Fully Stressed Design of Howe Truss using STAAD.Pro Software

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Abstract - **This paper presents the study of optimization of Howe Truss by Fully Stressed Design (FSD) technique utilizing STAAD.Pro software version STAAD.Pro V8i (SELECT series4). Three span ranges of the trusses i.e. 8m, 10m and 12m have been considered and each truss has been subjected to 24 sorts of load cases by changing nodal load locations but load applied will always be symmetric. The four arrangements of load condition are taken, i.e., 100 kN, 125 kN, 150 kN and 175 kN. The total 72 number of trusses have been optimized in this study to achieve a target stress of 100 MPa. The optimal mass of all the trusses for each case and maximum deflection for each case have been calculated. Further deflection per unit mass have also been calculated and compared for each span with graph. Results of the study will be helpful in the designing of a truss that must fulfill the requirement of economy as well as strength.**

Keywords: **Howe Truss, STAAD, Fully Stressed Design, Optimization**

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I.INTRODUCTION

The resources are depleting day by day in present time and also the cost is increasing of material as well as labor cost is also increasing. As per the popular concept of present time in building construction i.e. the concept of green building we must conserve resources for the betterment of society in all aspect and for this the term optimal structure is widely used. Optimization of the structure can be done in various aspects which are known as objectives which could be weight, volume, cost or stiffness of the structure. By using optimization technique cost as well as material to be used in structure is saved. Optimality of the structure can be defined in terms of weight, volume, cost, stiffness etc. Some constraints are used for optimization. Some structures that lie within the constraints are generally known as feasible solutions to the optimization problem. These optimizations were supported (based on) size, shape and topology factors. So as to urge the truss optimized the cross sectional area of each member of truss are modified. It reduces the weight of structure and what is more the overall cost of the structure as well and hence Light weight structures are made instead of traditional heavy weight structures. Traditionally the structural optimization techniques includes; mathematical programming, optimality criteria, method of approximation and fully stressed design and fully utilized design.

Patrikar Avanti, Pathak K. K. (2016) has published a paper on Fully Stressed Design of Fink Truss using STAAD.Pro Software which is based on optimization technique of structures in this paper truss of three different spans has been considered with set of three loads and 27 different load cases. Result of the study may helpful in analysis and designing a truss that doesn't waste material (1). Goel Shivam, Pathak K. K. (2016) presented a paper on the Optimization of Warren Truss using Topology Optimization in which 9 warren trusses have been considered with distinct span and height and each truss was subjected to 9 different loading conditions and 81 cases were formulated and each case was optimized to get a target stress of 100 MPa and Result of this study may be useful in the efficient utilization of the material and hence reducing the cost of the structure (2). David Greiner, Jose M. Emperador, Blas Galvan and Gabriel Winter (2015) published a paper on Comparing the Fully Stressed Design and Minimum Constrained weight Solutions in Truss Structures in which the optimization structural design problems of Fully Stressed Design (FSD) and Minimum Constrained Weight (MCW) are compared in a simple truss test case with discrete cross-section type bar sizing where both optimum designs are coincident (3). Ahrari A, Atai A. A. & Deb K. (2014) presented a paper on Simultaneous Topology, Shape and Size Optimization of Truss Structures by Fully Stressed Design based on Evolution Strategy (FSD-ES), and It has been also proved in this paper that fully stressed design is suitable method for optimal design of structure in which trusses are used and optimality is derived (4). **C.** Maraveas, A. Papagiannakis, K Miamis& K. Tasiouli(2014) presented a paper on Optimal Design of through-truss steel bridges which is based on shape and sizing optimal design for open-top through-truss steel bridges in this paper optimal design (in terms of shape and sizing) of through steel bridges is performed in which several cases of simply supported bridges with different spans and varying width corresponding to different traffic lanes (i.e. 1 or 2 traffic lanes), were examined. The effect of three deck types which are reinforced concrete deck, fiber reinforced polymer deck and steel deck on the weight of the truss and the total weight had been investigated in which the least-weight shape and sizing optimal design was executed, with the height of the truss and cross-sectional area of its members constituting the design variables of the problem (5).

In this study, Fully Stressed Design method has been utilized for optimization of Howe Trusses by using STAAD.Pro V8i (SELECT series 4) software. For this, 24 different load cases have been considered for three different spans where Load applied was always symmetric throughout the analysis. That's why by the combination of load and spans, the total 72 cases have been analyzed and steel mass, deflection and deflection per unit mass are calculated in this analysis the section used in this study is circular section.

