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Optimum Plane Trusses among Different Cross Sections

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ABSTRACT

This work aims to find the optimum cross section shape that offers optimum plane trusses. The expression optimal structure is extremely vague because of the structure may be optimal in different aspects. These aspects are known as objectives. Weight optimization of structures plays a major role due to its significant effect to overall costs. The research uses finite element method by the aid of STAAD software for analysis and sizing optimization design for six trusses types which are common used for span12m. Different cross sections shapes are used to verify the one that gives optimal truss weight. Many of previous existing researches employ the areas of cross sections as design variables without heightening to the shape of cross section at the beginning of the process: accordingly the result area may be not sufficient in case that the designer do not select the effective shape than others. Results of this paper show that the chosen cross section shape has a significant impact on the weight trusses optimization which is formulated selecting a set of design variables that represent the structural and architectural configuration of the system.

1. Introduction

The structural steel has become exhaustively used for different constructions anywhere in the world because of its many specific attributes that will be very much recommended for construction. Structural steel is durable that will be very well moulded to offer the required shape to give an ultimate view the structure that has been designed.

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The optimum design of a truss should satisfy the minimization of the cost of the truss and the role of various constraints such as proper stress levels, displacement limits and element stability conditions. Nowadays, the cost is not directly related to the mass of material, but the cost of labor, building difficulties, has been also considered. However the truss's weight is an effective function due to its significant effect to overall costs. The designer's goal is to reach the minimum of the material quantity while the truss is as stiff as possible.

The parameters of the truss that are changed through the optimization process, called the design variables. The design variables may be discrete or continuous. Although the utilize of continuous optimization process more explicit, will lead to unfeasible design due to unavailable cross sections which needs to round these result values by the nearest commercial cross sections (Croce & Ferreira, 2004).

The optimum shape of a truss or sizing should not be optimized independently, because of its' impact on the sizing optimum design. Thus many studies such as Gil & Andreu (2001), Wang, Zhang, & Jiang (2002), Hultman (2010) combined the shape and sizing problems in their applied optimization methods. However, the configuration of initial structure is completely different from the final configuration after the optimization process.

In this article, still, a fixed shape during sizing optimization is to be discussed, the chosen shape of (Fink fan, Fan, Fink, Howe, Pratt, mansard) for the economical span lengths of 12meters,are to be tested among different cross sections optimizations (Davison & Owens, 2012; Kumar, 2011)

2. Methodology

Following procedures for particular truss shape is to be applied as shown in Figure 1:

2.1 Generate model of a truss

Generate basic input data of geometry that demanded to form the model in STAAD Pro software like joint coordinates, member number, member incidences height of the truss, span length. Select cross section and define material, Select support condition. Add load cases and the combination of loads.

2.2 Perform analysis after creating STAAD file

The main function of this step is to pass all required input data of truss for STAAD software to implement analysis.

2.3 Perform steel design

After giving common steel design command, check code, define parameters. Then, select optimized command. This command is to select optimum section size for all members using a procedure consisting of multiple cycles of analysis as well as iteration on section sizes until an overall structure least weight is obtained from the current chosen cross section. Then perform steel design in STAAD.

2.4 Result

Call STAAD results and result interpretation.

2.5 Repetition

Change the cross section shape, repeat analyses and design, the input data of geometry, support condition, loading cases, and span length are still the same.

2.6 Analysis for optimum

After calling the results, the data are to be analyzed to investigate the effective cross section that gives optimum truss weight from the optimum for this type of the truss.

2.7 Economical S/D

Change the depth of the truss to assign the economical S/D. Re-apply the steps from 2.1 to 2.6.

2.8 Truss type

Change the type of the truss and re apply the above orders.

2.9 Final result

Analyse the results to find the optimum truss type weight among the different cross sections shapes.

