Vol-08 Issue 07, July -2024
ISSN: 2456-9348
Impact Factor: 7.936

iJETRM
International Journal of Engineering Technology Research & Management
Published By:
https://www.ijetrm.com/

OPTIMIZATION OF STEEL ROOF TRUSSES

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ABSTRACT

The main purpose of this project was to study and apply the topology optimization on nine different truss geometry as plane truss by only using angle section. The need of this study arises when time is a constraint in the project, and it is difficult or taking much time to choose effective and economical truss geometry during the design period. Its main purpose is to determine the minimum angle section which can be used to design a truss geometry which should be safe and should be able to take loads which are common in Hamirpur region. Design loads were distributed to the joints so that no moment is generated over the members. Total five span (6m, 7m, 8m, 9m,10m) were analysed and designed with the guide of STAAD Pro in various geometries mentioned till the minimum steel take off was achieved. Optimal geometries from each span of each 9 trusses ((Pitched Pratt Roof Truss, Pitched Howe Roof Truss, Fan Roof Truss, Pratt Roof Truss, Howe Roof Truss, Warren Roof Truss, Fink Roof Truss, Diamond Roof Truss, K roof truss) with pin and roller support ,were compared to determine whether it is the same effective geometry for different combinations of spans and heights. This work and analysis shows that no fixed most effective geometry can be determined for different as well as same span, height nor height over span ratio. For each case different geometry was obtained. However, close results were obtained where it does help to provide a good guideline in choosing a truss that does not waste much material. From the results it has been concluded that the warren truss geometry can be considered as the most effective geometry in terms of bearing loads. In this study it has been attributed that the arrangement of the web members and chord members has been done in symmetric manner which helps in better distribution of loads in trusses. It was also observed that if we increase the angle between the chords (tension and compression) then the truss geometry distributes the loads in more effective way. From the results obtained, an optimality curve has been derived for a better understanding of correlation between span, optimum depth and minimum self-weight for various configurations.

Keywords:
Optimization, Span, Depth, least weight

1. INTRODUCTION

Trusses are most common type of structure used in constructing building roofs, bridges, and towers etc. The truss is types of structural frames formed from structural members. A truss consists of a group of ties and struts designed and connected to form a structure that acts as a large span beam. A truss can be constructed by straight slender members joined together at their end by bolting, riveting or welding (Fig. 1). Generally, a designer needs to decide member sizes, joint locations and the number of members for a truss design. Trusses are subjected to nodal loads only, which only generate tension or compression forces therefore trusses are lighter than their load capacities.

A truss behaves like a deep beam and its strength and stiffness gets increased with its depth but when the length of the span is too long, and the value of applied load is small then it may waste the material as it just bears its self-weight. This happens because the depth of section governs the bending moment capacity of that section. If we use only a single section, a large portion of the web is unused. A truss better performs its function when the depth is more considerably with respect to span.

The members used in steel trusses are normally angles, double angles, C-channels, double C-channels, square hollow section (SHS), circle hollow section (CHS). While choosing a configuration for a truss, we prefer even number of bays in Pratt and modified Warren trusses to avoid a central bay with crossed diagonals. Truss Girders, lattice girders or open web girders experience essential axial forces and hence the material is fully utilized due this reason they are considered efficient and economical. Members installed in truss girder bridges generally behave as chord members and web members. Overall bending moment of the structure is resisted by these chord members in the form of direct tension and compression and the overall shear force generated in the structure is resisted by the web members in the form of direct tension and compression. This increases the efficiency of the material used and overall efficiency of the truss bridges as mentioned above. Therefore, these truss bridges are built over wide range of spans. Truss bridges compete against plate girders for shorter spans, against box girders for medium spans and cable-stayed bridges for long spans. Due to the increased efficiency trusses require fewer materials to support the same load when compared to solid beams. These truss structures are required to be designed in such a way that they have enough strength and rigidity to satisfy the strength and serviceability limitation. General approach of optimizing a truss and increasing its overall efficiency is done by using less material in chords and more in the bracing elements. When it comes to the criteria of strength, rigidity and safety, many structures with different shapes, meets the requirement. But structural designers generally, prefer the most economical one. Before this optimization technique was introduced, designer's intuition and experience was the only way to obtain the optimum solution. In the field work these day new designers feel under confident whether the design provided will be safe or not. So, they generally choose a heavy design. As mentioned above it waste a lot of material and this is where optimization comes into the picture. If these new designers get a study or research which provide them with a norm or a benchmark which they can use for their reference, then this can save lot material and cost of the structures.

2. LITERATURE REVIEW

There has been much advancement in the field of optimization. Many research scholars have identified various algorithms and methodology to optimize various components and its applications has been extended to every stream of engineering. As far as this research work is concerned the structural optimization of truss structure involves series of systematic procedures that may be iterative procedures or mathematical analysis systems. Essentially there are three types of structural optimization Size, Shape and Topology Optimization.

Weight Optimization of Steel Structures by Genetic Algorithm

Genetic Algorithms are considered as most appropriate option for optimization of beam structures. This choice is appropriate because of simple mathematical formulation, its independence from objective function and due to the possibility of working with discrete variable.

Shanthi mercy et. al. [2] did sizing optimization of a 10-bar truss structure through the application of Genetic algorithm. She reduced the weight of the truss which is subjected to constraint that is mentioned: -

1. Stress Constraints
2. Displacement Constraints
3. Stress and Displacement Constraints

In sizing optimization problems, the member cross section is restricted to take certain pre specified discrete values.

Fransa and Arfiadi [3] carried out size, shape and topology optimization using hybrid genetic algorithm. Hybrid algorithms use both real and binary coding to solve problem. In this research work nodes of trusses were optimized by using real coded GA's. The hybrid coded GA's were validated by comparing hybrid GA's used in this research with other methods for problem benchmarking of a truss structure. The hybrid-coded GA's were then used to optimize the size, shape and topology of the roof structures.

Paolo Cicconi et. al.[4] worked over developing a methodology and a workflow for optimizing steel structures. The main aim of the research work was the development of a platform tool to support the automatic optimization of a steel structure using virtual prototyping tools and genetic algorithms. The focus was on oil and gas power plants. The research describes in detail the design methodology and estimates the weight saving related to the redesign process of a test case structure.

Minimum Weight Design of Structural Topologies

Kirsch and Topping [8] in their work introduced a procedure for topology optimization of a structure. The cross-section area of the members is taken as the design variable and the constraints applied are related to the stresses, displacements, and the boundary variables. The Procedure developed was applied with the aim of reducing the basic difficulties occurred during solution process. Problems were divided into various sub problems and an optimal solution was achieved by solving them sequentially. The main focus of the procedure produced was that there was no need of doing repeated exact analysis of the structure during the solving period. Many illustrated examples were solved and analysed for demonstration of the solution procedure developed and the results were very much clear in terms of topology optimization.

