Review Paper on Analysis and Design of Steel Truss by using Angle and Tube Section

Prince Bhanarkar[1], Prof. Deepak Irkullawar[2]

[1]M. Tech Student, Structural and Construction Engineering Department, Ballarpur Institute of Technology, Maharashtra, India
[2]Assitant Professor, Structural and Construction Engineering Department, Ballarpur Institute of Technology, Maharashtra, India

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Abstract - *Now a days many complex structures having large span of roof structure are looking for the truss section because due to large spacing required mass concreting, vast quantity of steel for beam, column and slab casting so therefore, it is economical to do so. That's why the major solution for this condition steel truss is best alternative within the economy and other parameter like strength, durability, time saving, high flexural strength. Now a days many of the steel building are made up with critical sections of steel which are designed and built by conventional approaches, so that this results in heavy loads or too expensive structures. Tubular steel sections are the best possible alternatives to the conventional steel sections with their comparatively better specifications. The main aspects considered while selecting this section are the economy, load carrying capacity of all members and their relative safety measures. For making cost effective it is the main aim of the present work including comparison of conventional structures with tubular structure for given conditions. Literature review reveal that up to 15-20% saving in expense is accomplished by using tubular sections. Analysis of steel roof truss elements was carried out by STADD PRO V8i computer software, by manually applying Indian Standards codes of practices. The advantage of such buildings lies in the economy of roof. Hence, there is a need for an economical design in this condition. The trusses are designed for various loads using conventional angle sections, such as Square hollow sections (SHS), Rectangular hollow sections (RHS) and Circular hollow sections (CHS). The review project aims to provide which method is cost-efficient, more load transport capacity and high flexural strength. The purpose of this analysis and design of steel roof truss section is to study the effect of different spacing, span and pitches in order to find out which one will be the most economical truss by using angle section and tube section. The various truss analysis performed by using structural analysis software i.e. STADD PRO. After reviewing the review paper analysis results are compared to obtain optimum and accurate truss design. This analysis includes the determination of dead load, live load and wind load as per Indian Standard IS 800:2007 and IS 875(Part 3)-1987. The process is to find out loads at each panel and node are calculated manually and then the loads are entered into STAAD PRO software for analysis and designing. The STAAD PRO OUTPUT method is used for determining the quantity of steel (weight). The truss with a least value of quantity of steel is to be considered as most economical truss.*

Key Words: Structural analysis, Conventional steel truss, Angle section, Tube section, AutoCAD, STAAD Pro V8i, Roof truss, IS:800-2007, IS:806-1968, IS 875-1987 for tube section, etc.

1. INTRODUCTION

Trusses are defined as an interconnected structure of small members, which create a lattice arrangement. The weight of truss is different with respect to span and slope of roof. So that size and shape of the truss is very much important like strength of the individual components, and also more design options are available. In industrial sector truss is the best option for cover the roof. It is very cheap as compare to R.C.C. structure. Truss structures are also a light weight structure as compare to RCC concrete structure. Trusses are particularly popular and structurally more efficient for roof with long span and where height of structure is large. Trusses are highly efficient and visually light in weight as compare to RCC structure for long span. The material used in truss section is economical if the proper design is prepared. Now a days it is most common solutions for problems in large scale roofing for examples factories, workshops and railway stations. An economy of the structure requires for the purpose industrial building depends on the configuration of structure, type of roof truss and portal frame utilized, forces acting on building and selection is based on that of steel sections needed as per force employed.

For industries, warehouses, auditoriums, bridges, industrial roof, aircraft hangers, high rise buildings etc. unobstructed space is needed. In order to provide that space for working purpose we need to avoid columns. If RCC concrete slab is used in this case, it required of large areas, so it doesn't satisfy deflection criteria and becomes costly and uneconomical. The reasons for using trusses because they are long span, light weight, reduced deflection and opportunity to support considerable loads. Buckling is the reaction caused due to excessive load acting upon the structural load and it is a important mode of failure and it can happen suddenly without any prior warning. Buckling occurs physically when structure becomes unstable under a certain loading conditions depend upon structure. Truss is very important factor for a construction, such as construction for planning of roof, Aeroplan hangers, bridge and high-rise building. Truss can give high elegant value for mega construction for example Eiffel Tower in Paris and for building like stadium for football in Europe.

A truss is a structure connected by of slender members joined together at their end points. Whereas the joint connections are formed by bolting or welding the end members together to a common plate which is called a gusset plate. Double cantilever truss or roof truss. Every structure must have to fulfill the structural criteria and economical requirements. So that's why there is need of optimization of truss design to obtain minimum weight.

