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OPTIMIZATION OF DIFFERENT TYPES OF STEEL TRUSSES USING FULLY STRESSED DESIGN CONCEPT

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Abstract

To achieve the most optimized design for any structure the material which we are using must be utilized to its full capacity for most critical load cases. In this research the optimization of three different types of truss geometries (Fink, Howe and Pratt Truss) with three different spans (small- 10m, medium – 25m, large – 20m)with two different types of cross sections (Pipe and Tube) by Fully Stressed Design (FSD) approach in STAAD. Pro CONNECT Edition V22 update 9 has been performed. The total 18 number of trusses have beenoptimized in this study to achieve a target stress of 250 MPa with considering steel sections from STAAD Pro. library for Indian sections for selecting the most suitable cross section. Each truss has been subjected to 2 types of load cases. The optimized self-weight of all the trusses for each case and maximum nodal displacement for each case have been calculated. Results of the study will be helpful in the selecting and designing of a truss that must fulfil the requirement of economy as well as strength.

Keywords: Fully Stressed Design (FSD), Optimization, steel trusses

1. INTRODUCTION

1.1 Background

Trusses are used everywhere, on roofs, bridges, antenna towers, cranes, and even in the parts of the International Space Station. It allows you to create a strong structure by using efficient and economical materials. What is a truss? A truss is a structure consisting of straight elements arranged in connected trianglessuch that the whole assembly forms a stable structure. Straight members are connected at joints called nodes,and all forces are assumed to act only at these nodes. A triangle has three sides and three corners, each cornerbeing rigidly attached to the opposite side. In other words, the angles of a triangle are fixed and, unlike othershapes, nodal loads applied to the nodes of the triangle do not change the angles. There are two main reasonstriangles are used to form trusses the very first is unique geometric properties of triangles and how loads are transmitted. As a result, the truss member is subjected to axial loads (tension and compression) without bending. A pinned connection can represent any joint in the structure that means this members are free to rotate at the joint. To utilize the full capacity of truss member, it must be optimized in such a manner that the stresses generated in truss must reach allowable stress for that particular member for critical loading condition.

Hence, in Fully Stressed Design (FSD) the area can be increase or decrease according to upcoming load intensity to utilize its full member capacity to achieve the utilization ratio as unity.

Patrikar Avanti, Pathak K. K. (2016) has done research on the Fully Stresses Design of a Fink truss using STAAD.Pro software. It is based on the structural optimization, in this paper truss with 3 different spans, considered with 3 loads and a set of 27 different load cases are considered. The results of the research will help analyse and build trusses that don't waste material. (1). **Goel Shivam, Pathak K. K. (2016)** has publisheda paper on truss optimization using topology optimization. In this paper, 9 trusses with different spans and heights were considered, each truss was subjected to 9 different loading conditions, 81 cases were formulated,and each case was optimized to obtain a target stress of 100 MPa. The results of this study will help us use materials more efficiently and reduce the cost of construction. (2). **David Greiner, Jose M. Emperador, BlasGalvan and Gabriel Winter (2015)** has published a paper comparing Full and minimum constrained weightsolutions for truss structures, addressing Fully Stresses Design (FSD) and Minimum Constrained Weight (MCW) structural design optimization problems for simple discrete section type truss test cases also comparedthe sizing that best fits designs. **Mustafa Sumayah et al. (2015)** has done work on optimization of plane trusses using software STAAD.Pro. Six types of trusses were analyzed using a set of design constraints to describe their structural configuration. **Ganzreli (2013)** published a paper on an optimization method for fullyloaded structures to determine trusses using displacement constraints. **Atai Ahrari and Ali A. Atai (2013)** carried out a study on fully stressed design evolution strategy of truss.

1.2 Aim

The aim is to study how to reach optimized truss geometry of steel roof trusses using different spans and crosssections by using Fully Stressed Design (FSD) for most critical load case and compare the most optimized truss geometry with different cross-sections for applied loads considering actual site condition.

1.3 Methodology

This research will be carried out in four phases:

- The first phase is to study different truss geometries and different cross sections used in roof trusses and selecting a type of truss and cross section to be used for optimization.
- The second phase is to calculate loads acting on the truss geometry as per IS code and then convert itas a nodal lodes on panel points of the roof truss. (2 Different load combinations are considered foroptimization of steel truss)
- The third phase is to modelling and analyzing the selected truss geometry in STAAD.Pro to reach theutilization ratio as 1 to achieve Fully Stressed Design (FSD)
- The last phase is to analyze the results of the most optimized Fully Stressed Design steel trusses for 10m - small, 15m – medium, and 20m - long span using tube and pipe sections.

2. ROOF TRUSSES

The most common type of truss is the pitch truss, which has sloped top chords to facilitate the natural drainageof rainwater and the removal of dust/snow. These trusses have a greater depth in the middle. Therefore, the overall bending effect is greater in the middle of the span, but the stresses in the cord and web members are smaller towards the span and larger towards the supports. Typical span-to-maximum depth ratios for pitchedtrusses range from 4 to 8, with higher ratios being more economical for longer spans. Sloped roof trusses come in a variety of configurations.

The different types of roof trusses used for analysis were fink truss, Pratt truss, and Howe truss as follow:

2.1 Fink truss

A Fink truss as shown in figure 1.1 such truss web elements are subdivided to obtain shorter elements and aretherefore used for long spans with steep roofs.

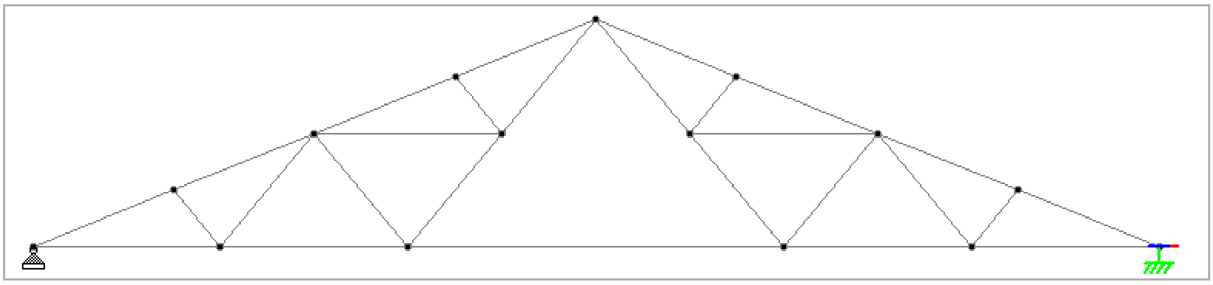

Figure 1.1: Fink Truss

2.2 Pratt Truss

In a Pratt truss as shown in figure 1.2, the web members are arranged so that the longer diagonal members arein tension and the shorter vertical members are in compression under gravity load. This allows for an efficientdesign as the short elements are under pressure. However, wind-induced lift can induce stress reversals in these elements, negating this advantage.

