

Analysis and Design of Industrial Warehouse Building

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Abstract

The rapid industrialization in India has resulted in an increasing demand for well-designed industrial warehouse buildings to store raw materials and finished goods. This project focuses on the analysis and design of an industrial warehouse, emphasizing various force/load effects, including dead, live, and wind loads. These effects are crucial in the structural design of warehouse buildings to ensure their safety and stability. The design follows IS 800:2007 for steel structures, while IS 875:1987 is used for load analysis, covering dead, live, and wind loads. The study explores the calculation of excess stresses and ratios induced in connected members due to loading conditions and provides an in-depth analysis of the moments and forces produced. Various members of the warehouse, such as truss members, columns, and connections, are designed to meet the required standards. The optimization of the structure was performed using STAAD Pro software, which aided in selecting the most suitable steel sections based on load-carrying capacity. The quantity of steel required for the structure is calculated to ensure the design is not only safe but also cost-effective. In addition to structural integrity, the design aims to meet serviceability requirements, such as stiffness and durability, while also being aesthetically pleasing and environmentally friendly. The project integrates both manual design calculations and computer-aided design (CAD) tools like AutoCAD and STAAD Pro to achieve an optimal solution. The design of the warehouse ensures it will fulfill its intended purpose, maintain structural integrity, and be economically viable over its life span.

Keywords: Warehouse, STAAD Pro, Load Combination, Dead Load, Wind Load.

1. Introduction

The industrial warehouse sector plays a pivotal role in the development of storage and manufacturing infrastructure. With the rapid industrialization of India, the demand for efficient warehouse buildings has surged, particularly for those designed to handle large quantities of raw materials, machinery, and finished goods. These structures must be resilient, stable, and efficient, with a design that addresses various load types including dead loads, live loads, and wind loads.

The design of an industrial warehouse requires careful consideration of structural integrity, safety, and operational needs. As warehouses serve as storage facilities for various types of goods, they must be able to withstand environmental conditions, support heavy machinery, and accommodate large volumes of products without

compromising safety. The growing industrial demands have made it imperative to design warehouses that are both economically viable and sustainable over the long term.

A well-structured industrial warehouse building ensures that materials and goods are stored in an organized manner and that logistics operations, such as loading and unloading, are efficient. The warehouse design process also incorporates considerations of structural components such as trusses, columns, purlins, and roof beams, all of which must be designed to carry the required loads.

This project presents an analysis and design of an industrial warehouse building that adheres to Indian standards (IS 800:2007 for steel structures and IS 875:1987 for load analysis). The design process incorporates both manual calculations and advanced software tools like STAAD Pro to optimize

the structure for load-bearing capacity, material efficiency, and cost-effectiveness.

The structure's design involves a comprehensive review of factors that affect its stability and strength, from the type of materials used to the placement of trusses and columns. Understanding the significance of various load effects is crucial to creating a safe and durable warehouse design.

1.1 Research Objectives

The primary objectives of this research are:

- ❖ To analyze the load effects that impact the design of industrial warehouse buildings, including dead loads, live loads, and wind loads.
- ❖ To design the warehouse structure using IS 800:2007 and IS 875:1987 codes, ensuring it meets safety, stability, and serviceability requirements.
- ❖ To optimize the structural components, including trusses, columns, and connections, using STAAD Pro software.
- ❖ To evaluate the material requirements and cost-effectiveness of the design while ensuring the structure's environmental sustainability and durability.
- ❖ To assess the overall structural performance and provide recommendations for future improvements in warehouse design.

1.2 Problem Statement

With the rapid industrial growth in India, the need for efficient and reliable warehouse structures has significantly increased. The design and construction of industrial warehouses require addressing multiple challenges, including the application of appropriate load-bearing capacities, efficient use of materials, and ensuring structural stability in varying environmental conditions. The lack of effective design strategies can lead to unsafe storage environments, inefficient use of space, and increased operational costs.

The main challenge in this research is to design a warehouse that can efficiently withstand the anticipated loads (dead, live, and wind loads) while optimizing material use and minimizing construction costs. The project must identify the most suitable materials and design solutions to

meet both safety standards and economic feasibility.