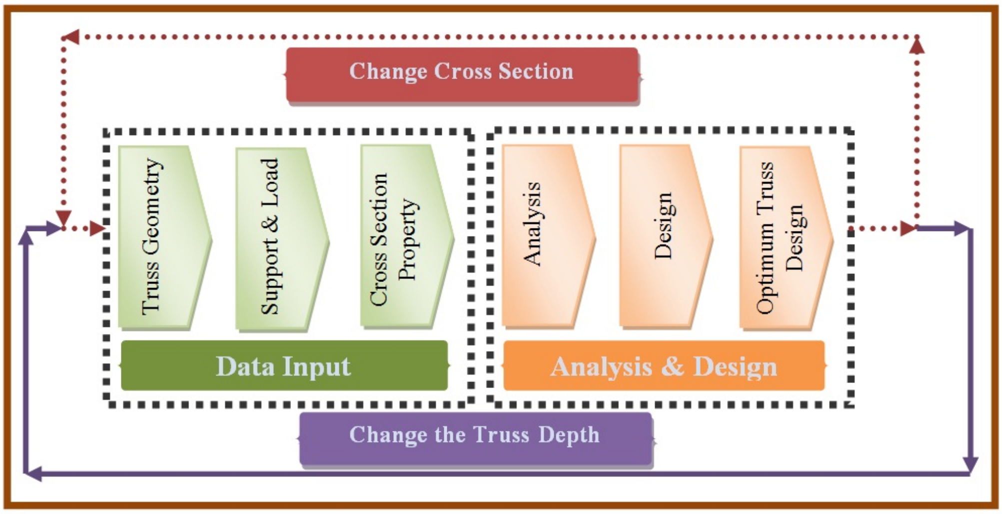

Figure1: Research methodology

The properties of the material and constraints are displayed in Table 1.

Table 1: Truss data.

Span length	12m
Young modulus (e)	205GPa
Specific weight-steel	76.8195kN/m3
Design strength of steel	275000kN/m2
Poisson's ratio	0.30
Dead load (unit weight cladding, purlins, and services load). Self-truss weight assigned in Staad software in each case.	0.38kN/m2
Live load	0.75kN/m2
Available Database Contains angle-sections (UA), C sections, TUB-sections and PIP-sections	

3. Results and Discussion

Table 2 shows the comparison of optimum weight of each truss type among different cross sections (angle, tube, channel, and pipe) with the same span 12m but with various spans over a depth ratio of 4, 5, 6, 7, and 8. The purpose is to compare whether the least truss weight among deferent cross section shape is still the same for each truss type (Fink fan, Fan, Fink, Howe, Pratt, and Mansard).

Table 2: Optimum Weights of Truss among Different Cross Sections and Types of Truss.

Shape of Truss	Depth (m)	S/D	Opt. W. [kN] (Angle)	Opt.W. [kN] (tube)	Opt.W. [kN] (Channal)	Opt.W. [kN] (Pipe)
Fink fan	3	4	1.729	1.125	3.565	1.176
Fink fan	2.4	5	1.722	1.127	3.639	1.165
Fink fan	2	6	1.766	1.208	3.82	1.242
Fink fan	1.7	7	1.824	1.259	3.719	1.273
Fink fan	1.5	8	1.864	1.306	3.656	1.320
Fan	3	4	2.002	1.284	3.291	1.195
Fan	2.4	5	1.93	1.22	3.308	1.154
Fan	2	6	2.144	1.251	3.75	1.159
Fan	1.7	7	2.247	1.261	3.668	1.243
Fan	1.5	8	2.289	1.333	3.617	1.228
Fink	3	4	1.818	1.124	3.707	1.149
Fink	2.4	5	1.789	1.167	3.5	1.148
Fink	2	6	1.839	1.205	3.554	1.152
Fink	1.7	7	1.912	1.247	3.608	1.218
Fink	1.5	8	2.021	1.276	3.694	1.271
Howe	3	4	1.736	1.156	4.206	1.233
Howe	2.4	5	1.607	1.09	3.684	1.56
Howe	2	6	1.551	1.072	3.684	1.139
Howe	1.7	7	1.526	1.089	3.486	1.142
Howe	1.5	8	1.53	1.116	3.36	1.182
Pratt	3	4	1.787	1.184	3.866	1.183
Pratt	2.4	5	1.64	1.102	3.599	1.146
Pratt	2	6	1.547	1.049	3.457	1.085
Pratt	1.7	7	1.609	1.11	3.377	1.137
Pratt	1.5	8	1.637	1.144	3.27	1.164
Mansard	3	4	1.548	1.073	4.014	1.147
Mansard	2.4	5	1.494	1.033	3.613	1.11
Mansard	2	6	1.445	0.974	3.358	1.07
Mansard	1.7	7	1.511	1.001	3.602	1.088
Mansard	1.5	8	1.504	1.028	3.621	1.108

Table 3 is based on the analyses results of Table 2: firstly, Fink fan, Fink, Howe, Pratt, mansard trusses, the minimum value of optimum weight is with tube section. In spite of the fan truss with the pipe section as shown in Figures 2, 3, and 4.

Table 3: Optimum Weights of Different Truss Types among Each Cross Section.