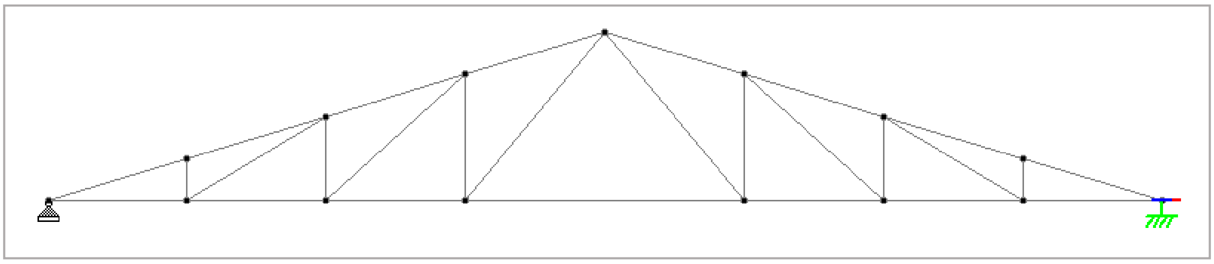

Figure 1.2: Pratt Truss

2.3 Howe Truss

Pratt's opposite is Howe truss as shown in figure 1.3. This type of truss is often used on lightweight roofs toallow long diagonals to be stressed during stress reversal due to wind loads.

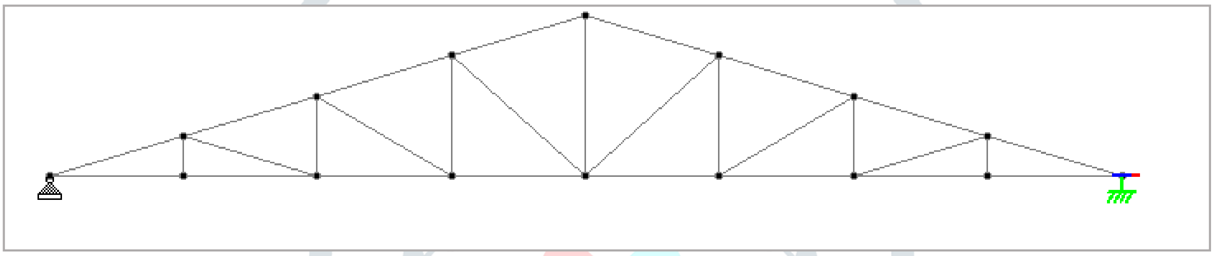

Figure 1.3: Howe Truss

Fink, Howe and Pratt type of trusses are used for optimization out of many different types of trusses considering three different span length small (10m), medium (15m) and large (20m) and their results has beencompared.

3. FULLY STRESSED DESIGN CONCEPT

FSD is perhaps the most successful of the optimality criterion methods, and the growth of this class of methods is of most interest. This approach is often used in structural design. Only stress and minimum thickness constraints are applicable for critical problems. The FSD optimality criterion statement is mentionedas per (Ganzreli, 2013):

“For the optimum design, each member of the structure which are not in there minimum gage must be fullystressed under at least one of the design load conditions”.

So when a structure no longer reaches its allowable stress its area can be reduced in order to make it fullystressed. The convergence of FSD can be done through number of iterations.

In this study target stress of 250 MPa has been considered for analysis. Since stress is inversely proportionalto the area as shown below in equation (1),

$$\sigma = \frac{F}{A} \qquad .... (1)$$

Where, σ is stress, F is applied load and A is cross-section area. Therefore in

FSD cross-sectional area of the member can be given as:

$$\sigma_o A_O = \sigma_n A_n \qquad .... (2)$$

$$A_n = \frac{\sigma_O A_O}{\sigma_n} \qquad .... (3)$$

Where, σ_o is stress in the older section, A_O is area of the older section, σ n is stress in the required section i.e.,250 MPa, A_n is area in the newer section. Hence by this formulation area in each member is calculated and target stress is achieved in STAAD.Pro.

The analysis carried out on STAAD. Pro CONNECT Edition V22 update 9 software is performed step by stepwith the following process:

1. Load calculation is made from given problem statement i.e. dead load, live load and wind loads are calculated with help of loading details given in IS: 875 (Part1 - 3), 1987 and then converted to nodal point loads for end panel points and intermediate panel points.
2. Creating models on software by using beams and nodes.
3. Giving the member properties.
4. Defining the loads which have calculated.
5. Making the load combination and assigning to the members.
6. Analysing the model and design.
7. Optimizing the model to achieve minimum quantity of steel required for the structure for most criticalload case.
8. Final results are obtained.

Before we proceed with the actual analysis and design of structure following points are considered –

1. The structural system and type
2. The selection of the construction material
3. The location, ground conditions i.e. geography of the area
4. The design concept.
5. IS codes used with the use of proper method, IS code and also all analysis and design done by STAAD.Pro CONNECT Edition V22 update 9.

4. STRUCTURAL MODELLING AND ANALYSIS

4.1 Geometry Description

Total Three types of trusses geometries are considered for optimization having following dimensions asshown in table 4.1.

Table 4.1: Truss Geometry Description for optimization

Geometry Description		
Design Data of Building	**Dimension (m)**	
Plan Dimension	10.00	30.00
	15.00	30.00
	20.00	30.00
Height of Truss	3	
No of Bay in Y Direction	6	
Typical Story Height	5	
Sections	Pipe, Tube	
Trusses	Fink, Howe, Pratt	
Grade of steel	Fe 250	
Spacing of Truss	5.00	

To simplify identifying the analysis results the different types of trusses are coded as shown in table 4.2 considering truss geometry, length and type of section used.

