Design of an Industrial Structure Using Limit State Method and Working Stress Method by Angle and Compare with Tubular Section

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***Abstract*:**

Most of the design studies deal with cross section as variable. However, weight can be reduced by using different shapes i.e., Square Hollow Sections (SHS), Rectangle Hollow Sections (RHS), and Cylindrical Tubular Sections (CTS). A humble attempt has been made here to identify weight difference with Rolled Sections and Tubular Sections, and to arrive at a minimum weight of the structure. The primary aim of the present work is also to find difference of weight of Rolled Sections and Closed Formed Sections per kilogram meter for an Industrial Building. In Limit State Method of design partial safety factors for both material and load variability is considered. These partial safety factors are determined on probabilistic basis. In Working Stress Method of code IS: 800-1984 we are applying the same factor of safety for different load combinations, whereas in Limit State Method of IS: 800 – 2007, there are separate partial factors for different load combinations. The main work doing in this study is the design of an industrial building with LSM and WSM method and uses of conventional steel and compare with Tubular steel and also find the weight difference between rolled and tubular steel. Separate worksheets were prepared for all types of members that are discussed above for both the methods (WSM and LSM) for the purpose of comparison. Study shows that for the same design loads for round and square tubes i.e., Square Hollow Sections (SHS) and Rectangular Hollow sections (RHS) as compared to hot-rolled steel Angles, ISMC and ISMB indicates marginal saving of 15 to 20 percent steel.

Keywords: *Rolled section, SHS, RHS, Limit state method, Working stress method, IS:800, WSM, LSM.*

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I. INTRODUCTION

Steel has the advantages of strength and faster construction in the site. The steel sections available in basic shapes of angles, channels, plates, etc., since their dead loads are less and they are comfort in transportation. Workability is more, since it can be easily cut, welded or riveted. Steel have required no formwork during construction stage. Hence in many situations steel can be better alternative construction material. Due to their high ratio of gyration radius to area, uniform gyration radius in all directions, and high torsional rigidity, thinwalled cylindrical tubular members (CTS) are cost-effective sections for compression and torsional members. The structural effectiveness of such tubular components in building construction has just been highlighted.

A. *Conventional Steel*

Rolled steel section are that section which is manufactured in rolling mills and they can be used as structural members. They are manufactured in standard shapes and sizes for each shape. The steel section is named according to their cross-sectional shape and dimensions like channel section, I-section, T-section etc.

Fig. 1. Conventional Steel

B. *Cold Formed Section*

Use of enclosed/hollow sections, particularly tubular sections has been growing in popularity over the years. Now that fabrication by welding has become normal connection/joining practice, and in certain cases preferable to bolted structures. (Riveting having become almost obsolete), it has automatically followed that use of tubular structure should have received the attention of structural engineers. More so, because, they are predominantly welded structures, except where bolts are used for erection purpose, or for joining at site of individual pre-fabricated components. This may be attributed to the fact that the trusses by its very nature is most suitable for the optimization of the topology.

Fig. 2. Tubular Steel

C. *Tubular structural sections (RHS/SHS/CTS) have many advantages over Conventional structural sections they are follows :*

- Torsional rigidity and compressive strength of closed formed section is high, so they behave more efficiently than conventional structural members.
- Their highe ... ıst helpful, that

- Closed for ... ıth uniform prc ... nd facilitates ea
- Closed structural members also give the aesthetic appeal of structures.
- Such sections have a higher resistance to bending, also in torsion also they show a marked superiority over conventional/unconventional open sections such as channels, angles, etc.
- Such sectior ... tio on weight-t ... ıal sections. Tl ... 'or higher stres

- RHS have ... to double web. They are light to handle, allow easy shop fabrication and quick and economic erection.
- While RHS/SHS have flat sides, fabrication can use existing equipment designed for fabrication with conventional sections.
- Special profiling, cutting (i.e. making edge of section) and welding technique, usually not required associated with tubular fabrication. Joints are generally less complicated in closed form than joints with conventional sections.
- Painting cost is less as the painting surface of RHS/SHS is about 20% to 30% less than other conventional sections.