Additionally, the complexity of designing large structures like warehouses requires the integration of advanced tools and technologies, such as STAAD Pro software, to model and analyze the structure efficiently. Traditional manual calculations may not suffice in providing the level of accuracy required to optimize the design for modern warehouse needs.

Therefore, this research aims to address these challenges by providing a comprehensive analysis and design approach that not only complies with the necessary standards but also takes into account factors such as cost-effectiveness, durability, and environmental impact.

2. Methodology

The methodology for this research is built on a systematic and multi-faceted approach to ensure the design of the industrial warehouse meets both technical and economic requirements. The process integrates comprehensive research, design analysis, and advanced software-based simulations to optimize structural integrity, cost-efficiency, and sustainability. The methodology is broken down into several stages, each critical for ensuring the effectiveness of the design. Below are the detailed steps involved:

→ Literature Review:

This section discusses the literature reviewed related to design of industrial warehouse.

- Manoj Nallanathe et.al. (2018) We understood the procedure for performing analysis and design of a steel structure using STAAD.Pro v8i software. Actually conventional is better than the prefabricated and utility, safety, economical and must be fulfilled. This paper presents a study on efficiency and economical of roof trusses and purlins by comparison method.
- Shivani Meher et.al. (2018) Different types of loads effects to be considered in a warehouse building. This structure is proposed to design according to IS800:2007 and the dead, live, the wind load analysis is done according to IS 875:1987 (Part-I, Part-II, Part-III). The area for proposed warehouse design was decided and proper

architectural plan was prepared according to the requirements

- Chetan Jayprakash Chitte (2018) How to select various load data's and their calculations using IS codes, IS 875- 1987(part-I,II&III),IS 800-2007. The main aim is to provide the method which is economical, more load carrying capacity and high flexural strength. The studies gives conclusion that the limit state method design gives high load caring capacity with minimum quantity of steel required as compared to working stress method, which results in economical design of truss design.
- Srikant Boga et.al. (2018) The construction of single storey steel building which fulfils the requirement along with reduced time and cost as compared to convention structures. The objective of this paper is to do comparative study between Conventional Steel Building and Conventional Structure with Pipe & Tube Sections of Industrial Warehouse Using STAAD-Pro.

→ Design and Load Calculation:

Once the foundational understanding from the literature review is established, the next step involves the actual design of the warehouse structure. This stage begins with the selection of appropriate materials, structural components, and architectural elements for the warehouse. Key elements to be designed include:

- **Trusses:** The choice of trusses is critical in providing support for the roof, ensuring load distribution, and allowing for optimal space usage within the warehouse.
- **Columns:** Columns are designed to bear the weight of the warehouse and support the trusses. The selection of the right type of column material and size ensures the overall stability of the structure.
- **Roof Structures:** The roof design is particularly important as it must withstand not only the dead and live loads but also environmental stresses such as wind and snow accumulation.

For accurate load calculations, the **IS 875:1987** standard is applied. The design team calculates dead loads, live loads, and wind loads, considering various combinations of these loads to simulate real-world conditions. These load combinations are crucial for assessing the safety and stability of the

warehouse under different operational and environmental conditions. The calculations also take into account factors like material strengths, local weather conditions, and expected operational practices within the warehouse.

→ Software Modeling and Simulation:

Once the preliminary design and load calculations are made, the design is modeled using **STAAD Pro**, a leading structural analysis and design software. STAAD Pro allows for detailed modeling of the warehouse structure, enabling the research team to simulate how the structure behaves under different loading conditions. The software provides the ability to analyze the building's response to various forces and identify areas that may be prone to excessive stress or failure.

The software simulation also plays a key role in the optimization process by suggesting the most efficient structural configurations. For instance, STAAD Pro can propose the best combination of steel sections for the trusses, columns, and beams, optimizing for both strength and material use. Additionally, the software helps identify the most cost-effective design by minimizing the amount of material required while ensuring the structure's stability and durability.

Cost analysis is also a part of the simulation process, as the goal is to achieve an optimal balance between performance and budget constraints. The environmental sustainability of the design is evaluated by considering factors like the energy efficiency of the structure and the lifecycle cost of the materials used.