Table 4.2: Combination of Trusses and assigned model ID

Sr. No	Model ID	Types of Trusses	Length	Section
1	1FT10P	Fink Truss	10	Pipe
2	2FT10T	Fink Truss	10	Tube
3	3FT15P	Fink Truss	15	Pipe
4	4FT15T	Fink Truss	15	Tube
5	5FT20P	Fink Truss	20	Pipe
6	6FT20T	Fink Truss	20	Tube
7	7HT10P	Howe	10	Pipe
8	8HT10T	Howe	10	Tube
9	9HT15P	Howe	15	Pipe
10	10HT15T	Howe	15	Tube
11	11HT20P	Howe	20	Pipe
12	12HT20T	Howe	20	Tube
13	13PT10P	Pratt	10	Pipe
14	14PT10T	Pratt	10	Tube
15	15PT15P	Pratt	15	Pipe
16	16PT15T	Pratt	15	Tube
17	17PT20P	Pratt	20	Pipe
18	18PT20T	Pratt	20	Tube

4.2 Load calculations

Problem statement:

Design is done for Fink, Howe & Pratt type roof truss for an industrial building using pipe & tube section foreach type of truss for the following data:

1) Overall length of the building = 30 m
2) Overall width of the building = 10 m/ 15 m/ 20 m
3) Spacing of the trusses = 5 m
4) Rise of truss = 3 m
5) Self-weight of purlin = 200 N/ m
6) Height of structure = 9 m
7) Roofing = Asbestos cement sheets = 170 N/m^2
8) Both the ends are hinged.

The building assumed located in industrial area at Nagpur.

Load calculation

Step 1: Given data.

- Type of truss = Fink type truss
- Length = 30 m
- Span = 20 m
- Spacing of truss = 6 m
- Rise of truss =3m
- Self-weight of purlin = 160 N/m^2
- Height of column = 9 m
- Roofing = GI sheets = 200N/ m^2

Step 2: Figure 4.1 shows structural arrangement of fink truss.

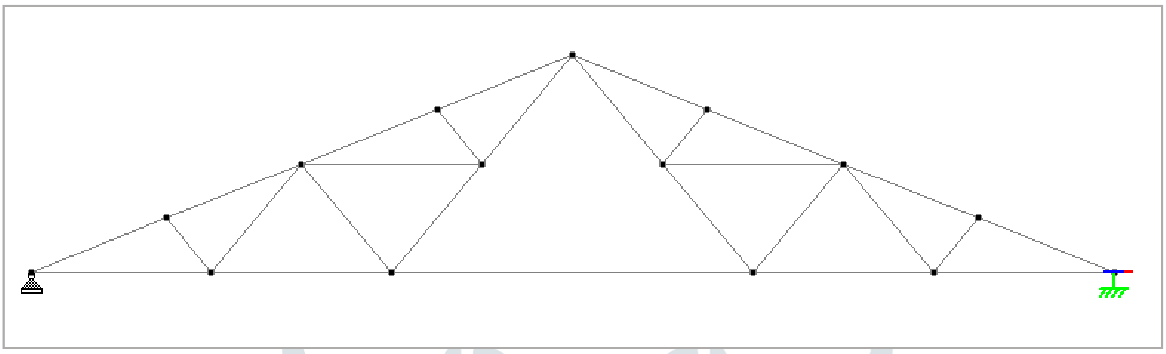

Figure 4.1: Fink truss

Step 3: Calculation of length of top chord, Sloping Area & Plan Area of roof truss

- Length of top chord = √ rise 2 + (span/2) 2 = 10.44 m
- Length of each panel = 10.44/ 4 = 2.61 m
- Sloping area of roof truss = 2 x 10.44 x 5 = 104.4 m^2
- Plan area of roof truss = 20 x 5=100 m^2
- No. of purlins = 10
- Calculation of slope of top chord
- Tan θ =3/10
- θ =16.71˚

Step 4: Calculation of dead load.

- Dead load of GI sheet = 200 N/m^2
- Self-weight of purlin = 160 N/m
- Self-weight of sheet on panel area = 104.4 x 200 = 20880.61 N
- Self-weight of purlin = 160 x 5 x 10 = 8000 N
- Total dead load = 20880.61 + 8000 = 28880.61 N
- DL on each intermediate panel points = 28880.61/ 8 = 3610.08 N
- DL on end panel points = 3610.08/ 2 = 1805 N

Step 5: Calculation of live load.

- θ = 16.71˚
- Live load = 750 - 20 (16.71-10) = 615.85 N/m2
- Live load on truss = 615.82 × 5 × 104.40 = 61584.57 N
- Live load on each end panel = 61584/ 2 = 3849.04 NStep

7: Calculation of wind load as per IS 875 (Part 3): 2015

- Basic wind velocity = V_b = 44 m/sec
- Mean probable design life of structure in years = 50 years
- Calculation of wind speed (V_Z):
- V_Z = Design wind speed at height z = $V_b \times K_1 \times K_2 \times K_3$ x K_4

Where, K_1 = 1, K_2 = 1, K_3 = 1, K_4 = 1.15

V_Z = 44 x 1 x 1 x 1 x 1.15 = 50.60 m/ s

P_z = 0.6 x Vz^2 = 0.6 x 50.60^2 = 1537.43 N

- Calculation of design wind pressure (P_d):

P_d = Design wind pressure = Kd x Ka x Kc x Pz

Where, Kd = 0.9, Ka = 0.91, Kc = 0.9

Pd = 0.9 x 0.91 x 0.9 x 1537.43 = 1132.34 N/ m^2

- Calculation of wind load:- Wind load = F = (Cpe ± Cpi) Pd

- Cpe calculation:

Assuming wind normal to the ridge

Angle (α)	Windward side	Leeward side
20	-0.40	-0.4
16.70771433	?	?
30	0.00	-0.4

By Interpolation:

- Cpe for Windward side = -0.53
- Cpe for leeward side = -0.40

As per IS 875 (Part 3): 2015, cl. no. 7.3.2.1

For windward side slope		
	1	-0.33
	2	-0.60
For leeward side slope		
	1	-0.20
	2	-0.73

Assuming wind parallel to the ridge

Angle (α)	Windward side	Leeward side
20	-0.70	-0.8
16.70771	?	?
30	-0.70	-0.8

By Interpolation:

- Cpe for Windward side = -0.70
- Cpe for leeward side = -0.80

As per IS 875 (Part 3): 2015, cl no 7.3.2.1

For windward side slope		
	1	-0.50
	2	-1.00

For leeward side slope

1	-0.60
2	-0.90

- Maximum Value from all values Cpe = -1.00
- Intensity of wind = Pd x (-(-1)) = 1132.34 N/ m^2
- Total wind pressure = sloping area × intensity of wind = 118220.27 N
- Wind load per panel point = 14777.53 N
- Wind load per end point = 7388.77

Dead load, live load and wind load per panel point for 20 m span truss are summarized in table.

