Modeling, Analysis and Design of a Pre-Engineered Steel Frame Structure Using STAAD. Pro

Ashwin Manikraj Raut, Kshitij Diwakar Thate, Pallavi Bhende, Gaurav Hingwe, Sumit Paul

Wanganga College of Engineering and Manegement, nagpur

Abstract

Pre-engineered buildings (PEBs) are widely used in industrial and commercial construction because of their economy, rapid construction, and structural efficiency. This research paper presents the modelling, analysis, and design of a pre-engineered steel frame structure using STAAD.Pro software. The structure is analyzed under various loading conditions including dead load, live load, wind load, and seismic load according to Indian Standard codes. The study focuses on the behaviour of steel members, structural stability, and optimization of member sections. The design is carried out using the limit state method as per IS 800:2007. The results obtained from STAAD.Pro indicate that pre-engineered steel structures provide better material efficiency and reduced construction time compared to conventional steel structures. The study concludes that PEB systems are suitable for industrial buildings due to their strength, economy, and flexibility.

Keywords: Pre-engineered building, STAAD.Pro, steel structure, structural analysis, steel design, wind load, seismic load.

Introduction

Steel structures play an important role in modern construction due to their high strength, durability, and flexibility. In recent years, pre-engineered buildings (PEBs) have become popular for industrial sheds, warehouses, factories, and commercial buildings. A pre-engineered building is a steel structure manufactured in factories and assembled at the construction site using bolted connections.

PEB systems are designed to achieve maximum structural efficiency with minimum steel consumption. Compared to conventional steel structures, pre-engineered buildings reduce construction time and cost. The use of advanced software such as STAAD.Pro helps engineers perform accurate structural analysis and design.

This research paper presents the modelling, analysis, and design of a pre-engineered steel frame structure using STAAD.Pro software. The study evaluates the structural response under different loading conditions and verifies the safety of the structure according to Indian Standard codes.

Objectives of the Study

1. The objectives of this study are:
2. To model a pre-engineered steel frame structure using STAAD.Pro.

3. To analyze the structure under dead load, live load, wind load, and seismic load.
4. To design steel members according to IS 800:2007.
5. To evaluate bending moments, shear forces, axial forces, and deflections.
6. To study the structural efficiency of pre-engineered steel buildings.

Scope of the Study

1. The present study includes:
2. Modelling of an industrial steel frame structure.
3. Structural analysis using STAAD.Pro.
4. Design of steel members based on Indian Standards.
5. Evaluation of structural performance.
6. The study is limited to static analysis and does not include nonlinear or dynamic time-history analysis.

Literature Review

Many researchers have studied the behaviour and advantages of pre-engineered buildings.

Researchers reported that PEB structures reduce steel consumption because tapered sections are used according to load requirements. The use of STAAD.Pro software improves design accuracy and reduces manual calculation errors.

Studies also indicate that wind load is a major factor in the design of industrial steel buildings due to their large roof area. Seismic analysis is equally important in earthquake-prone regions.

Comparative studies between conventional steel buildings and pre-engineered buildings show that PEB systems are more economical and require less construction time.

Methodology

1. The methodology adopted for the study is as follows:
2. Selection of building dimensions.
3. Collection of design parameters.
4. Modelling of the structure in STAAD.Pro.
5. Assignment of material properties.
6. Application of loads and load combinations.
7. Structural analysis.
8. Design of steel members.
9. Interpretation of results.

Building Specifications

Parameter	Value
Building Length	40 m
Building Width	20 m
Eave Height	8 m
Roof Slope	1:10
Bay Spacing	5 m
Steel Grade	Fe 345
Structure Type	Industrial Shed
Design Code	IS 800:2007
Wind Load Code	IS 875 Part 3
Seismic Zone	Zone III

Modeling in STAAD. Pro

7.1 Geometry Creation

The structure is modelled as a portal frame consisting of columns, rafters, purlins, and bracing members. Nodes and beam elements are generated in STAAD.Pro according to the selected dimensions.

