E-ISSN: 2321–9637
Volume 1, Issue 5, December 2013
International Journal of Research in Advent Technology
Available Online at: http://www.ijrat.org

ANALYSIS OF INDUSTRIAL SHEDS USING DIFFERENT DESIGN PHILOSOPHIES

Trilok Gupta[1], Ravi K. Sharma[2]

1Assistant Professor, College of Technology and Engineering, MPUAT, Udaipur
2Professor, College of Technology and Engineering, MPUAT, Udaipur.
Email-guptatrilok@rediffmail.com

ABSTARCT:
The structural steel all over the world pre-dominates the construction scenario. Structural steel is durable and can be well molded to give the desired shape to give an ultimate look to the structure that has been constructed. In this study, comparison of truss of three types of section has been analyzed using conventional working stress method and recently adopted limit state method. The study includes different types of industrial roof trusses by using the software. It also includes the knowledge regarding steel trusses and the design philosophies with worked examples. From the results we can observe that, the sections designed using limit state method are more economical than the sections that are designed by working stress method. It can also be observed that the tube section designed by limit state method is the most economical among the three sections which are used. The limit states provide a checklist of the basic structural requirements for which design calculations may be required. Limit states design, by providing consistent safety and serviceability, ensures an economical use of materials and a wide range of applications.

Keywords: *structural steel, angle section, pipe section, tube section, limit state design.*

1. INTRODUCTION

A Structural steel is a material used for steel construction, which is formed with a specific shape following certain standards of chemical composition and strength. They can also be defined as hot rolled products, with a cross section of special form like angles, channels and beams/joints. There has been an increasing demand for structural steel for construction purposes in India.
Steel has always been more preferred to concrete because steel offers better tension and compression thus resulting in lighter construction. Usually structural steel uses three dimensional trusses hence making it larger than its concrete counterpart. There are different new techniques which enable the production of a wide range of structures and shapes, the procedures being the following:

- High-precision stress analysis
- Computerized stress analysis
- Innovative jointing

1.1 Advantages of steel as a structural material

Structural steel sections are usually used for construction of buildings, buildings, and transmission line towers (TLT), industrial sheds and structures etc. They also find in manufacturing of automotive vehicles, ships etc.
Steel exhibits desirable physical properties that make it one of the most versatile structural materials in use. Its great strength, uniformity, light weight, ease of use, and many other desirable properties makes it the material of choice for numerous structures such as steel bridges, high rise buildings, towers, and other structure.
Elasticity: steel follows hooks law very accurately.

Ductility: A very desirable of property of steel, in which steel can withstand extensive deformation without failure under high tensile stresses, i:e., it gives warning before failure takes place.
Toughness: Steel has both strength and ductility.
Additions to existing structures: Example: new bays or even entire new wings can be added to existing frame buildings, and steel bridges may easily be widened.

1.2 Disadvantages of steel as a structural material

Some of the disadvantages of steel are summarized below:
Maintenance cost: Steel structures are susceptible to corrosion when exposed to air.
Fire proofing cost: steel is an incombustible material; however, its strength is reduced tremendously at high temperature due to common fires.
Fatigue: The strength of structural steel member can be reduced if this member is subjected to cyclic loading.
Brittle fracture: under certain conditions steel lose its ductility, and brittle fracture may occur at places of stress concentration. Fatigue type loadings and very low temperature trigger the situation.

2. DESIGN PHILOSOPHIES

The aim of design is to decide shape, size and connection details of the members so that the structure being designed will perform satisfactorily during its intended life. With an appropriate degree of safety the structure should

- Sustain all loads expected on it.
- Sustain deformations during and after construction.
- Should have adequate durability.
- Should have adequate resistance to misuse and fire.
- Structure should be stable and have alternate load paths to prevent overall collapse under accidental loading.

The design philosophies used are listed below:
(i) Working Stress Method (WSM)
(ii) Limit State Design (LSD)

2.1 Working Stress Method (WSM)

This is old systematic analytical design philosophy (IS 800:1984). In this philosophy stress strain relation is considered linear till the yield stress. To take care of uncertainties in the design, permissible stress is kept as a fraction of yield stress, the ratio of yield stress to working stress itself known as factor of safety. The members are sized so as to keep the stresses within the permissible value.

