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Performance Study of Conventional Steel Warehouse Structure Under Various Supports

Anil Disale[1], Chittaranjan Nayak[2]*, Umesh Jagdale[3], Avinash Kolekar[4]

Vidya Pratishthans Kamalnayan Bajaj Institute of Engineering and Technology Baramati, Maharashtra India

Corresponding Author (cbnnayak@gmail.com)

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Abstract:
This research investigates the performance of conventional steel warehouse structures under varying support conditions. The study focuses on understanding how different support systems influence the structural behavior, stability, and overall performance of steel warehouse buildings, which are commonly used in industrial applications. The analysis includes both theoretical and computational methods to evaluate the behavior of these structures under different load combinations, including dead loads, live loads, seismic loads, and wind loads. Various support configurations, including fixed, pinned, and roller supports, are considered to assess their impact on the internal forces, deformations, and overall stability of the structure. Finite element analysis (FEA) software, such as STAAD.Pro, is employed to model and simulate the structural behavior under these different support conditions. The results of this study provide valuable insights into the most efficient and cost-effective support systems for steel warehouse structures, helping engineers optimize design parameters and improve safety and functionality. The findings highlight the importance of considering different support conditions in the design phase to ensure the structural integrity and long-term durability of the warehouse buildings. This research contributes to the advancement of structural engineering practices by offering a comprehensive understanding of how support systems influence the performance of steel warehouse structures, thus aiding in the development of more resilient and efficient building designs.

Keywords: Steel Warehouse, Support Condition, STAAD Pro

INTRODUCTION:

Steel warehouse buildings are increasingly favored in industrial and commercial sectors for their adaptability, strength, and economic benefits. These structures often serve as storage facilities, production units, or logistic hubs where large column-free spaces and efficient material handling are essential. The structural framework of such buildings typically consists of steel columns, rafters, purlins, bracings, and connections, all of which must be designed to withstand a variety of loads, including dead, live, wind, and seismic forces. In the pursuit of economic and efficient construction, optimizing the structural design of these frameworks is crucial.

Optimization not only helps in reducing the quantity of steel used but also improves the overall performance of the structure under different loading conditions. Additionally, the behavior of support conditions, such as pinned, fixed, and spring supports, plays a significant role in influencing the internal force distribution, displacements, and stability of the system. Modern engineering tools like STAAD.Pro has revolutionized the way structural systems are analyzed and designed. With its advanced finite element capabilities and support for multiple design codes, STAAD.Pro allows engineers to simulate realistic loading scenarios and evaluate the performance of various structural elements in detail. By leveraging this software, the present study investigates the impact of different support conditions and optimizes the steel sections for an industrial warehouse structure. The research aims to provide a comparative assessment of support behaviors and identify the most effective design solutions in terms of structural efficiency and material economy. The outcome of this study is expected to serve as a guideline for engineers and designers involved in steel warehouse construction, promoting the adoption of optimized, safe, and cost-effective structural systems.

REVIEW OF LITERATURE:

Steel warehouse structures are widely used in industrial construction due to their economy, rapid construction, and structural efficiency. Several researchers have studied the analysis, design, optimization, and behavior of steel warehouse systems under various loading and support conditions.

M. S. Shrikant and P. S. Kadam (2020) conducted analysis and design of industrial warehouse structures using STAAD.Pro software. Their study focused on structural modeling, load application, and design validation as per Indian standards. The results emphasized safe and economical member design under dead, live, and wind loads[1]. Similarly, S. Sharma and P. Mehta (2020) investigated the effect of different support conditions on steel frame behavior using STAAD.Pro. Their research highlighted that support conditions significantly influence bending moments, deflections, and axial forces in structural members[2].

H. A. Qureshi, K. R. Dabhekar, and A. Shahakar (2020) compared fixed and pinned supports in steel frames. Their findings showed that fixed supports reduce lateral displacement but increase moment demand at the base, whereas pinned supports allow higher displacement but reduce base moments. This comparison forms an important basis for evaluating warehouse support performance[3]. R. Chauhan and A. Yadav (2019) carried out a comparative study of Howe and Pratt truss systems for industrial buildings. Their study concluded that truss configuration significantly affects material consumption and structural efficiency, thereby influencing overall performance[4].