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II.FULLY STRESSED DESIGN

In this method it is assumed that each area carries a constant force, dependent only on the external load which means the internal force of one member is supposed not to affect the force in the other members. A **re-sizing** technique is used by assuming that F_i i.e. the internal force in the ith member, is constant and F_i can be expressed by stress (σ_i) times the cross-sectional area (A_i) and further this leads to the subsequent formulation and the formulas used in Fully Stressed Design are –

$$Fi = \sigma i,new\ Ai,new = \sigma i,old\ Ai,old \quad ------ (i)$$

$$Ai, new = Ai, old\ \sigma i, old\ /\ \sigma i,o \quad ------ (ii)$$

This is an iterative technique and it is in huge practice nowadays. As our basic purpose is to maintain a same stress in each member of the truss after application of the load and we also know that stress is inversely proportional to area of cross section so if we reduce the area of cross section of any member, stress gets increase in the member and vice versa. So by increasing the area of cross section of any member, stress gets reduced and vice versa. After several iterations we can get same stress in all the member of truss as we required.

$$Stress = Force\ /\ Area \quad ------ (iii)$$

We take Howe truss of three different spans i.e. 8m, 10m and 12m with 2m height and analyzed them for 24 different load cases. In this way the total numbers of the trusses to be analyzed are 72.

III.STRUCTURAL MODELLING AND ANALYSIS

In our study we have taken 13 members Howe Truss having loads at all the joints as shown in figure 1. The loads at corner on upper chord are A and loads at centre of upper chord are B and loads acting on bottom chord are C. We have taken four sets of loads 100 ,125 ,150 ,175 and 3 positions that loads are acting at corners of upper chord(A) , loads acting at centre of upper chord (B) and loads acting on nodes of bottom chord of truss (C). Hence in this way by applying combinations we get 24 different Load Cases.
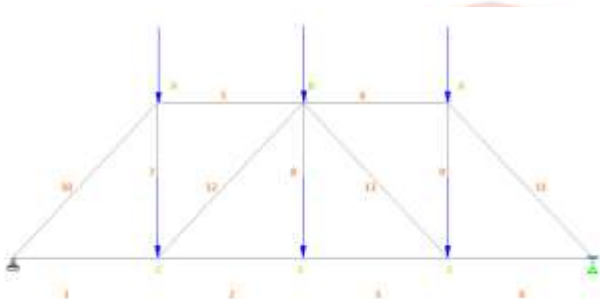
Table 1.Geometrical Parameters of Howe truss

Sr. No.	PARAMETER	VALUE
1	Members	13
2	Material	STEEL
3	Nodes	8
4	Modulus of elasticity	200GPa
7	Poisons ratio	0.25
8	Density	7800Kg/m³

Figure 1.Modeling of Howe Truss

Table 2. Properties of Howe Truss

Sr. No.	PARAMETER	For 8m span	For 10m span	For 12m span
1	Length of bottom chord members	2m	2.5m	3m
2	Length of top chord members	2m	2.5m	3m
3	Length of inclined members	2.83m	3.2m	3.61m
4	Height	2m	2m	2m

Table 3. Load Cases

Sr. No.	LOAD A (KN)	LOAD B (KN)	LOAD C (KN)
1	100	125	150
2	100	150	125
3	100	125	175
4	100	175	125
5	100	150	175
6	100	175	150
7	125	100	150
8	125	150	100
9	125	150	175
10	125	175	150
11	125	100	175
12	125	175	100
13	150	100	125
14	150	125	100
15	150	125	175
16	150	175	125
17	150	100	175
18	150	175	100
19	175	100	125

20	175	125	100
21	175	125	150
22	175	150	125
23	175	100	150
24	175	150	100

IV.RESULTS AND DISCUSSION

FSD has been carried out in iterative manner to the target stress of 100 MPa and cross sectional areas of the members were noted down. Since the density of steel was known the steel i.e. 7800 kg/m^3, mass of steel has been calculated for the overall truss structure. Circular section has been used for analysis in this study and diameter of each member each is considered to be different as per need. Optimal mass of the Howe trusses of three different spans i.e., 8m, 10m and 12m has been calculated for all 24 load cases and compared.