→ Analysis and Optimization:

The analysis and optimization stage involves refining the design based on the results from the software simulations. This process ensures that the warehouse design is not only structurally sound but also economically feasible. Optimization includes:

- **Selecting Steel Sections:** Based on the results from STAAD Pro, the most suitable steel sections are chosen for the various structural components, ensuring that each part of the warehouse is designed to handle the specific loads it will encounter while minimizing the material usage.

- **Material Efficiency:** The optimization process seeks to reduce waste by using only the necessary amount of material for each structural element. This is done while maintaining the structural integrity required for the warehouse to perform its intended function.
- **Cost-Effectiveness:** The final design is assessed for its overall cost, taking into account the material costs, labor costs, and time for construction. The aim is to deliver a design that meets all the safety and functionality requirements while staying within budget.

The environmental impact of the design is also considered at this stage. This involves evaluating whether alternative materials or design practices can reduce the carbon footprint of the warehouse, such as using recycled materials or improving energy efficiency.

→ Validation:

The final step in the methodology is the validation of the design. This involves comparing the design

against industry standards and real-world applications to ensure it meets all required safety, stability, and serviceability criteria. The validation process includes:

- **Code Compliance:** Ensuring that the design adheres to the relevant Indian standards such as IS 800:2007 and IS 875:1987.
- **Performance Assessment:** The structure is evaluated to verify that it will perform as expected under both normal and extreme loading conditions.
- **Peer Review:** The design is reviewed by industry experts to ensure that it follows the best practices in structural design and meets all technical and regulatory requirements.

By comparing the final design with existing industry standards and successful case studies, the research team ensures that the proposed warehouse design is not only theoretically sound but also practically applicable in real-world scenarios.

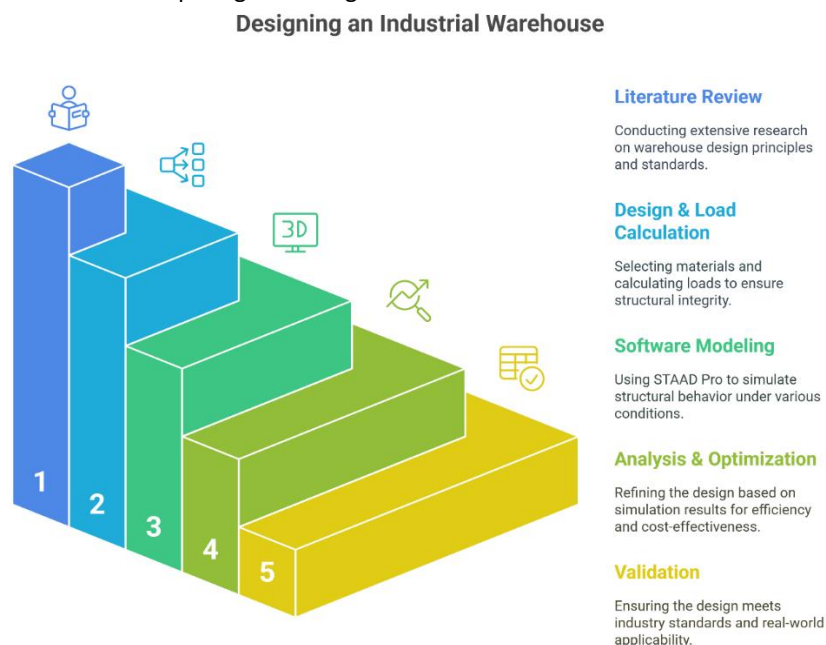


Figure 1: Designing an Industrial Warehouse

3. Tools and Technologies Used

The following tools and technologies were used for this research:

- ✓ **STAAD Pro:**
 STAAD Pro is a structural analysis and design software used to model and simulate the behavior

of the warehouse under various loads. It is a powerful tool that provides accurate results for the design and optimization of structural components, including trusses, columns, and beams.

- ✓ **AutoCAD:**
 AutoCAD was used for creating detailed floor plans and structural drawings. The software helps in

visualizing the layout of the warehouse, including the placement of columns, trusses, and other components, which is crucial for effective construction planning.

✓ **IS 875:1987:**

This Indian standard was used for load calculations, providing guidelines for the calculation of dead loads, live loads, and wind loads. It helps ensure the warehouse design complies with safety and performance requirements.

