COMPARATIVE ANALYSIS ON STRUCTURAL PROPERTIES OF PERIMETER AND HARP BRACING PEB STRUCTURE SUBJECTED TO DYNAMIC LOAD USING STAAD PRO

Ravindra Kumar Jangid[1],Vinod Kumar Modi[2], Ramanuj Jaldhari[3]
[1]M.Tech Scholar, Department of Civil Engineering, Kautilya Institute of Technology and Engineering, Jaipur, India, ravindra725jangid@gmail.com
[2]Associate Professor,, Department of Civil Engineering, Kautilya Institute of Technology and Engineering, Jaipur, India,, vkmodiaen@gmail.com
[3]Assistant Professor, Aayojan School of Architecture, Jaipur, India, rd01586@gmail.com

Abstract: Pre-engineered buildings (PEB) are becoming more and more common in contemporary construction because of their flexibility and affordability. The selection of bracing configurations has a major impact on the structural integrity of PEB steel warehouse structures under dynamic loads. In order to assess how well perimeter and harp bracing systems improve stability and safety, this study compares their structural characteristics.

The study uses STAAD Pro software to analyze the performance of bracing systems in dynamic loading situations. It examines axial forces, deflections, shear forces, and bending moments, highlighting the importance of bracing designs in maximizing structural performance of PEB warehouses. Simulations show varying performance.

According to the results, the best bracing for improving lateral stability and lowering shear forces in the X and Y directions is peripheral bracing. The findings also demonstrate that careful bracing design greatly minimizes node displacements, minimizes bending moments, and regulates structural deflections, so guaranteeing the stability and durability of PEB steel warehouse structures under varied loading scenarios.

Keywords: Bracing, Harp, PEB, Perimeter, Warehouse

1. Introduction

Industrial warehouses are crucial for the storage and distribution of goods across various industries. Originating from ancient civilizations, they evolved from simple structures to more sophisticated solutions during the Middle Ages. These warehouses, located near ports and trading hubs, provided secure storage for valuable goods like spices, textiles, and precious metals, facilitating trade and facilitating the functioning of supply chains and logistics networks.

Industrial warehouses play a crucial role in storage, distribution, and value-added services, offering integrated logistics solutions. Design and construction are influenced by factors like location, site conditions, functional requirements, and regulatory standards. With climate change increasing, there's a growing emphasis on enhancing warehouse resilience against natural disasters and extreme weather events. In India, where seismic activity and cyclonic winds are high, the design of warehouses must adhere to stringent codes and standards. This thesis examines the effectiveness of harp and perimetral bracing systems in enhancing warehouse structural performance, providing valuable insights for engineers and designers in construction and retrofitting.

This study aims to assess the effectiveness of harp and perimetral bracing systems in industrial warehouses, focusing on their structural resilience and safety. It will examine real-world case studies and numerical simulations to evaluate their performance in mitigating wind and seismic forces. The study will also explore design considerations, such as building geometry, material selection, construction methodology, and regulatory compliance, to inform decision-making processes and promote innovative structural solutions. It will also address the gap in research regarding the integration of harp and perimetral bracing systems within Indian standards and regulations, ensuring compliance with relevant codes and standards. The study aims to contribute to the development of safer and more resilient warehouse infrastructure.

Objectives of Study

1. Conduct a comprehensive analysis of industrial warehouses equipped with harp and perimeter bracing systems, focusing on their structural response to wind and earthquake loading conditions.
2. Perform a comparative analysis of the shear forces and bending moments experienced by industrial warehouses equipped with harp and perimeter bracing systems under wind and earthquake loading.

3. Conduct a comparative analysis of the deflection and axial forces experienced by industrial warehouses equipped with harp and perimeter bracing systems under wind and earthquake loading.
4. Analyze the utilization ratio of industrial warehouses equipped with harp and perimeter bracing systems under wind and earthquake loading conditions.

