© MAR 2026 | IRE Journals | Volume 9 Issue 9 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV9I9-1715749

Design Optimization of Long-Span Pre-Engineered Steel Warehouse Buildings Using Finite Element Modelling

DR. SRINIVAS VASAM[1], SHESHADRI SANTHOSH KUMAR[2], SODEM NARASIMHA RAO[3], PITLA KARTHIK[4], MEEGADA SAIVENU[5]

[1] *Associate Professor, Department of Civil Engineering, Siddhartha Institute of Technology and Science Engineering (Autonomous), Narapally(V), Ghatkesar(M), Medchal(D), Telangana, India*

[2, 3, 4, 5] *B. TECH, Department of Civil Engineering, Siddhartha Institute of Technology and Science Engineering (Autonomous), Narapally(V), Ghatkesar(M), Medchal(D), Telangana, India*

Abstract- Pre-Engineered Buildings (PEBs) have emerged as an efficient structural solution for industrial warehouses due to their superior performance in long-span applications, reduced construction time, and material efficiency. This study presents a comprehensive finite element–based analysis and optimal design of a steel warehouse structure using STAAD.Pro software in accordance with Indian Standard codes. The structural model is developed by considering realistic geometric configurations, loading conditions, and boundary constraints. Dead loads, live loads, and wind loads are applied as per IS 875, and member design is carried out following IS 800:2007 provisions. Various steel sections, including tapered members and bracing systems, are evaluated to achieve material optimization while satisfying strength, stability, and serviceability requirements. The structural response in terms of deflection, shear force, bending moment, and stress distribution is critically examined. Results indicate that the adoption of tapered sections and optimized bay spacing significantly reduces steel consumption without compromising structural safety. The study demonstrates that pre-engineered steel warehouses offer an economical, sustainable, and structurally reliable alternative to conventional steel buildings, particularly for large clear-span industrial structure

Keywords: Pre – Engineered Buildings (Ware House), STAAD Pro, Finite element method.

I. INTRODUCTION

The rapid growth of industrialization and logistics infrastructure has significantly increased the demand for large clear-span warehouse structures that are economical, durable, and quick to construct. Steel warehouse buildings play a crucial role in storage, manufacturing, and distribution sectors due to their flexibility and high strength-to-weight ratio. Among various structural systems, Pre-Engineered Buildings (PEBs) have emerged as a modern and efficient alternative to conventional steel structures. Unlike traditional buildings where structural members are designed individually at site, PEBs are factory-fabricated, optimized steel structures designed based on specific loading and span requirements. The present study focuses on the design optimization of long-span pre-engineered steel warehouse buildings using finite element modelling in STAAD.Pro software. The objective is to evaluate structural behavior under dead load, live load, and wind load as per IS 875 and to design members in accordance with IS 800:2007. Optimization techniques are applied by varying section properties, bay spacing, and tapered member configurations to achieve minimum steel consumption while satisfying strength and serviceability criteria. Structural analysis plays a vital role in determining whether the warehouse can withstand different loading conditions without excessive deflection or stress. Through detailed modelling and simulation, the critical structural responses such as bending moment, shear force, axial force, and deflection are assessed. The study aims to provide a practical and economical design approach for long-span warehouse structures suitable for modern industrial applications.

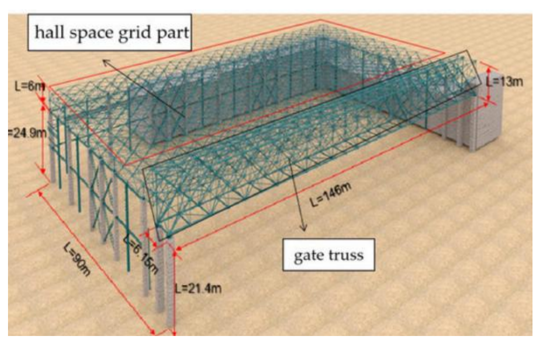

Fig.1. Design Model

Pre-engineered buildings offer several advantages over conventional steel buildings, especially for spans exceeding 30 meters. In long-span warehouses, interior columns are undesirable because they obstruct operational activities and material movement. PEB systems utilize tapered I-sections and optimized built-up members that efficiently resist bending moments while reducing material usage in low-stress regions. The structural framing typically consists of portal frames, purlins, girts, bracing systems, and sheeting supported on steel columns. Proper lateral bracing is essential to resist wind forces and ensure overall stability. Finite Element Method (FEM)–based analysis enables accurate modelling of such complex framing systems. STAAD.Pro provides advanced tools for geometry creation, load application, and design verification under multiple load combinations. In this study, the warehouse geometry is developed using 3D space frame modelling. Structural members are grouped for easy property assignment and optimization. The application of wind loads, internal pressure coefficients, and load combinations is performed according to codal provisions. Through numerical simulation, the study evaluates how different section types—such as tubular sections and tapered built-up sections—affect structural performance and material economy.