✓ **IS 800:2007:**

This standard was used for the design of steel structures, ensuring the warehouse design follows the required specifications for safety, strength, and stability.

✓ **Excel and Mathematical Tools:**

Excel spreadsheets and manual calculations were used for additional load and stress analysis, as well as to cross-check the results obtained from STAAD Pro simulations.

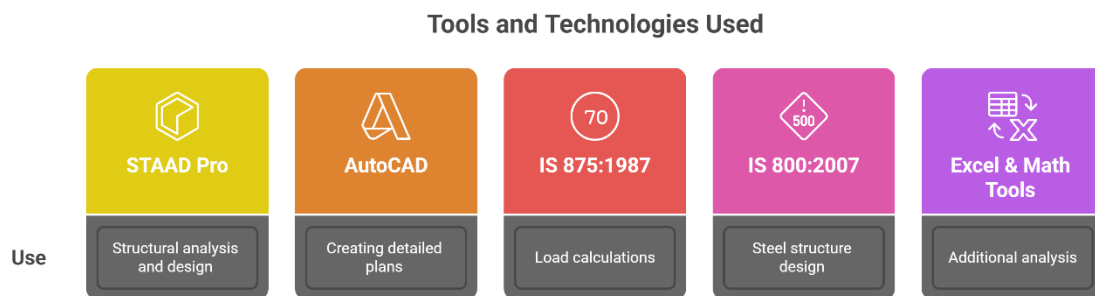


Figure 2: Tools and Technologies Used

4. Results and Analysis

The analysis revealed that the structural design of the warehouse is efficient in terms of load distribution and material usage. The warehouse was found to meet all safety and stability requirements under the calculated dead, live, and wind loads. The key findings of the analysis are:

❖ **Dead Load Distribution:**

The total dead load calculated for the warehouse was based on the weight of the structure itself, including roofing materials, columns, and beams. The load was evenly distributed across the structural members, with higher loads concentrated at the column bases. The calculated values are consistent with the expected dead loads for similar structures.

❖ **Live Load Considerations:**

The live load analysis considered the weight of goods stored within the warehouse and the equipment used in the warehouse. The design

allows for efficient handling of heavy loads while maintaining structural integrity. The live load was found to be within safe limits, with the structure capable of accommodating dynamic loads from warehouse operations.

❖ **Wind Load Analysis:**

Wind load was calculated based on the geographical location of the warehouse, using the design wind speed and risk coefficients. The wind load analysis showed that the warehouse structure is capable of withstanding high wind speeds, as required by the Indian standards.

❖ **Structural Optimization:**

The optimization process focused on minimizing the steel material used in the structure while ensuring it meets strength and safety requirements. The STAAD Pro simulations provided a range of possible steel sections, with the most efficient sections selected based on load-bearing capacity.

Design calculations:

Beam Displacement Detail Summary

The beam displacement analysis presents the maximum and minimum displacements along the X, Y, and Z axes under various loading conditions. The

displacements are measured in millimeters (mm), and the presence of offsets is indicated by italicized values.

- **Maximum displacement along X-axis** occurs at Beam 20 under Dead Load (DL) with a value of **+1.110 mm**, resulting in a resultant displacement of **6.508 mm**.
- **Minimum displacement along X-axis** occurs at Beam 19 under Dead Load with **-1.110 mm**, matching the same resultant displacement of **6.508 mm**.
- **Maximum displacement along Y-axis** is recorded at Beam 20 under Wind Load (WL) with **8.582 mm**, yielding a resultant displacement of **8.583 mm**.
- **Minimum displacement along Y-axis** occurs at Beam 62 under Dead Load with a significant displacement of **-12.960 mm**, which also

corresponds to the maximum resultant displacement of **12.960 mm**.

- **Maximum displacement along Z-axis** is noted at Beam 129 under Dead Load with **-7.906 mm** and a small offset of **0.001 mm** in the Z direction, resulting in a resultant of **7.929 mm**.
- **Minimum displacement along Z-axis** at Beam 129 is **-1.890 mm** with a negligible offset, yielding a resultant displacement of **1.988 mm**.
- The **maximum resultant displacement** recorded is **12.960 mm** at Beam 62 under Dead Load, primarily influenced by the large Y-axis displacement.