2.2 Limit State Method (LSM)

In the Limit State Design philosophy (IS800:2007), the structure shall be designed to withstand safely all loads likely to act on it throughout its life. It shall also satisfy the serviceability requirements, such as limitations of deflection and vibration and shall not collapse under accidental loads such as from explosions or impact or due to consequences of human error to an extent not originally expected to occur.

The acceptable limit for the safety and serviceability requirements before failure occurs is called a *limit state*. The objective of design is to achieve a structure that will not become unfit for use with acceptable target reliability. In other words, the probability of a limit state being reached during its lifetime should be very low. In general, the structure shall be designed on the basis of the most critical limit state and shall be checked for other limit states.
Steel structures are to be designed and constructed to satisfy the design requirements for stability, strength, serviceability, brittle fracture, fatigue, fire, and durability.

3. DESIGN PROBLEM

In this study, analysis and design of a truss has been considered. The analysis of trusses for the secondary moments and hence the secondary stresses are carried out by an indeterminate structural analysis, usually using computer software. Compression members of the trusses have to be checked for their buckling strength about the critical axis of the member. This buckling may be in plane or out-of-plane of the truss or about an oblique axis as in the case of single angle sections. All the members of a roof truss usually do not reach their limit states of collapse simultaneously. Further, the connections between the members usually have certain rigidity. Depending on the restraint to the members under compression by the adjacent members and the rigidity of the joint, the effective length of the member for calculating the buckling strength maybe less than the centre-to-centre length of the joints. The design codes suggest an effective length factor between 0.7 and 1.0 for the in-plane buckling of the member depending upon this restraint and 1.0 for the out of plane buckling.
In the case of roof trusses, a member normally under tension due to gravity loads (dead and live loads) may experience stress reversal into compression due to dead load and wind load combination. Similarly the web members of the bridge truss may undergo stress reversal during the passage of the moving loads on the deck. Such stress reversals and the instability due to the stress reversal should be considered in design. The design standard (IS: 800) imposes restrictions on the maximum slenderness ratio (l/r).

Selection of configuration:

In this work, a typical truss problem has been considered for analysis and design by working stress and limit state design philosophies. Span of truss is taken as 15 m with spacing of truss in between 4 m to be built near New Delhi. Class of Building as general with life of 50 years of terrain category 2 with maximum dimensions 40 m and Width of Building: 15 m. Height of eve level is considered as 8 m with topography less than 30. Permeability of structure is assumed as medium with span of Purlins taken as 1.35 m.

Let a pitch of $\frac{1}{5}$ be provided
∴ Height of truss =$\frac{1}{5} \times 15 = 3$ m
∴ Slope of top chord = $\tan^{-1}\frac{3}{7.5} = 21.8°$
If purlins are to be placed on top panel point only, panel length should be around 1.4 m so that sufficient lap can be provided when 1.65 m A.C. sheets are used

Length of top chord =$\sqrt{7.5^2 + 3^2} = 8.078$ m
If we select 6 panels, length of panel =$\frac{80.78}{6} = 1.346$ m
Hence fan-Type truss is selected.

E-ISSN: 2321–9637
Volume 1, Issue 5, December 2013
International Journal of Research in Advent Technology
Available Online at: http://www.ijrat.org