Table 4.3: Panel point loads for 20 m span truss

Nodal Load on Truss calculation for 20m span truss		
Loads	Load on each intermediate panel point (KN)	Load at end point (KN)
Dead load (DL)	3.61	1.81
Live load (LL)	7.70	3.85
Wind load (WL)	14.78	7.39

Same calculations has been performed using excel spreadsheet for all truss geometries to minimize the calculation time and load results are obtained for different spans are shown in table 4.3, table 4.4 and table 4.5.

Table 4.4: Panel point loads for 10 m span truss

Nodal Load on Truss calculation for 10m span truss		
Loads	Load on each intermediate panel point (KN)	Load at end point (KN)
Dead load (DL)	2.46	1.23
Live load (LL)	1.38	0.69
Wind load (WL)	8.25	4.13

Table 4.5: Panel point loads for 15 m span truss

Nodal Load on Truss calculation for 15m span truss		
Loads	Load on each intermediate panel point (KN)	Load at end point (KN)
Dead load (DL)	3.02	1.51
Live load (LL)	3.21	1.60
Wind load (WL)	11.43	5.72

4.3 Load combination:

The following 2 load combinations which are enlisted in table 4.6 are considered for optimization of rooftruss.

Table 4.6: Load combination

Sr. No.	Load combination
1	1.5DL + 105LL
2	1.2DL + 1.2LL + 1.2WL

5. RESULTS AND DISCUSSION:

FSD was performed repeatedly for a target stress of 250 MPa and the cross-sectional area of the member wasrecorded. Since the density of steel was known, i.e. 7800 kg/m3 steel take off was calculated for the entire truss structure. In this study, the pipe and tube sections of the steel sections from STAAD Pro. library for Indian sections were used for analysis. The structure was analyzed for all load cases as mentioned in table 4.6and critical load cases were considered in the selection of truss section dimensions.

5.1 Analysis and optimization

Analysis and optimization of roof trusses are done as mentioned in chapter no 4 and 5, using Fully Stressed Design (FSD) by considering utilization ratio of actual stress to allowable stress as unity then deflection andquantity for most optimized cross section has been obtained. Details of optimized results for Fink Truss (5FT20P) for 20m span with pipe cross section are enlisted below:

5.1.1. Member and node location

In figure 5.1 node number and member numbers are mentioned to get an Idea of which location of optimizedcross section.

Same cross sectional material has been applied for group of top chord and bottom chorda and pin joints has been assigned for the intermediate members.

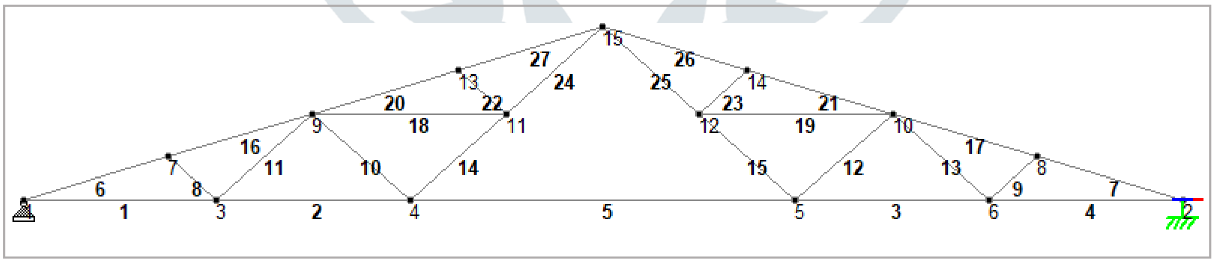

Figure 5.1: Fink Truss (5FT20P) 20m span node number and beam number.

5.1.2. Utilization ratio for different members

One of the table for optimized truss for critical load case has been given below in table 5.1 along with most critical load combination for respective truss member. Same representation of utilization ratio i.e. actual stressto allowable stress in the form of bar graph in figure 5.2 to get better understanding of results.

Table 5.1: Utilization Ratio of Optimized Fink Truss (5FT20P) 20m span with pipe cross section

Member	Design Property	Ratio (Act./Allow.)	Clause	L/C (cm^2)	Ax (cm^2)	Iz (cm^4)	Iy (cm^4)
1	PIP1270L	0.936	Sec. 9.3.2.2	1	17.3	324.997	324.997
2	PIP1270L	0.935	Sec. 9.3.2.2	1	17.3	324.997	324.997
3	PIP1270L	0.935	Sec. 9.3.2.2	1	17.3	324.997	324.997
4	PIP1270L	0.936	Sec. 9.3.2.2	1	17.3	324.997	324.997
5	PIP1270L	0.855	Slenderness	1	17.3	324.997	324.997
6	PIP1270L	0.874	Sec. 9.3.2.2	2	17.3	324.997	324.997
7	PIP1270L	0.874	Sec. 9.3.2.2	2	17.3	324.997	324.997
8	PIP269H	0.883	Sec. 9.3.2.2	2	2.38	1.7	1.7
9	PIP269H	0.883	Sec. 9.3.2.2	2	2.38	1.7	1.7

10	PIP603L	0.669	Sec. 9.3.2.2	2	5.23	21.6	21.6
11	PIP424L	0.884	Slenderness	1	3.25	6.46	6.46
12	PIP603L	0.669	Sec. 9.3.2.2	2	5.23	21.6	21.6
13	PIP424L	0.884	Slenderness	1	3.25	6.46	6.46
14	PIP603L	0.619	Sec. 9.3.2.2	1	5.23	21.6	21.6
15	PIP603L	0.619	Sec. 9.3.2.2	1	5.23	21.6	21.6
16	PIP1270L	0.829	Sec. 9.3.2.2	2	17.3	324.997	324.997
17	PIP1270L	0.829	Sec. 9.3.2.2	2	17.3	324.997	324.997
18	PIP603L	0.911	Slenderness	1	5.23	21.6	21.6
19	PIP603L	0.911	Slenderness	1	5.23	21.6	21.6
20	PIP1270L	0.946	Sec. 9.3.2.2	2	17.3	324.997	324.997
21	PIP1270L	0.946	Sec. 9.3.2.2	2	17.3	324.997	324.997
22	PIP269M	0.951	Sec. 9.3.2.2	2	1.98	1.48	1.48
23	PIP269M	0.951	Sec. 9.3.2.2	2	1.98	1.48	1.48
24	PIP603L	0.846	Sec. 9.3.2.2	1	5.23	21.6	21.6
25	PIP603L	0.846	Sec. 9.3.2.2	1	5.23	21.6	21.6
26	PIP1270L	0.951	Sec. 9.3.2.2	2	17.3	324.997	324.997
27	PIP1270L	0.951	Sec. 9.3.2.2	2	17.3	324.997	324.997

In figure 5.2 Utilization Ratio of Fink Truss (5FT20P) Members has been represented by using bar chart. Onhorizontal axis member no and optimized cross section has been mentioned and on vertical axis utilization ratio has been mentioned.