Truss Depth as a Parameter

Selvam and Divyameena [5] worked over optimizing a space truss by just varying the truss shape and keeping the cross section of the element constant. The shape variation was done on the basis of height only. They chose space frame because it provides the benefit of using interior space in variety of ways and thus is ideally suited for such requirements. Space frames are highly statically indeterminate, and their analysis leads to extremely tedious compulsion if by hand. The difficulty of the complicated analysis of such systems contributed to their limited use. They did their research modelling in ACAD software and concluded that three sections with particular thickness and depths were the most optimum choice.

Truss Geometrical Parameter Optimization

Lluis Gil and Antoni Andreu [13] optimized the shape and cross section of a truss Structure. They implemented a methodology in which they identified the optimum shape and cross section of a plane truss considering stress and geometrical constraints. Algorithm for optimization included a penalty function, optimization of cross section and optimization of nodal coordinates for the constraints considered. In the study the methodology implemented for optimization of cross section was based on fully stress design strategy (FSD) and the coordinate's optimization is driven by the conjugate gradient's strategy. The efficiency of the structure obtained in bearing the loads was increased by avoiding local failure of the members and by reducing the quantity of material needed

Truss Shape Optimization with Multiple Displacement Constraints

Wang. et. al. [12] worked over an evolutionary method in which he shifted the nodes of the truss to perform the shape optimization for minimum weight criteria. The structure had multiple displacement constraints for different load cases. Generally nodal coordinates are the design variables. According to the analysis based on sensitivity, optimum shape was achieved gradually from the initial design configuration. This was done by shifting the most efficient nodes for minimum weight increase. Directions for the node shift and its interval are determined automatically.

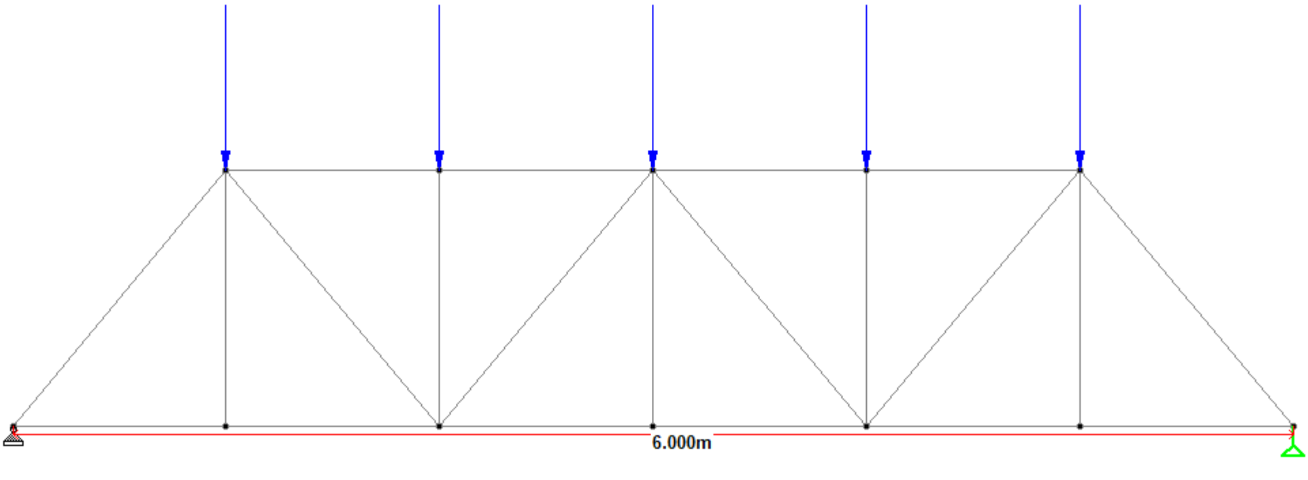
3. METHODOLOGY

Basically, the nine types of roof trusses (Pitched Pratt Roof Truss, Pitched Howe Roof Truss, Fan Roof Truss, Pratt Roof Truss, Howe Roof Truss, Warren Roof Truss, Fink Roof Truss, Diamond Roof, K roof truss) will be analysed, towards finding out minimum self-weight of truss for single span to variable depth of trusses.

The loading subjected to a truss system could be dead loads, live loads, and wind load. For roof truss system, the dead loads may be consisting of cladding, insulation, self-weight of trusses and purlins, services etc

In local practice, especially for buildings up to three storeys, no additional wind load is considered on the roof. Therefore, the loadings used in this research include dead load (includes roof sheet, fixing purlin and other services). and as per IS : 875 (part 3-wind loads)-1987, six wind zones have been formed which correspond to basic wind speed of 55, 50, 47, 44, 39 and 33 m/sec, respectively. Conservatively wind speed is considered 55 m/sec on plan whereas live load is not considered in this study due to constant value.

The example of detailed loading calculation is as below (for Truss 1 with span = 6m):



a) Dead load: -

i) G.I Sheathing = 0.085 kN/m2
ii) Fixing = 0.025 kN/m2
iii) Services = 0.1 kN/m2
iv) Weight of purlins = 0.07 kN/m2

v) For welded sheet Roof Truss, self-weight given by: -
W= 53.7+0.53xArea (N/m2) = 53.7+0.53x5(Bay spacing) x L (Length of truss span)

b) Wind load: = (.6x55x55)/1000= 1.8 kN/m2 (for Vz=55m/s)

Total load with factor of safety = (Dead load + Wt. of purlins + Welded sheet + Wind load) x1.5

For 6m span: -

a) Dead load
= 0.21x5x6=6.3 KN

b) Wt. of purlins
= 0.07x5x6= 2.1 KN

c) Welded sheet
=53.7+0.53x5x6 = 69.6 N/m2

= 69.6x5x6/1000

= 2.088 KN

d) Wind load
= .6x55x55xA/1000
=1.8x6x5
= 54KN

Total load with FOS = (6.3 + 2.1 + 2.088 + 54) x1.5 = 96.73 KN

Similarly, for span 7m to 10m can be calculated by following above steps

Table 1 Roof truss loading for different nodes on truss

Span, m	Total load with factor, KN	5 Node, KN	7 Node, KN
6	96.73	19.34	13.8
7	112.99	22.6	16.14
8	129.29	25.85	18.47
9	145.63	29.12	20.8
10	162	32.4	23.14

Table 2 Roof truss loading for different nodes on truss

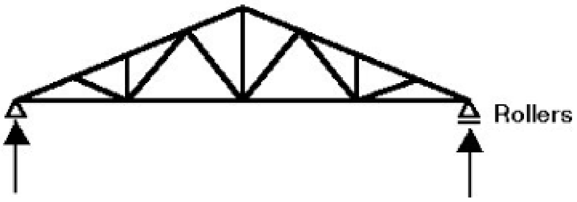
Span, m	Total load with factor, KN	9 Node, KN	10 Node, KN
6	96.73	10.74	9.67
7	112.99	12.55	11.29
8	129.29	14.36	12.92

9	145.63	16.18	14.56
10	162	18	16.2

4. ANALYSIS OF DIFEFRENT TYPES OF TRUSSE

In this analysis, we evaluated and designed 9 unique truss structures with spans ranging from 6m to 10m. Each fixed span, the height of truss is varying with difference of 0.2m to determine the least weight configuration. Each truss type was analysed to find the minimum self-weight at various depths, influenced by the truss's geometry for the given span. The trusses consist of three chords: a sloped top chord parallel to the bottom chord and a middle chord for vertical and inclined members, all made from different single angle sections. In some trusses used double angle section due to failure in single angle section.

