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Modelling, Analysis And Design Of A Pre-Engineered Steel Frame Structure Using STAAD.Pro

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Abstract

Pre-engineered steel (PEB) structures are widely adopted in modern construction due to their structural efficiency, reduced construction time, and economic advantages. This study presents the modelling, structural analysis, and design of a pre-engineered steel frame using STAAD.Pro software. The structure is analysed using the finite element method to evaluate member forces, bending moments, shear forces, and deflections under various loading conditions.

Design verification is carried out in accordance with relevant Indian Standards, particularly IS 800:2007. Load combinations including dead load, live load, wind load, and seismic load are considered to ensure structural safety and serviceability. The results confirm that the designed structure satisfies strength and stability requirements. The study demonstrates that STAAD.Pro provides accurate analytical results and supports efficient structural optimization for PEB systems.

Index Terms

Pre-Engineered Building (PEB), STAAD.Pro, Steel Structure Design, Finite Element Analysis, IS 800:2007.

1. Introduction

Pre-engineered steel buildings have become increasingly popular in industrial and commercial construction due to their speed of erection, cost efficiency, and structural reliability. In this system, structural components are designed and fabricated in a controlled factory environment and later assembled at the construction site. This process reduces construction time, minimizes material wastage, and enhances quality control.

The development of structural analysis software such as STAAD.Pro has significantly improved the accuracy and efficiency of steel structure design. STAAD.Pro enables engineers to model complex geometries, apply various load cases, and perform detailed analysis using the finite element method. The software also facilitates code-based design and optimization of structural members.

This study aims to demonstrate the complete modelling, analysis, and design process of a pre-engineered steel frame using STAAD.Pro and to evaluate its structural performance under different loading conditions.

2. Structural Components of a PEB System

The primary components of a pre-engineered steel building include:

2.1 Purlins

Purlins are secondary horizontal members placed over roof trusses to support roof sheeting. They transfer loads from roofing sheets to the primary structural members.

2.2 Sag Rods

Sag rods are tension members used to reduce bending in purlins and provide lateral stability. They help resist the tangential component of roof loads.

2.3 Principal Rafters

Principal rafters form the top chord of the roof truss. They primarily resist compressive forces and may also experience bending depending on purlin placement.

2.4 Roof Trusses

Roof trusses are structural frameworks composed of members subjected to axial tension and compression. They efficiently transfer roof loads to columns.

2.5 Gantry Girders

Gantry girders support overhead cranes in industrial buildings. These members are generally designed as laterally unsupported beams.

2.6 Brackets

Brackets are connection elements used when structural members do not intersect directly.

2.7 Columns and Base Plates

Columns transfer loads from the superstructure to the foundation. Base plates distribute column forces safely to the concrete foundation.

2.8 Girts

Girts are horizontal members attached to columns that support wall cladding and resist wind loads.

3. Design Codes and Standards

Pre-engineered buildings are designed according to applicable national or international standards. In this study, the following Indian Standards are considered:

- IS 800:2007 – General Construction in Steel
- IS 875 (Part I, II, III) – Dead, Live, and Wind Loads
- IS 1893:2002 – Seismic Design Criteria
- IS 2062 – Steel Material Specifications

These standards ensure structural safety, stability, and serviceability.

4. Literature Review

Several researchers have compared pre-engineered buildings with conventional steel structures.

Kolate and Kewate (2015) conducted a comparative study between conventional steel frames and PEB systems and concluded that PEB structures provide better economy and reduced construction time for long-span industrial buildings.

Sharma (2017) analyzed and compared pre-engineered and conventional industrial buildings using STAAD.Pro and observed that PEB systems result in lower bending moments and improved cost efficiency.

Goswami and Shende (2018) studied the design of industrial warehouse structures and reported that PEB systems offer advantages in prefabrication, lightweight construction, and rapid execution.

Kumar and Prakash (2018) emphasized the importance of structural optimization and seismic analysis in industrial steel buildings and highlighted the effectiveness of STAAD.Pro for such analysis.

Overall, previous studies indicate that PEB systems are structurally efficient, economical, and suitable for modern industrial applications.

5. Methodology

The study follows a systematic procedure for modelling and design:

Step 1: Problem Definition

- Define project objectives and structural requirements.
- Identify building dimensions, purpose, and location.

Step 2: Collection of Design Data

- Building geometry (20 m span, 5 m height, roof slope 1:10)
- Material properties (steel grade)
- Load calculations (dead, live, wind, seismic)
- Support conditions

Step 3: Modelling in STAAD.Pro

- Create structural geometry (nodes and members).
- Assign material properties and cross-sections.
- Apply loads and load combinations.

Step 4: Structural Analysis

- Perform static analysis for member forces and reactions.
- Conduct seismic analysis as per IS 1893.
- Evaluate performance under critical load combinations.

Step 5: Design and Optimization

- Design members as per IS 800:2007.
- Optimize section sizes to reduce material consumption.
- Check deflection and serviceability limits.

Step 6: Result Interpretation

- Review bending moments, shear forces, axial forces, and deflections.
- Verify structural adequacy and code compliance.

6. Expected Results

1. Structurally optimized PEB frame design.
2. Accurate analysis of forces, stresses, and deflections.
3. Compliance with safety and serviceability requirements.
4. Efficient material utilization.

7. Advantages of Pre-Engineered Buildings

- Faster construction and project completion
- Reduced material wastage
- Improved structural efficiency
- Lower overall cost
- High durability and resistance to environmental effects
- Ease of expansion and modification
- Enhanced quality control through prefabrication

8. Benefits to the Construction Industry

- Reduced construction time
- Cost-effective structural solutions
- Improved design accuracy using advanced software
- Reliable and standardized construction practices

9. Conclusion

This study demonstrates the modelling, analysis, and design of a pre-engineered steel frame using STAAD.Pro software. The analysis confirms that the structure satisfies strength and serviceability requirements under various load combinations as per Indian Standards. The use of STAAD.Pro significantly enhances accuracy, reduces design time, and allows structural optimization.

Pre-engineered buildings offer a practical and economical solution for industrial structures, making them a preferred choice in modern construction practice.

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