Shape of Truss	Angle		Tube		Channal		Pipe		Opt.W. for each Shape	S/D	Cross Section	Min Of All
	kN	S/D	kN	S/D	kN	S/D	kN	S/D				
Fink fan	1.722	5	1.125	4	3.565	4	1.165	5	1.125	4	Tube	0.974 Mansard (tube)
Fan	1.930	5	1.220	5	3.291	4	1.154	5	1.154	5	Pipe	
Fink	1.789	5	1.124	4	3.500	5	1.148	5	1.124	4	Tube	
Howe	1.526	7	1.072	6	3.360	8	1.139	6	1.072	6	Tube	
Pratt	1.547	6	1.049	6	3.270	8	1.085	6	1.049	6	Tube	
Mansard	1.445	6	0.974	6	3.358	6	1.070	6	0.974	6	Tube	

Figures 2, 3, and 4 show clearly the comparison of optimum weight by using angle, tube, channel, and pipe sections, for S/D (4, 5 6, 7, and 8).

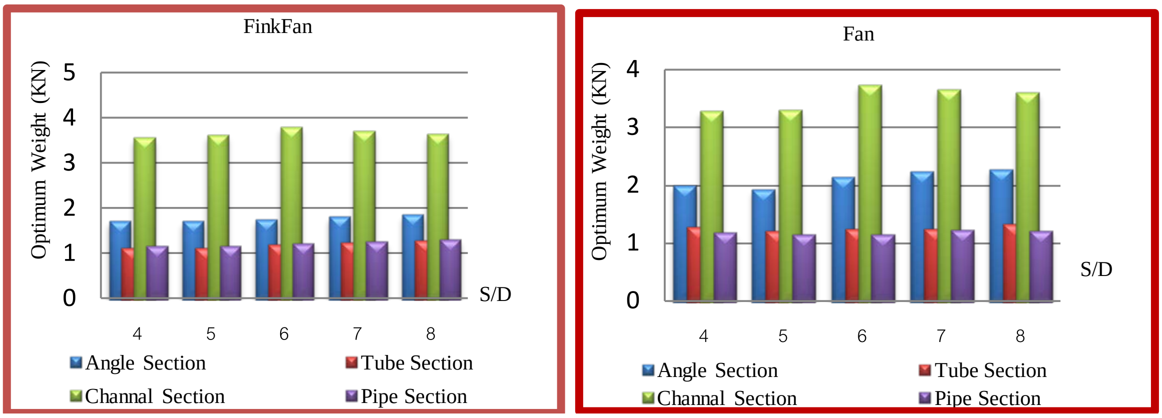

Figure 2: Optimum Fink fan and Fan Truss Weights among Different Cross Sections under Various S/D.

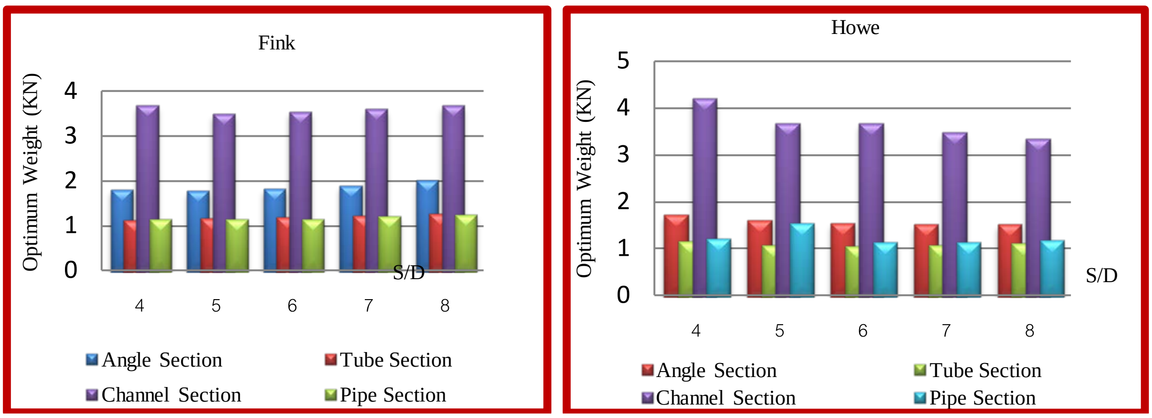

Figure 3: Optimum Fink and How Truss Weights among Different Cross Sections under Various S/D.