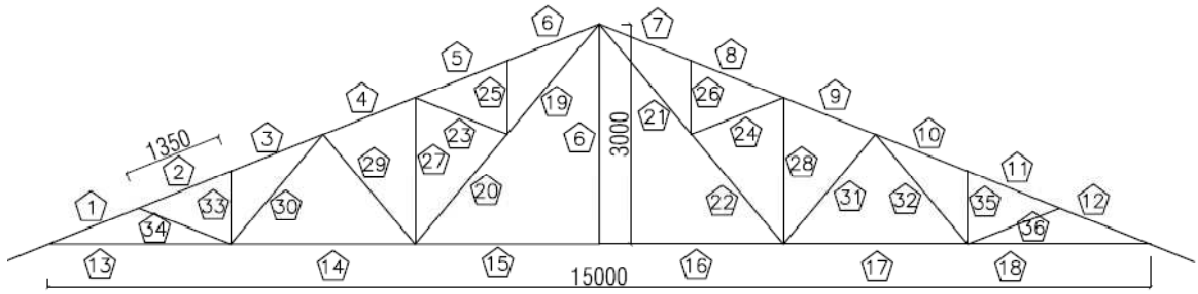

Fig.1. Configuration of truss

3.1 Load Calculations:

Loads	Pressure	Load on each intermediate panel point	Load at end point
DL	0.410 N/m^2	2.21 KN	1.47 KN
LL	0.514 N/m^2	2.77 kN	1.85 kN
Wind normal to ridge (windward side)	-1.598 kN/m^2	-8.63 kN	-5.72 kN
Wind normal to ridge (leeward side)	-1.44 kN/ m^2	-7.77 kN	-5.18 kN
Wind parallel to ridge (windward side)	-1.87 kN/ m^2	-10.11 kN	-6.74 kN
Wind parallel to ridge (leeward side)	-1.63 kN/ m^2	-8.83 kN	-5.9 kN

3.2 Analysis of truss by working stress method

Analysis of truss has been carried out by standard software STAAD Pro. The truss is analyzed for the dead load, live load and wind load forces in various members are entered in Table 1.

a) Design Forces:

It may be observed that in a member dead load and live load produce forces of same nature while wind load produces force of opposite nature. Hence for getting design forces the following combinations are to be considered:

i) DL + LL
ii) DL + LL + WL at 0˚
iii) DL + LL + WL at 90˚

From IS 800-1984, we find load factor is 1 for case (i), case (ii) and case (iii). However the permissible stresses are increased by 33.33% for case (ii) and case (iii). The design forces are entered in Table 1.

i) DL + LL
ii) 0.75 (DL + LL + WL at 0˚)
iii) 0.75 (DL + LL + WL at 90˚)

E-ISSN: 2321–9637
Volume 1, Issue 5, December 2013
International Journal of Research in Advent Technology
Available Online at: http://www.ijrat.org

Table 1: Member forces by working stress method

Members	D.L.in kN	L.L. in kN	WL in kN (ϴ=0˚)	WL. in kN (ϴ=90˚)	Case 1 = DL+ LL	Case 2 = 0.75(DL+ LL+ WL at 0 ˚)	Case 3 = (0.75 * (DL + LL + WL at 90˚))
1	-41.105	-41.105	116.09	133.438	-82.21	25.410	38.421
2	-29.807	-37.368	106.856	122.823	-67.175	29.761	41.736
3	-29.807	-37.368	110.374	126.867	-67.175	32.399	44.769
4	-28.317	-35.5	107.515	123.581	-63.817	32.774	44.823
5	-25.336	-31.763	98.28	112.966	-57.099	30.886	41.900
6	-25.336	-31.763	101.798	117.01	-57.099	33.524	44.933
7	-25.336	-31.763	94.9	112.621	-57.099	28.351	41.642
8	-25.336	-31.763	94.9	109.084	-57.099	28.351	38.989
9	-28.317	-44.5	102.97	118.36	-72.817	22.615	34.157
10	-29.807	-37.368	105.47	121.23	-67.175	28.721	40.541
11	-29.807	-37.368	102.397	117.698	-67.175	26.417	37.892
12	-32.784	-41.105	110.463	126.97	-73.889	27.431	39.811
13	30.443	38.165	-108.285	-124.466	68.608	-29.758	-41.894
14	24.908	31.226	-84.602	-97.244	56.134	-21.351	-30.833
15	16.605	20.817	-49.07	-56.41	37.422	-8.736	-14.241
16	16.605	20.817	-49.07	-56.41	37.422	-8.736	-14.241
17	24.908	31.226	-80.1	-92.071	56.134	-17.975	-26.953
18	30.443	38.165	-100.785	-115.845	68.608	-24.133	-35.428
19	10.807	13.548	-46.243	-53.154	24.355	-16.416	-21.599
20	6.484	8.041	-27.746	-31.892	14.525	-9.916	-13.025
21	10.807	13.548	-40.384	-46.42	24.355	-12.022	-16.549
22	6.484	8.041	-24.231	-27.852	14.525	-7.280	-9.995
23	-6.484	-8.041	27.746	31.892	-14.525	9.916	13.025
24	-6.484	-8.041	24.231	27.852	-14.525	7.280	9.995
25	5.535	6.939	-23.684	-27.223	12.474	-8.408	-11.062
26	5.535	6.939	-20.683	-23.774	12.474	-6.157	-8.475
27	4.323	5.42	-18.497	-21.261	9.743	-6.566	-8.639
28	4.323	5.42	-16.154	-18.568	9.743	-4.808	-6.619
29	-2.981	-3.757	12.756	14.66	-6.738	4.514	5.942
30	-2.214	-2.776	9.473	10.889	-4.99	3.362	4.424