Classical design methodologies are extensively discussed in standard textbooks such as Bridge Engineering Handbook by W. F. Chen and L. Duan (2010), which provides theoretical background on steel structural behavior and load distribution principles. Likewise, Structural Steel Design: Concepts and Applications by R. M. Tomas (2002) presents fundamental concepts of steel member design and stability considerations[5]. Optimization and design methodology were explored by B. M. Gillespie and S. W. Jones (2004), who discussed systematic approaches for steel frame optimization to achieve cost-effective structural solutions[6]. Dynamic performance of trussed steel frames was examined by K. C. Soo and Q. Li (2008), who analyzed the response under dynamic loads. Their work is particularly relevant when evaluating seismic performance of warehouse structures[7]. In addition, L. Ming and X. Jingpin (2007) proposed design methodologies for light industrial steel structures based on Chinese codes, highlighting the influence of codal provisions on member sizing and structural safety[8,9]. Similarly, H. Patel and M. Heshmati (2011) studied cost and structural behavior optimization in steel warehouse frames, emphasizing the balance between safety and economy[10].

The design and analysis in most Indian studies are governed by standard codal provisions such as Bureau of Indian Standards codes: IS 800:2007 for general construction in steel, IS 875 for design loads (dead, live, wind, etc.), and IS 1893 Part 1:2016 for earthquake-resistant design criteria.

METHODOLOGY:

Model Development and Geometry Creation:

Structure Geometry: The steel warehouse framework is modeled with precise dimensions based on the given project specifications, including the warehouse length, width, number of bays, and height.

Material Properties: Steel material properties are assigned as per IS 2062 or relevant codes, ensuring that the warehouse framework is designed with structural steel of appropriate yield strength and modulus of elasticity.

Structural Elements: The model is created with columns, beams, rafters, and bracing systems using appropriate sections (such as ISMC and tapered sections) for their respective elements. Connection points and member lengths are calculated according to the design requirements.

Boundary Conditions: Pin supports are assigned at all column bases to model the support conditions. The boundary conditions are set to simulate realistic load transfer within the warehouse framework.

Load Application:

Dead Load (DL): The self-weight of the structure, including beams, columns, and roof purlins, is calculated and applied. The material density is defined in the software based on the properties of the steel.

Live Load (LL): A uniform live load is applied based on the intended usage of the warehouse. Specific live load values are derived from relevant standards and building codes.

Wind Load (WL): Wind load is calculated using the IS 875 (Part 3) code. Wind pressure is applied based on the geographical location (Pune), considering factors like terrain, height, and exposure category.

Earthquake Load (EL): Earthquake load is calculated using the seismic design provisions in IS 1893 (Part 1). The response spectrum method is used to evaluate the dynamic response of the structure under seismic forces.

Support Behavior Study:

Support Reactions: The reactions at the supports are extracted from the STAAD.Pro analysis results. These reactions help determine the magnitude and distribution of forces across the foundation.

Displacement and Deflection Analysis: The deflection behavior of the structure is analyzed under different loading conditions, focusing on maximum displacements and ensuring that they fall within permissible limits.

Design Optimization:

Initial Design and Load Analysis: Using the loads calculated above, an initial design of the steel members (columns, beams, and trusses) is carried out in STAAD.Pro. The structural elements are sized and checked against code requirements.

