pre- Engineered Building Design of an Industrial warehouse”. International Journal of Engineering Sciences and Emerging Technologies.

6.2 IS-Codes

1.Indian Standard: 1893 (Part1); 2002. Criteria for Earthquake Resistant Design Structures: New Delhi: BIS; 2002.

2.IS 875: Part 1 to 5 Code Of Practice For Design Loads (Other Than Earthquake) For Buildings and Structures,1st Revision, New Delhi: BIS.

3.Indian Standard: 801 – 1975; Code Of Practice For Use Of Cold-Formed Light Gauge Steel Structural Member ‘s In General Building Construction, 1st Revision, New Delhi: BIS.

4Indian Standard: 800 – 2007; General Construction in Steel — Code of Practice; 3rd S Revision, New Delhi: BIS.

6.3 Books/ Manuals

1.MBMA: Metal Building Manufacturers Association-2006, Metal Building Systems Manual.

2.Dr. N. Subramanian, ‗Design of steel structures‘.

3.Dr. N. Subramanian (2008), ―Pre-engineered Buildings Selection of Framing System, Roofing and Wall Materials‖.

4.Technical Manual, Zamil Steel, Saudi Arabia, Pre-Engineered Buildings Division.