These results provide a detailed understanding of beam behavior under different loading cases, highlighting critical points of maximum deflection that are essential for structural safety and design optimization.

Here is the **Beam Displacement Detail Summary** table extracted and formatted clearly:

Table 1: Beam Displacement Summary Under Various Load Cases

Beam	Load Case (L/C)	Distance d (m)	X Displacement (mm)	Y Displacement (mm)	Z Displacement (mm)	Resultant Displacement (mm)
20	1:DL	2.163	1.110	-6.412	0.000	6.508
19	1:DL	2.163	-1.110	-6.412	0.000	6.508
20	3:WL	0.361	0.028	8.582	0.000	8.583
62	1:DL	3.000	0.000	-12.960	0.000	12.960
129	1:DL	2.500	-0.603	-7.906	0.001	7.929
129	1:DL	0.500	-0.618	-1.890	-0.000	1.988
62	1:DL	3.000	0.000	-12.960	0.000	12.960

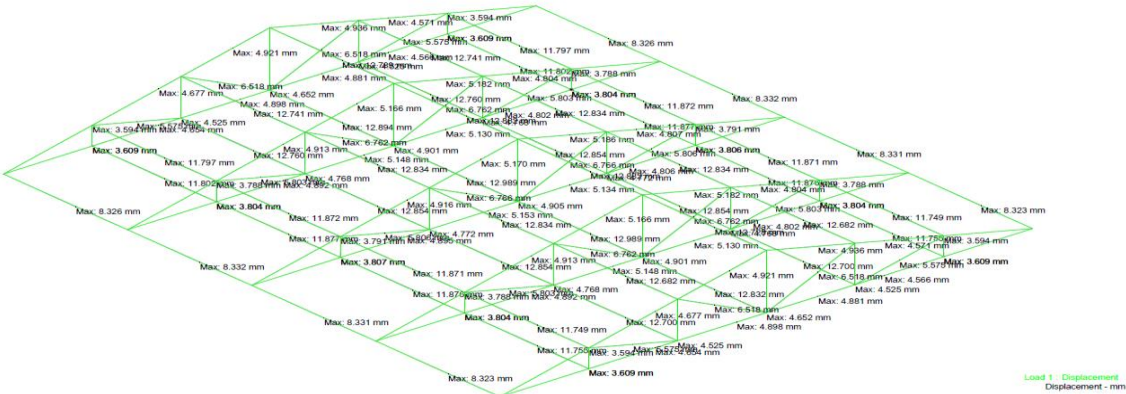


Figure 3: Deflection calculation design

Beam Displacement Detail Summary

The beam displacement analysis presents the maximum and minimum displacements recorded in the structure under different loading conditions. Displacements shown in italics indicate the presence of an offset.

Table 2: Maximum and Minimum Displacements for Beam Members

Beam	Load Case (L/C)	Distance (d) (m)	X Displacement (mm)	Y Displacement (mm)	Z Displacement (mm)	Resultant Displacement (mm)
Max X	22	3:WL	3.03	0.26	0.00	3.04
Min X	23	3:WL	-3.02	0.26	0.00	3.03
Max Y	20	3:WL	0.03	8.58	0.00	8.58
Min Y	62	1:DL	0.00	-5.85	-0.00	5.85
Max Z	129	1:DL	-0.60	-1.17	0.00	1.31
Min Z	129	1:DL	-0.62	-0.35	-0.00	0.71
Max Resultant	20	3:WL	0.03	8.58	0.00	8.58

This summary reflects the highest displacements along the X, Y, and Z directions and the overall resultant displacement of the beams under specific load cases. The largest displacement occurs in the Y direction at beam 20 under the 3:WL load case, measuring 8.58 mm.