II. METHODOLOGY

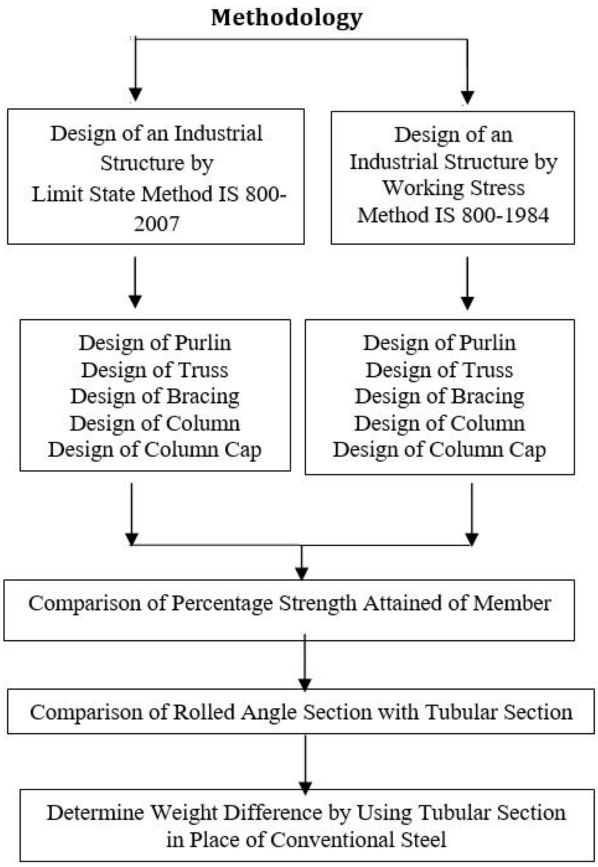

Fig. 3. Methodology for Design and Comparison of Industrial structure

III. EXPERIMENTAL PROGRAM

Height of building (upto eave) = 10 m
Length of building = 27 m
Building location = Raipur (Chhattisgarh)
Design life of building = 50 years
Basic wind speed = 39 m/s
Roof covering material = Asbestos cement sheet
Building category = category– 2, class - B
Topography = plane horizontal ground
Internal pressure coefficient = Medium (±0.5)
Truss type = Howe truss
Span of truss = 18 m
Grade of steel = Fe 410
Pitch of truss = 1/6 to 1/12
Rise of truss = 1/6 x 18 = 3 m
Slope $\tan\theta$ = 3/9
θ = 18.43°
Length of principal rafter = 9.49 m
Spacing of truss = 1/4 to 1/5 of span length
= 1/4 x 18 = 4.5 m
Number of bays = 27/4.5 = 6 bays
Half plan area = Truss spacing x span
= 4.5 x 9 = 40.5 m^2
Half slope area = Truss spacing length of principal rafter
= 4.5 x 9.49
= 42.71 m^2
Assume spacing of Purlins = 1.57m
Number of panels on truss = 9.49/1.57=6 panels
Number of purlins = 7 purlins @ 1.57 m apart

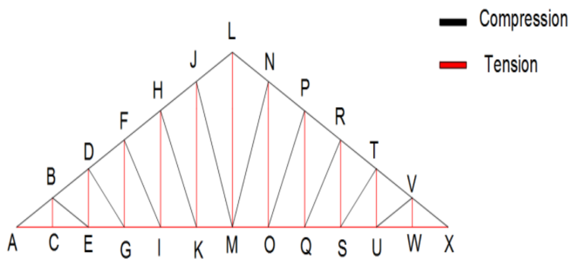

Fig. 4. Truss Configuration

A. Dead Load

D.L. assume to be acting on top panel points
weight of Asbestos cement sheet = 120 N/m^2
Fixing & services weight = 30 N/m^2
Total = 150 N/m^2
Dead Load of Roof = 150 x half slope area
= 150 x (4.5 x 9.49) = 6405 N
Assume self weight of purlin = 100 N/m^2
Load of purli = 100 x half plan area
= 100 x (4.5 x 9)
= 4050 N
Self weight of = 10 {span/3 + 5 } N/m^2
= 10 x {18/3 + 5 }
= 110 N/m^2
Weight of one t = 110 x half plan area
= 110 x (4.5 x 9)