Trusses may be single span, statically determinate or indeterminate, or may be continuous over two or more spans, only single span, statically determinate, trusses are considered in this research.



The detailed summary after the optimization procedure has been shown in following tables and graphs.

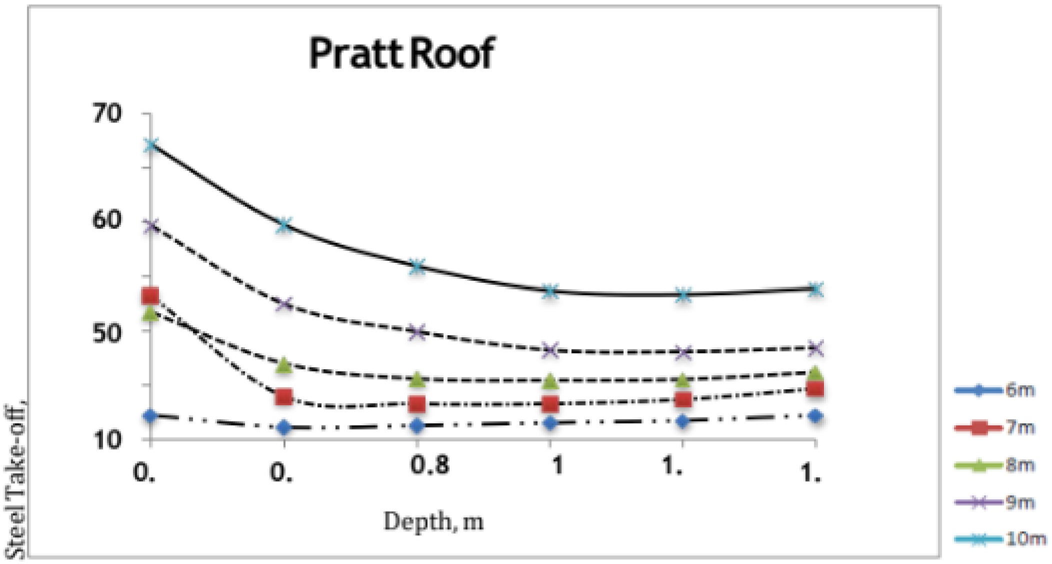


Fig. 1 Self Weight V/s Depth for spans 6m to 10m for Pratt Roof truss

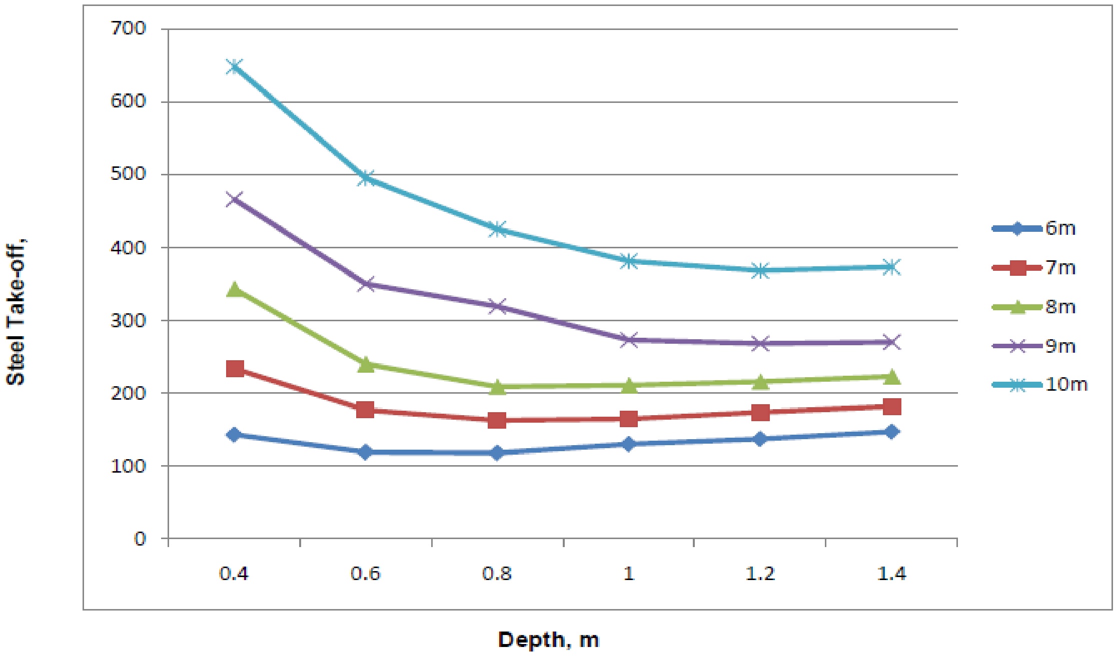
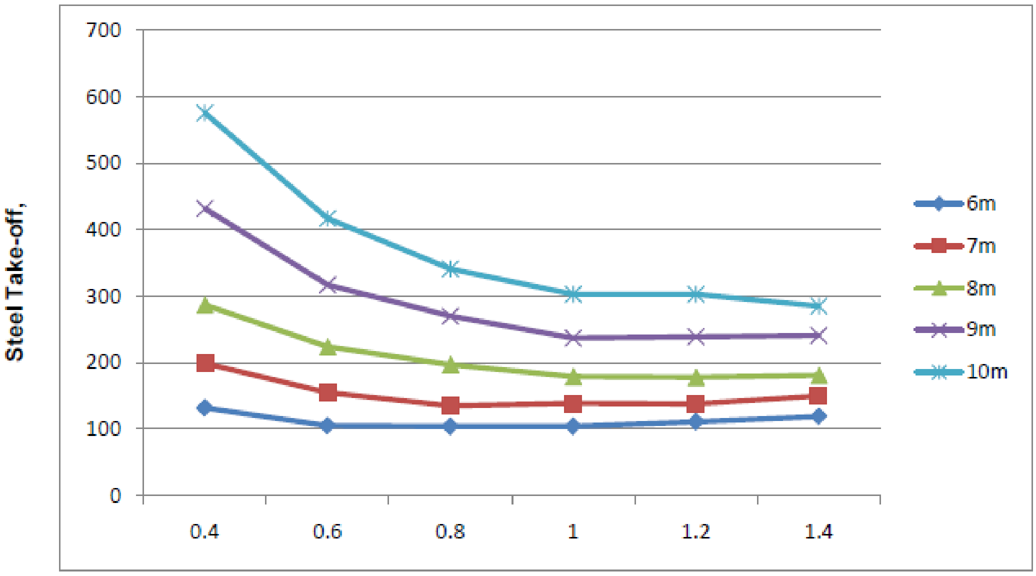