31	-2.981	-3.737	12.754	14.66	-6.718	4.527	5.957
32	-2.214	-3.737	12.754	14.66	-5.951	5.102	6.532
33	-2.981	-2.776	9.473	10.889	-5.757	2.787	3.849
34	-2.214	-3.737	11.143	12.809	-5.951	3.894	5.144
35	-2.281	-3.737	11.138	12.803	-6.018	3.840	5.089
36	-2.244	-2.813	8.293	9.51	-5.057	2.427	3.340

[Tension +ve, Compression -ve]

b) Design of members using angle section, tube section and pipe section

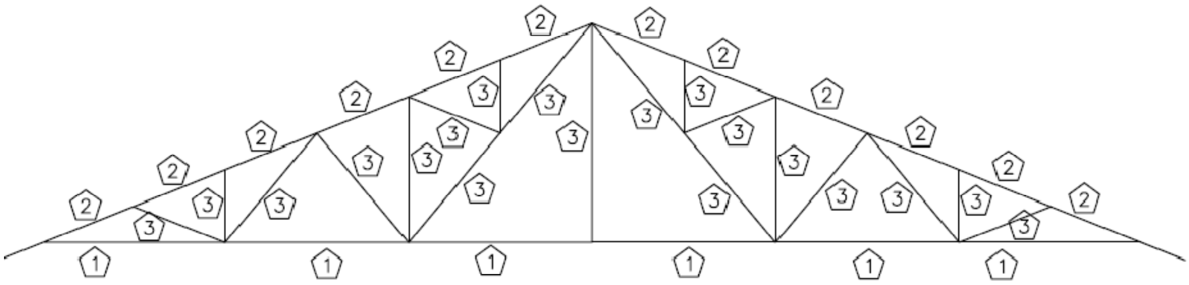

Fig. 2. Truss with member number of design for working stress method

Table 2: Comparison among Angle, Tube and Pipe Sections by WSM

Sr. no.	Angle section	Tube section	Pipe section
1	2 ISA 75×75×6	89×89×3.6	101× 6.0 M
2	2 ISA 50×50×6	70×70×4.05	88× 9.0 M
3	80×80×6	63×63×3.6	76× 1.0 M
Total Weight	5.761kN	4.752 kN	4.876 kN

3.3 Analysis of truss by limit state method

Analysis of truss has been carried out by standard software STAAD Pro. The truss is analyzed for the dead load, live load and wind load forces in various members are entered in Table 3.

a) Design Forces:

It may be observed that in members dead loads and live loads produce forces of same nature while wind load produces force of opposite nature. Hence for getting design forces the following combinations are to be considered:

i) DL + LL
ii) DL + LL + WL at 0˚
iii) DL + LL + WL at 90˚

From IS 800-2007, we find load factor is 1.5 for case (i) whereas for load case (ii) it is 0.9 for DL and LL and 1.5 for WL. Hence the factored force in the member is to be found for

i) 1.5 (DL + LL)
ii) 0.9 (DL + LL) + 1.5 WL at 0˚
iii) 0.9 (DL + LL) + 1.5 WL at 90˚

The design forces are entered in Table 3.