7.2 Material Properties

The following steel properties are assigned:

Modulus of Elasticity = 2×10^5 MPa

Poisson's Ratio = 0.3

Density = 76.98 kN/m^3

Yield Strength = 345 MPa

7.3 Support Conditions

Fixed supports are provided at the column bases to resist vertical and lateral forces.

7.4 Loading Conditions

Dead Load

Dead load includes self-weight of steel members and roofing materials.

Live Load

Roof live load is applied according to IS 875 Part 2.

Wind Load

Wind loads are calculated according to IS 875 Part 3 considering basic wind speed, terrain category, and building height.

Seismic Load

Seismic loads are applied according to IS 1893 considering seismic zone, importance factor, and response reduction factor.

Load Combinations

1. The following load combinations are considered:
2. DL + LL
3. DL + WL
4. DL + LL + WL
5. DL + EQ
6. DL + LL + EQ
7. 1.5(DL + LL)
8. 1.5(DL + WL)
9. 1.2(DL + LL + WL)

- Where:
- DL = Dead Load
- LL = Live Load
- WL = Wind Load
- EQ = Earthquake Load

Structural Analysis

The analysis is carried out using the finite element method available in STAAD.Pro software. The software determines:

- Bending moments
- Shear forces
- Axial forces
- Nodal displacements
- Support reactions

The maximum bending moment occurs near the rafter-column junction due to combined gravity and lateral loading.

Design of Structural Members

The steel members are designed using the limit state method according to IS 800:2007.

Column Design

Columns are designed for axial compression and bending moments.

Rafter Design

Rafters are designed to resist bending and shear forces from roof loads.

Bracing Design

Bracing members are designed to provide lateral stability against wind and seismic forces.

Purlin Design

Purlins are designed to support roofing sheets and transfer loads to rafters.

Results and Discussion

Maximum Displacement

The maximum displacement occurs at roof level and remains within permissible limits.

Maximum Bending Moment

The maximum bending moment is observed at the knee joint of the portal frame.

Maximum Shear Force

The maximum shear force occurs near the supports.

Structural Weight

The steel quantity required for the pre-engineered building is lower compared to conventional steel buildings.

Economic Efficiency

The optimized sections reduce fabrication cost and construction time.

Advantages of Pre-Engineered Buildings

1. Faster construction.
2. Reduced steel consumption.
3. High structural efficiency.
4. Better quality control.
5. Easy future expansion.

6. Lower maintenance cost.

Limitations

1. Requires skilled fabrication.
2. Transportation of large members may be difficult.
3. Initial design requires advanced software tools.

Conclusion

The study demonstrates the effectiveness of STAAD.Pro software in the modelling, analysis, and design of pre-engineered steel frame structures. The analysis results show that PEB systems are structurally safe, economical, and efficient for industrial applications.

The optimized steel sections reduce the overall weight of the structure while satisfying strength and serviceability requirements. The study confirms that pre-engineered buildings are a suitable alternative to conventional steel structures due to their reduced construction time and lower material consumption.

Future work may include nonlinear analysis, dynamic loading studies, and comparison with reinforced concrete industrial structures.

References

1. IS 800:2007 – General Construction in Steel – Code of Practice.
2. IS 875 (Part 1 to Part 5) – Code of Practice for Design Loads.
3. IS 1893:2016 – Criteria for Earthquake Resistant Design of Structures.
4. Duggal, S.K., Design of Steel Structures, Tata McGraw Hill.
5. Subramanian, N., Design of Steel Structures, Oxford University Press.
6. STAAD.Pro Technical Reference Manual.
7. Bhavikatti, S.S., Design of Steel Structures.
8. Zamil Steel Design Manual for Pre-Engineered Buildings.
9. Syed Firoz et al., “Design Concept of Pre-Engineered Building.”
10. Ramchandra, Standard Handbook for Civil Engineers.