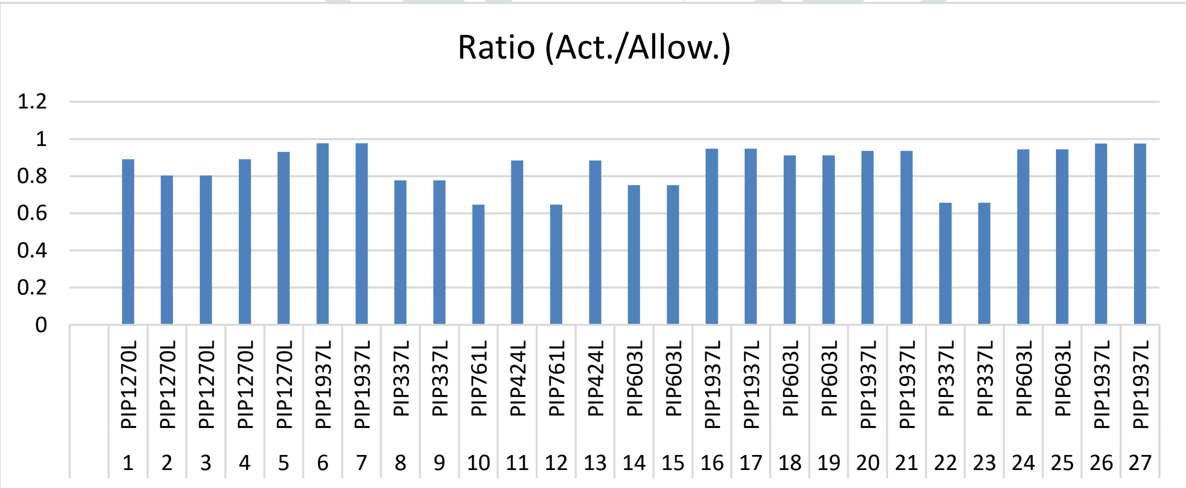

Figure 5.2: Utilization Ratio of Fink Truss (5FT20P) Members

5.1.3 Maximum node displacement summary

Maximum node displacement summary has been shown in table 4.6 for most critical load cases. It is observed that most critical load cases are number 1, (1.5DL+1.5LL) and number 2, 2(DL+LL+WL).

Table 5.2: Maximum Node Displacement Summary

	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)
Max Y	14	1	-1.928	37.974	0	38.022
Min Y	14	2	2.961	-48.542	0	48.632

5.1.4 Total weight of optimized roof truss

Steel quantity have been calculated for different type of sectional sizes as shown in table 5.3 Top chord andbottom chord sectional parameters has been kept same for entire chord section considering installation of roof truss on actual site condition.

Table 5.3: Total weight of Fink truss (5FT20P)

5FT20P - Weight of Truss		
PROFILE	**LENGTH (m)**	**WEIGHT(KN)**
PIP1270L	40.88	5.433
PIP269H	2.24	0.041
PIP603L	20.12	0.808
PIP424L	4.48	0.112
PIP269M	2.24	0.034
TOTAL		6.428

Same analysis is done for remaining truss geometries and results are obtained to get most optimized trussusing Fully Stressed Design (FSD) concept as discuss in section 5.2.

5.2 Optimized trusses deflection and steel quantity

All trusses are optimized by using Fully Stressed Design (FSD) by achieving utilization ratio near to 1 considering STAAD Pro. database for Indian cross sections, for most critical load case. Deflection summary and steel quantity in (kN) has been calculated to analyse the most optimized geometry for the considered steel trusses.

5.2.1 Deflection summary

Deflection summary of nodal points has been shown in following table for optimized cross sections for most critical load case for all 18 types of trusses. Maximum deflection for most optimized truss geometry must be minimum then and then only that geometry has been considered as good for that particular span.

5.2.1.1 Deflection Summary for 10 m truss

The most optimized truss is having minimum deflection with in most critical load case compared to other trusses. More deflection is found in following truss geometry:

- Maximum upward deflection = 14.066 mm in Fink truss with pipe cross section
- Maximum downward deflection = 11.244 mm in Pratt truss with tube cross section

Less deflection is found in following truss geometry:

- Minimum upward deflection = 12.684 mm in Howe Truss with tube cross section
- Minimum downward deflection = 10.326 mm in Fink truss with tube cross section

Please note here the maximum and minimum upward and downward deflection are mentioned for most critical load cases as shown in figure 5.5 and table 5.4 same will be applied for remaining trusses.

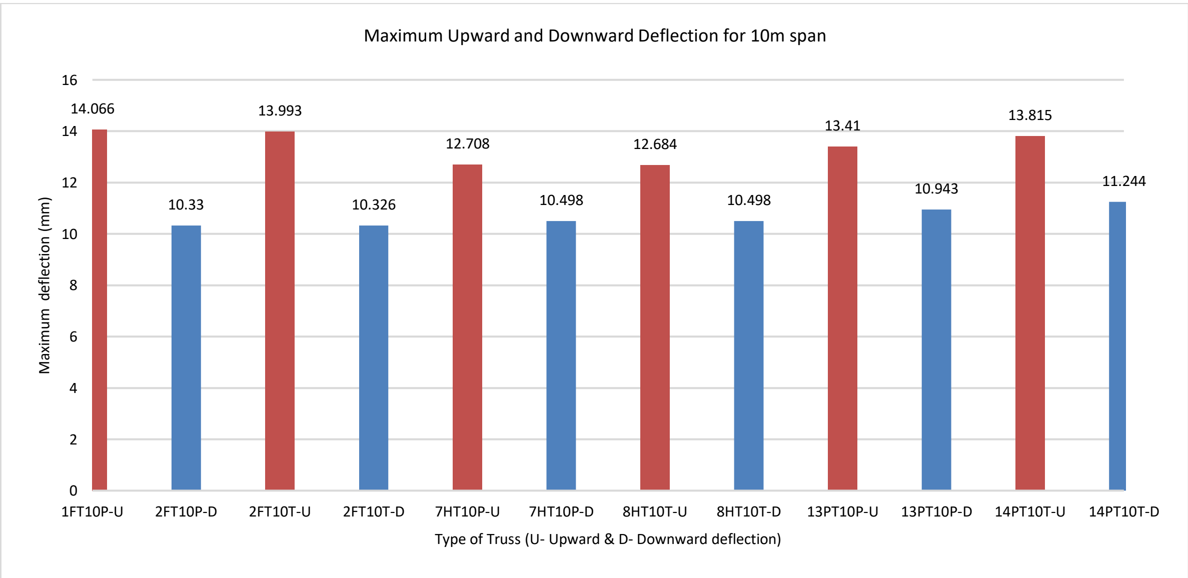

Figure 5.5: Graph showing maximum upward and downward deflection

Table 5.4, shows maximum upward and downward deflection for all three type of trusses, Fink, Howe and Pratt and conclusion has been made as above.