Fig. 2 Self Weight V/s Depth for spans 6m to 10m for Howe Roof Truss



Depth, m

Fig. 3 Self Weight V/s Depth for spans 6m to 10m for Warren Roof Truss

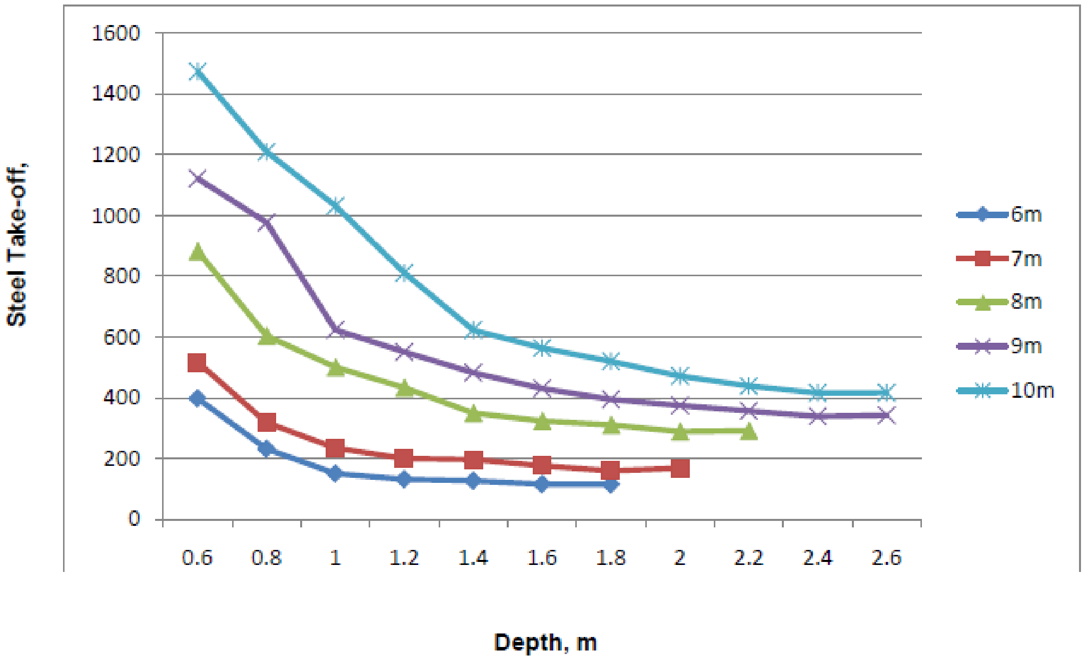


Fig. 4 Self Weight V/s Depth for spans 6m to 10m for Pitched Pratt roof Truss

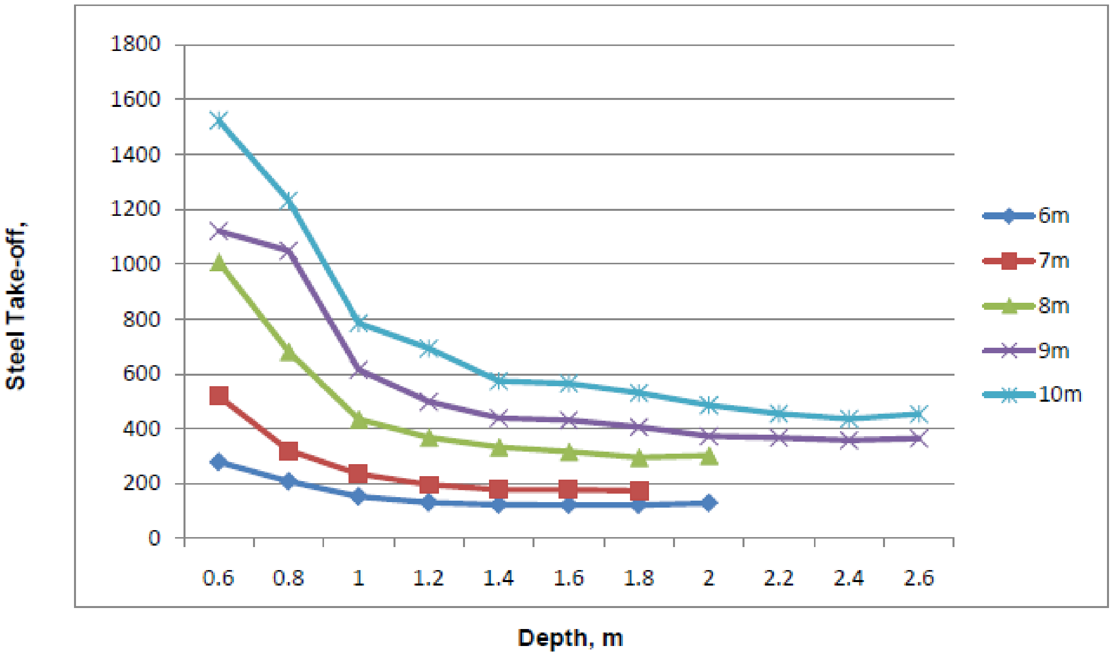


Fig. 5 Self Weight V/s Depth for spans 6m to 10m for Pitched Howe Roof Truss

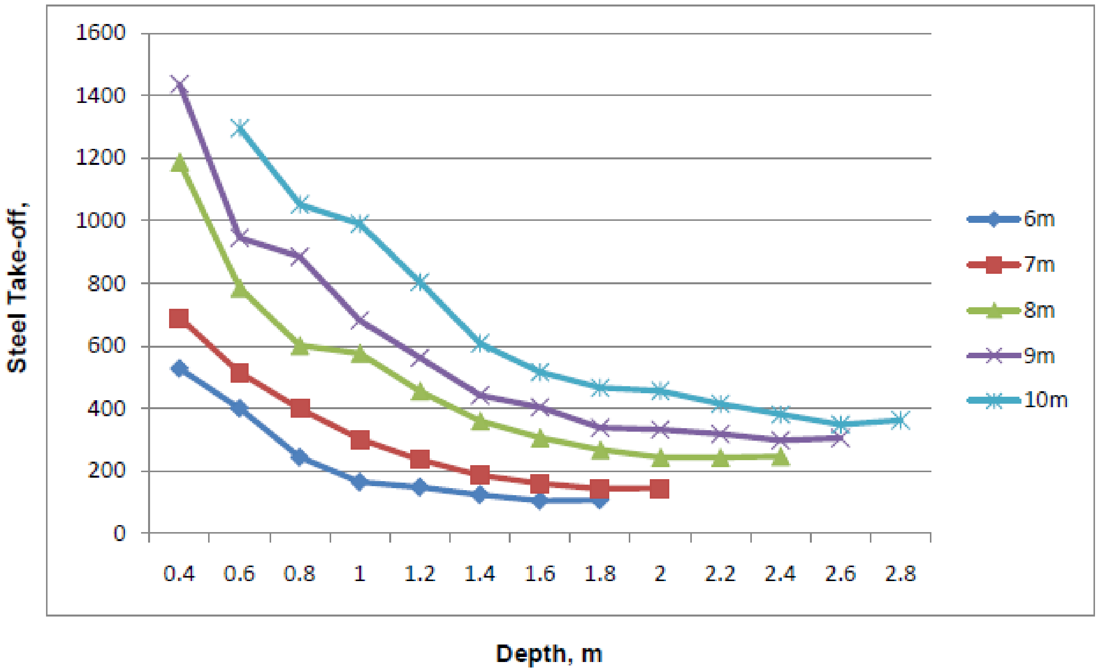


Fig. 6 Self Weight V/s Depth for spans 6m to 10m for Fan Roof truss