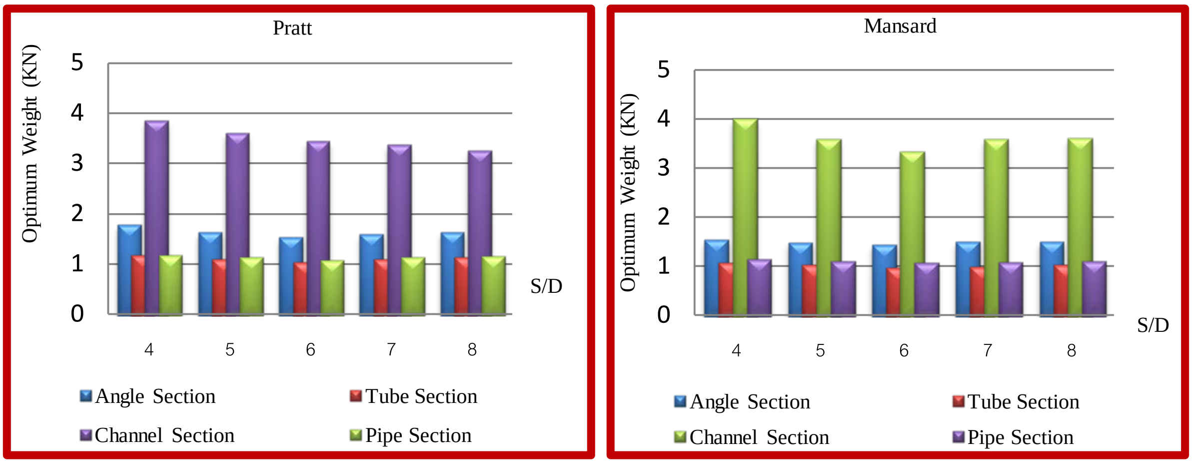

Figure 4: Optimum Pratt and Mansard Truss Weights among Different Cross Sections under Various S/D.

In addition, for the same type of truss, such as Fink fan, in comparison of the values (1.722, 1.125, 3.565, 1.165) kN corresponding the angle, tube, channel, pipe sections, respectively, the difference between the lowest optimum truss weight with tube section (1.125) and the highest value of it with channel section (3.565) kN is 216.9% as shown in Figure 5.

For fan truss, in comparison of the values (1.93, 1.22, 3.291, 1.154) corresponding the angle, tube, channel, pipe sections respectively, the difference between the lowest optimum truss weight with pipe section (1.154) and the highest value of it with channel section (3.291) is 185.2% as shown in Figure 5.

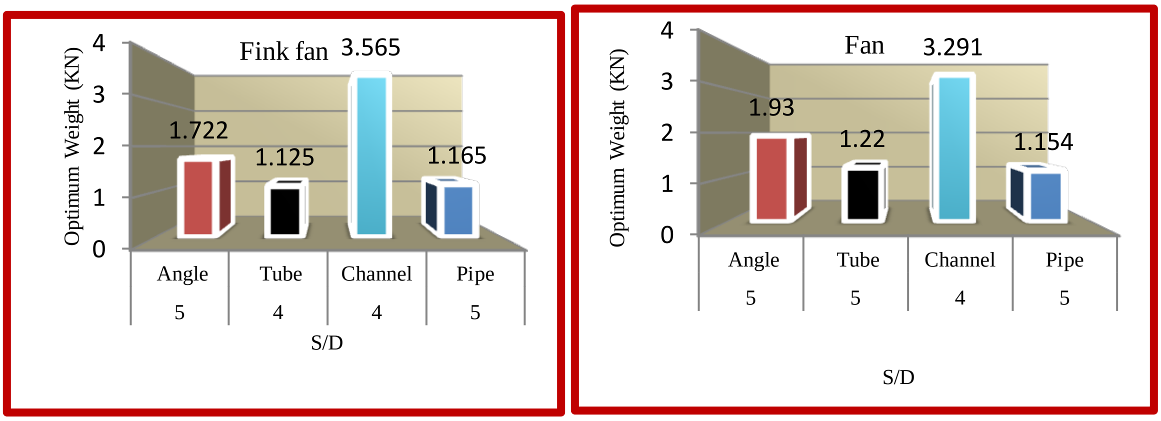

Figure 5: Optimum Fink fan and Fan Truss weights among different cross sections under optimum S/D.

For fink truss as shown in Figure 6, in comparison of the values (1.789, 1.124, 3.5, 1.148) corresponding the angle, tube, Channel, pipe sections respectively, the difference between the lowest optimum truss weight with tube section (1.124) kN and the highest value of it with Channel section (3.5)kN is 211%.