It has been observed that, the Optimal Maximum and Minimum Mass of Howe Truss of 8m span with 2m height are
- Maximum Mass of truss = 1010.315 Kg at LOAD CASE 15
- Minimum Mass of truss = 748.964 Kg at LOAD CASE 8
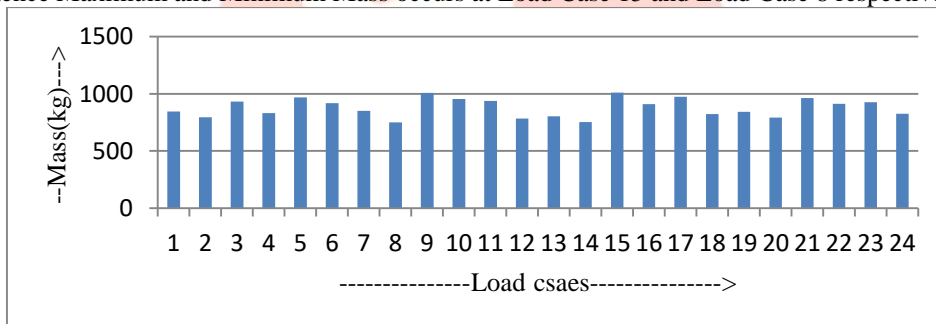Hence Maximum and Minimum Mass occurs at Load Case 15 and Load Case 8 respectively.

Figure 2. Mass for Howe Truss of 8m span

It has been observed that, the Optimal Maximum and Minimum Mass of Howe Truss of 10m span and 2m height are
- Maximum Mass of truss = 1395.957 Kg at LOAD CASE 15
- Minimum Mass of truss = 1038.189 Kg at LOAD CASE 8
Hence Maximum and Minimum Mass occurs at Load Case 15 and Load Case 8 respectively.
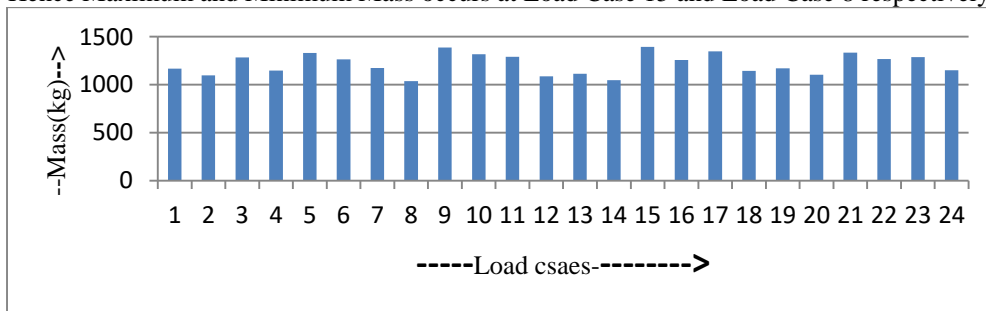

Figure 3. Mass for Howe Truss of 10m span

It has been observed that, Optimal Maximum and Minimum Mass of Howe Truss of 12m span and 2m height are
- Maximum Mass of truss = 1612.538 Kg at LOAD CASE 15
- Minimum Mass of truss = 1200.649 Kg at LOAD CASE 8
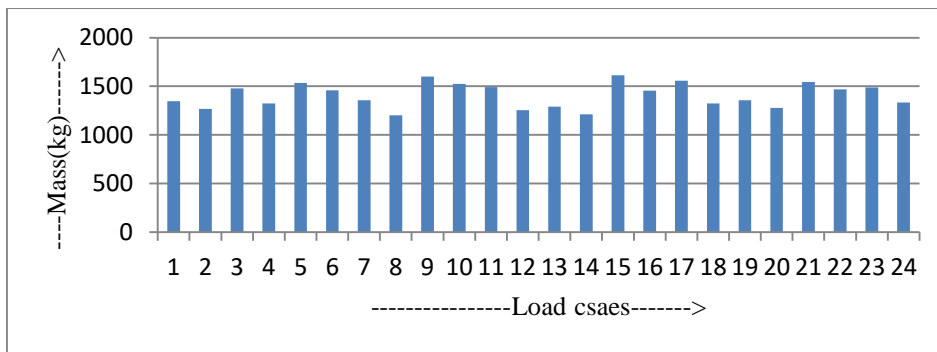Hence Maximum and Minimum Mass occurs at Load Case 15 and Load Case 8 respectively.

