Comparison of Conventional Steel Roof Trusses with Tubular Trusses

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***Abstract*— Steel roof trusses find their application in a wide variety of industrial structures including steel plants, metal industries, automobile industries, air craft hangers etc. The characteristics of such units are long span storage area, column free space for uninterrupted view and movement of vehicular traffic for loading and unloading of material and goods. The most suited roof for such structures is steel trusses. These buildings require extra large spans, extra height and may involve heavy loads. The advantage of such buildings lies in the economy of the roof. Hence, there is a need for an economical design. Most of the steel structures are builted-up with conventional sections of steels which are designed and constructed by conventional methods. This leads to heavy or uneconomical structures. Tubular steel sections are the best replacements to the conventional ones with their useful and comparatively better properties. It is obvious that due to the cross sectional properties of the tube section, dead weight is likely to be reduced for many structural members which derives overall economy. In this study an attempt is made to compare two types of truss configurations namely Howe truss and Pratt truss for span of 35m with two different span to depth ratios. The trusses are designed for various loads using conventional angle sections, Square hollow sections (SHS), Rectangular hollow sections(RHS) and Circular hollow sections(CHS). The results are compared by plotting graphs for both configurations in terms of their weight using different sections. Study reveals that, upto 30 to 40% saving in weight and cost is achieved by using tubular sections.**

Keywords*—*IS 806, tubular trusses, wind load, IS 4323

I. INTRODUCTION

Steel roof trusses are one of the cheapest and most convenient roofing systems for various types of buildings. The roof trusses are used at places which require sloping roofs. These are most commonly used for industrial buildings, workshop buildings, storage godowns and warehouses, where large column free spaces are required for operational purposes. Some of the advantages of the roof truss are:

- In a roof truss, the entire section of each member is subjected to uniform stress and hence the strength of member is fully utilized. This results in the most efficient use of material.
- The midspan depth is the greatest, especially where bending moment is the maximum, thus resulting in great economy.
- It permits a wider variety of roof shapes and greater unobstructed interior floor area at less cost.
- The sloping faces of the roof trusses facilitate in easy drainage of rain water

Roof trusses being advantageous, there is a need to achieve economy in the design of truss members and also while selecting the sections. In this paper an attempt is made to derive economy by designing the truss by using tubular sections and comparing it with conventional steel sections. The truss configurations used in this study are Howe truss & Pratt truss of 35m span with different span/depth ratios. The study concludes, highlighting various advantages associated with each type of the compared trusses. In this comparison, only trusses are involved; purlin weights, roof sheeting, truss supports, foundations, walling and flooring are excluded.

II. LOADS ON ROOF TRUSSES

A. Dead Load

Dead load on the truss includes self weight of truss, purlins, roof sheeting. The self weight of purlins is assumed as 100 N/m.

B. Live Load

IS:875 (Part 3)-1987 recommends that for roofs with slope upto and including 10°, live load measured on plan should be taken as 1500 N/m^2 where access to roof is provided and as 750 N/m^2 where access is not provided except for the maintenance.

For sloping roofs if the slope greater than 10°, the live load will be taken as 750 N/m^2 less 20 N/m^2 for every degree increase in slope over 10°, subjected to a minimum of 400 N/m^2 of the plan area.

C. Wind Load

The load due to wind is one of the most important loads to be considered in the design of roof trusses. The magnitude of wind pressure depends on the wind velocity and the shape of the structure. The magnitude of wind velocity varies with the geographical location of the structure and the height of the structure. The analysis of the truss due to wind load is carried out as per IS: 875 (Part 3)-1987.

Basic wind speed (V_b)

The basic wind speed, as applicable to 10 m height above mean ground level for different zones of the country is obtained from *Fig 1* of IS:875 (Part 3)-1987.