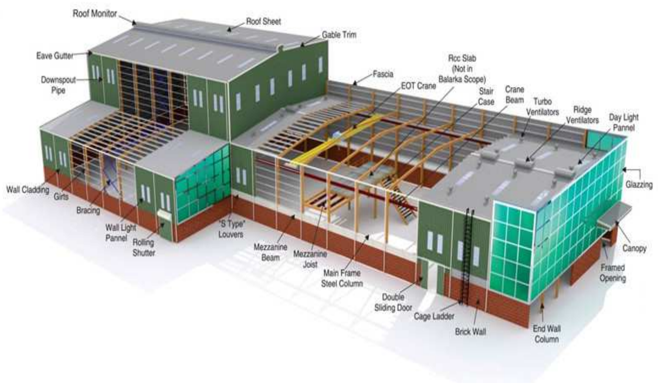


Fig.1Components of Ware House

2. Literature Review

Zhang et al. (2024) proposed the Post-Tensioned Precast Warehouse structure with Sliding Keys on Inclined Deflecting-cantilevers Device (PTPW-SKID structure), which combines a PT outer frame with a SKID inner frame for self-centering capabilities and additional damping for industrial buildings. The study uses a case frame in L'Aquila, Italy, and a 3D numerical model in OpenSees to investigate the seismic behavior and seismic response of the case structure. Bharmal et al. (2024) examined the behavior of Pre-designed structures (PEB) with different propping types across seismic zones II, III, IV, and V on medium soil. Results showed that corner to corner propping significantly reduced uprooting and regular time span by 13% and 15.80%, respectively, compared to other supporting types. Suwondo et al. (2024) explored the impact of plan boundaries on encapsulated fossil fuel byproducts in steel stockrooms, highlighting the importance of length size in determining carbon emissions. The study identified an ideal range for carbon power per unit region, providing insights into sustainable design practices. Gautam S et al (2023) analyzes the progressive collapse of reinforced concrete buildings due to natural and man-made hazards, aiming to minimize external forces and minimize structural reliability theory impact on high-rise buildings.Khote et al (2023) discussed pre-engineered buildings (PEB) as an affordable and time-efficient solution for steel structures, offering a quick development process and cost savings. Goswami et al (2022) examined the viability of on-rooftop support plans, focusing on moderating issues related to horizontal loads, uprooting times, story uprooting, and potential primary failures. Uday et al (2021) highlighted steel's inherent properties, such as flexibility and adaptability, making it an ideal material for modern structures.

Ichsan et al (2020) found that using ideal steel cross-area (PEB) can reduce costs and make PEB more practical for low-ascent development. They found that CSB is around 25.60% heavier than PEB and 30% more practical. Gilbile et al (2020) examined the benefits of pre-designing structure plans, such as using high strength steel plates (Fe350) and lighter yet high strength purlin 550Mpa aroused sheet. Patel et al (2020) highlighted the importance of adjusting the development of weighty Gantry Crane spans and their effectiveness. They proposed a Limited Component System to improve the design and execution of 550 tons of Gantry cranes by changing the size of the gantry crane brace and the state of the crab in Support by keeping a few boundaries. Zhang et al (2020) discussed the impact of dynamic power load coefficients on crane activity and the use of rooftop brackets and purlins for wide ranges for material savings and economy. Runhaar (2019) considered the use of roof brackets and purlins for wide ranges for material saving and economy. Guoxing Zhang (2019) studied the powerful reaction of steel-framed structures due to external blasts for various charge weights. They used ATBLAST programming to determine the impact load at the mid-level of the steel segment for each situation. The results showed that when the charge weight was to 400kg, there was minor impact on the middle level of the story compared to the first floor. Krasyuk (2018) compared different approaches for steel-framed structure progressive collapse analysis, finding that non-linear analysis passed linear output requirements but almost failed. These studies highlight the importance of considering the impact of steel-framed structures on construction costs and efficiency in the construction industry.

Research Gaps

Research on wind and earthquake loading on industrial warehouses with harp and perimeter bracing systems is limited. Existing studies focus on individual wind or earthquake stacking effects, neglecting the combined effect. There is a lack of investigation into the primary reaction between harp and edge supporting structures under wind and earthquake stacking conditions. Additionally, there is a lack of exploration on the avoidance and pivotal powers experienced by modern warehouses under wind and earthquake stacking.

