IJCEM International Journal of Computational Engineering & Management, Vol. 21 Issue 2, March 2018
ISSN (Online): 2230-7893
www.IJCEM.org

Analysis and Design of Pratt Truss by IS 800:2007 & IS 800:1984

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Abstract

Trusses are triangular frame works, consisting of axially loaded members. They are more efficient in resisting external loads as the cross sections of all the members are nearly uniformly stressed. They are extensively used for larger spans. Truss members are regarded as being pinned joints. They are assumed to be joined together so as to transfer only the axial forces and not moments and shears from one member to the adjacent members. The loads are assumed to be acting only at the nodes of the trusses. External forces and reactions to those forces are considered to act only at the nodes and result in forces in the members that are either tensile or compressive. The top beams in a truss are called top chords and are typically in compression, the bottom beams are called bottom chords, and are typically in tension. This paper represents the analysis and design of Pratt Truss for 30m span by Limit State Method (IS 800:2007) and Working Stress Method (IS 800:1984). The data's are calculated using Indian Standard code IS 875-1975 (part I, II & III), IS 800 – 2007 using limit state method, IS 800-2007 using working stress method and the section properties of the specimens are obtained using steel table. The structure is designed under Wind loading with fixed supported condition. The main aim is to provide the method which is economical, more load carrying capacity and high flexural strength. The studies gives conclusion that the limit state method design gives high load caring capacity with minimum quantity of steel required as compare to working stress method, which results in economical design of truss design.

Keywords: *Pratt truss, Limit State Method (IS 800:2007, Working Stress Method (IS 800:1984), IS 875-1975 (Part I, II & III)*

1. Introduction

Steel roof truss is an important element in structural engineering. It is made of individual members with equal tensile and compressive forces; it is designed to behave as a single object which carries/supports a load over whole span. A roof truss is a structural framework designed to connect the space above a room and to provide support for a roof. Trusses usually occur at regular intervals. Roof truss is linked by longitudinal members such as purlins. The space between each truss is known as a bay. Software plays a important role in analysis and design of different types of structures. There are many members used in industrial building .Steel is most widely used material. The primary aim of the present work is to Analysis of roof truss of an industrial building using STAAD.PRO software.

2. Objective

Objective of this paper is to analyze and design Pratt truss of 30m span with Limit State Method (LSM) and Working Stress Method (WSM) of design of steel structures. Pratt truss model is analyzed in STAAD Pro. The truss is analyzed for the dead load, live load and wind loads. Load combination considered in design is as per Table 4, IS 800:2007 for LSM and as per Cl. No. 3.4.2.1, IS 800:1984 for WSM. Members are designed as per load combinations in WSM & LSM. Total weight of steel required is found out in both methods and results are compared.

3. Problem Statement

A truss problem has been considered for analysis and design by working stress and limit state design philosophies. Span of truss is taken as 30 m with spacing of truss is 6 m to be built near Nasik. 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 12 m with topography less than 30. Permeability of structure is assumed as medium with span of Purlins taken as 3.95 m. no. of purlins are 10.

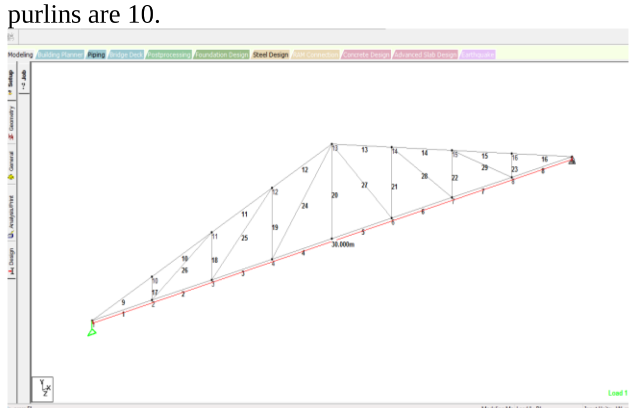

Fig.1 Node & Member Numbers of Pratt Truss

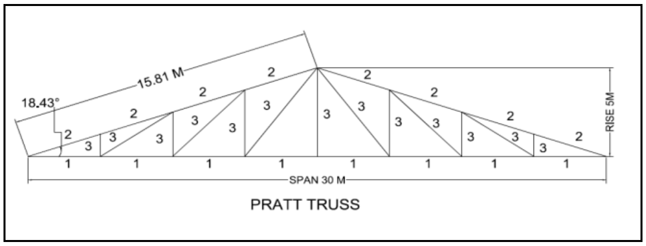

Fig.2 Grouping of Members of Pratt Truss

Let a pitch of $\frac{1}{6}$ be provided

∴ Height of truss = $\frac{1}{6} \times 30 = 5$ m

Spacing of truss = $\frac{L}{5} = \frac{30}{5} = 6$ m

∴ Slope of top chord = $\tan^{-1}\frac{5}{15} = 18.43^{\circ}$

Length of top chord = $\sqrt{15^2 + 5^2} = 15.81$

Spacing of purlin = $\frac{15.81}{8}$ = 3.952 m

Sloping area of roof truss = 2 (sloping length x spacing of truss) = 2 (15.81 x 6) = 189.72 m^2