Design wind speed (V_z)

The Design wind speed is obtained from the following expression

$$V_z = V_b \times k_1 \times k_2 \times k_3$$

Where,

V_z = design wind speed at any height 'z' in m/s.
k_1 = probability factor (risk coefficient
k_2 = terrain, height and structure size factor.
k_3= topography factor.
The values of k_1, k_2 and k_3 are obtained from IS: 875(Part 2)-1987.

Design wind pressure (p_z)

The design wind pressure at any height above mean ground level is given by

$$p_z = 0.6 \times V_z^2$$

Pressure coefficients

Internal pressure coefficient (C_{pi})

Internal air pressure in a building depends on the degree of permeability of the cladding to the flow of air. The pressure inside a building may be positive or negative, that is, a positive pressure or suction depending on the direction of flow of air in relation of the openings in the building.
The internal pressure coefficients, based on degree of permeability, as specified by IS: 875 (Part 3) -1987

External pressure coefficient (C_{pe})

Based on the building height to width ratio, IS: 875 (Part 3)-1987 specifies the average external pressure coefficients for pitched roofs of rectangular clad buildings. Table 5 of IS:875 (Part 3)-1987 gives the external pressure coefficients on windward and leeward side for different slopes of the pitched roof, for the wind blowing in the plane of truss and perpendicular to the plane of truss.

Wind load on individual members

Wind load acting in a direction normal to the roof, is calculated by the expression as given in IS:875 (Part 3)-1987, as follows:

$$F = (C_{pe} - C_{pi}) A p_z$$

Where,
A = surface area of structural element or cladding unit

III. LOAD COMBINATION

A judicious combination of the working loads keeping in view of probability
a) of their acting together and b) their disposition in relation to their loads and the severity of stresses or deformations caused by the combination of the various loads, is necessary to ensure the required safety in the design of structure
The various loads specified above should therefore be combined in accordance with the stipulation in the relevant design codes. The following load combinations may are adopted:

a) Dead load alone.
b) Dead load + partial or full live load whichever causes the most critical condition in the structure.
c) Dead load + Wind

IV. DESIGN EXAMPLE

Truss configuration: Howe truss, Pratt truss
Span of the truss: 35m
Depth/Rise of the truss: 4m, 3.5m
Height of Eaves = 10.0 m
Type of roofing = A.C. Sheeting
Location of shed = Panjim(Goa)
Depth of truss = 4.0 m, 3.5m, 3m
Class of building = A Type (Open Terrain)
Spacing of truss =6.0 m
No of panel points on each side=15
Spacing of Purlins=1.36m

A. Load calculations

Dead Load

Total Dead load =75.348 KN
No. of Panels= 26
Load acting on one intermediate panel =75.348 /26 =2.898 KN
So, Dead load is taken as = 2.9 kN/node

Live Load

Total live load = 145.6 KN
Load acting on one intermediate panel point = 5.60 KN

WindLoad

Total wind load =-306.8 KN
Load acting on one intermediate panel point= -11.8 KN (uplift)

V ANALYSIS AND DESIGN

The steel trusses have been analyzed as simply supported on columns. The support at one end is assumed to be hinged and the other end on rollers for the purpose of analysis. The truss has been analyzed for dead load, live load and wind load according to IS: 875(Part 1, 2&3)-1987. However, the permitted increase in allowable stress by 33% due to wind is implemented. The whole assembly of truss (2.4) is analysed using StaadPro 2006 Programme.
Based on the forces obtained, the design of truss is performed using IS 800-1984. Other codes which are used are IS 4923-1997 for design of Hollow steel sections & IS 1161-1998 in design of Tubular sections.Design results are given in Table 1 and Table 2.