Figure 4. Mass for Howe Truss of 12m span

And after finding optimal mass we calculate the maximum deflection of the trusses and it is observed that the maximum deflection of truss is

For 8m span = 9.949 mm occurs at central node of bottom of the truss.

For 10m span = 13.275 mm occurs at central node of bottom of the truss.

For 12m span = 17.322 mm occurs at central node of bottom of the truss.

Then we have calculated the value of deflection per unit of mass for all spans and draw the graph for each span as below:
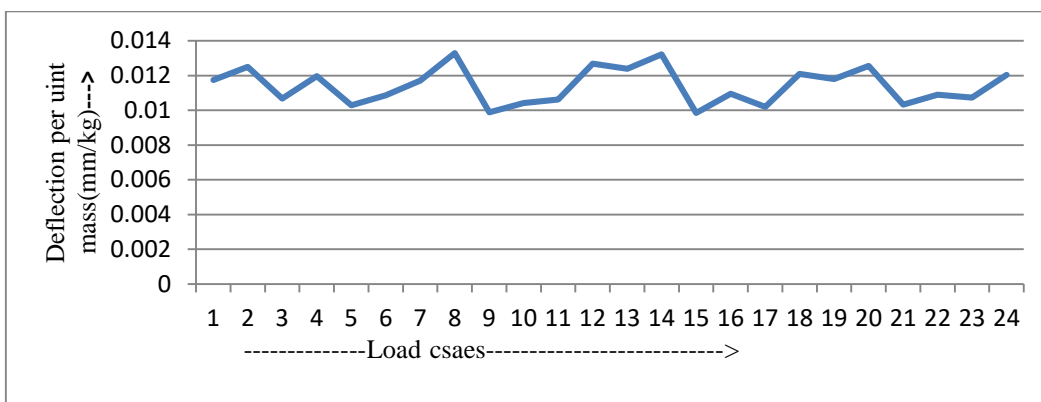
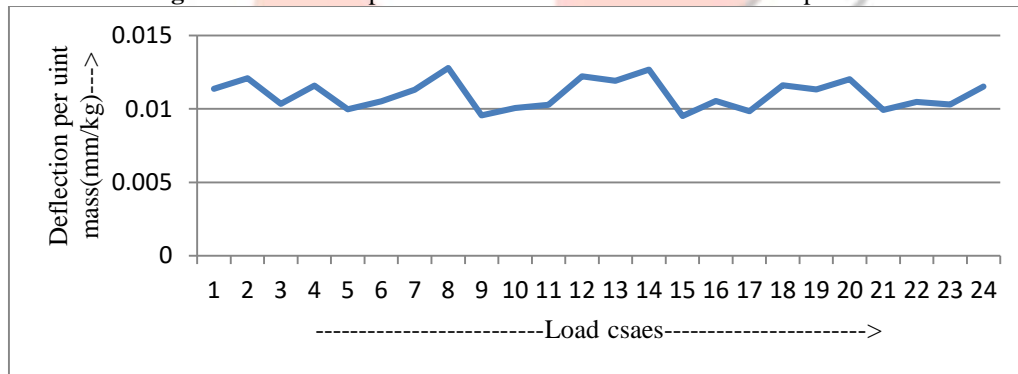**Figure 5.**Deflection per unit of Mass for Howe Truss of 8m span

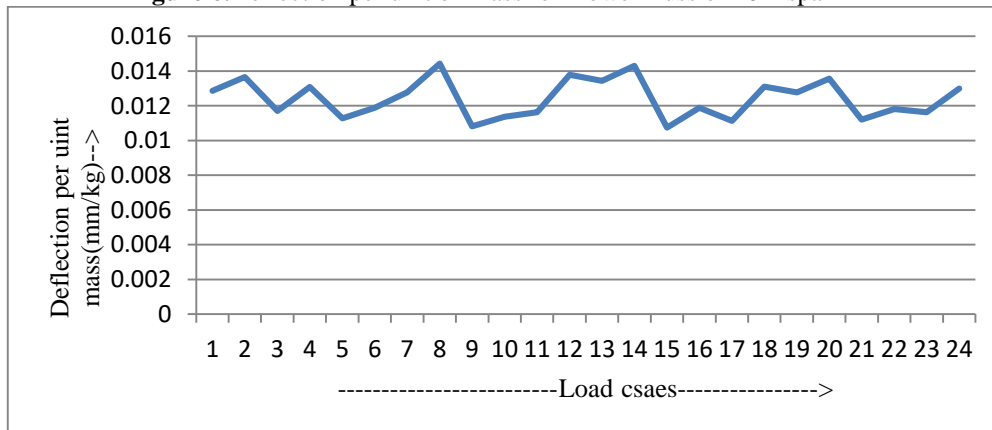**Figure 6.**Deflection per unit of Mass for Howe Truss of 10m span