Table 3: Members Forces by limit state method

Members	D.L.in kN	L.L. in kN	WL in kN (ϴ=0˚)	WL. in kN (ϴ=90˚)	Case 1 = 1.5(DL+ LL)	Case 2 = 0.9(DL+LL)+ 1.5 WL at 0˚	Case 3 0.9(DL + LL) + 1.5 WL at 90˚
1	-41.105	-41.105	116.09	133.438	-123.315	100.146	126.168
2	-29.807	-37.368	106.856	122.823	-100.762	99.826	123.777
3	-29.807	-37.368	110.374	126.867	-100.762	105.103	129.843
4	-28.317	-35.5	107.515	123.581	-95.725	103.837	127.936
5	-25.336	-31.763	98.28	112.966	-85.648	96.0309	118.059
6	-25.336	-31.763	101.798	117.01	-85.648	101.3079	124.125
7	-25.336	-31.763	94.9	112.621	-85.648	90.9609	117.542
8	-25.336	-31.763	94.9	109.084	-85.648	90.9609	112.236
9	-28.317	-44.5	102.97	118.36	-109.225	88.9197	112.004
10	-29.807	-37.368	105.47	121.23	-100.762	97.7475	121.387
11	-29.807	-37.368	102.397	117.698	-100.762	93.138	116.089
12	-32.784	-41.105	110.463	126.97	-110.833	99.1944	123.954
13	30.443	38.165	-108.285	-124.466	102.912	-100.680	-124.951
14	24.908	31.226	-84.602	-97.244	84.201	-76.382	-95.345
15	16.605	20.817	-49.07	-56.41	56.133	-39.925	-50.935
16	16.605	20.817	-49.07	-56.41	56.133	-39.925	-50.935
17	24.908	31.226	-80.1	-92.071	84.201	-69.629	-87.585
18	30.443	38.165	-100.785	-115.845	102.912	-89.4303	-112.020
19	10.807	13.548	-46.243	-53.154	36.532	-47.445	-57.811
20	6.484	8.041	-27.746	-31.892	21.787	-28.546	-34.765
21	10.807	13.548	-40.384	-46.42	36.5325	-38.656	-47.710
22	6.484	8.041	-24.231	-27.852	21.787	-23.274	-28.705
23	-6.484	-8.041	27.746	31.892	-21.787	28.546	34.765
24	-6.484	-8.041	24.231	27.852	-21.787	23.274	28.705
25	5.535	6.939	-23.684	-27.223	18.711	-24.299	-29.607
26	5.535	6.939	-20.683	-23.774	18.711	-19.797	-24.434
27	4.323	5.42	-18.497	-21.261	14.614	-18.976	-23.122

E-ISSN: 2321–9637
Volume 1, Issue 5, December 2013
International Journal of Research in Advent Technology
Available Online at: http://www.ijrat.org

28	4.323	5.42	-16.154	-18.568	14.614	-15.462	-19.083
29	-2.981	-3.757	12.756	14.66	-10.107	13.069	15.925
30	-2.214	-2.776	9.473	10.889	-7.485	9.718	11.842
31	-2.981	-3.737	12.754	14.66	-10.077	13.084	15.94
32	-2.214	-3.737	12.754	14.66	-8.926	13.775	16.634
33	-2.981	-2.776	9.473	10.889	-8.635	9.028	11.152
34	-2.214	-3.737	11.143	12.809	-8.926	11.358	13.857
35	-2.281	-3.737	11.138	12.803	-9.027	11.290	13.788
36	-2.244	-2.813	8.293	9.51	-7.585	7.888	9.713

[Tension +Ve, Compression -Ve]

b) Design of members using angle section, tube section and pipe section by LSM

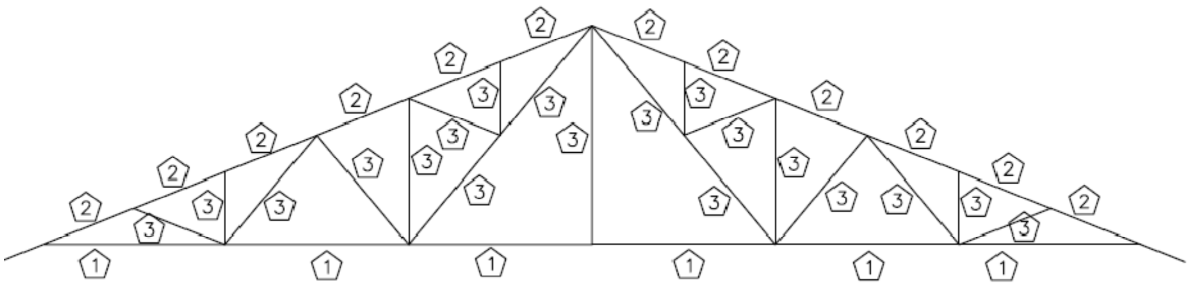

Fig. 3. Truss with member number for limit state method design

Table 4: Comparison among angle, tube and pipe Sections by LSM

Sr. no.	Angle section	Tube section	Pipe section
1	2 ISA 70×70×6	89×89×3.6	NB 88M
2	2 ISA 55×55×6	70×70×3.25	NB 76M
3	75×75×6	63×63×3.2	NB 76M
Total Weight	5.607 kN	4.310 kN	4.383kN