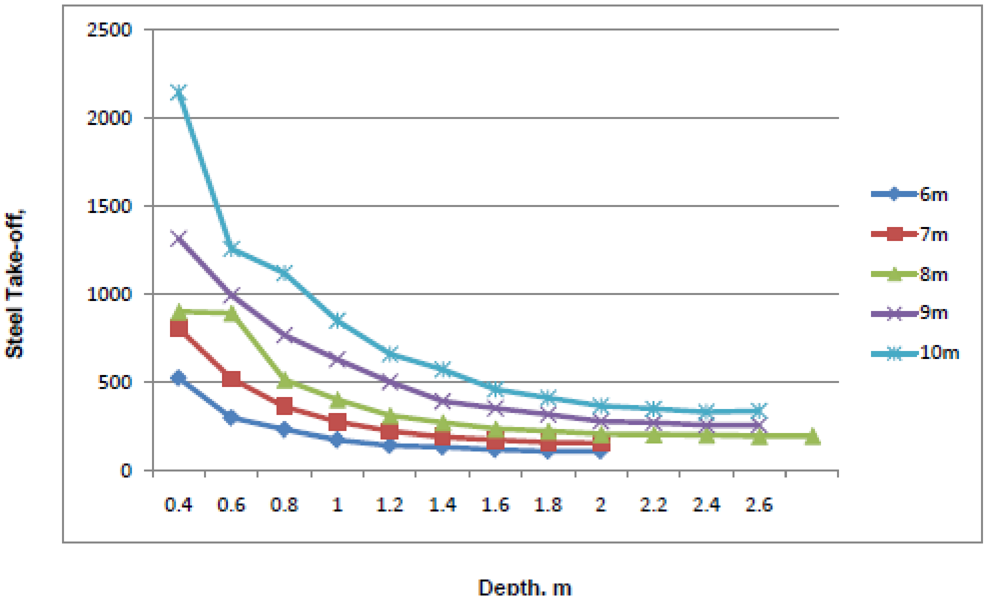


Fig. 7 Self Weight V/s Depth for spans 6m to 10m for Fink Roof Truss

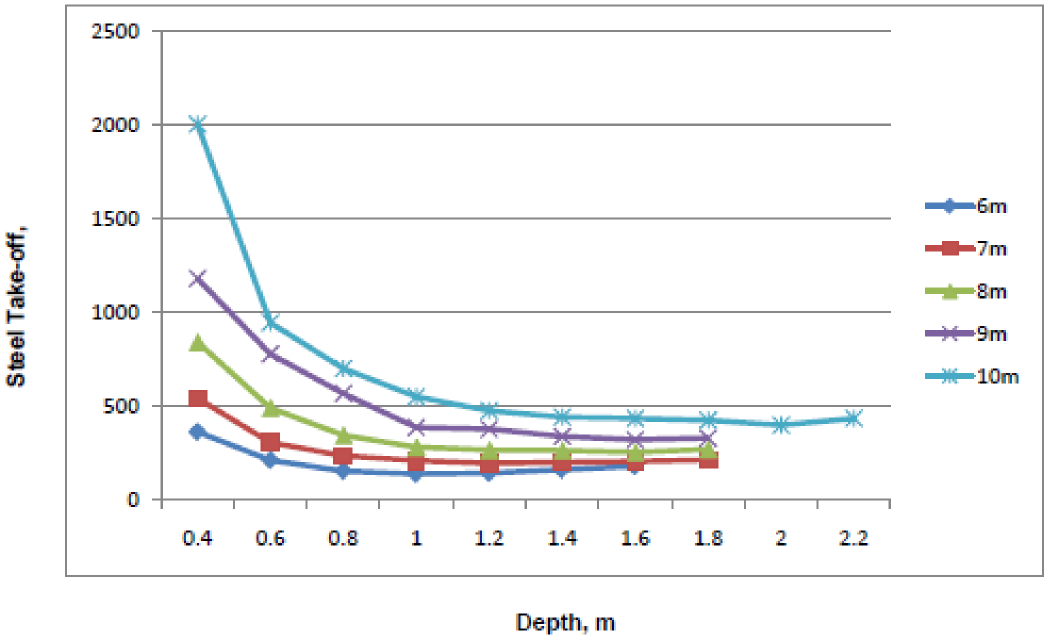


Fig. 8 Self Weight V/s Depth for spans 6m to 10m for K Roof Truss

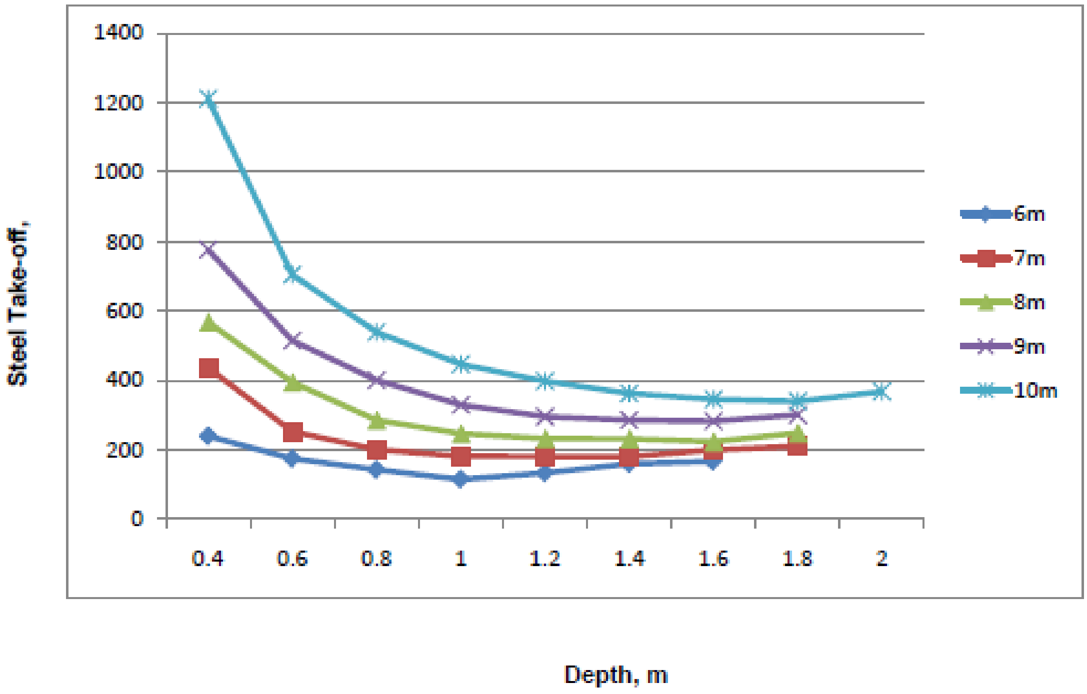


Fig. 9 Self Weight V/s Depth for spans 6m to 10m for Diamond Roof Truss

After the analysis was done, minimum weight of each type of truss configuration is summarized in the table no 3 to table 7. For each span the results are arranged in the ascending order of self-weight obtained.