The significance of this research lies in optimizing steel consumption while maintaining safety and structural integrity. Material cost constitutes a major portion of warehouse construction expenses; hence, optimization directly impacts economic feasibility. The study investigates the influence of bay spacing and section variation on overall structural weight. By comparing different design alternatives, the most economical configuration is identified. Foundation design is also incorporated to ensure safe load transfer to soil strata. The findings indicate that pre-engineered steel warehouses are more suitable for long-span structures compared to conventional buildings, offering up to 30% reduction in steel weight when optimized properly. Additionally, the use of computer-aided structural design significantly reduces manual errors and design time. Overall, the study demonstrates that finite element modelling combined with codal design provisions provides a reliable framework for designing efficient, sustainable, and cost-effective industrial warehouse structures.

II. LITERATURE REVIEW

Pre-Engineered Buildings (PEBs) have gained significant attention in structural engineering research due to their efficiency in long-span industrial applications. G. Durga Rama Naidu (2014) conducted a comparative study between pre-engineered buildings and conventional steel frames and concluded that PEB systems provide considerable savings in steel quantity and construction time. The study emphasized that tapered built-up sections used in PEBs are structurally more efficient because material is distributed according to bending moment demand. Similarly, S.D. Charkha (2014) investigated the economization of steel in industrial buildings and reported that optimized steel sections significantly reduce material consumption without compromising safety. These studies highlight the importance of structural optimization in warehouse design.

C.M. Meera (2013) carried out a detailed comparative analysis between Pre-Engineered Buildings (PEB) and Conventional Steel Buildings (CSB) using STAAD.Pro software. The results indicated that PEB structures are lighter and more economical for longer spans due to the use of tapered members and efficient load distribution systems. Milind Bhojkar (2014) further analyzed the cost and time effectiveness of PEB structures and found that factory fabrication and standardized components reduce construction time considerably. Vaibhav B. Chavan (2014) studied the effect of span length on structural economy and concluded that optimization of bay spacing plays a critical role in reducing structural weight. These findings support the need for computational modelling to identify the most economical design configuration.
Research on tubular and hollow steel sections has also demonstrated their structural advantages in industrial sheds. Manan D. Maisuri (2013) compared tubular sections with conventional rolled steel sections and concluded that hollow sections provide better strength-to-weight ratio and improved torsional resistance. Yash Patel et al. analyzed the performance of tubular roof trusses and highlighted their economic benefits in large-span applications. Shaiv Parikh discussed the behavior of steel compression members and emphasized the importance of buckling considerations in long-span steel structures. These studies confirm that proper section selection

significantly influences the performance and economy of warehouse buildings.

Suryakant Mohamud examined the structural behavior of industrial warehouses under joint failure conditions and stressed the importance of bracing systems in resisting lateral loads. Subhrakant Mohakul and Dr. Shaikh Yajdani analyzed stress distribution in industrial storage sheds and observed that failure at connections can critically affect structural integrity. These findings underline the need for detailed finite element modelling and accurate joint design in PEB systems. Furthermore, the integration of wind load analysis as per IS 875 (Part 3) is essential for ensuring stability in long-span warehouse structures.

Recent advancements in computational structural analysis have enhanced the reliability of PEB design. STAAD.Pro has been widely used for finite element modelling and design verification as per IS 800:2007. Studies by M. Suneetha and others demonstrated that computer-aided structural analysis provides accurate results and reduces manual calculation errors. The literature collectively indicates that while PEB systems are structurally efficient and economical for long spans, optimization of geometry, section type, and load combinations is essential to achieve maximum material savings. However, limited research focuses specifically on systematic optimization using finite element modelling for long-span warehouse structures, which forms the basis of the present study.