3. Methodology

An industrial warehouse shed, measuring 20.40mx55.40 meters, requires meticulous engineering to ensure its integrity, durability, and safety under various loading conditions. Three models have been developed to evaluate the structural performance of the shed: Bare Frame, Harp Bracing Pattern, and Perimeter Bracing Pattern. The methodology involves a detailed geometric and material characterization, finite element modeling, and loading simulations. Shear forces, bending moments, reaction forces, deflection, and utilization ratio are analyzed to assess load distribution, potential failure mechanisms, serviceability criteria, and overall structural performance. This methodology aims to enhance the structural integrity, durability, and safety of warehouse structures in industrial environments, enabling engineers and designers to make informed decisions regarding structural configurations, bracing systems, and material selections.

Table 1: General Design Parameters

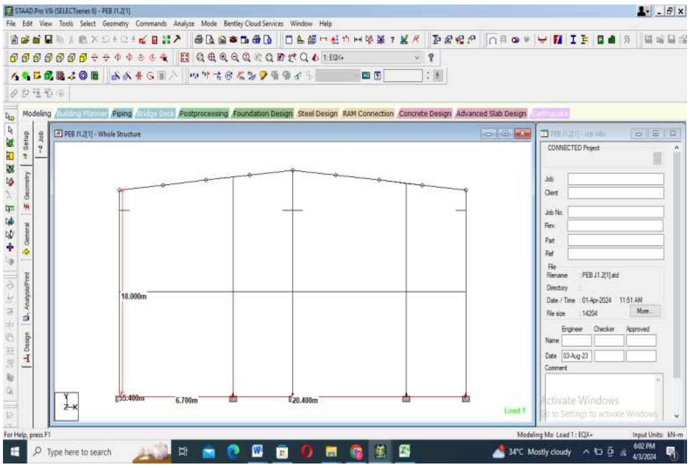
Dimensions	20.40mx55.40 meters
No of bays in X direction	4
No of bays in Y direction	8
Model-I	Bare Frame
Model-II	Harp Bracing Industrial Shed Structure
Model-III	Perimeter Bracing IndustrialShed Structure
Type of Structure	Industrial Ware House
Ware House Size	20.40m x 55.40m
Modelling Software	STAAD Pro
Wind Zone	IV
City	Jaipur
Wind Speed	47 m/s
K1	1
K2	1
K3	1
K4	1

The models of industrial warehouse sheds are tested under various loads, including Dead Load, Live Load, Wind Load, and Seismic Load. Model-III uses Perimeter Bracing for lateral stability and wind resistance, while Model-I&II maintain structural uniformity. The analysis of these models provides insights into their structural behavior under diverse loading conditions, allowing engineers to make informed decisions about structural configurations, ensuring safety, efficiency, and durability in industrial warehouses like Jaipur.

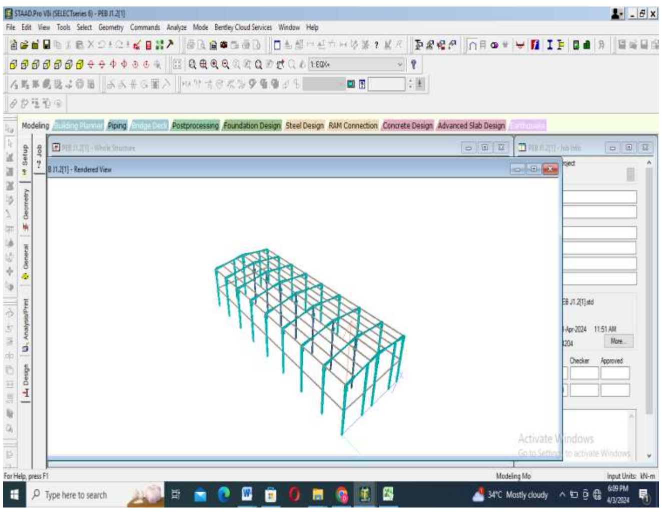
The study will evaluate the structural performance of three models of an industrial warehouse shed: Model-I (Bare Frame), Model-II (Harp Bracing), and Model-III (Perimeter Bracing). Key parameters like shear force, bending moment, deflection, reaction forces, and utilization ratio will be analyzed. The analysis aims to determine the influence of bracing configurations on the structure's behavior and performance, particularly in regions with high wind speeds.