Plan area of roof truss = span x spacing

= 30 x 6 = 180 m^2

3.1 Load Calculations

3.1.1 Dead Load Calculation

Self weight of C.G.I. = 150 N/m^2

Self weight of purlin = 100 N/m^2

i) Self wt. of truss = $\frac{span}{3} + 5 \times 10 =$ 150 N/m^2

Total self wt. of truss on plan area = 150 × 30 × 6 = 27000 N

ii) Total self wt. of C.G.I. sheet and wind bracing on sloping area

= (150 + 20) × 189.72

= 32252.40 N

iii) Self wt. of purlin = no. of purlin × spacing of truss × wt. per m^2

= 10 × 6 × 100

= 6000 N

iv) Total dead load = addition of i), ii) and iii)

= 65252.40 N

v) Dead load on each panel point = $\frac{65252.40}{8}$ = 8156.55 N = 8157 N = 8.157 kN

vi) Dead load on end point = $\frac{8157}{2}$ = 4078.5 N = 4079 N = 4.079 kN

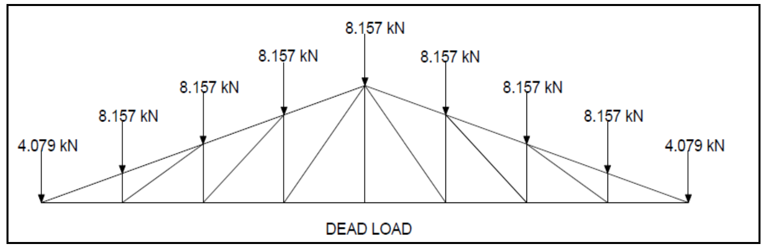

Fig.3 Dead Load per panel point

3.1.2 Live Load Calculation

i) Imposed load on truss = 750−20 (θ−10)

= 581.4 N/m^2

ii) Live load on the truss = $\frac{2}{3}$ × imposed load × plan area

= 69768 N

iii) Live load on each panel point = $\frac{69768}{8}$= 8721N = 8.721 kN

iv) Live load on end panel point = $\frac{8721}{2}$= 4360.5 N = 4361 N = 4.361 kN

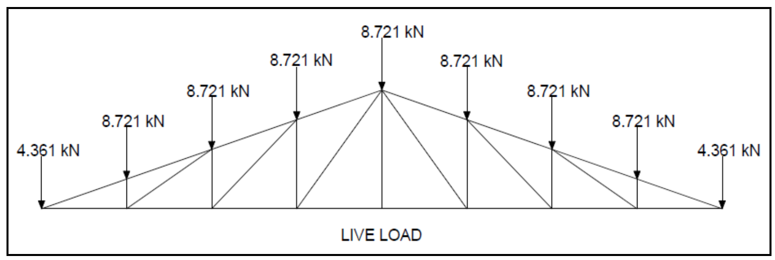

Fig.4 Live Load per panel point

3.1.3 Wind Load Calculation

i) Find design wind speed (Vz)

Vz = Vb × K_1 × K_2 × K_3

Where,

Vb = basic wind speed for Nasik region

= 39 m/sec (Table 1, IS 875-1987)

K_1= probability factor for risk coefficient of life of building= 50 years (Table 1, Cl.5.3.1, IS 875-1987) = 1

K_2= terrain, heights, structures, size factor

= for terrain category 2and class A

= 1 (Table 2, Cl.5.3.2.2, IS 875-1987)

K_3= topography factor it is taken as unity for plain load

= 1 (Cl.5.3.3 IS 875-1987)

Vz = 39 x 1 x 1 x 1 = 39 m/sec

ii) Design wind pressure (Pz) (Cl.5.4, IS 875-1987)

Pz = 0.6 $(Vz)^2$ = 0.6 x 39^2 = 912.6 N/m^2

iii) Wind load F on building

F = (Cpe ± Cpi) Pz

(Cl.6.2.1, IS 875-1987)