Table 3 Optimum weight for Span 6m

TRUSS TYPES	**DEPTH**	**TOP CHORD ISA, mm**	**MIDDLE CHORD ISA, mm**	**BOTTOM CHORD ISA, mm**	**STEEL TAKE OFF, Kg**
Warren	1	70x70x6	60x60x6	45x45x6	104
Fan	1.6	75x75x6	40x40x6	50x50x6	105
Fink	1.8	75x75x6	35x35x6	50x50x6	109
Pitched Pratt	1.8	75x75x6	45x45x6	50x50x6	115
Diamond	1	45x45x6	35x35x6	40x40x6	115
Howe	0.8	70x70x6	65x65x6	50x50x6	118
Pitched Howe	1.8	75x75x6	45x45x6	50x50x6	122
Pratt	0.8	70x70x6	70x70x6	55x55x6	126
K truss	1	75x75x6	45x45x6	50x50x6	122

Table 4 Optimum weight for Span 7m

TRUSS TYPES	DEPTH	TOP CHORD ISA, mm	MIDDLE CHORD ISA, mm	BOTTOM CHORD ISA, mm	STEEL TAKE OFF, Kg
Warren	0.8	100x100x6	65x65x6	55x55x6	135
Fan	1.8	90x90x6	45x45x6	60x60x6	143
Fink	2	90x90x6	45x45x6	60x60x6	156
Pitched Pratt	1.8	90x90x6	50x50x6	75x75x6	160
Howe	0.8	90x90x6	80x80x6	60x60x6	163
Pratt	0.8	80x80x6	80x80x6	70x70x6	166
Pitched Howe	1.8	100x100x6	50x50x6	75x75x6	174
Diamond	1.4	50x50x6	45x45x6	45x45x6	181
K truss	1.2	70x70x6	60x60x6	45x45x6	198

Table 5 Optimum weight for Span 8m

TRUSS TYPES	DEPTH	TOP CHORD ISA, mm	MIDDLE CHORD ISA, mm	BOTTOM CHORD ISA, mm	STEEL TAKE OFF, Kg

Warren	1.2	100x100x6	80x80x6	50x50x6	178
Fink	2.6	90x90x6	50x50x6	60x60x6	194
Pratt	1	90x90x6	90x90x6	65x65x6	209
Howe	0.8	125x95x6	90x90x6	70x70x6	209
Diamond	1.6	50x50x6	50x50x6	45x45x6	224
Fan	2.2	90x90x8	55x55x6	70x70x6	243
K truss	1.6	75x75x6	65x65x6	45x45x6	255
Pitched Pratt	2	110x110x8	60x60x6	90x90x6	289
Pitched Howe	1.8	90x90x10	50x50x6	75x75x8	295

Table 6 Optimum weight for Span 9m

TRUSS TYPES	DEPTH	TOP CHORD ISA, mm	MIDDLE CHORD ISA, mm	BOTTOM CHORD ISA, mm	STEEL TAKE OFF, Kg
Warren	1	110x110x8	90x90x6	65x65x6	237
Fink	2.4	90x90x8	55x55x6	80x80x6	255
Pratt	1.2	100x100x6	100x100x6	65x65x6	262
Howe	1.2	125x95x6	100x100x6	65x65x6	268
Fan	2.4	80x80x8	60x60x6	80x80x6	298
Diamond	1.6	70x70x6	55x55x6	60x60x6	301
K truss	1.6	90x90x6	75x75x6	50x50x6	322
Pitched Pratt	2.4	90x90x8	70x70x6	100x100x6	339
Pitched Howe	2.4	90x90x8	70x70x6	100x100x6	358

Table 7 Optimum weight for Span 10m

TRUSS TYPES	DEPTH	TOP CHORD ISA, mm	MIDDLE CHORD ISA, mm	BOTTOM CHORD ISA, mm	STEEL TAKE OFF, Kg

Warren	1.4	110x110x8	90x90x6	55x55x6	285
Fink	2.4	90x90x10	60x60x6	100x100x6	329
Diamond	1.8	70x70x6	60x60x6	65x65x6	340
Fan	2.6	80x80x8	65x65x6	90x90x6	348
Pratt	1.2	100x100x8	100x100x8	80x80x6	367
Howe	1.2	110x110x8	100x100x8	70x70x6	368
K truss	2	100x100x6	80x80x6	50x50x6	400
Pitched Pratt	2.4	90x90x10	75x75x6	90x90x8	416
Pitched Howe	2.4	90x90x10	75x75x6	90x90x8	436

In carrying out the process of optimization for different truss geometry for least weight configuration it has been observed that the orientation of the structural members such as compression chords and tension chords plays vital role in determining the resultant forces that acts in the corresponding members.

And hence as a consequence of the decisive resultants on the structural members by the truss component forces affect geometry the sections required to resist such design forces. Thus, the problem arises when it is urged to find the best truss configuration where the depth and span becomes the dominating parameters rather than loads in deciding the best truss configuration.

Also, it has been noted that as the span of a given truss increases the minimum depth required to carry the design loads effectively also increases as a linear function of length. The component forces in the respective truss systems are greatly dependent on the inclination of the structural members. To quantify exactly the relation between the angle of inclination of the members and the resultant forces in the members we need to understand the influence of the alignment of the members in various truss configurations.

In all the cases of different spans and trusses it has been observed that Warren Truss configuration becomes the best and optimum system for carrying any type of load. The main reason that has been derived from its behaviour as best truss is that such an alignment of compression and tension chords in a symmetrical fashion tends to distribute the load uniformly thereby allowing all the members to take stress uniformly resulting in maximum utilization of the materials.

The graph showing the relation between the spans and self-weight for all nine truss configurations from which we can infer that warren truss configuration is the optimum truss configuration (Fig. 10, Fig. 11, and Fig. 12).