Model-I Bare Frame

Front View

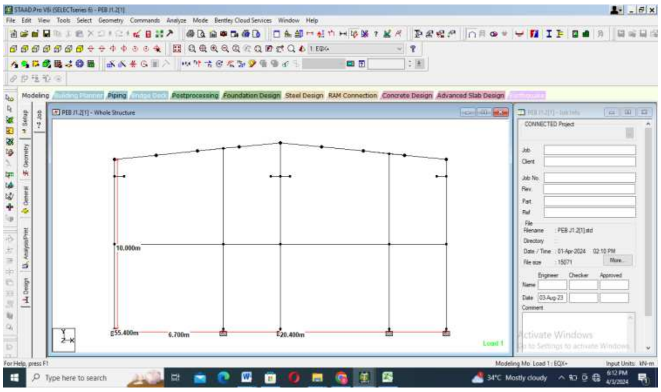


3D rendered View



Model-II Harp Bracing Pattern

Front View



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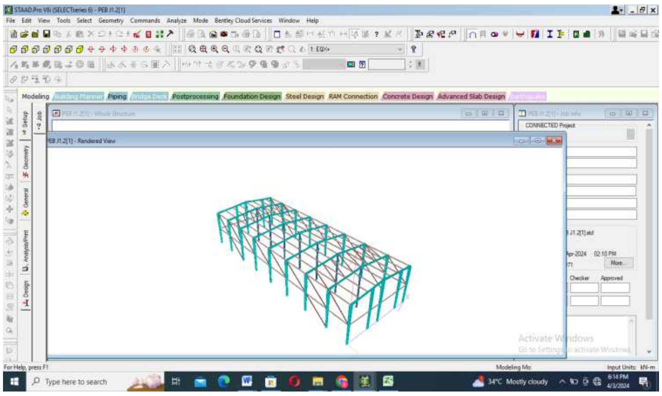
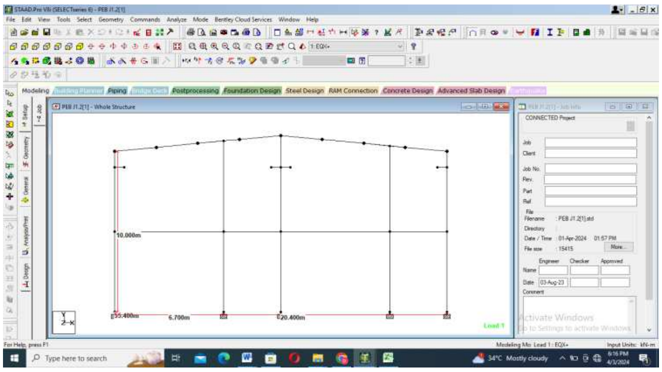


Model-III Perimeter Bracing

Front View



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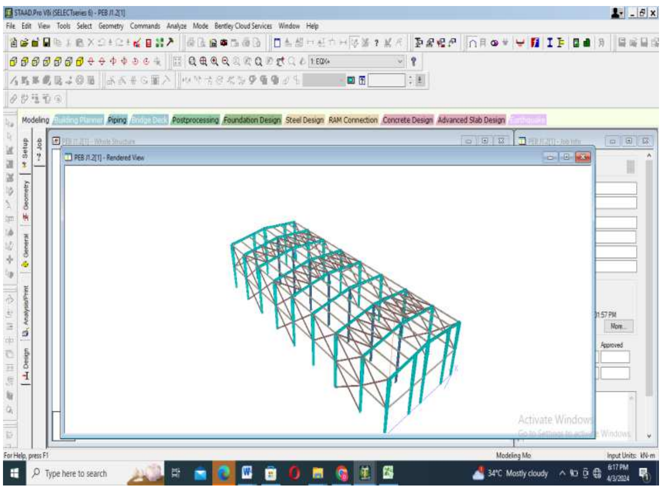