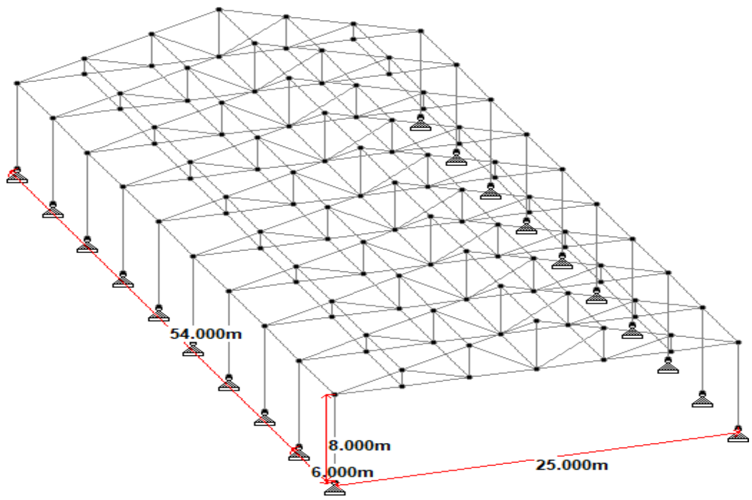


Figure 1: Warehouse Wire Frame Pinned Support.

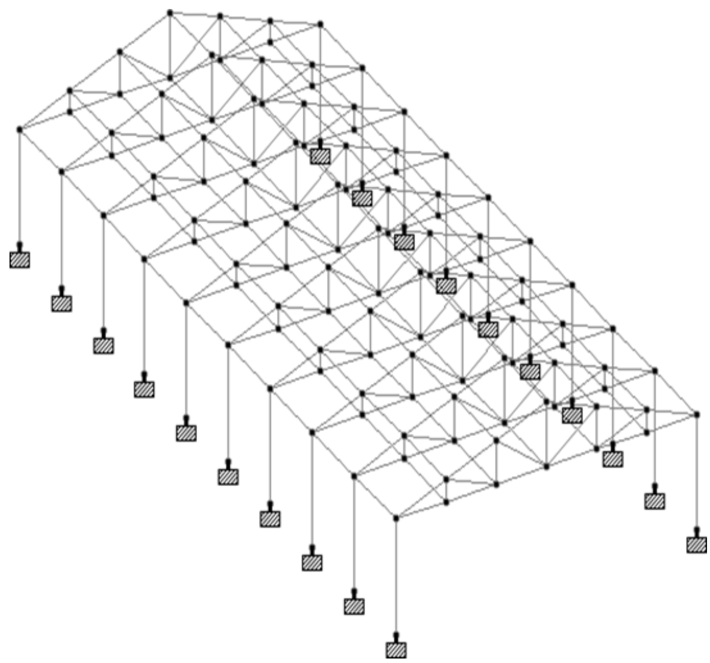


Figure 2: warehouse Wire Frame Fixed support

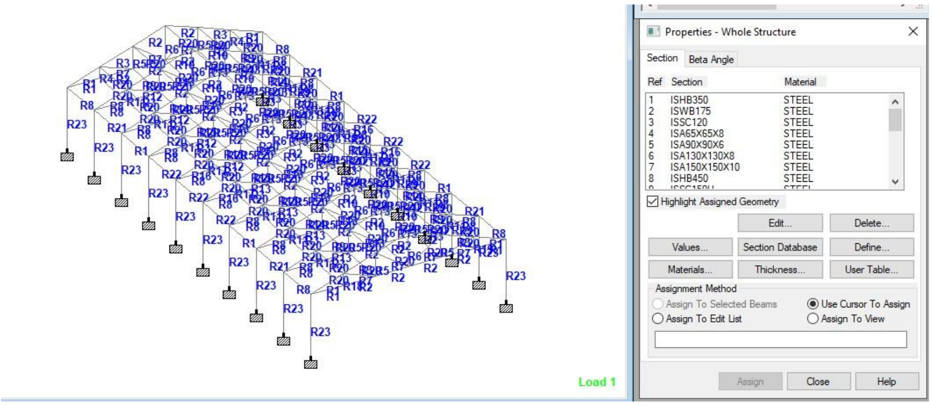
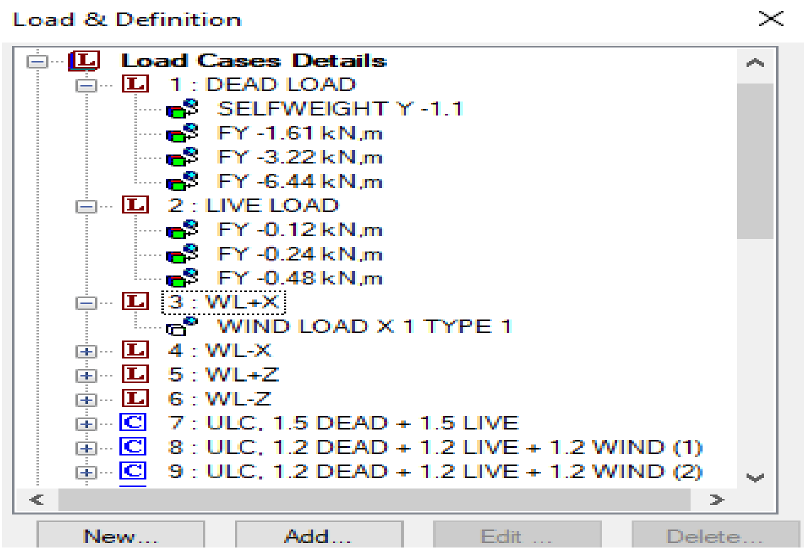