Cpe is found by interpolation

a) Assuming wind normal to the ridge

Angle (α)	Windward side	Leeward side
10	-1.2	-0.4
18.43	?	?
20	-0.4	-0.4

Cpe for

Windward side   Leeward side

Cpe = - 0.526   **Cpe = - 0.4**

Net pressure calculation

For windward side slope

1. -0.526 + 0.2P = -0.326P
2. -0.4 – 0.2P = -0.6P

For leeward side slope

1. -0.4 + 0.2P = -0.2P
2. -0.526 – 0.2 P = -0.726 P

b) Assuming wind parallel to the ridge

Angle (α)	Windward side	Leeward side
10	-0.8	-0.6
18.43	?	?
20	-0.7	-0.6

Cpe for

Windward side   Leeward side

Cpe = - 0.715   **Cpe = - 0.6**

Net pressure calculation

For windward side slope

1. -0.715 + 0.2P = -0.515P
2. -0.6 – 0.2P = -0.8P

For leeward side slope

1. -0.6 + 0.2P = -0.4P
2. -0.715 – 0.2 P = **-0.915P**

From the values of both windward and leeward for both cases normal to the ridge and parallel to the ridge. Considering worst case i.e. maximum value from all values

Consider (Cpe ± Cpi) = **-0.915P**

F = 0.915 × 912.6 = 835.02 N/m^2

iv) Total wind pressure

= sloping area × intensity of wind

= 189.72 × 835.02

= 158421.70 N

v) Wind load per panel point = $\frac{158421.70}{8}$ = 19802.71 N = 19.80 kN

vi) Wind load per end panel point = $\frac{19803}{2}$ = 9901.5 N = 9.90 kN

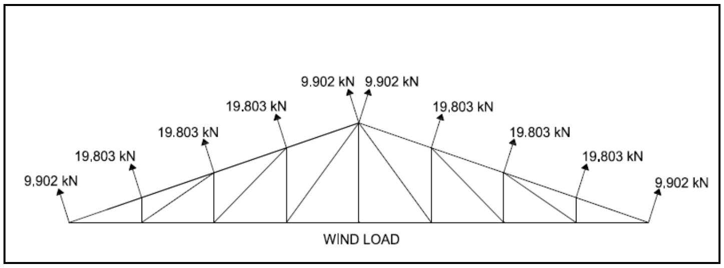

Fig.5 Wind Load per panel point

Dead load, live load and wind load per panel point are summarized in Table 1.

Table 1: DL, LL & WL per Panel Point

Loads	Load on each intermediate panel point	Load at end point
Dead load (DL)	8.157 kN	4.079 kN
Live load (LL)	8.721 kN	4.361 kN
Wind load (WL)	19.800 kN	9.902 kN

Dead load and wind load analysis is performed in STAAD Pro. Member forces are found out. Live load is found out by taking ratio of LL per panel point to DL per panel point. (8.721/8.157=1.069).

Analysis for all members of truss is as shown in Table 2 below.

Table 2: DL, LL & WL Analysis in members of Pratt Truss

Truss Members	Member	Length (m)	DL (kN)	LL (kN) = DL x 1.069	WL (kN)
Main Tie	1	3.75m	86	92	-194
	8	3.75m	86	92	-194
	2	3.75m	73	78	-163
	7	3.75m	73	78	-163
	3	3.75m	61	65	-132
	6	3.75m	61	65	-131
	4	3.75m	49	52	-100
	5	3.75m	49	52	-100

Table 2: DL, LL & WL Analysis in members of Pratt Truss (continued….)

Truss Members	Member	Length (m)	DL (kN)	LL (kN) = DL x 1.069	WL (kN)
Principal Rafter	9	3.95m	-90	-97	208
	16	3.95m	-90	-97	208
	10	3.95m	-90	-97	215
	15	3.95m	-90	-97	215
	11	3.95m	-77	-83	188
	14	3.95m	-77	-83	188
	12	3.95m	-64	-69	162
	13	3.95m	-64	-69	162
Vertical Ties	17	1.25m	-8	-9	21
	23	1.25m	-8	-9	21
	18	2.5m	-12	-13	31
	22	2.5m	-12	-13	31
	19	3.75m	-16	-17	42
	21	3.75m	-16	-17	42
	20	5m	0	0	0
Inclind Ties	24	6.25m	20	22	-52
	27	6.25m	20	22	-52
	25	5.3m	17	18	-44
	28	5.3m	17	18	-44
	26	4.51m	15	16	-38
	29	4.51m	15	16	-38