Table 2: Load Combinations

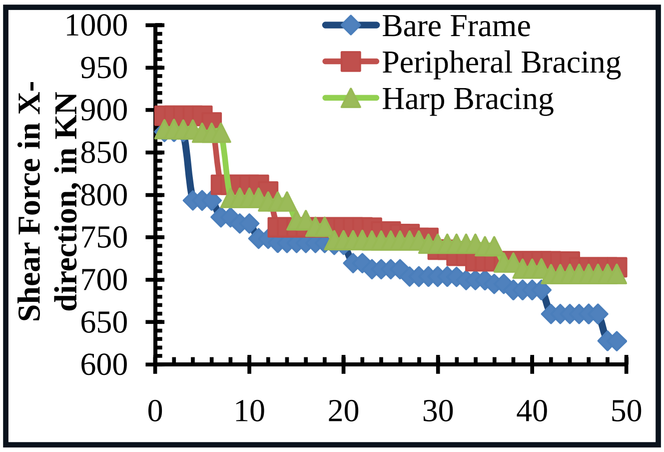
Load Case	Load Combinations
Combo 1	DL
Combo 2	LL
Combo 3	WL (+X)
Combo 4	WL (-X)
Combo 5	WL (+Z)
Combo 6	WL (-Z)
Combo 7	1.5 (DL+LL)
Combo 8	1.5 (DL+ WL (+X))
Combo 9	1.5 (DL+ WL (-X))
Combo 10	1.5 (DL+ WL (+Z))
Combo 11	1.5 (DL+ WL (-Z))
Combo 12	1.2 (DL+LL+ WL (+X))
Combo 13	1.2 (DL+LL+ WL (-X))
Combo 14	1.2 (DL+LL+ WL (+Z))
Combo 15	1.2 (DL+LL+ WL (-Z))
Combo 16	1.2 (DL+LL+ EL(X)
Combo 17	1.2 (DL+LL+ EL(-X)
Combo 18	1.2 (DL+LL+ EL(Z)
Combo 19	1.2 (DL+LL+ EL(-Z)
Combo 20	1.5 (DL+ELX)
Combo 21	1.5 (DL+EL (-X)
Combo 22	1.5 (DL+EL (Z)
Combo 23	1.5 (DL+EL (-Z)

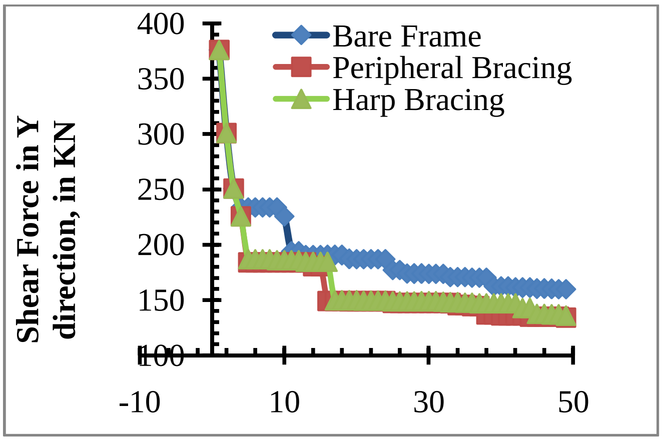
4. Result and Discussion

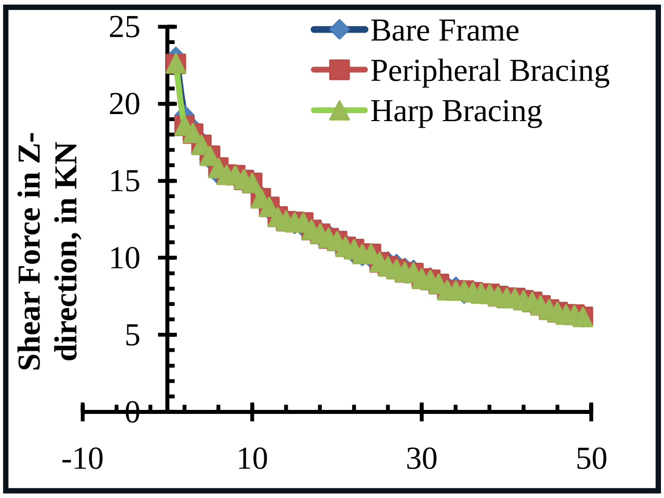
Comparison of Shear Force in X, Yand Zdirection