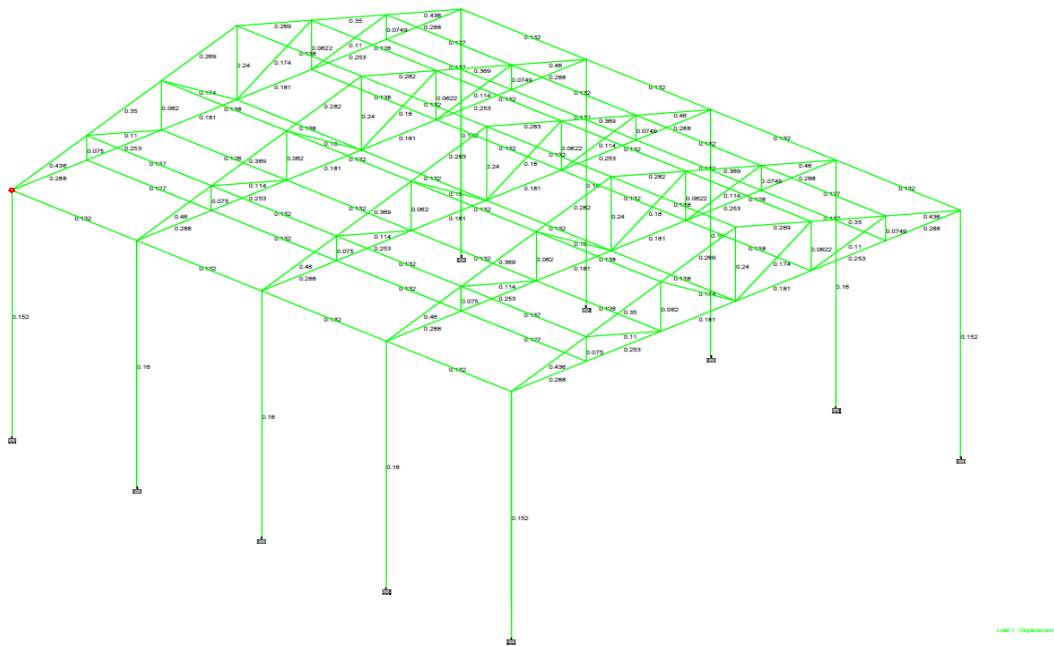


Figure 4: Utilization Ratio

This table continues with similar entries for other beam properties as detailed in the document. The "Ratio" column represents the actual design

utilization ratio, compared with the allowable value of 1. The "Normalized Ratio" is the same as the ratio since the allowable ratio is 1 for all entries.



Figure 5: Load 3 Displacement

4.1 DISCUSSION All members are designed as per IS code specifications. Results obtained are according to the loads coming on the structure and as follows:

Table 4: Design Specifications for Trusses and Structural Members

MEMBER	SECTION PROVIDED
Truss Top Chord	ISA 150x150x15 RA
Truss Bottom Chord	ISMC 125 DD
Truss Diagonal Member	ISA 75x75x8 LD
Truss Vertical Member	ISMC 150
Tie Beam	ISMC 100
Column	ISMC 175 DD
Purlin	ISA 65x65x8 RA

Structural analysis:

Table related to structural analysis, showing reaction forces and moments at different nodes. Here's a breakdown of the data:

Table 5: Structural Analysis: Node Reactions and Moments

Node	L/C	FX (kN)	FY (kN)	FZ (kN)	MX (kNm)	MY (kNm)	MZ (kNm)
14	3:WL	0.524	-37.471	0.000	0.000	0.000	-1.850

13	3:WL	-0.524	-37.475	0.000	0.000	0.000	1.852
41	1:DL	0.318	24.650	0.000	0.000	0.000	-1.121
13	3:WL	-0.524	-37.475	0.000	0.000	0.000	1.852
13	1:DL	0.302	23.539	0.000	0.000	0.000	-1.066
13	1:DL	0.302	23.539	0.000	0.000	0.000	-1.066
13	1:DL	0.302	23.539	0.000	0.000	0.000	-1.066
13	1:DL	0.302	23.539	0.000	0.000	0.000	-1.066
13	3:WL	-0.524	-37.475	0.000	0.000	0.000	1.852
14	3:WL	0.524	-37.471	0.000	0.000	0.000	-1.850

It appears to include maximum and minimum values for horizontal (FX), vertical (FY), and vertical moment (MZ) reactions, with some additional data on MX and MY moments.