4. Design of Members

4.1 Design 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 as per Table 78. Maximum forces to be considered for design of members are calculated by the following load combinations.

i) DL + LL
ii) DL + LL + WL
iii) DL + WL

} (Cl. No. 3.4.2.1, IS 800:1984)

4.2 Design of Truss by Limit State Method:

From IS 800-2007, we find load factor is 1.5 for case (i) whereas for load case (ii) it is 1.2 for DL, LL and WL and 0.9 for DL and 1.5 for WL. Hence the factored force in the member is to be found for

i) 1.5 (DL + LL)
ii) 1.2 (DL + LL + WL)
iii) 0.9 DL + 1.5 WL

} (Table 4, IS 800:2007)

Member forces from above load calculations are tabulated below.

Table 3: Load Combinations by WSM (Cl. No. 3.4.2.1, IS 800:1984)

Truss Members	Member	Load Combinations (kN) Working Stress Method (IS 800:1984)		
		DL+LL	DL+LL+WL	DL+WL
Main Tie	1	177	-17	-108
	8	177	-17	-108
	2	152	-11	-89
	7	152	-11	-89
	3	127	-5	-70
	6	127	-5	-70
	4	101	1	-51
	5	101	1	-51
Principal Rafter	9	-187	21	118
	16	-187	21	118
	10	-187	28	124
	15	-187	28	124
	11	-160	28	111
	14	-160	28	111
	12	-133	28	97
	13	-133	28	97
Vertical Ties	17	-17	4	13
	23	-17	4	13
	18	-25	6	19
	22	-25	6	19
	19	-34	8	25
	21	-34	8	25
	20	0	0	0
Inclind Ties	24	42	-10	-32
	27	42	-10	-32
	25	36	-8	-27
	28	36	-8	-27
	26	30	-7	-23
	29	30	-7	-23

Table 4: Load Combinations by LSM (Table 4, IS 800:2007)

Truss Members	Member	Load Combinations (kN) Limit State Method (IS 800:2007) 1.5 (DL+LL)	1.2 (DL+LL+WL)	0.9DL+1.5 WL
Main Tie	1	266	-20	-214
	8	266	-20	-214
	2	228	-13	-178
	7	228	-13	-178
	3	190	-6	-142
	6	190	-6	-142
	4	152	1	-106
	5	152	1	-106
Principal Refter	9	-280	25	231
	16	-280	25	231
	10	-280	33	241
	15	-280	33	241
	11	-240	34	213
	14	-240	34	213
	12	-200	34	185
	13	-200	34	185
Vertical Ties	17	-25	5	24
	23	-25	5	24
	18	-38	7	36
	22	-38	7	36
	19	-51	10	48
	21	-51	10	48
	20	0	0	0
Inclind Ties	24	63	-12	-60
	27	63	-12	-60
	25	54	-10	-51
	28	54	-10	-51
	26	46	-9	-43
	29	46	-9	-43

5. Results & Discussion

Members are designed as per above load combinations in WSM & LSM. Sections are selected form Steel table. Results for the same are summarized in Table 5 & 6. From Table 5 & 6, it can be seen that quantity of steel required is more in working stress method as compare to limit state method.

Table 5: Design of Pratt Truss by LSM

Limit State Method (IS800:2007)			
Member	Main Tie	Principal Rafter	All Other Members
Section Required	2 ISA 90 x 90 x 8	2 ISA 100 x 100 x 8	ISA 130 x 130 x 8
Total Length	30	32	47
Weight/m (kg/m)	10.8	12.1	15.9
Total Wt. (kg)	648	774	747
Total Weight (Kg)	2170		

Table 6: Design of Pratt Truss by WSM

Working Stress Method (IS800:1984)			
Member	Main Tie	Principal Rafter	All Other Members
Section Required	2 ISA 100 x 100 x 8	2 ISA 130 x 130 x 8	ISA 130 x 130 x 10
Total Length	30	32	47
Weight/m (kg/m)	12.1	15.9	19.7
Total Wt. (kg)	726	1018	926
Total Weight (Kg)	2670		

6. Conclusion

From above analysis and design of Pratt truss following points can be concluded:

- Limit state method is more reliable and economical than the working stress method for designing roof trusses (For the same configuration of truss, total percentage saving in weight of steel is by limit state method is 23% as compare to working stress method).
- 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.
- Limit states design, by providing consistent safety and serviceability, ensures an economical use of materials and a wide range of applications.

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