The bare frame configuration has lower shear forces in the X direction, indicating a limited capacity to resist lateral loads. However, the peripheral bracing pattern shows significantly higher shear forces in the X direction, indicating the effectiveness of peripheral bracing in improving lateral stability. The bare frame's shear forces in the Y direction range from 159.722 kN to 375.893 kN, despite the presence of vertical columns and horizontal beams. The peripheral bracing configuration shows a more consistent distribution of shear forces in the Y direction, reducing the magnitude of shear forces experienced by individual members. The triangular geometry of the bracing elements contributes to distributing applied loads more evenly, resulting in lower shear forces compared to the bare frame.

In Z direction, Peripheral bracing involves X bracing along the building's perimeter, enhancing lateral stability and load-bearing capacity. It reduces localized shear forces, while harp bracing uses diagonal bracing patterns to provide lateral support. Both systems contribute to overall stability but may not distribute shear forces as effectively due to their interior-focused placement.

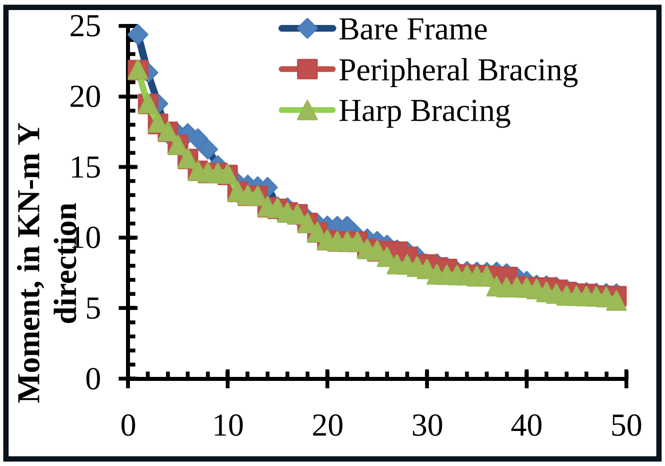


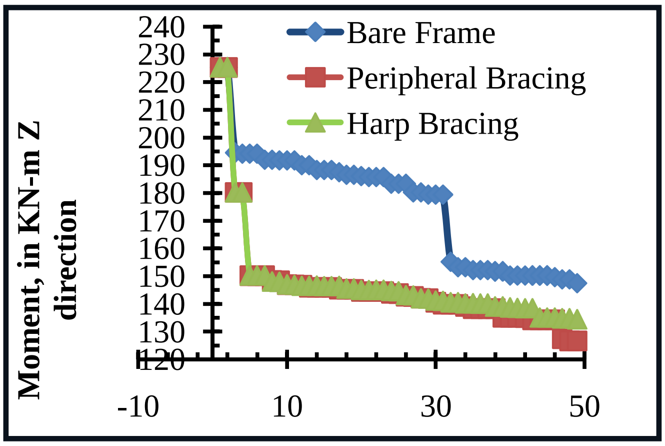




Comparison ofMoment in Yand Zdirection

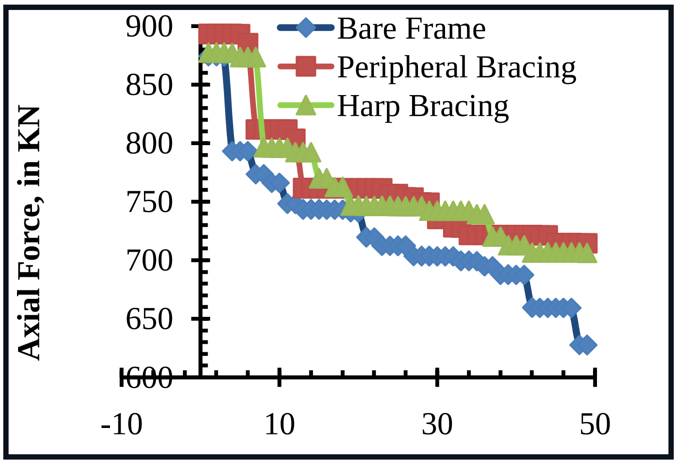
The bare frame configuration has high bending moments in the Y direction, influenced by beam span, load distribution, and structural member stiffness. Peripheral bracing enhances stability, while harp bracing contributes to stability but may not distribute bending moments effectively. The bare frame configuration has high bending moments in the Z direction due to the