Figure 3: Properties Define

Figure 4:Load Cases



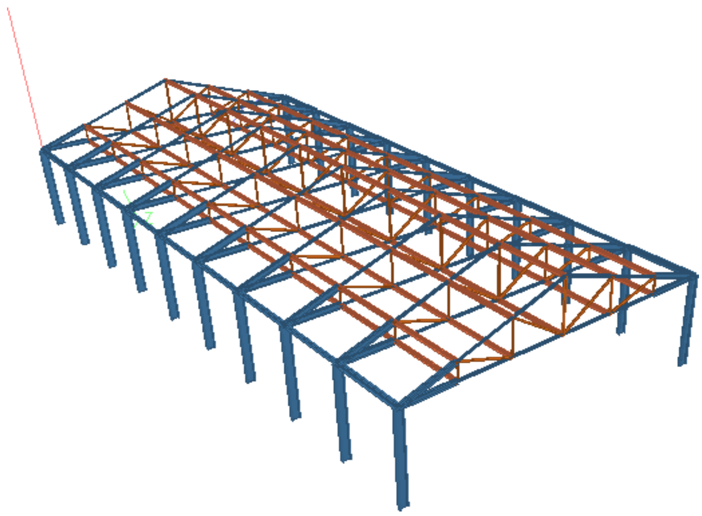


Figure 5: Warehouse Rendered View

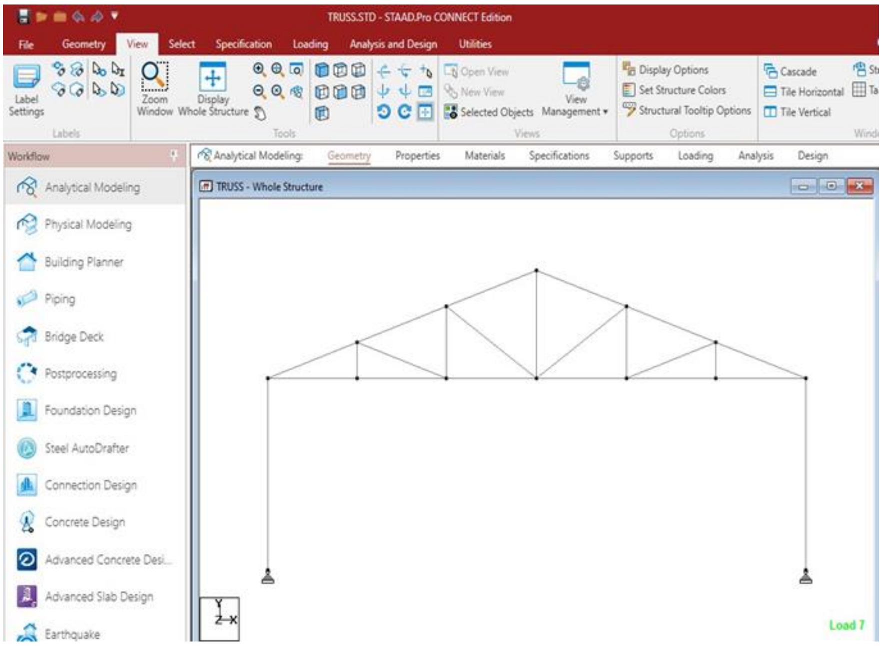