Table 5.4: Defection summary of optimized 10 m

Deflection Summary for 10 m Truss						
Type of Truss		**L/C**	**X (mm)**	**Y (mm)**	**Z (mm)**	**Resultant**
Flink Truss Pipe Cross Section	Max Y	1	-4.469	13.337	0	14.066
	Min Y	2	-0.148	-10.329	0	10.33
Flink Truss Tube Cross Section	Max Y	1	-4.531	13.239	0	13.993
	Min Y	2	0.018	-10.325	0	10.326
Howe Truss Pipe Cross Section	Max Y	1	-2.126	12.529	0	12.708
	Min Y	2	1.952	-10.315	0	10.498
Howe Truss Tube Cross Section	Max Y	1	-2.242	12.484	0	12.684
	Min Y	2	2.065	-10.293	0	10.498
Pratt Truss Pipe Cross Section	Max Y	1	-4.176	13.168	0	13.41
	Min Y	2	3.502	-10.685	0	10.943
Pratt Truss Tube Cross Section	Max Y	1	-4.176	13.168	0	13.815
	Min Y	2	3.502	-10.685	0	11.244

5.2.1.2 Deflection Summary for 15 m truss

More deflection is found in following truss geometry:

- Maximum upward deflection = 27.829 mm in Pratt truss with pipe cross section
- Maximum downward deflection = 25.243 mm in Howe truss with pipe cross section

Less deflection is found in following truss geometry:

- Minimum upward deflection = 25.899 mm in Pratt truss with tube cross section
- Minimum downward deflection = 23.521 mm in Fink truss with pipe cross section

Please note here the maximum and minimum upward and downward deflection are mentioned for most critical load cases as shown in figure 5.6 and table 5.5 same will be applied for remaining trusses.

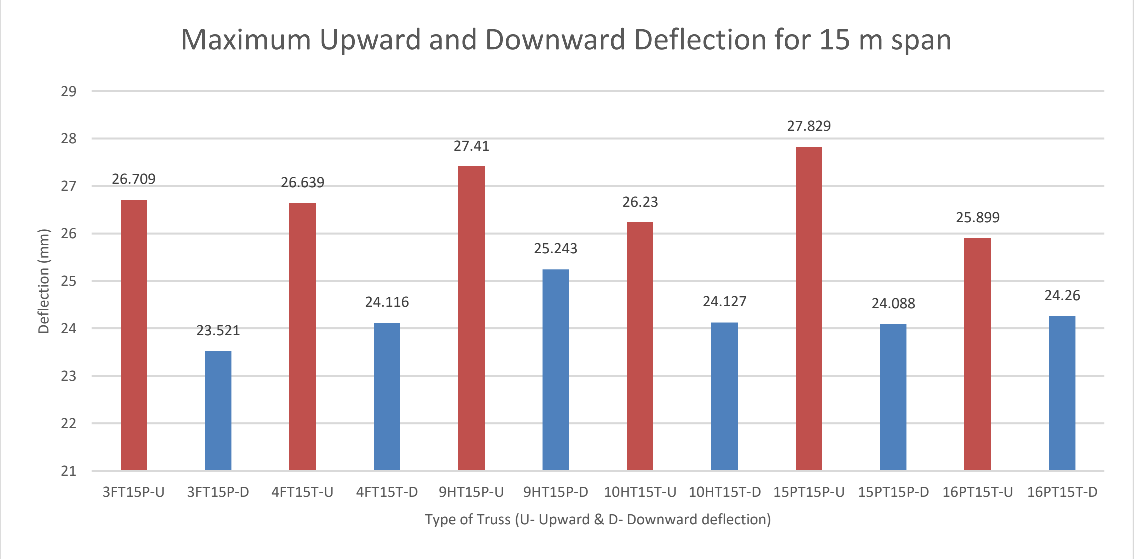

Figure 4.6: Graph showing maximum and minimum upward and downward deflection

Table 5.5 shows maximum upward and downward deflection for all three type of trusses, Fink, Howe and Pratt and conclusion has been made as above.

Table 5.5: Deflection summary of optimized 15m Truss

Deflection Summary for 15 m Truss						
Type of Truss		**L/C**	**X (mm)**	**Y (mm)**	**Z (mm)**	**Resultant**
Flink Truss Pipe Cross Section	Max Y	1	-6.257	25.966	0	26.709
	Min Y	2	0.997	-23.5	0	23.521
Flink Truss Tube Cross Section	Max Y	1	-6.258	25.893	0	26.639
	Min Y	2	5.694	-23.434	0	24.116
Howe Truss Pipe Cross Section	Max Y	1	-4.703	27.003	0	27.41
	Min Y	2	4.589	-24.822	0	25.243
Howe Truss Tube Cross Section	Max Y	1	-3.406	26.008	0	26.23
	Min Y	2	3.273	-23.904	0	24.127
Pratt Truss Pipe Cross Section	Max Y	1	-2.181	27.743	0	27.829
	Min Y	2	5.323	-23.493	0	24.088
Pratt Truss Tube Cross Section	Max Y	1	-5.775	25.247	0	25.899
	Min Y	2	5.566	-23.613	0	24.26

5.2.1.3 Deflection Summary for 20 m Truss

More deflection is found in following truss geometry:

- Maximum upward deflection = 55.604 mm in Howe truss with pipe cross section
- Maximum downward deflection = 43.713 mm in Howe truss with pipe cross section

Less deflection is found in following truss geometry:

- Minimum upward deflection = 48.632 mm in Fink truss with pipe cross section
- Minimum downward deflection = 38.022 mm in Fink truss with pipe cross section

Please note here the maximum and minimum upward and downward deflection are mentioned for most critical load cases as shown in figure 5.7 and table 5.6 same will be applied for remaining trusses.

