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Analysis and Design of Steel Roof Trusses for Warehouse

Arya Khalatkar[1] and Amruta Yadav[2]
[1-2]Department of Civil Engineering, Yeshwantrao Chavan College of Engineering, Nagpur, Maharashtra, India
Email: aryakhalatkar55@gmail.com

***Abstract*— This work aims to study low-cost alternate roof construction techniques for industrial warehouse structures. This paper deals with the design of a steel truss for an industrial warehouse based on limit state design. High strength-to-weight ratio, low dead load, easy prefabrication and speed of construction are some significant advantages offered by steel trusses. As per (IS 800:2007 and IS 875), the design and analysis of Pratt, Howe & Fink truss systems are compared with different loading conditions. The behaviour characteristics of two sections, namely Indian Standard Angles (ISA) and Square Hollow Section (SHS), are studied in this work using the STAAD. Pro software and manual computations. The findings indicate that compared with the conventional angle sections, SHS sections provide a substantial increase in material effectiveness and total truss weight saving as well as a decrease in cost.**
These instructions give you basic guidelines for preparing camera-ready papers for Grenze Scientific Society's conference proceedings/Journal Publications.

***Index Terms*— first term, second term, third term, fourth term, fifth term and sixth term.**

I. INTRODUCTION

Both the commercial and industrial sectors depend strongly on warehouses. They offer accessible, secure spaces for the storage of goods and supplies. These structures must have wide open spaces, few internal supports, and economical construction technologies. Traditionally, reinforced cement concrete (RCC) structures have been employed for this purpose; however, they are cumbersome, take longer to build, and are less flexible for future modifications. Whereas steel structures are nowadays becoming popular as the new alternative because of their excellent mechanical properties, great strength-to-weight ratio and rapid construction. The steel roof trusses design consists of slender steel members that are connected from triangular units, providing rigidity and efficient load distribution to the structure. As truss parts are prefabricated, they can be put together much faster on site with less labor which makes them perfect for large span buildings like warehouses, factories and industrial sheds. Since steel trusses are modular, easy to maintain, update or expand, which leads to long-term utility of the structure. Using steel for truss designs, it lowers the overall weight of the structures, which directly reduces the deadload, so we can use smaller and less expensive foundations. However, steel is a very eco-friendly choice, and it's both recyclable and reusable. To design a safe and high-performing structure, it is necessary to evaluate different loading combinations like wind, live and dead loads based on Indian Standards (IS 800:2007 and IS 875:1987). Modern computational tools like STAAD. Pro [1] can do accurate structural analysis and optimization by ensuring stability and economical design. The study aims to design and analyze the different types of steel roof trusses, such as Pratt, Howe and Fink trusses [2], for a warehouse structure.

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Both manual design methods (based on IS codes) and software-based analysis [3][4] are used to compare results in terms of member forces, deflection, and material amount. The study emphasises the most economical and structurally efficient truss type that fulfills safety and serviceability criteria. In general, this research shows that steel roof trusses are an efficient and economical alternative to traditional RCC construction for industrial warehouse structures. [5]

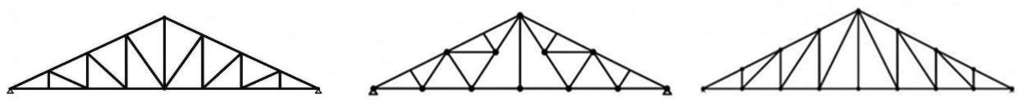

Figure 1. Howe truss, fink truss and pratt truss

II. Methodology

Workflow chart of truss design and analysis procedure:

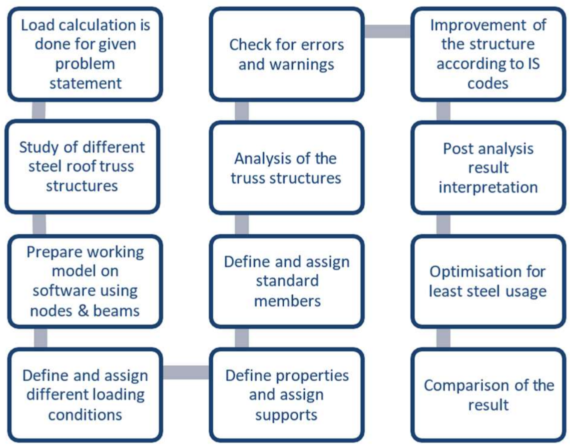

Figure 2. Workflow chart

III. Calculations

Problem statement

Design of a steel roof truss for an Industrial Warehouse building for the following given data Length of the Industrial Warehouse = 64m

Span of truss = 16m

c/c spacing of roof truss = 4m Height of column = 11m

The structure is positioned in the MIDC of Katol, Dist- Nagpur, Maharashtra, India. Use of Steel grade Fe410.

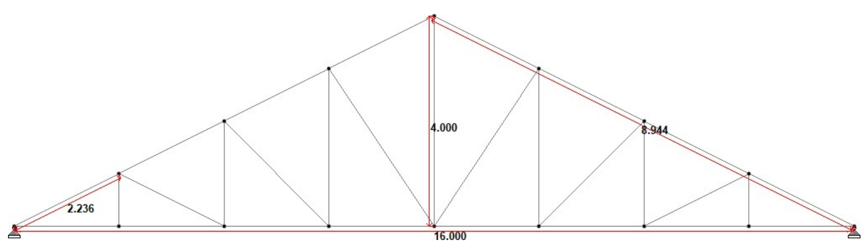

Figure 3. Dimensions of truss

Given Data:

The height (h) of the Industrial Warehouse Building = 64 m

Span of the Truss= 16 m

Roof Truss Centre-to-centre Spacing = 4 m

Rise of Steel Roof Truss = 1/4 [6]

Span = 4 m
The Weight of Purlins = 318mm
The Height of Columns = 11m
Roofing and Side coverings = A.C. Asbestos Cement Sheet (171 N/m²)
Where = Katol, Dist-Nagpur, Maharashtra, India
The truss is pinned at both ends. Steel Grade = Fe410
Dimension of Truss:
Central Rise of Roof Truss = 1/4 of Span = 4 m
Inclination (θ) of Roof Truss = $\tan^{-1}(4/8) = 26.565°$
Length of Principal Rafter = $\sqrt{(8^2 + 4^2)} = 8.944$ m
Distance Between Panel Points = 8.944 / 4 = 2.236 m
Purlins are provided at 2.236 m intervals.
Dead Load Calculation:
Dead Load Components:
Weight of A.C. Sheet = 171 N/m²
Weight of Bracing = 12 N/m² (Assumed)
Weight of Roof Truss = (Span + 5) / 3 = 110 N/m²
Weight of Purlins = 318 N/m (Assumed)
Weight of Steel roof truss = 318 × 8 = 2.544 KN
Panel Length = 2.236
Panel Length in Plan = 2.236 cos(26.56) = 2 m
Total Load = (171 + 12 + 110)(8 × 2) + 2.544 = 7.232 KN ≈ 7.5 KN
Load on Each Intermediate Panel = 7.5 KN Load on Each End Panel = 7.5 / 2 = 3.75 KN Live Load Calculation:
Angle θ = 26.565°
Let us assume that no access is provided to roof.
Live Load (LL) is reduced by 20 N/m² for each 1° above 10° slope. LL = 750 – [20 × (26.565 – 10)] = 418.7 N/m²
Load on Each Intermediate Panel due to LL= 418.7 × (8 × 2) = 66.992 N = 6.7 KN Load on Each End Panel due to LL = 6.7 / 2 = 3.35 KN
Wind Load Calculation:
[IS 875 (Part-3):2015]
Basic Wind Speed (V_b) = 44 m/s (for Katol, Nagpur District) Design Wind Speed for roof truss (V_z) = $V_b \times K1 \times K2 \times K3$
K1 = 1.0
K3 = 1.0
K2 (Terrain Category 3, Height = 11 m) = 0.9221 Vz = 44 x 1 x 0.9221 = 40.57 m/s
Design wind pressure, $P_d = 0.6 V^2z$ = 0.987 kN/m² ≈1 kN/m²
Wind Load, F = (Cpe - Cpi) x Ae x Pd h/w = 11/16 = 0.69
Then Building Height Ratio = 1/2<h/w<3/2
For θ = 0° (Wind Angle θ)
By Interpolation:
at θ = 26.565°→ EF= -0.372, GH= -0.5
For θ = 90° (Wind Angle θ)
By Interpolation:
θ = 26.565°→ EG = -0.8, FH = -0.731
Wind Load on Panel Points:
Windward Side:
Wind Load per intermediate panel point =12.54 KN Wind Load on each end panel point = 12.54/2 = 6.27 KN
Leeward Side:
Wind Load in each intermediate panel point =17.92KN Wind Load on each end panel point = 17.92/2 = 8.96 KN.