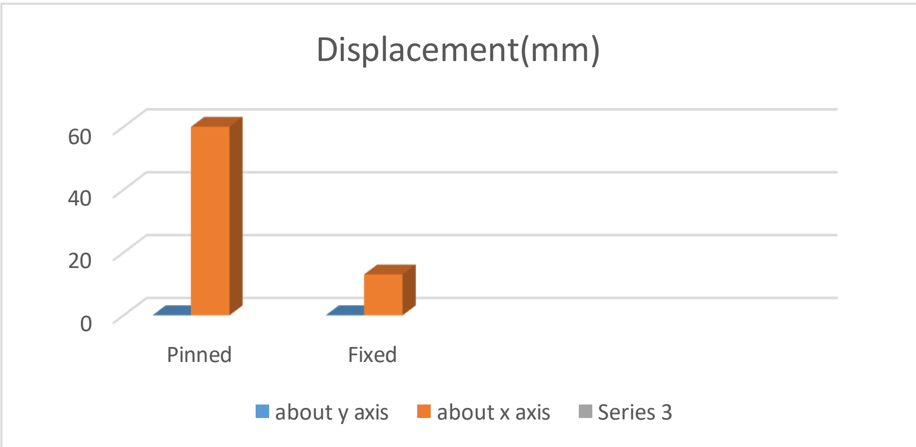


Figure 6: Elevation View

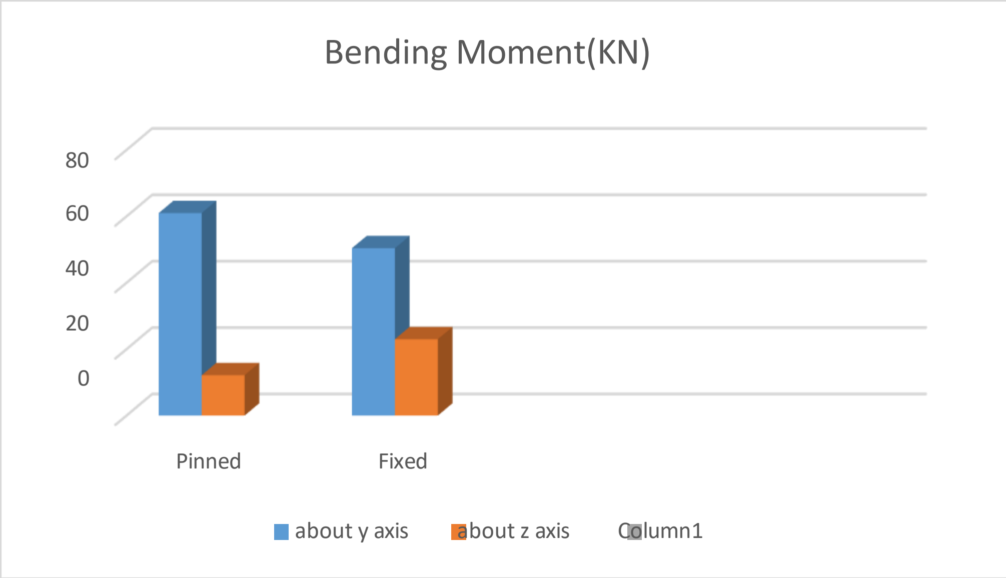
RESULT & DISCUSSION:

Displacement:



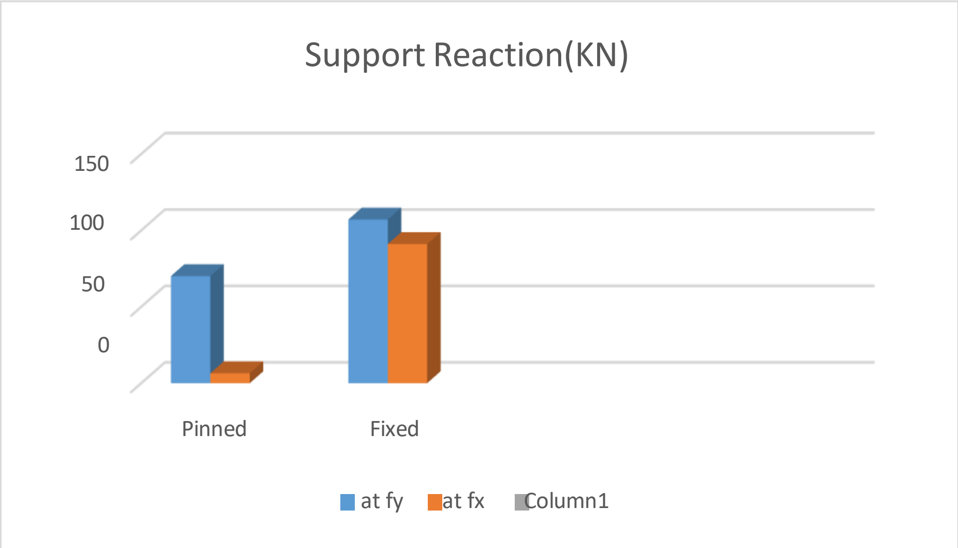
Under fixed support conditions, the displacement in the Y-direction is negligible (0 mm), and the displacement in the X-direction is limited to 10 mm. This indicates higher stiffness and superior lateral stability. In contrast, with pinned supports, the displacement in the Y-direction also remains zero, but the X-direction displacement rises significantly to 64 mm, highlighting a considerable loss in lateral restraint due to rotational freedom at the base.

Bending Moment:



Regarding bending moments, fixed supports carry higher moment values—My = 50.4 kNm and Mz = 23 kNm—demonstrating their ability to resist rotational forces. In the pinned case, moments increase to My = 61.1 kNm and Mz = 12.16 kNm, showing a redistribution of internal forces due to the support's inability to restrain rotations completely.

Support Reactions:



The support reactions also reflect this behavioral difference. For the fixed support case, the vertical and horizontal reactions are Fy = 107.9 kN and Fx = 92.3 kN, respectively, indicating effective load transfer and base restraint. For pinned supports, the vertical reaction drops to Fy = 70.91 kN, and horizontal reaction reduces to Fx = 6.4 kN, suggesting less resistance to horizontal forces.

Steel Optimization:

Table 1. Steel Optimization

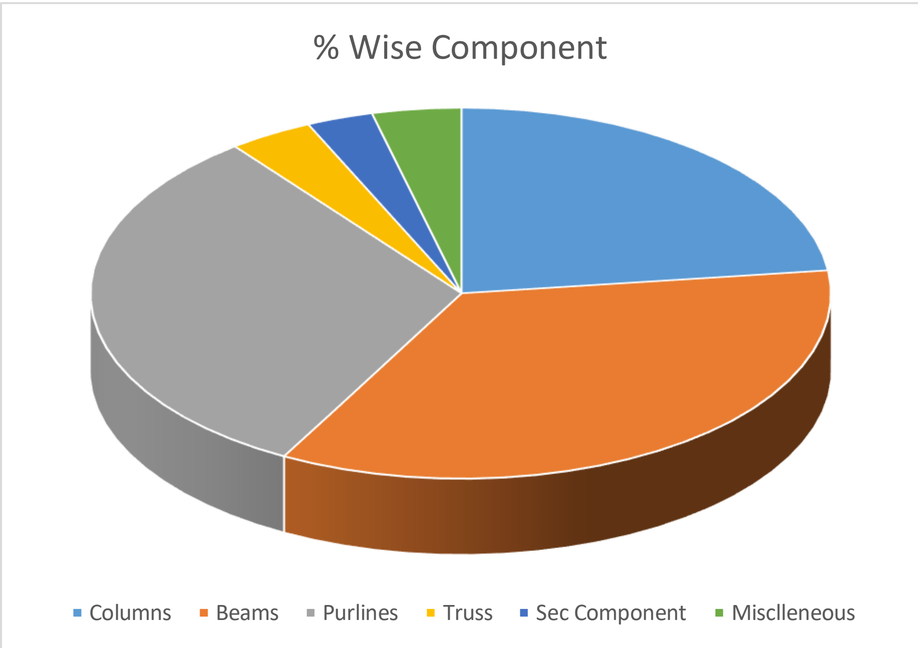
Components	Profile Included	Weight(KN)	Total(%)
Coloumns	ISHB Sections	195.5	23.1%
Beams/Rafters	ISWB Sections	295.5	35%
Purlins	ISMC 400	264.6	31.3%
Truss	All ISA Sections	31.44	3.7%
Channel/Secondary	ISSC120	24.86	2.9%
Misc	Minor Part	33.07	3.9$
Total		845KN	100%