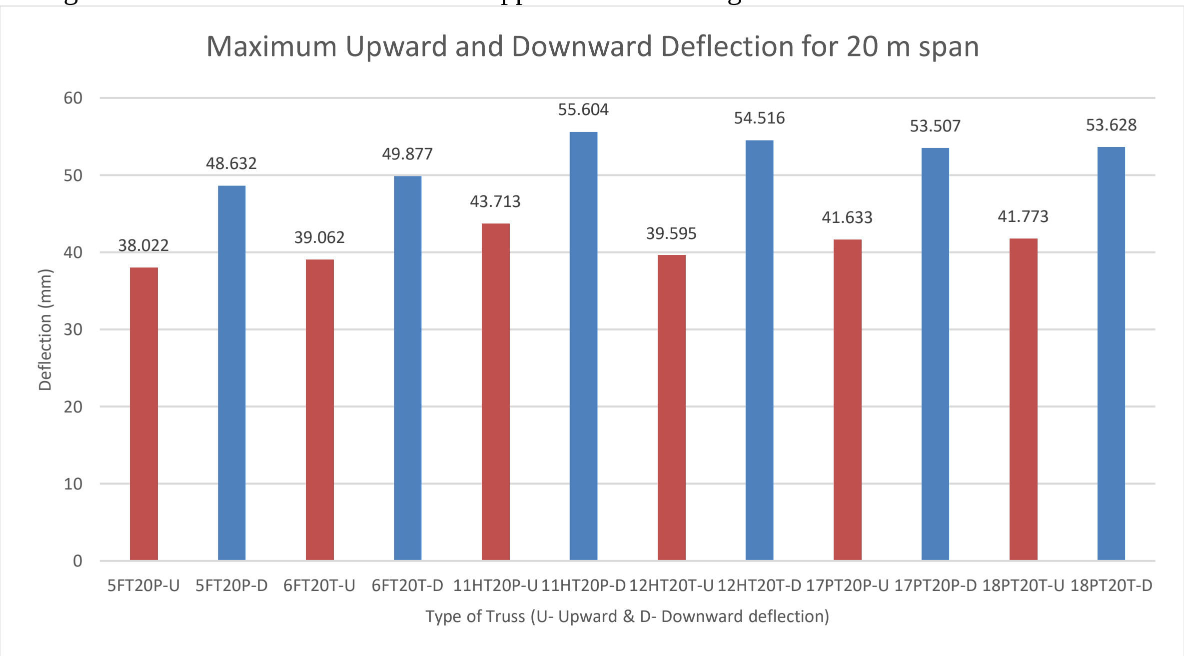

Figure 5.7: Graph showing maximum and minimum upward and downward deflection

Table 4.6 shows maximum upward and downward deflection for all three type of trusses, Fink, Howe and Pratt and conclusion has been made as above.

Table 5.6: Deflection summary of optimized 20 m Truss

Deflection Summary for 20 m Truss						
Type of Truss		**L/C**	**X in mm**	**Y in mm**	**Z in mm**	**Resultant**
Flink Truss Pipe Cross Section	Max Y	1	-1.928	37.974	0	38.022
	Min Y	2	2.961	-48.542	0	48.632
Flink Truss Tube Cross Section	Max Y	1	-1.76	39.022	0	39.062
	Min Y	2	2.734	-49.802	0	49.877
Howe Truss Pipe Cross Section	Max Y	1	-5.528	43.362	0	43.713
	Min Y	2	7.177	-55.139	0	55.604
Howe Truss Tube Cross Section	Max Y	1	-7.842	38.811	0	39.595
	Min Y	2	6.885	-54.08	0	54.516
Pratt Truss Pipe Cross Section	Max Y	1	-7.892	40.879	0	41.633
	Min Y	2	10.31	-52.504	0	53.507
Pratt Truss Tube Cross Section	Max Y	1	-7.477	41.098	0	41.773
	Min Y	2	9.776	-52.73	0	53.628

5.2.2 Quantity analysis

Quantity analysis has been performed to get optimized quantity for most critical load case for all 18 types of trusses.

5.2.2.1 Optimized quantity analysis for 10m span truss

Following observations are made in terms of optimized quantity of steel for pipe and tube cross section. The truss with minimum quantity will be the considered as most economical truss.

Minimum quantity of steel = 1.006 kN, Fink truss with pipe cross section as shown in figure 5.8 and table 5.7 below.

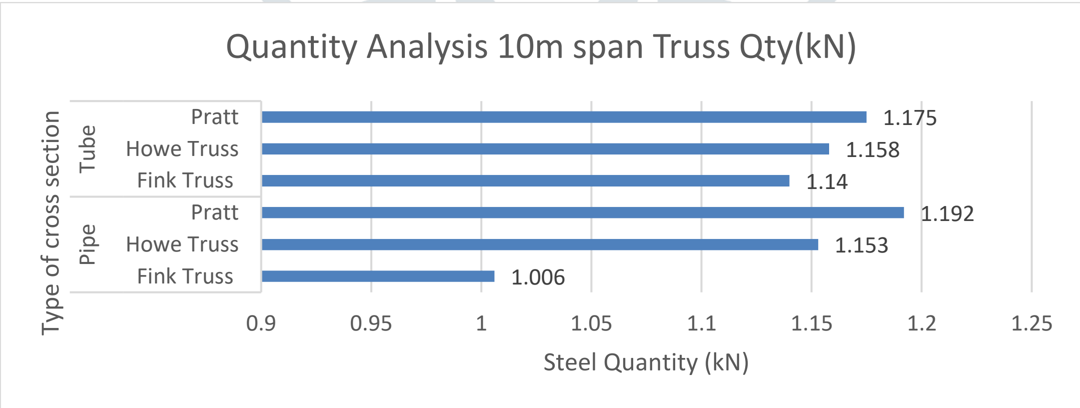

Figure 5.8: Quantity analysis 10m span truss quantity (kN)

Table 4.7 shows quantity of steel required for most optimized steel truss in kN considering most critical load cases.

Table 5.7: Quantity analysis 10m span truss

Quantity Analysis 10m span Truss		
Sections	Truss	(KN)
Pipe	Flink Truss	1.006
	Howe Truss	1.153
	Pratt	1.192
Tube	Flink Truss	1.14
	Howe Truss	1.158
	Pratt	1.175

5.2.2.2 Optimized quantity analysis for 15m span truss

Following observations are made in terms of optimized quantity of steel for pipe and tube cross section. The truss with minimum quantity will be the considered as most economical truss.
Minimum quantity of steel = 2.483 kN Fink truss with pipe cross section as shown in figure 5.9 and table 5.8 below.