IV. Experimental Work Overview

The objective of the project is to achieve the minimal possible steel take-off through systematic structural optimization and to evaluate the utilization ratios of the members after optimization[6][8]. This is accomplished by comparing three widely used roof truss designs: the Howe, Pratt, and Fink trusses. The truss components are modelled, analyzed, and optimized under identical geometric and loading conditions using STAAD.Pro [4]Connect Edition (2025). To ensure a fair comparison, the span, rise, and truss height are kept constant across all designs[5]. Two different structural section types—Angle sections (ISA) and Square Hollow Sections figure 2 (SHS)— are assigned to the truss members to assess their influence on overall steel usage and structural efficiency[7]. The software identifies the most suitable members, which helps determine the economical section design that meets the adequate strength and efficiency standards specified in relevant codes. After comparing the total steel weight, steel take-off and individual member utilization ratios, it makes an assessment easier of the relative structural and economic performance of each truss type and section category[9],[10],[11]. Ultimately, this project is to give insight into the most suitable truss design and type of sections for steel roof structures on specified geometric constraints.

Calculation for steel take-off:

For the steel section ISA Fe410,

The price per kg, depending upon region and quantity, ranges between Rs 48 and Rs 58.

The price is between Rs 48,000 and Rs 58,000 per metric ton. For the SHS steel section of standard Fe410 grade, Traditionally standard brands such as Apollo, Jindal or Tata rate per kg range between Rs 61 and Rs 70.

The price per metric ton ranges between Rs 61000 and Rs 70000. The cost per metric ton varies from Rs 61000 to Rs 70000.

To convert price from mass (kg) to force (kN):

Since 1000 N = 9.806 m/s^2, Mass of 1 kN steel = 101.97 kg.

Rated cost/kg x 101.97 = Cost per Kn.

TABLE I. COST OF STEEL

Section Type	Grade	Avg. Cost per kg	Avg. Cost per kN
ISA (Angle)	Fe 410	Rs 53	Rs 5,404
SHS (Tube)	Fe 410	Rs 65	Rs 6,628

V. RESULT AND DISCUSSION

To acquire the highest performance and make the design more reasonable, we look at the outcomes of different shapes, sections, and member positions.

TABLE II. TOTAL COST FOR DIFFERENT TRUSS GEOMETRIES AND SECTION COMBINATIONS

Truss Geometry	Type of Section	Members			Purlins	Total Weight (KN)	Total Cost (Rs.)
		Top Chord	Bottom Chord	Other Members			
Howe Truss	Angle Section	ISA 100×100×10	ISA 120×120×10	ISA 90×90×10 & ISA 120×120×10	ISJC 100	202.336	10,93,424/-
	Square Hollow Section	72×72×3.2 SHS	80×80×3.2 SHS	60×60×3.2 SHS & 72×72×3.2 SHS	ISJC 100	99.947	6,62.449/-
Pratt Truss	Angle Section	ISA 110×110×10	ISA 130×130×12	ISA 100×100×10 & ISA 130×130×12	ISJC 100	251.725	13,60,322/-
	Square Hollow Section	72×72×3.2 SHS	80×80×3.2 SHS	60×60×3.2 SHS & 72×72×3.2 SHS	ISJC 100	105.294	6,97,889/-
Fink Truss	Angle Section	ISA 110×110×10	ISA 120×120×10	ISA 100×100×10 & ISA 110×110×10	ISJC 100	211.974	11,45,507/-
	Square Hollow Section	91.5×91.5×5.4 SHS	80×80×4.0 SHS	60×60×3.2 SHS & 91.5×91.5×5.4 SHS	ISJC 100	150.606	9,98,217/-