Steel Consumption Rate-

Building area = 54 m × 25 m = 1350 m² Steel weight = 784.29 kN = 84,510 kg

Steel used per m² = 84,510 / 1350 = 62.6 kg/m²

(This is within the standard Steel warehouse range of 40–80 kg/m², confirmingmaterial efficiency.)



CONCLUSION:

The present study focused on the comparative structural behavior of a conventional steel warehouse framework with a Howe truss, analyzing both fixed and pinned support conditions using STAAD.Pro. Based on the analysis results, it was observed that fixed supports significantly improve the structural response in terms of displacement control and moment resistance. For fixed supports, the horizontal displacement in the X-direction was limited to just 10 mm, while the Y-direction displacement remained zero, indicating strong lateral restraint. In contrast, pinned supports allowed a much larger displacement of 64 mm in the X-direction, highlighting their reduced capacity to resist horizontal forces.

Moreover, fixed supports demonstrated much higher moment resistance, with My and Mz values of 50.4 kNm and 23.0 kNm, respectively, compared to 6.1 kNm and 12.16 kNm for pinned supports. This clearly reflects the ability of fixed supports to transfer and resist bending moments, which contributes to better load distribution and overall structural stability. The reaction forces were also considerably different—Fy and Fx were 107.9 kN and 92.3 kN for fixed supports, as opposed to 70.91 kN and 6.4 kN for pinned supports. This again emphasizes the enhanced load-bearing capacity of fixed supports.

From a structural engineering perspective, the results clearly indicate that while pinned supports may be sufficient for small or less demanding structures, fixed supports are far more suitable for large-span industrial buildings like warehouses, especially under the influence of lateral loads such as wind and earthquakes. However, it is important to note that fixed supports demand stronger foundation systems to resist the additional moments and shear forces. Therefore, the selection between fixed and pinned support types should be based on the functional requirements, design complexity, and stability criteria of the project.

FUTURE SCOPE:

The study on the structural performance of a steel warehouse with different support conditions opens up several promising areas for future research and practical improvements. One potential direction is the incorporation of advanced optimization algorithms, such as genetic algorithms or particle swarm optimization, to further refine member sizing and material efficiency. The current analysis was limited to Howe truss systems and conventional steel sections; future work could investigate alternative truss configurations and innovative materials like cold-formed steel or hybrid composites to achieve higher strength-to-weight ratios and improved sustainability. Moreover, dynamic load conditions such as vehicular impact, crane loads, and thermal effects can be integrated into the analysis to simulate real-world operational demands more accurately. The structural behavior under progressive collapse and fire scenarios also warrants detailed examination, especially for structures in industrial zones. Additionally, integrating Building Information Modeling (BIM) with structural analysis tools like STAAD.Pro can improve coordination, error reduction, and decision-making throughout the design and construction process. Long-term structural health monitoring using sensors and IoT-based technologies can also be explored to evaluate the in-service performance of such steel frameworks. These advancements will contribute to the development of smarter, safer, and more efficient warehouse structures in the future.

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