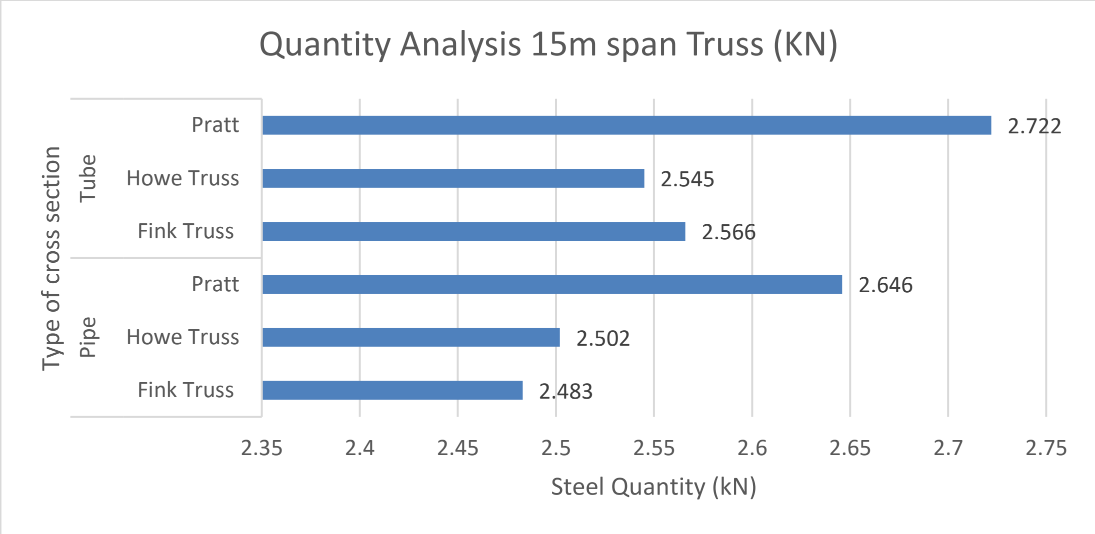

Figure 5.9: Quantity Analysis 15m span Truss (kN)

Table 5.8 shows quantity of steel required for most optimized steel truss in kN considering most critical load cases.

Table 5.8: Quantity Analysis 15 m span Truss

Quantity Analysis 15m span Truss		
Sections	Truss	(KN)
Pipe	Fink Truss	2.483
	Howe Truss	2.502
	Pratt	2.646
Tube	Fink Truss	2.566
	Howe Truss	2.545
	Pratt	2.722

5.2.2.3 Optimized quantity analysis for 20m span truss

Following observations are made in terms of optimized quantity of steel for pipe and tube cross section. The truss with minimum quantity will be the considered as most economical truss.
Minimum quantity of steel = 5.615 kN, Howe truss with pipe cross section as shown in figure 5.10 and table 5.9 below.

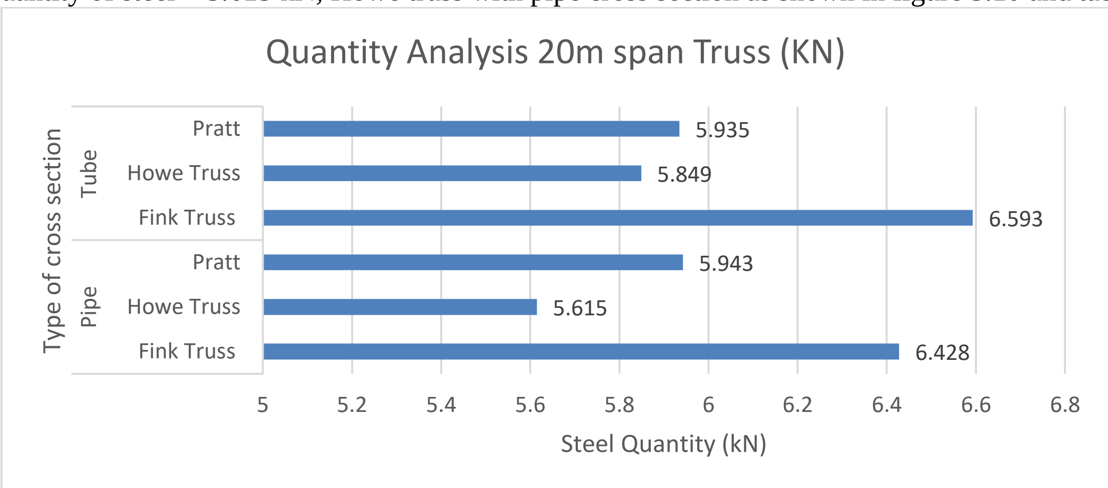

Figure 5.10: Quantity Analysis 20 m span Truss (kN)

Table 5.9 shows quantity of steel required for most optimized steel truss in kN considering most critical load cases.

Table 5.9: Quantity Analysis 20 m span Truss

Quantity Analysis 20m span Truss		
Sections	Truss	(KN)
Pipe	Fink Truss	6.428
	Howe Truss	5.615
	Pratt	5.943
Tube	Fink Truss	6.593
	Howe Truss	5.849
	Pratt	5.935

6. CONCLUSION

Following conclusions are made based on obtained results of Fully Stressed Design (FSD) of three different truss geometries (Fink, Howe and Pratt truss) with three Different spans (small-10m, meadium-15m and large-20m) and considering two different cross sections (pipe and tube) as per available cross sections in STAAD.Pro library for Indian sections.

6.1 Most optimized truss for deflection criteria

The most optimized truss for deflection criteria will be having minimum deflection for most critical load case amongst all other trusses.

1. Best Truss for small -10 m span
   - Minimum upward deflection = 12.684 mm in Howe Truss with tube cross section
   - Minimum downward deflection = 10.326 mm in Fink truss with tube cross section
2. Best Truss for medium - 15 m span
   - Minimum upward deflection = 25.899 mm in Pratt truss with tube cross section
   - Minimum downward deflection = 23.521 mm in Fink truss with pipe cross section
3. Best Truss for large - 20 m span
   - Minimum upward deflection = 48.632 mm in Fink truss with pipe cross section
   - Minimum downward deflection = 38.022 mm in Fink truss with pipe cross section

6.2Most optimized truss having minimum quantity

The Most optimized roof truss in terms of quantity will be having minimum weight compared to other roof trusses.

1. Best Truss for small -10 m span
   In terms of quantity: Fink truss with pipe cross section
2. Best Truss for medium - 15 m span
   In terms of quantity: Fink truss with pipe cross section
3. Best Truss for large - 20 m span
   In terms of quantity: Howe truss with pipe cross section

From above observations we can conclude that the behavior of truss geometry is different for different spans lengths.

- In terms of quantity for small and medium span Fink truss with pipe cross section, and for larger span Howe truss gives minimum quantity for most critical load combination.

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