= 4455 N

Weight of wind bracing (assume) = 12 N/m^2

= 12 x half plan area

= 12 x (4.5 x 9)

= 486 N

Total dead load = { 6405 + 4050 + 4455 + 486 }

= 15396 N = 15.396 kN

Dead Load on full panel point =15.396/6=2.57 kN

Dead Load at End panel point = 2.57/2 = 1.28 kN

B. Live Load

L.L. on Purlins = 750 – 20 (α – 10) N/m^2

= 750 - 20 (18.43 – 10)

= 581.4 N/m^2

L. L. on roof truss = 2/3 x L.L. on purlins

= 2/3 x 581.4

= 387.6 N/m^2

L.L. on Roof truss = 387.6 x half plan area

= 387.6 x (4.5 x 9)

= 15697.8 N

= 15.697 kN

Live Load on full panel point = 15.697/6 = 2.62 kN

L.L. on End panel point = 2.62/2 = 1.31 kN

C. Wind Load

Basic wind speed of Raipur V_b = 39 m/s

Design wind speed V_z = $V_b \times K_1 \times K_2 \times K_3$

K_1 = Risk Factor = 1

K_2 = Terrain height & structure size factor = 0.98

K_3 = Topography Factor = 1 { upwind slope < 3° }

Design wind speed V_z = 39 x 1 x 0.98 x 1 = 38.22 m/s

Design wind pressure P_z = 0.6 V_z^2

= 0.6 x $(38.22)^2$

= 876.46 N/m^2

Wind Load (F) = ($C_{pe} \pm C_{pi}$) x A x P_z

h/w = 10/18 = 0.56

1/2 < h/w < 3/2

Cpe = -0.8

Internal pressure coefficient Cpi = ±0.5

Wind Load = (Cpe ± Cpi) x A x Pz

= (-0.8 -0.5) x (4.5 x 9.49) x 876.46

= - 48658 N

= - 48.658 kN

Wind Load on full panel point = 48.658/6 = 8.12 kN

Wind Load on end panel point = 8.12/2 = 4.06 kN

IV. Results and Discussions

A. Load on each members and component

TABLE I. LOAD ON EACH MEMBERS AND COMPONENT

MEMBER	D.L.	L.L.	W.L.	1.5 (DL+LL)	1.5 (DL+WL)	1.2 (DL+LL+WL)
RAFTER						
AB XV	-47.85	-45.55	134.03	**-140.10**	129.27	48.75
BD VT	-43.50	-41.41	121.84	-127.37	117.52	44.32
DF TR	-39.15	-37.27	109.66	-114.63	105.76	39.89
FH RP	-34.80	-33.13	97.47	-101.89	94.01	35.45
HJ PN	-30.45	-28.99	85.29	-89.16	82.26	31.02
JL NL	-26.10	-24.85	73.11	-76.42	70.51	26.59
TIES						
AC WX	45.41	43.23	-127.19	**132.96**	-122.68	-46.26
CE WU	45.41	43.23	-127.19	132.96	-122.68	-46.26
EG US	41.28	39.30	-115.63	120.87	-111.52	-42.06
GI SQ	37.15	35.37	-104.06	108.78	-100.36	-37.85
IK QO	33.02	31.44	-92.49	96.68	-89.20	-33.64
KM OM	28.88	27.49	-80.89	84.56	-78.02	-29.42
VERTICAL						
BC BW	0.00	0.00	0.00	0.00	0.00	0.00
BE TU	1.38	1.31	-3.87	4.04	-3.73	-1.41
FG RS	2.75	2.62	-7.70	8.05	-7.43	-2.80
HI PQ	4.15	3.95	-11.62	12.15	-11.21	-4.23
JK NO	5.52	5.26	-15.46	16.16	-14.91	-5.62
LM	13.75	13.09	-38.51	**40.26**	-37.15	-14.01
INCLINED						
MEMBER	D.L.	L.L.	W.L.	1.5 (DL+LL)	1.5 (DL+WL)	1.2 (DL+LL+WL)
RAFTER						
AB XV	30.79	29.31	-86.24	**90.15**	-83.18	-31.37
BD VT	33.29	31.69	-93.24	97.47	-89.93	-33.91
DF TR	35.79	34.07	-100.24	104.78	-96.68	-36.46