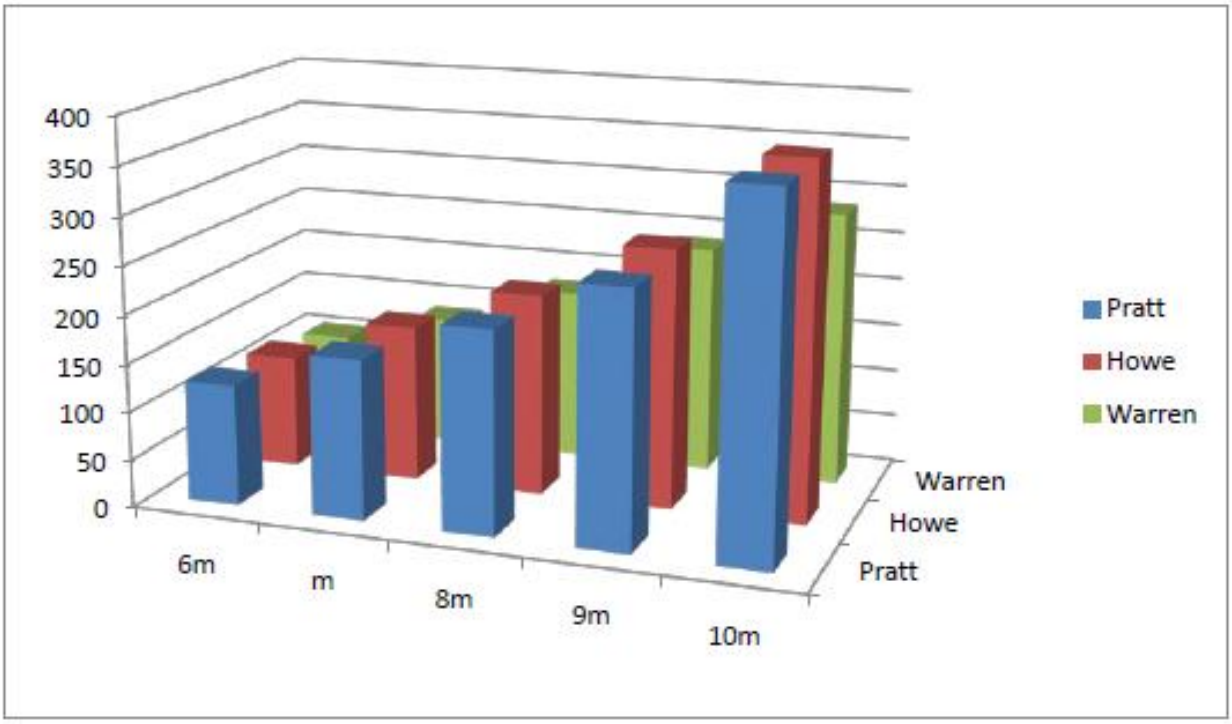


Fig. 10 Comparison of Span vs. self-weight for Pratt, Howe, Warren

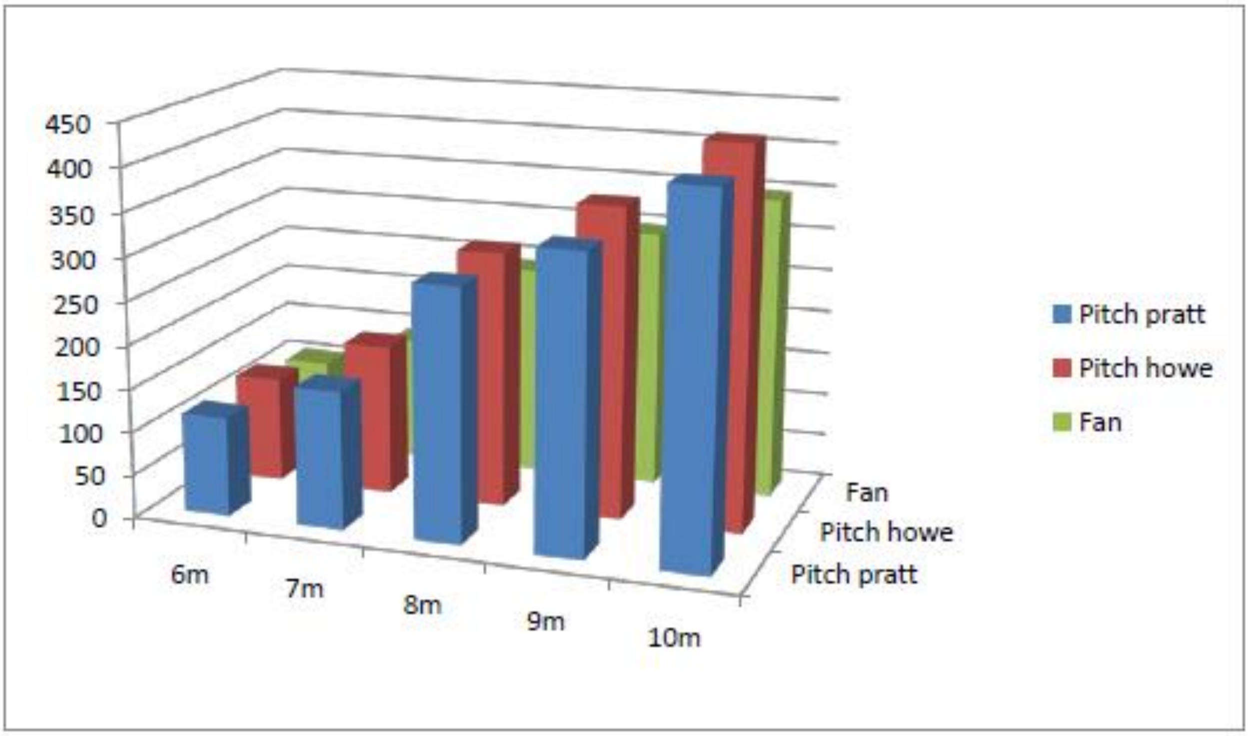


Fig. 11 Comparison of Span vs. self-weight for Fan, Pitch Howe, Pitch Pratt

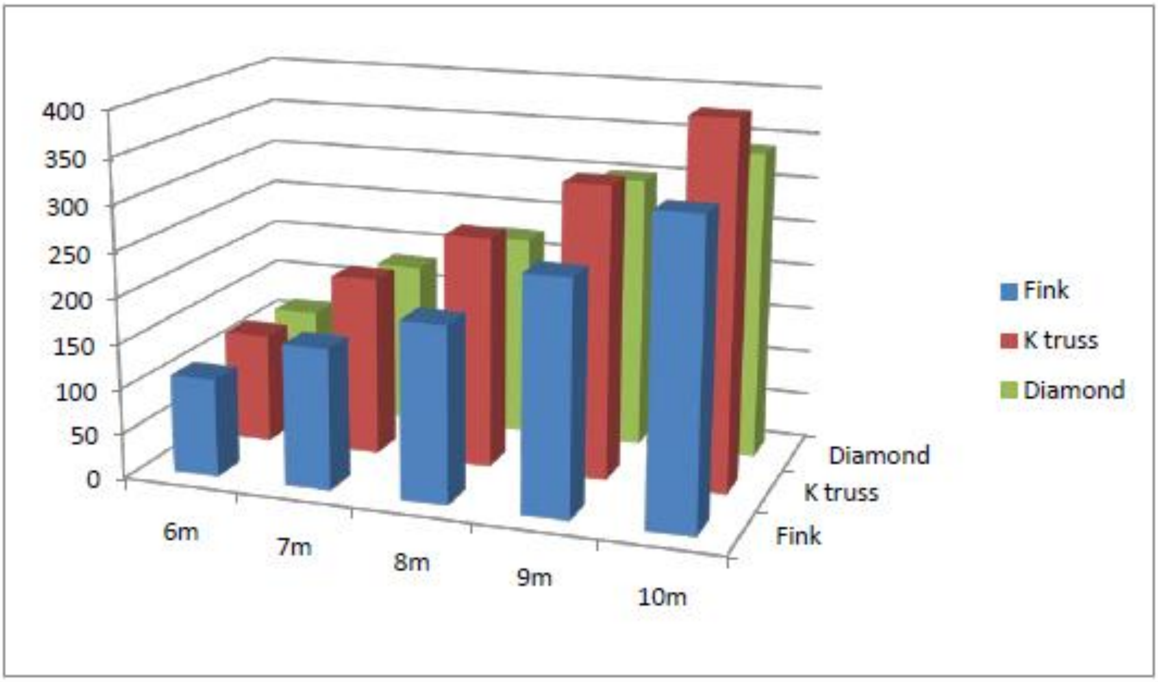


Fig. 12 Comparison of Span vs. self-weight for Fink, K Truss, Diamond

CONCLUSION

Based on the study carried out, a few outcomes are,

- It was observed that among all nine trusses, the geometry of warren truss was the most optimum configuration. It almost saved 10% in weight when compared to its closest contenders Pratt truss or Howe truss.
- From the optimality curve it was concluded that optimum depth of any truss increases linearly with respect to its span.
- No defined pattern or no clear relation can be developed between the geometrical parameters such as depth of truss configuration, span and the topology of the structure. It was observed that it was varying in a piece wise linear function. Therefore, only a trial-and-error method coupled with structural engineer's experience can accomplish the difficult task of choosing a optimum truss system.
- The optimized truss geometry that is effective in distributing load to their members might not be practical to use in the construction of real structures.
- The optimized minimum weight section obtained through analysis was of different cross sections so to make it look more practical a uniform section was chosen to make it ready for use in field.

The scope of the future work besides considering weight of material, this study can be advanced by determining the impact of other factors on the overall cost of the structure. Other factors which can be included are fabrication cost, erection, cost for detailed connection etc. In terms of loading snow load can be included for particular areas where snow can affect the structure to determine the truss types that are the most economical in practical usage. For example, it is not necessary that any structure with members of minimum self-weight will be the most optimized or most efficient cause number of joints also increases.

5. REFERENCES

1) A. B. Templeman, “Optimization methods in structural design practice 3,” J.Struct. Eng., vol. 109, no. 10, pp. 2420–2433, 1984.

2) R. M. Shanthi, V. Sheela, R. Gayathri, and A. Edwin, “WEIGHT OPTIMIZATION OF STEEL TRUSSES USING GENETIC ALGORITHM,”Int. J. Civ. Eng. Technol., vol. 9, no. 11, pp. 853–859, 2018.

3) R. Frans and Y. Arfiadi, “Sizing , shape , and topology optimizations of roof trusses using hybrid genetic algorithms,” in Procedia Engineering, 2014, vol. 95, no. Scescm, pp. 185–195.

4) P. Cicconi, M. Germani, S. Bondi, A. Zuliani, and E. Cagnacci, “A Design Methodology to Support the optimization of steel structures,” in *26th CIRP Design Conference*, 2016, vol. 50, pp. 58–64.

5) S. K and D. R, “INFLUENCE OF DEPTH PARAMETER IN PLANE SPACE TRUSS,” in *International Conference on Emerging Engineering Trends and science*, 2016, no. June, pp. 32–37.