For all three truss types examined, the study shows that Square Hollow Sections (SHS) are much more cost-effective and efficient than Angle Sections (ISA) in terms of weight reduction.

Analysis of Weight

By applying SHS, the weight of the truss system is significantly reduced:

Howe Truss: The weight reduction was about 50.6% %, from 202.336 kN (Angle) to 99.947 kN (SHS). Pratt Truss: The weight reduced by approximately 58.2%, from 251.725 kN (Angle) to 105.294 kN (SHS).

Fink Truss: Weight dropped by approximately 28.9%, passing from 211.974 kN (Angle) to 150.606 kN (SHS).

Analysis of Costs

The significant decrease in the quantity of steel results in lower overall costs, even though the unit rate for square hollow section is higherFigure 1:

Howe Truss: Savings of almost 39% from Rs 10,93,424 to Rs 6,62,449.

Pratt Truss: Shows a saving of 48.7% from Rs 13,60,322 to Rs 6,97,889, significantly. Fink Truss: Shows a saving of 12.8% from Rs 11,45,507 to Rs 9,98,217 significantly.

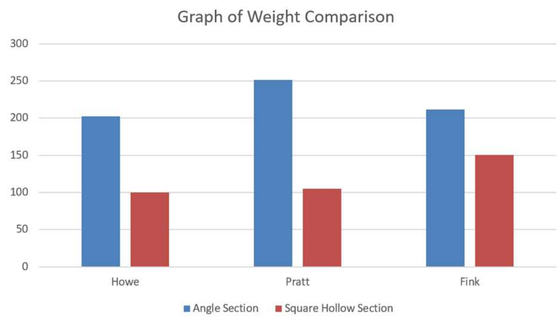

Figure 4. Graph of Weight Comparison

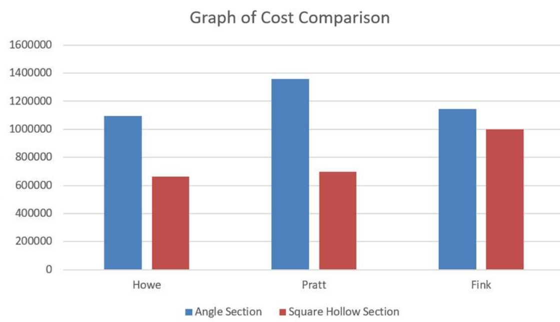

Figure 5. Graph of Cost Comparison

VI. CONCLUSION

The comparative analysis of different geometric arrangements and section types leads to the following conclusions:

- The Howe truss structure with square hollow sections is the most economical for constructing the warehouse based on the stimulus statement.
- By using SHS and ISA when overall weight reduction and economical section across the various types of Trusses (Howe/ Pratt/Fink), SHS was found to be Overall Cost Saving and Lighter.
- Optimal Truss Configuration: The Pratt Truss made with SHS yielded the most reduction in weight of 58.2% and cost savings of 48.7%, compared against its equivalent angle section, which is considered the best design.
- SHS is even more economic in terms of industrial applications even with a higher unit price (₹65/kg for SHS vs 53/kg and ISA) due to the huge reduction in total steel,figure 5 .
- The dead load of the whole structure is substantially reduced by using hollow sections (e.g., Howe truss: 202.336 kN to 99.197 kN).
- As opposed to classical RCC systems, the steel trusses, especially optimally designed hollow sections, provide for faster and sustainable construction as well as recyclable options that conform to all safety regulations required by modern industrial warehouses figure4.

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