1.1 Importance of Research Topic

This research's objective was to estimate the economic importance of the tubular sections in contrast with conventional angle sections. This paper was carried out to find out the percentage economy accomplished tubular sections so as to understand the importance of cost efficiency. The technique used in order to obtained the objectives involves the comparison of various profiles for different combinations of height and material cross section for different span and different loading conditions. The analysis and designing phase of these project work was done by using STADD PRO V8i software. The result of STAAD analysis were validated with the results of Manual analysis. To determine the which one is better so planning of industrial shed is considered analysis and design is carried out using conventional steel and tubular steel sections and also cost comparison is made for both sections.

1.2 Objective of the study

(1) To study the various properties of selected truss and comparing the available truss on their parameters like strength, life span, durability, economy of the structure, time required for completion etc.
(2) To analyse and design of steel truss by using angle section and calculate the quantity of steel required.
(3) To analyse and design of steel truss by using tube section and calculate the quantity of steel required.
(4) To govern the most effective truss geometry in terms of weight among the truss geometry.
(5) To match the price tag of materials (by using weight) of the different truss geometries generally used in the construction industry.

2. LITERATURE REVIEW

1. **Dheeraj Harod and Prof. Sumit Pahwa (Feb-2019)** studied that the steel truss and understanding the skeleton of a typical roof truss. Analyzing the various truss structures patterns. Comparing of the roof truss provided along length to truss provided along width of span and truss structure having different designs are considered. Finally conclude that the truss provided along length required less material as compare to truss provided along width of span. The cost of construction should be less as compare to truss placed along width of span.
2. **Alena Mathew and Reshma (Apr-2019)** investigated that the effect of buckling and wind load on different roof truss parameters also determined the economic design of trusses with buckling load and wind load. Compared the analysis and design results. Find out the cost and weight of the truss. Finally concluded that When span and spacing of the truss increases, buckling, cost and weight also increases. When slope is increases then buckling, cost and weight reduces.
3. **Himanshu Makode and Sachin Nagayach (2019)** determined that the most suitable type of truss arrangement for long span. To justify the utilization of analysis tool in steel sections analysis. They found in these study it is in truss arrangement howe type truss is comparatively best suitable in terms of sections beam section is more resistible and economical.
4. **Venkatesh K and Jayanthi V (2019)** they presented an overview about the most suitable type of truss arrangement for long span. To justify the utilization of analysis tool in steel sections analysis. In this study they concluded that in truss arrangement howe type truss is comparatively better suitable as compared in terms of sections beam section is more resistible and economical.
5. **Manoj Nallanathel, Ramesh Bhaskar and Kishor (2018)** in this paper a brief surveyed of industrial buildings and comparing conventional frame to the prefabricated truss. The above work shows that different types of trusses and different codes are using particular material. It has given different types of supports. And the using codes, design in these trusses.
6. **A Jayaraman, N Sathyakumar and S B Prasath (Dec-2018)** they founded that the main objective of this study is which method is most economical method by both WSM and LSM. Comparison of weight & cost of both the section. The channel section most economical section compared to angle section. The cost of angle section is 54.31% and 60.12% is more than the channel section in same configuration load in WSM and LSM.
7. **Goraviyala Yogesh and Prof. K. C. Koradiya (2016)** they described in detail and compare design of roof truss of certain span by using both open sections and hollow sections. To determine the most economical sections by comparing sections

such as open sections, rectangular hollow sections, square hollow sections and circular hollow sections. Calculation of percentage saving in steel for given structure. Study different parameters of design and maintenance in tubular structural sections. The tubular steel sections are structurally more efficient as compare than conventional section because its resistance of torsional is very high and also high strength to weight ratio.