III. WORKING METHODOLOGY

The working methodology adopted in this study involves systematic modelling, analysis, design, and optimization of a long-span pre-engineered steel warehouse building using STAAD.Pro software based on the Finite Element Method (FEM). The process begins with the creation of a new project in STAAD.Pro by selecting the "Space" structure type, which allows three-dimensional modelling of the warehouse frame. The geometry of the warehouse is defined according to the required span length, bay spacing, ridge height, and eave height. Portal frames are generated using the "Add Beam" option, and node points are inserted at critical locations such as column bases, rafter junctions, and bracing connections. Translation repeat is used to replicate frames along the longitudinal direction to create multiple bays. Bottom beams that are not required in portal frame systems are removed. Bracing members are then added at side walls and roof levels to provide lateral stability. After completing geometry, structural members are grouped into columns, rafters, purlins, and bracings to simplify property assignment and optimization. This modelling approach ensures accurate representation of load paths and structural behavior under different loading conditions.

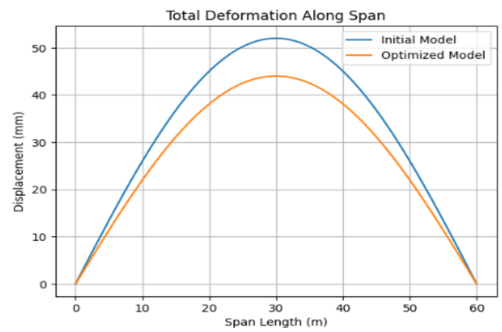

Fig.2. Total Deformation Along Span

Following geometry creation, material properties and sectional properties are assigned to all structural members. Steel material conforming to IS 800:2007 specifications is applied. Different steel sections such as tapered I-sections, rolled I-sections, channels, and tubular sections are selected from the section database. Support conditions are defined by assigning fixed supports at column bases to simulate realistic foundation restraints. Load definitions are then created, including dead load (self-weight of structural components and roofing materials), live load (as per IS 875 Part 2), and wind load (as per IS 875 Part 3). Wind intensity parameters such as basic wind speed, exposure factor, internal and external pressure coefficients are defined in the load definitions menu. Load combinations are generated automatically according to IS code provisions to account for worst-case scenarios. The analysis is performed using the "Run Analysis" option, and the structural responses including deflection, shear force, bending moment, axial force, and beam stress are evaluated in post-processing mode. Deflection checks are carried out using permissible L/d ratios to ensure serviceability compliance.

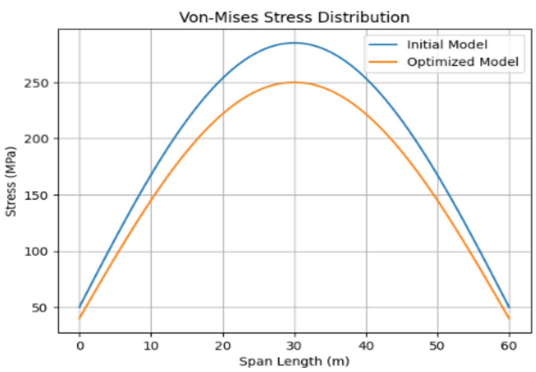

Fig.3. Von-Mises Stress Distribution

The final stage of the methodology focuses on structural design and optimization. Steel design parameters are selected under IS 800:2007 (Limit State Method), including yield strength (Fy), deflection limits, and tracking options for detailed output. Code checking is performed to verify whether members satisfy strength and stability requirements. Members failing design criteria are resized and re-analyzed iteratively to achieve optimal weight without compromising safety. The effect of varying bay spacing and tapered section dimensions on total steel quantity is studied to identify the most economical configuration. Foundation design is carried out using STAAD Foundation by transferring load combinations and designing isolated footings. The entire workflow—from modelling to optimization—ensures that the warehouse structure is safe, stable, economical, and compliant with Indian Standard codes. This systematic finite element–based approach enables efficient design of long-span pre-engineered warehouse buildings suitable for modern industrial applications.