absence of additional bracing elements. This results in significant bending forces on structural members. The harp bracing configuration, which uses a diagonal bracing pattern, also contributes to stability but may not distribute bending moments as effectively as peripheral bracing. This results in localized concentrations of bending moments.



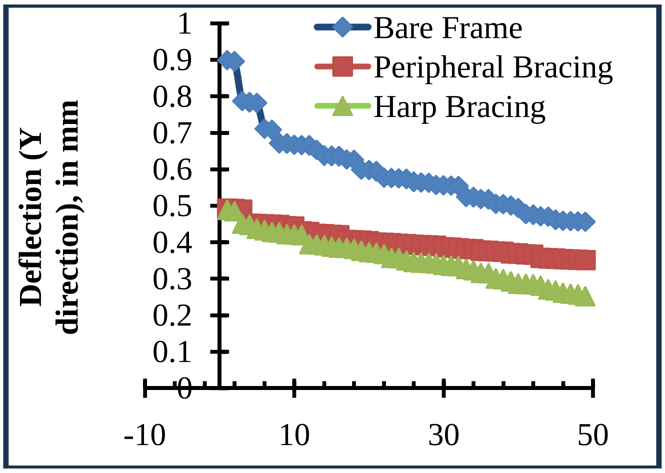


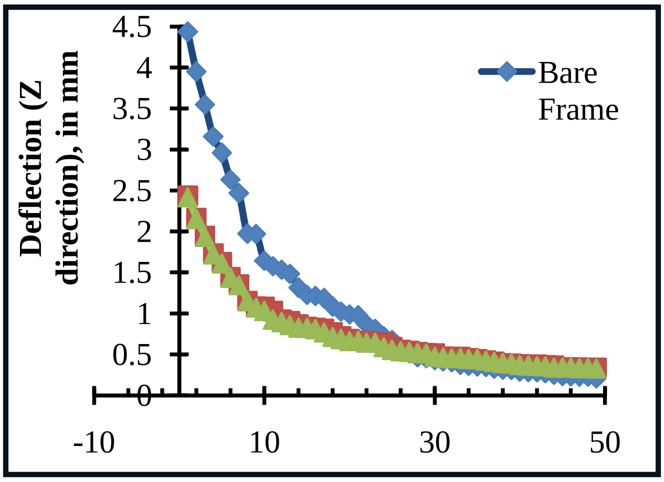
Comparison on Axial Forces

The peripheral bracing configuration reduces maximum axial forces in the Y direction by adding X bracing along the perimeter, increasing structure stiffness and evenly dispersing forces. This configuration resists axial loads and prevents stress concentrations, resulting in lower forces compared to the bare frame configuration. Harp bracing, on the other hand, increases structure stiffness but may not be as effective due to localized bracing forces.



Comparison of Defection in Y direction





5. Conclusions

The study reveals that the peripheral and harp bracing model, which increases shear force in x and y directions, does not significantly impact the bare frame. However, the bracing location is optimal, resulting in lower shear force in the Z direction. The impact of bracing pattern and location is evident.

Higher reaction in peripheral and harp bracing models results from increased resisting force and reduced node displacement, as confirmed by results on bare frames.

The study reveals that different bracing configurations affect maximum axial forces, with peripheral bracing being the most effective for reducing Y-directional forces, while harp bracing and bare frame configurations have higher forces.

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