Howe truss as shown in Figure 6, in comparison of the values (1.526, 1.072, 3.36, 1.139) kN corresponding the angle, tube, Channel, pipe sections respectively, the difference between the lowest optimum truss weight with tube section (1.072) kN and the highest value of it with Channel section (3.36) kN is 213.

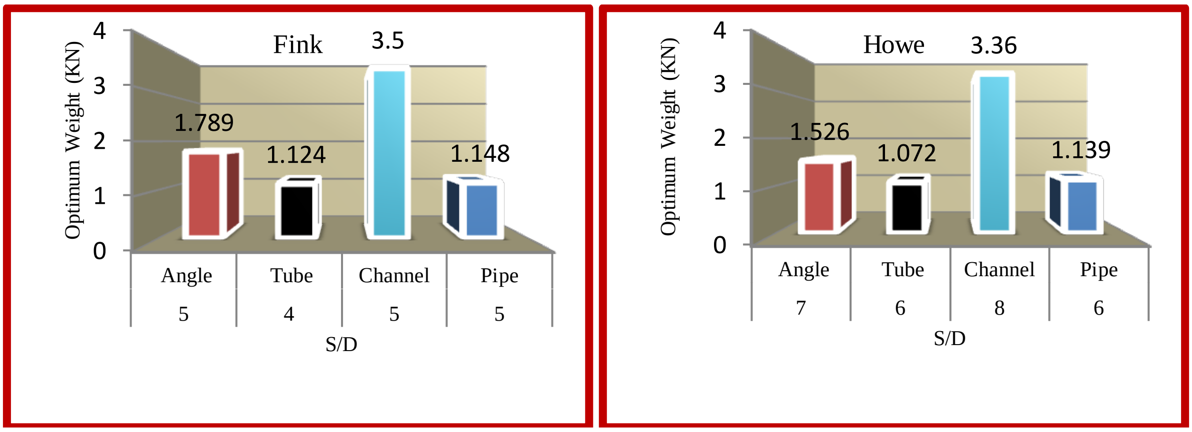

Figure 6: Optimum Fink and Howe truss weights among different cross sections under optimum S/D.

Pratt truss that shown in Figure 7, in comparison of the values (1.547, 1.049, 3.27, 1.085) kN. corresponding the angle, tube, Channel, pipe sections, S/D 6, 6, 8, 6 respectively, the difference between the lowest optimum truss weight with tube section (1.049) kN and the highest value of it with Channel section (3.27) kN is 211 %.

Mansard truss as shown in Figure 10, in comparison of the values (1.445, 0.974, 3.358, 1.070)kN corresponding the angle, tube, channel, pipe sections respectively, the difference between the lowest optimum truss weight with tube section (0.974) kN and the highest value of it with Channel section (3.358) is 244%.

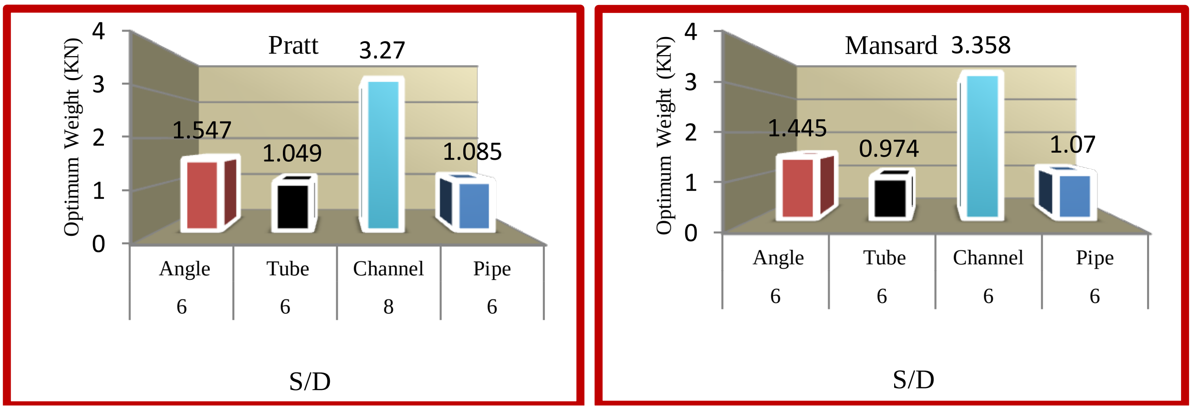

Figure 7: Optimum Pratt and Mansard truss weights among different cross sections under optimum S/D.