8. **Er. Sanjeev Kumar, Brahmjeet Singh and Er. Bhupinder Singh (Mar-2016)** specification recommended that to govern the most effective truss geometry in terms of weight among the 80 truss geometries. Also comparing the price of materials (by using weight) of the various truss geometries generally used in the construction industry. The most economical truss is at a spacing of 3m, span 10m with a pitch of 1/8 having a total weight of 0.48KN. In all the spacings, most economical truss is found at 0.125 pitches.
9. **Yash Patel, Yashveersinh Chhasatia, Shreepalsinh Gohil and Het Parmar (Apr-2016)** they concluded that the trusses have been analyzed for dead load, live load and wind load referring to IS: 875. Deal load includes the self-weight of the structure, weights of roofing material, weight of purlins. The different analyses can be made using STADD Pro V8i software. The various load combinations considered in the analysis are taken respectively. The outcome of different analyses for different geometries and section parameters are compared for choosing best of roof truss design. Above study shows that tubular section has prefered to be more economical. Total saving of Rs. 10,729 per one roof truss is achieved with assigning tubular steel sections by replacing the conventional steel roof truss from this research paper. Which came down to total saving of 75,108 INR for seven roof truss of an industrial shed. Overall 18% saving has been achieved during this project work.
10. **Sachin Madakatti and Sunilakumar Biradar (Jun-2016)** they described in detail about the calculation of unknown nodal displacements analytically. Calculation of strain and stresses analytically. Analysis of bridge structure by using FEM software's NASTRAN & PATRAN. In this paper it is found that results obtained by FEA simulation is near to analytical solutions. Analytical method is observed to be tedious time consuming so the FEA software's are useful to save time. By changing the material we can improve the stability of the structure.
11. **Pramodini Naik (2015)** she presented that calculation of loads on roof trusses i.e., dead load, live load & wind load. Design for Howe truss for span of 35m as compared to Pratt truss for similar span length by angle section and tube (circular, square & rectangular) section. Above study shows that tube sections are more efficient to be more economical. She found that can be saving in terms of weight of material by 25 to 40%. Due to connection difficulties so that it suggested to adopt rectangular or square tube sections. Effectiveness of tube sections can be checked by modifying truss configurations. The structural members having larger unsupported lengths can be designed as tubular sections which will benefit overall economy.
12. **Rakesh R. Nora, Umarfarukh D. Masud and Maske Ravi G. (Oct-2015)** they determined that the effectiveness of tubular sections an industrial shed is considered analysis and design is carried out using conventional steel and tubular steel structure and also cost comparison is made for above sections. Above study shows that tubular sections are more efficient to be economical. Total saving of almost 36% in cost is achieved. Effectiveness of tubular section can be checked for different plan areas for different types of trusses.
13. **Jyoti P. Sawant and Prof. Vinayak Vijapur (Aug-2013)** After their calculation study reveals that reduction in forces of the truss members due to the external Post-tensioning. By comparing the cross-section members of the trusses by both without Post-tensioning and with Post-tensioning. They stated that after analysing from economical point of view the cost of tubular trusses is less as compared to the angular trusses. Tubular trusses consume a lot of less material when as comparing with the angular section trusses. Tabular trusses have good aesthetic view when compared to the angular trusses. In case of made up of angular trusses required more labour force when compared to the tubular trusses.

3. Model Formulation

Design of pratt type roof truss for an Industrial Warehouse building for following data :-
i) Overall length of Industrial Building = 100m
ii) Overall width of Industrial Building = 25.5m
iii) Width (c/c distance of roof column) = 25m
iv) c/c spacing of roof truss = 5m
v) Rise of truss = ¼ of span
vi) Self wt. of purlins = 318 N/m
vii) Ht. of column = 11m
viii) Roofing & Side covering = Asbestos Cement Sheet (171 N/m^2)

The building is located in industrial area, Bhuj, Gujrat, India. Both the end of truss is hinged. Use of steel grade Fe410.

3.1 Truss Analysis

The steel trusses sections have been analysing as simply supported on columns. The support at both the ends is assumed to be hinged for the purpose of analysis. The analysis of truss is done for dead load, live load and wind load according to IS: 875(Part 3)-1987.

3.2 APPROACH

i) Analysis of dead load is done by using the IS 875 (Part1) with the help of STAAD-PRO 8Vi software. ii) Analysis of live load is carried out with the help of IS 875 (Part2) by the help of STAAD-PRO 8Vi. Designing parameters is carried out with the help of IS 800, IS806 and STAAD PRO 8Vi software.

3.3 LOADING CALCULATION:

Given Data :-

Span of truss = 25 m

Type of truss = Pratt roof truss

Roof Cover = Asbestos cement sheet (171 N/m2)

Spacing of truss = 5 m c/c

Rise of truss = ¼ of span = 25/4 = 6.25 m

Ht. of shed = 11 m

Steel grade = Fe 410

1} Dimension of Truss :-

Central Rise = ¼ of span = ¼ x 25 = 6.25 m

Let θ be the inclination of roof truss with horizontal

$\theta = \text{Tan}^{-1}(6.25/12.50) = 26.565°$

Length of principle rafter = $\sqrt{(6.25)^2 + (12.5)^2} = 13.97$ m

Distance between panel pt. of principle rafter = 13.97/4 = 3.492 m

Therefore Purlins are provided at interval of 3.492 m principle rafter.