TABLE I. DESIGN RESULTS FOR HOWE TRUSS FOR SPAN OF 35M

Rise of Truss	Member	Weight of member in Kg			
		Angle	SHS	RHS	CHS
4m	Rafter	836.4	617	617	709
	Tie	1197	1122	1122	1103
	Main strut	60	38	39	39
	Main sling	28	13	12.6	12
3.5m	Rafter	1031	807	748	880.6
	Tie	1344	1203	1203	1383
	Main strut	62	32	34	34
	Main sling	18.5	12.2	12.9	12.42

TABLE II. DESIGN RESULTS FOR PRATT TRUSS FOR SPAN OF 35M

Rise of Truss	Member	Weight of member in Kg			
		Angle	SHS	RHS	CHS
4m	Rafter	869	711	711	709
	Tie	598.5	561	561	551
	Main strut	25	20	20	23.7
	Main sling	48	17.4	17.4	17.2
3.5m	Rafter	1031	807	807	920
	Tie	619.5	602	602	863.4
	Main strut	25	17.8	19.2	21.7
	Main sling	23.6	15.5	17	16.4

VI RESULTS AND DISCUSSIONS

A.Howe Truss

Truss is designed for the forces obtained from critical load combination. Design is done using angle sections, SHS, RHS and CHS. The results are compared for Rafters, Tie member, Main strut and main sling in terms of their weight for each section. Refer Fig.1 and Fig. 2.

. Following comparison is done for various members:

Principal Rafter: Percentage reduction in weight using SHS, RHS and CHS is 26.2%, 26.2%& 15.2% respectively compared to conventional angle sections when the depth of truss is 4m.

Whereas when the depth is 3.5m, Percentage reduction in weight is 21.7%, 27.5% and 14.6% respectively compared to angle sections

Tie member: Percentage reduction in weight using SHS, RHS and CHS is 6.28%, 6.28%& 7.8% respectively compared to conventional angle sections when the depth of truss is 4m.

Whereas when the depth is 3.5m, Percentage reduction in weight is 10.4%, 10.4% and 2.89% respectively compared to angle sections

Main Strut: Percentage reduction in weight using SHS, RHS and CHS is 35.2%, 35.2%& 34.5% respectively compared to conventional angle sections when the depth of truss is 4m.

Whereas when the depth is 3.5m, Percentage reduction in weight is 48%, 45.4% and 45% respectively compared to angle sections

Main sling: Percentage reduction in weight using SHS, RHS and CHS is 55%, 56%& 58% respectively compared to conventional angle sections when the depth of truss is 4m.

Whereas when the depth is 3.5m, Percentage reduction in weight is 34%, 30.4% and 33% respectively compared to angle sections

B.Pratt Truss

The results are compared for Rafters, Tie member, Main strut and main sling in terms of their weight for each section. Refer Fig. 3 and Fig. 4

Principal Rafter: Percentage reduction in weight using SHS, RHS and CHS is 18.2%, 18.2%& 18.4% respectively compared to conventional angle sections when the depth of truss is 4m.

Whereas when the depth is 3.5m, Percentage reduction in weight is 21.7%, 21.7% and 10.7% respectively compared to angle sections

Tie member: Percentage reduction in weight using SHS, RHS and CHS is 6.28%, 6.28%& 7.8% respectively compared to conventional angle sections when the depth of truss is 4m.

Whereas when the depth is 3.5m, Percentage reduction in weight is 2.8%, 2.8% and -39%% respectively compared to angle sections

Main Strut: Percentage reduction in weight using SHS, RHS and CHS is 19.1%, 19.1%& 5.6% respectively compared to conventional angle sections when the depth of truss is 4m.

Whereas when the depth is 3.5m, Percentage reduction in weight is 28%, 22.5% and 12.5% respectively compared to angle sections

Main sling: Percentage reduction in weight using SHS, RHS and CHS is 63.5%, 63.5%& 12.5% respectively compared to conventional angle sections when the depth of truss is 4m.