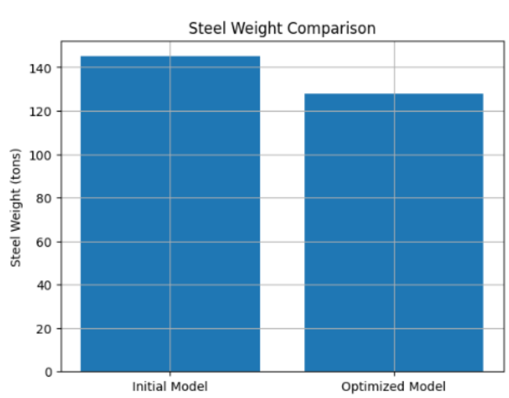

Fig.4. Steel Weight Comparison

IV. CONCLUSION

The following are the major observation and conclusion drawn from the present project work.

- The Pre Engineered Buildings (steel warehouse) is analysed for the respected loads acting on the structure as per the codes.
- The warehouse structure is analysed for the different load combinations.
- The materials quantity is calculated for the optimized design of the structure.
- Time saving design with respect to computer aided design of structure (CADS).

It can be said that pre engineered buildings are more economical and also environmental friendly than conventional steel structures since the steel used in pre engineered buildings can be recycled in case of demolition and hence it becomes a more sustainable approach. As it is seen in the present work, the weight of steel can be reduced to 30% for warehouse using Tapered I sections. For longer span structures, Conventional buildings are not suitable with clear spans. Pre-engineered building are the best solution for longer span structures without any interior column in between as seen in this present work, an industrial structure has been designed for 88m. With the advent of computerization, the design possibilities became almost limitless. More materials can be saved on low stress area of primary framing members and thus making it convenient for low rise building spanning upto 90 metres. PEB structures are found to be costly as compared to Conventional structures in case of smaller span structures. It is also seen that the weight of PEB depends on the Bay Spacing, with the increase in Bay Spacing up to certain spacing, the weight reduces and further increase makes the weight heavier. To conclude, pre engineered structures are more suitable for longer spans building as consumers prefers more space in a structure.

REFERENCES

[1] G.Durga Rama Naidu, Comparative study of analysis and design of pre-engineered buildings and conventional frames- IOSR Journal of mechanical and civil engineering ISSN: 2278-067X, 2014, 10, , pp 165-169.

[2] S.D.Charkha, Economizing steel building using pre-engineered steel sections – International journal of scientific and engineering research, 2014, 6 (12), pp 69-74.

[3] Milind Bhojkar, Comparison of pre-engineered building and steel building with cost and time effectiveness – International journal of innovative science engineering and technology ISSN 2348-7968, 2014, 1 (10), pp 784-789.

[4] VrushaliBahadur , Comparison between design and analysis of various configuration of industrial sheds – International journal of engineering research and applications, 2013, 3(1), pp-1565-1568.

[5] M.Suneetha1,Naresh Kumar, Gillela Reddy October 2016, "Design and Analysis of Industrial Building with Gable Roof by using STAAD.PRO" International Journal of Advance Technology In Engineering and Science.

[6] Vaibhav B. Chavan, Vikas N. Nimbalkar And Abhishek P. Jaiswal, Vol. 3, Issue 2, February 2014 " Economic Evaluation Of Open And Hollow Stuctural Sections In Industrial Trusses", Aci Structural Journal.

[7] C.M. Meera, June 2013 "Pre- Engineered Building Design of an Industrial warehouse". International Journal of Engineering Sciences and Emerging Technologies.

[8] SubhrakantMohakul, Dr. Shaikh Yajdani, Abhay Dhurde,August 2014 "Design of industrial storage shed and analysis of stresses produced on failure of a joint". International Journal of Civil Engineering and Technology.

[9] Manan D.Maisuri, Hitesh K.Dhameliya, Hiten L.Kheni, Vol.1 Issue 12, December 2013, "Review Of Comparison Between Conventional Steel And Tubular Steel Section For Multi Span Industrial Shed With Truss And Portal Frame" International Journal of Advance Engineering and Research Development.

[10] ShaivParikh ,"Design of Steel Compression Members" (According To IS: 800)

[11] Yash Patel, Shreepalsinh Gohil, Dr .TausifKauswala ,Het Parmar, volume 3 issue 10, april2006, "Analysis And Design Of Conventional Industrial Roof Truss And Compare It With Tubular Industrial Roof Truss" International Journal of Science Technology and Engineering.

[12] A. Jayaraman, R Geethamani, N Sathyakumar,NKarthigaShenbagam,"Design and Economical of Roof Trusses & Purlins (comparison of LSM and WSM)"

[13] Design of Steel Structures by N. Subramanian