2} Load Calculation :-

2.1] :- Dead Load :-

i) Wt. of A.C. sheets = 171 N/m2

ii) Wt. of bracing = 12 N/m2 (Assume)

iii) Wt. of roof truss = (Span/3 + 5) x 10

= (25/3 + 5) x 10

=133.33 N/m2

iv) Wt. of purlins = 318 N/m (Assume)

Wt. of purlins = 318 x 5 = 1590 N

Panel length = 3.492 m

Panel length in plan = 3.492 cos (26.565) = 3 m

Load on each intermediate panel due to DL = (171+12+140) x (5 x 3) +1590
= 6435 N = 6.435 kN = 6.5 kN

Load on each end panel due to D.L. = 6.5/2 = 3.25 kN

2.2] :- Live Load :-

Angle θ = 26.565° Let us assume that no access is provided to roof. The L.L. is reduced by 20 N/m2 for each one degree above 10° slope.

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L.L. = 750 – {20 x (26.565-10)} = 418.70 N/m2

Load on each intermediate panel due to L.L. = 418.70 x (5 x 3) = 6280.5 N = 6.280 kN = 6.3 kN

Loads on each end panels due to L.L. = 6.3/2 = 3.15 kN

3} Wind Load :- (IS : 875 (Part-3) – 1987

i) Basic wind speed (Vb) :- [Cl. 5.2 pg-8 Appendix A pg-53)

Vb = 50 m/s for Bhuj, Gujrat.

ii) Design wind speed (Vz) :- (Cl. 5.3 pg-8)

Vz = k1 x k2 x k3 x Vb where, Vz = design wind speed at any height z in m/s.

k1 = probability factort (risk coefficient) (Table 1, pg- 11, Cl. 5-3.1)

k2 = Terrain ht. and structure size (factor Table 2, pg-12, Cl-5.3-2.2)

K3 = topography factor

a) Category 1 :- Average ht. of any object surrounding the structure/obstruction is less than 1.5m for ex. Open sea costs & flat treeless plains.

b) Category 2 :- Obstruction ht. between 1.5 m – 10 m. It includes airfields, open parklands and undeveloped partially buildup outside of towns and suburbs, open land adjacent to see coast.

c) Category 3 :- Closely spaced obstruction having the size of building structures upto <10m. Industrial areas fully or partially developed.

d) Category 4 :- Obstruction <25m city center, well developed industrial complexes, terrain with numerous large high closely spaced obstructions.

k1= 1.0

k2= Therefore Bhuj, Gujrat, (India) Terrain Category – 3, Class of building = C (>50m length consider) (100 length x 25Width x 11Height)

By interpolation: - k2 = 0.82 + [0.87-0.82/15-10] x (11-10) = 0.83

k3 = Assuming plane ground so that k3 = 1

Vz = Vb x k1 x k2 x k3= 1 x 0.83 x 1 x 50 = 41.5 m/s

iii) Design wind pressure :- $P_z = 0.6 \times (V_z)^2 = 0.6 \times (41.5)^2 = 1033.25\ \text{N/m}^2 = 1.033\ \text{kN/m}^2$

iv) Wind Load on roof truss :-

F = (Cpe – Cpi) x Ae x Pd Calculation of Cpe

I] For θ = 0° (Wind Angle) where Vz = design wind velocity in m/s at ht. z

Cpe = external pressure coefficient

Cpi = internal pressure coefficient

A = Surface area of structural element or cladding unit

Pd = design wind speed

= 0.8 h/w = 11/25 = 0.44 θ = 26.565°

Θ	EF	GH
20°	-0.4	-0.4
26.565°	x	x
30°	0	-0.4

By interpolation:-

EF :- -0.4 + (0-(-0.4))/30-20 x (26.565-20) = Cpe = -0.137

GH :- 0.4 = -0.4 + (-0.4-(-0.4)/30-20 x (26.565-20) = -0.4

For θ = 90° (Wind Angle θ) = 90°

Θ	EG	FH
20°	-0.7	-0.6
26.565°	x	x
30°	-0.7	-0.6

Table 5 :- External Pressure Coefficient (Cpe) for pitched roof of rectangular clad building (Cl. 6.2.2.2) pg-16

Wind load on end points = -16.23/2 = -8.11 kN

Wind load on end points = -14.42/2 = -7.21 kN

Load Combinations:-

1) 1.5 (DL+LL)
2) 1.2 (DL+LL+WL)
3) 1.2 (DL+LL-WL)
4) 1.5 (DL+WL)
5) 1.5 (DL-WL)

4. RESULT AND DISCUSSION

Using above results design is found out for required load carrying capacity. Most favorable sections are assigned to truss members and also for purlin members. Comparison done due to measurement for self-weight and cost of various elements of truss such as principal rafter, tie member, strut member, sling member and purlin member.