Whereas when the depth is 3.5m, Percentage reduction in weight is 34.5%, 27.5% and 30.5% respectively compared to angle sections

It is seen that there is 25 to 50% reduction in weight if hollow section are used in the design

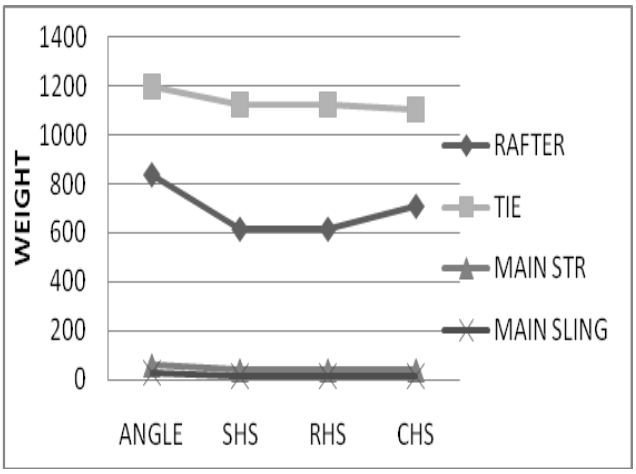

Fig. 1. Variation in weights for various memebers for howe truss with 4m rise

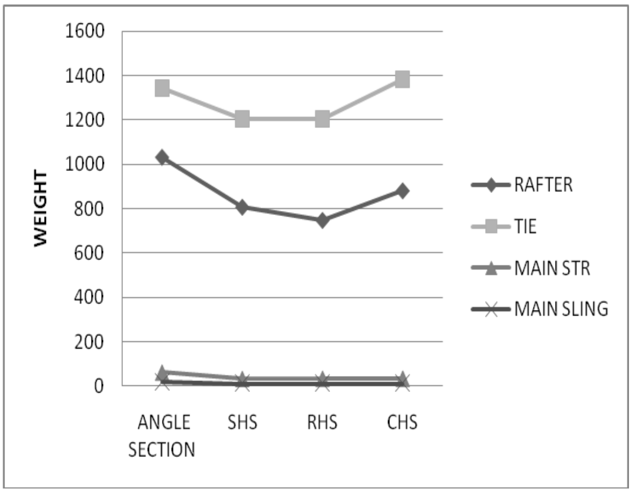

Fig. 2. Variation in weights for various memebers for howe truss with 3.5m rise

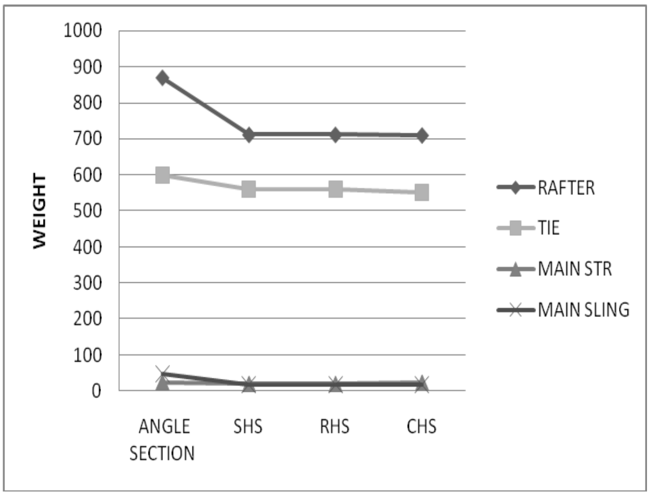

Fig. 3. Variation in weights for various memebers for Pratt truss with 4m

CONCLUSION

Above study reveals that tubular sections proves to be more economical. There can be savings in terms of weight of material by 25 to 40%. Out of circular, square and rectangular shapes, due to connection difficulties of circular tube sections, it is suggested to adopt rectangular or square tube sections. Effectiveness of Tubular section can be verified by modifying truss configurations. From above observations and results one can conclude that, the structural members having larger unsupported lengths can be designed as tubular sections which will derive overall economy. For smaller unsupported lengths one will have to design for minimum sections for both conventional and tubular sections so that economy is not considerably

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