6) M. Osaki and C. C. Swan, “Topology and Geometry Optimization of Trusses and Frames,” *Computer. Struct.*, vol. 57, no. 2, pp. 219–225, 1995.

7) N. K. Jha and K. Hornik, “Integrated computer-aided optimal design and finite element analysis of a plain milling cutter,” *Appl. Math. Model.*, vol. 19, no. 6,pp. 343–353, 1995.

8) U. Kirsch and B. H. V. Topping, “Minimum Weight Design of Structural Topologies,” *J. Struct. Eng.*, vol. 118, no. 7, pp. 1770–1785, 1992.
9) H. R. Thomas and D. M. Brown, “Optimum least-cost design of a truss roof system,” *Comput. Struct.*, vol. 7, no. 1, pp. 13–22, 1977.

10) M. P. Saka, “Optimum geometry design of roof trusses by optimality criteria method,” *Comput. Struct.*, vol. 38, no. 1, pp. 83–92, 1991.

11) K. Suzuki and N. Kikuchi, “Shape and topology optimization by a homogenization method,” *Am. Soc. Mech. Eng. Appl. Mech. Div. AMD*, vol.115, pp. 15–30, 1990.

12) D. Wang, W. H. Zhang, and J. S. Jiang, “Truss shape optimization with multiple displacement constraints,” *Comput. Methods Appl. Mech. Eng.*, vol.191, no. 33, pp. 3597–3612, 2002.

13) L. Gil and A. Andreu, “Shape and cross-section optimization of a truss structure,” *Comput. Struct.*, vol. 79, no. 7, pp. 681–689, 2001.

14) M. D. Maisuri, H. K. Dhameliya, and H. L. Kheni, “Review of Comparison Between Conventional steel and Tabular steel section For Multi Span Industrial shed with Truss and Portal Frame “Int J. Adv. Eng. Res. Dev. Vol 1, No 12, pp 116-118,2014.

15) S. Dimitrij and B. Rimantas, “Global optimization of trusses with a modified genetic algorithm,” J. Civ. Eng. Manag., vol. 14, no. July, pp. 147–154, 2008.

16) M. Hultman, “Weight optimization of steel trusses by a genetic algorithm,” Sweden, 2010.

17) G. Kaur, R. singh Bansal, and S. Kumar, “Shape Optimization of Roof Truss,” Int. J. Eng. Res. Technol., vol. 5, no. 06, pp. 696–700, 2016.

18) Y. Patel, S. Gohil, Y. Chhasatia, and H. Parmar, “Analysis and Design of Conventional Industrial Roof Truss and Compare it with Tubular Industrial Roof Truss,” Int. J. Sci. Technol. Eng., vol. 2, no. 10, pp. 943–948, 2016.

19) T. DEDE, M. Kripka, V. Togan, V. Yepes, and R. V. Rao, “Usage of Optimization Techniques in Civil Engineering During the Last Two Decades,” Curr. Trends Civ. Struct. Eng., vol. 2, no. 1, 2019.

20) J. S. Arora, Introduction to Optimum Design. London: Elservier, 2004.

21) H. An, S. Chen, and H. Huang, “Structural optimization for multiple structure cases and multiple payload cases with a two-level multipoint approximation method,” Chinese J. Aeronaut., vol. 29, no. 5, pp. 1273–1284, 2016.

22) W. R. Spillers and K. M. MacBain, “Structural optimization methods and algorithms,” in Structural Optimization, London, 2003, pp. 1–301.

23) M. B. Prendes Gero, A. B. García, and J. J. del Coz Díaz, “Design optimization of 3D steel structures: Genetic algorithms vs. classical techniques,” J. Constr. Steel Res., vol. 62, no. 12, pp. 1303–1309, 2006.

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