Secondly, when compared between the results (1.125, 1.154, 1.124, 1.072, 1.049, 0.974) kN for different types of trusses, it shows that the difference is 25% between the found lower value of optimum mansard truss weight (0.974) kN and highest value of optimum fan truss weight (1.154) kN as shown in Figure 8.

Finally, Figure 8 also shows that the minimum value of optimum weight is with S/D=4 for fink fan and fink trusses while it is 5 for fan truss, but it is still 6 for Howe, Pratt, and mansard.

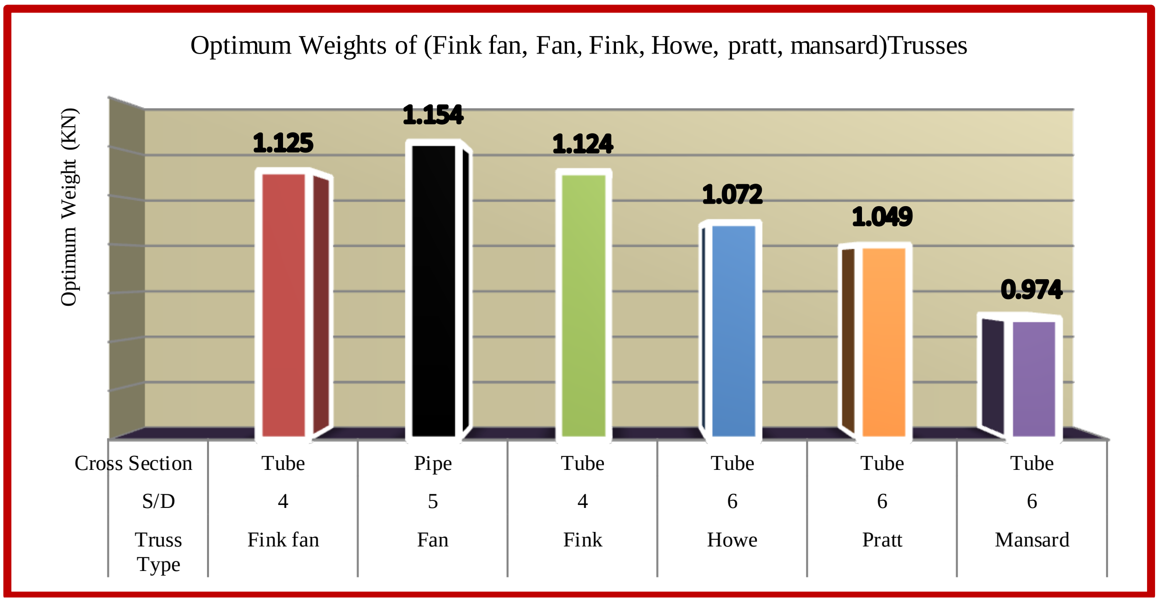

Figure 8: Optimum Weighs of various Truss Types among Best Cross Sections and S/D.

4. Conclusion

From this study, the result values of optimum truss weight present the following:

Significant effect of the cross section shape on the optimal truss weight: the difference between the minimum value and the highest value by using various shapes of cross sections varies from 185.2% to 244 % for these six types of trusses. Besides, the pipe section is the effective section for fan truss and the tube section is the effective for fink fan, fink, Howe, Pratt, and mansard truss.

The type of truss (geometry and topology of truss) has an impact on the optimum weight of truss. The difference in between the minimum value of mansard truss 0.974kN and the highest value of fan truss 1.154kN is 25%. Besides, the minimum optimal weights (1.722, 1.125, 1.165, and 3.565) kN report with the S/D from 4 to 5. Even the depths (3, 2.4) are bigger than (2, 1.7, 1.5) that corresponding S/D equal to (6, 7, 8) respectively.

The least value is 1.125kN with tube section is obviously shown in figure 8. Not only the fink fan truss, but also fan and fink truss, the minimum optimal weights (1.93, 1.22, 1.154 and 3.291) kN report with the S/D from 4 to 5. Despite, The minimum value is 1.154 kN with pipe section. This is clearly shown in figure 9. The minimum value of optimum weight is with S/D vary from 4to5 for Fink fan, Fan, and fink trusses. Whereas vary from 6 to 8 for Howe, Pratt, and

Mansard trusses.

The results show that the impact of the cross section shape is higher percentage of difference, in comparison with other variables as the shape and topology of the trusses.

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