B. Comparison in % strength attained of Component of Industrial Structure

TABLE II. COMPARISON OF % STRENGTH

S. N.	Component	LSM % strength attained	WSM % strength attained	Economical section
1)	Purlin	43.77%	62.24%	LSM
2)	Top Chord member	82.64 %	74.19 %	WSM
3)	Inclined member	80 %	81.17 %	LSM l
4)	Bottom Chord	75.39%	76.15 %	LSM
5)	Vertical member	63.95 %	74.37 %	LSM
6)	Rafter Bracing	10.20 %	9.01%	WSM
7)	Truss Column	16.06%	13.97 %	WSM
8)	Column Cap	T = 10 mm	T = 6 mm	WSM

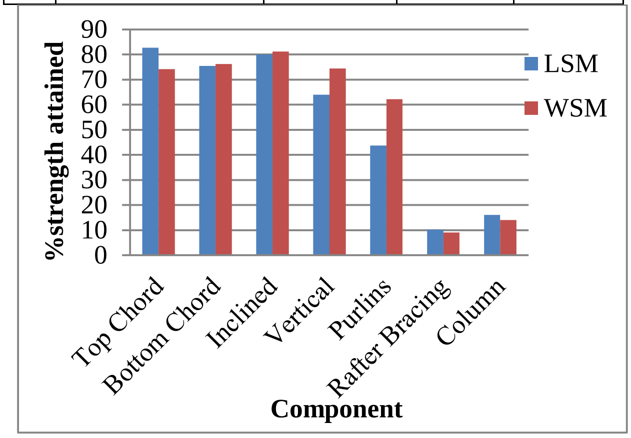

Fig. 5. Graphical Representation of % Strength Attained

C. Comparison of difference in weight between conventional & tubular steel

TABLE III. COMPARISON OF DIFFERENCE IN WEIGHT

Member	% Difference in weight using SHS	% Difference in weight using RHS
Purlin	30.18 %	29.15 %
Top chord Member	42.34 %	39.28 %
Incline Member	14.4 %	10 %
Bottom chord member	32.16 %	32.16 %
Vertical member	23.18 %	18.18 %
Rafter	3.50%	28.59 %
Average % Difference in Weight	***24.29 %***	***26.22 %***

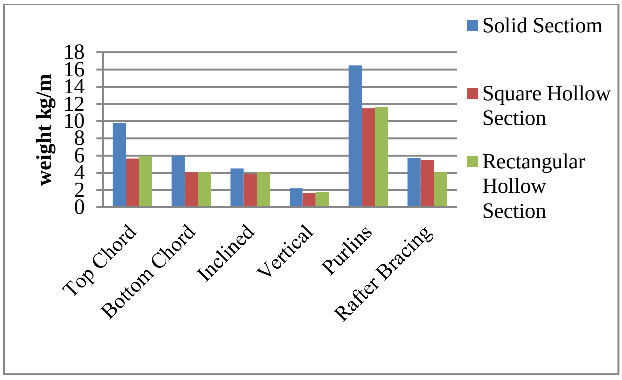

Fig. 6. Graphical Representation of Comparison in Difference in Weight

V. CONCLUSIONS

- For particular case for different types of truss profiles and all component of roof truss the DL + LL govern the design compared to DL + WL combination. It is found after above study that shape of the section also contributes for the economical design and this can be proved by the comparing the weight of the Rolled sections with Close form sections (Hollow sections), which gives less weight compared to conventional sections. Tubular sections are also good from architectural point of view. Study shows that for the same design loads for round and square tubes i.e., Square Hollow Sections (SHS) and Rectangular Hollow sections (RHS) as compared to hot-rolled steel Angles, ISMC and ISMB indicates marginal saving of 15 to 20 percent steel.
- In tension members the economy in LSM is marginal, even under consideration of wind load combination. In compression members the load carrying capacity by WSM is more than that by LSM; hence WSM is always economical. Members subjected to bending LSM gives economical design over the WSM.

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