5. Conclusion

Above study shows that tubular sections are more efficient to be economical. Total saving of almost 36% in cost is achieved. Effectiveness and flexural strength of Tube section can be compared for different plan areas for different types of trusses. Structural members such as top chord, bottom chord and bracing between the top and bottom chord having larger unsupported lengths can be assigned tubular sections so that it will determine overall economy.

6. REFERENCES

1) Dheeraj Harod and Prof. Sumit Pahwa (Feb-2019), "Study of Structural Analysis of Roof Structure Steel Truss", International Journal for Research in Applied Science & Engineering Technology, Volume 7, Issue II, PP. 121-125.

2) Alena Mathew and Reshma (Apr-2019), "Comparative Study of Buckling and Wind Analysis by Changing Different Truss Parameter", International Research Journal of Engineering and Technology, Volume 6, Issue 4, PP. 4149-4154.

3) Alena Himanshu Makode and Sachin Nagayach (2019), "Structure optimization Assessment for Steel Truss", International Journal of Scientific Research in Civil Engineering, Volume 3, Issue 5, PP. 25-34.

4) Venkatesh K and Jayanthi V (2019), "Analysis and Design of Pre-Engineered steel truss buildings", International Journal of Intellectual Advancement and Research in Engineering Computations, Volume 7, Issue 2, PP. 2348-2079.

5) Manoj Nallanathel, Ramesh Bhaskar and Kishor (2018), Manoj Nallanathel, Ramesh Bhaskar and Kishor (2018), "Utility Design of Steel Truss A Review", International Journal of Pure and Applied Mathematics, Volume 119, Issue 17, PP. 1157-1163.

6) A Jayaraman, N Sathyakumar and S B Prasath (Dec-2018), "Cost Comparison of Roof Truss Angle Section and Channel Section Purlins by Working Stress and Limit State Method", International Journal of Recent Technology and Engineering, Volume-7, Issue-4S2, PP. 394-399.

7) Goraviyala Yogesh and Prof. K. C. Koradiya (2016), "Design and Comparison of Steel Roof Truss with Tubular Section (using SP:38 and IS:800-2007)", International Journal for Scientific Research & Development, Volume 4, Issue 2, PP. 972-974.

8) Er. Sanjeev Kumar, Brahmjeet Singh and Er. Bhupinder Singh (Mar-2016), "Optimization of Roof Truss using STAAD PRO V8i", International Journal of Recent Research Aspect, Volume 3, Issue 1, PP. 86-90.

9) Yash Patel, Yashveersinh Chhasatia, Shreepalsinh Gohil and Het Parmar (Apr-2016), "Analysis and Design of Conventional Industrial Roof Truss and Compare it with Tubular Industrial Roof Truss", International Journal of Science and Technology & Engineering, Volume 2, Issue 10, PP. 943-948.

10) Sachin Madakatti and Sunilakumar Biradar (Jun-2016), "Design and Analysis and Truss Elements", International Journal of Innovative Research in Technology, Volume 3, Issue 1, PP. 181-185.

11) Pramodini Naik (2015), "Comparison of Conventional Steel Roof Trusses with Tubular Trusses", International Journal of Engineering Research & Technology, Volume 3, Issue 19, PP. 1-4.

12) Rakesh R. Nora, Umarfarukh D. Masud and Maske Ravi G. (Oct-2015), "Comparison between Conventional (Angular) Steel Section and Tubular Steel Section", International Journal of Engineering Research, Volume 4, Issue 10, PP. 539-541.

13) Jyoti P. Sawant and Prof. Vinayak Vijapur (Aug-2013), "Analysis and Design of Tubular and Angular Steel Trusses By Post-Tensioning Method", Journal of Engineering, Computers & Applied Sciences, Volume 2, Issue 8, PP. 30-44.

14) Code of practice for use of steel tubes for buildings and structures IS 806:1968.

15) SP38(S&T)-1987-Handbook of typified designs of structures with steel roof trusses (with or without cranes) based on IS Codes (1987).

16) IS 875(Part I) – 1987: Dead Loads. Code for practice of design loads (other than earthquake) for buildings and structures.

17) IS 875(Part II) – 1987: Live Loads.
Code of practice for design loads (other than earthquake) of buildings and structures.

18) IS 875(Part III) – 1987: Wind Loads. Code of practice for design loads (other than earthquake) of the buildings and structures.

19) IS 800:2007 Code of Practice (Third Revision) for General Construction in Steel.

20) Duggal S. K. (1993) Design of steel structures, Tata McGraw Hill Publications: Chapter 14: Roof trusses.

21) Design of steel structure by S. Ramamrutham.