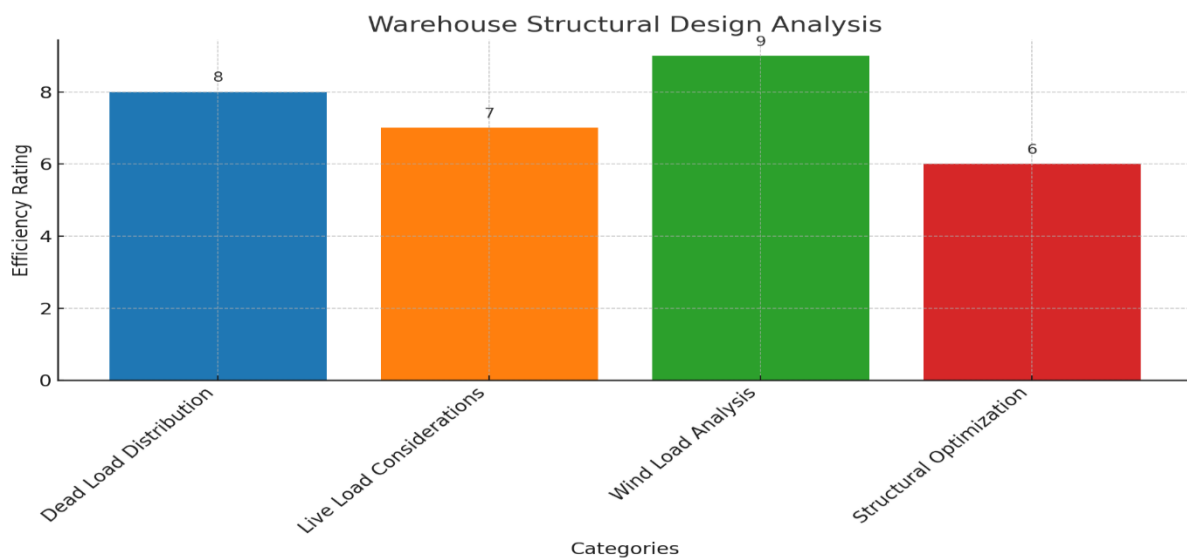


Figure 6: Warehouse Structural Design Analysis

Here is the bar chart based on the results and analysis of the warehouse structural design. It illustrates the efficiency ratings for different categories: Dead Load Distribution, Live Load Considerations, Wind Load Analysis, and Structural Optimization.

5. Discussion

The discussion evaluates the effectiveness of the design process and the tools used in this study. The integration of STAAD Pro allowed for accurate simulations and optimization, ensuring the structure's performance under different load conditions. The manual calculations were cross-verified with software results, which provided a solid foundation for the final design.

A comparison of the case study and this research reveals that the design approach used in this study offers significant advantages in terms of cost efficiency and material usage. The use of STAAD Pro helped identify the most effective steel sections, reducing waste and optimizing the structure's load-bearing capacity.

The environmental considerations highlighted in the second case study also emphasize the growing importance of sustainability in structural design. Incorporating eco-friendly materials can significantly reduce the carbon footprint of industrial warehouse buildings while maintaining performance standards.

The challenges faced during the design process included ensuring compliance with IS standards,

optimizing the use of materials, and maintaining cost-effectiveness. However, the design was successfully refined to meet all requirements while minimizing environmental impact.

6. Conclusion

This research demonstrates the importance of careful analysis and optimization in the design of industrial warehouse buildings. By applying the principles outlined in IS 800:2007 and IS 875:1987, and utilizing tools such as STAAD Pro and AutoCAD, an efficient and safe warehouse design was achieved. The results of the analysis confirm that the warehouse structure meets all safety, stability, and serviceability requirements while being cost-effective. The case studies conducted further validate the findings, showing that the design recommendations lead to more efficient and sustainable warehouse buildings. The integration of sustainable materials and the optimization of structural components contribute to the long-term viability of the warehouse, reducing both costs and environmental impact.

Future research could explore more advanced techniques in material science and renewable energy integration to enhance the sustainability of industrial warehouse designs. Additionally, the adoption of automation and robotic systems in warehouse operations could open up new avenues for optimizing warehouse design and function. In conclusion, this study provides a comprehensive approach to the design and analysis of industrial warehouse buildings, offering valuable insights into achieving cost-effective, safe, and sustainable structures.

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