3.7 Comparison of designed sections between Working Stress Method and Limit State Method:

Table 5: Comparison of designed sections between working stress method and limit state method

S. No.	Section	Wt. in Working Stress Method	Wt. in Limit State Method	% Decrease w.r.t. WSM
1	Angle	5.761	5.607	2.67
2	Tube	4.752	4.310	9.30
3	Pipe	4.876	4.383	10.11

From the table we can observe that, the sections designed using Limit State Method are more economical than the sections that are designed by Working Stress Method. It can also be observed that the tube section designed by Limit State Method is the most economical among the three sections which are used.

4. CONCLUSION

The successful design of structures goes back to ancient times. For many centuries, structures were designed using common sense, trial and error, and rules of proportion acquired through experience. Their effectiveness depended on the knowledge and skills of master craftsmen.

Industrialization and the mass-production of iron and steel in the nineteenth century led to rapid changes in construction types. This in turn provided an impetus to replace the traditional trial-and-error approach for designing structures, which was slow to adapt to innovations by calculations based on scientific principles. The only scientific tools available at that time for designing structures were Newton's laws of motion and the theory of elasticity. As time went on, these scientific principles were developed into a unified, practical tool for structural calculations called allowable stress design.

In allowable stress design, the adequacy of a structure is checked by calculating the elastic stresses in it due to the maximum expected loads, and comparing them with allowable stresses. The allowable stress is equal to the failure stress of the material divided by a safety factor. Safety factors were first determined by applying allowable stress design methods to successful structures existing at that time. The safety factors for new materials were estimated in comparison with those for traditional materials by taking into account the nature of failure for the new material and its uncertainty or variability. Allowable stress design using working stress method and limit state method has formed the basis of structural codes and standards for most of this century.

In this study with the help of the results obtained we can conclude that limit state method is more reliable and economical than the working stress method for designing roof trusses.

- The consumption of steel is less in LSM with respect to WSM. For same working forces, WSM will require higher steel section than LSM.
- Working stress method is simple to use but does not give consistent values of factor of safety. That is the reason Limit states methods were developed.
- Working stress method is not outdated and will remain in practice for structures subject to fatigue, water retaining structures, steel structures and structures subject to loadings (if any) without prescribed load factor.
- The limit states provide a checklist of the basic structural requirements for which design calculations may be required.
- Limit states design, by providing consistent safety and serviceability, ensures an economical use of materials and a wide range of applications.

- Limit states design provides both a basic calculation tool for designing and evaluating civil engineering structures and a means for unifying structural codes and standards.

As far as the angle, tube and pipe sections are concerned, we can also conclude the following facts:

- Tube section is the most economical of the given three sections. It has the lightest weight amongst the three, when designed for same forces. Also, their aesthetical appearance is good.
- Angle sections are the most easily available sections as the can be easily fabricated. For same design forces, angle sections are the heaviest sections amongst the three.
- The weight of the pipe sections is more than the tube section and less than the angle section, when designed for same forces. Their use is not common in use because of the difficulty faced in their connections.

References

[1]Bhavikatti, S.S., (2009). “Design of Steel Structures”, I.K. International Publishing House Pvt. Ltd., New Delhi.
[2]BIS 1161(1998), Steel tubes for structural purposes-specifications.
[3]BIS 800 (2007), General Construction in Steel
[4]BIS 800(1984), General Construction in Steel
[5]BIS 875 (1987) Part I, Code of practice for design loads (other than earthquakes) for buildings and structures (Dead Load)
[6]BIS 875(1987) Part II, Code of practice for design loads (other than earthquakes) for buildings and structures (Imposed Load)
[7]BIS 875(1987) Part III, Code of practice for design loads (other than earthquakes) for buildings and structures (Wind Load)
[8]Dayaratham, P., (1999). “Design of Steel Structures”, S. Chand, New Delhi.
[9]Duggal, S.K., (2000). “Design of Steel Structures “, Tata McGraw-Hill Education, New Delhi.
[10]Subramanian, N., (2010). “Design of Steel Structures”, Oxford Higher Education, New Delhi.