Figure 7. Deflection per unit of Mass for Howe Truss of 12m span

Comparison between the optimal mass of truss of three different spans for 24 load cases have been shown in the graph given below:
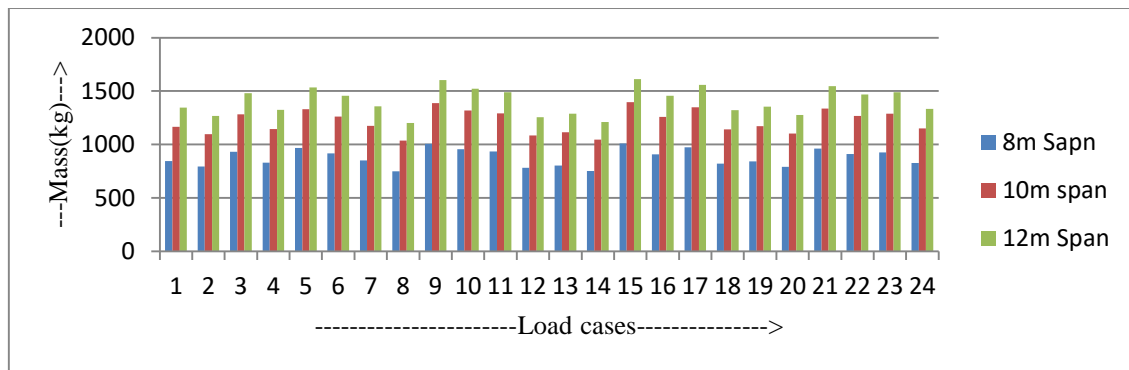
Figure 8. Optimal Mass and load graph of truss showing comparison between mass of three different spans

Comparison between the deflections per unit optimal mass of trusses of three different spans having 24 load cases have been shown in the graph given below:
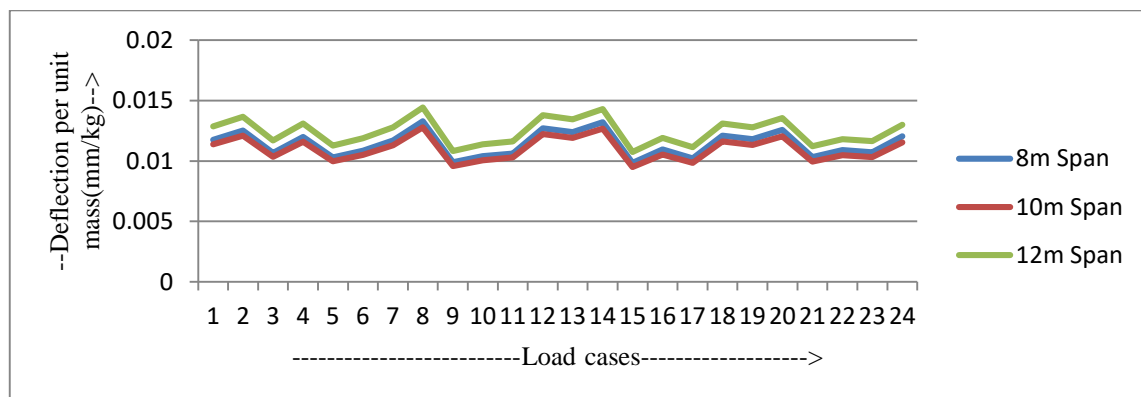

Figure 9. Deflection per unit Mass and load graph of truss showing comparison between the three different spans

V.CONCLUSIONS

The following conclusions can be drawn from above Figure 8:

1. For 8m span Howe Truss having a rise of 2 m, it is observed that as the load cases are varied there is significant variation in the total steel mass of the truss. As the span is smaller than the other two spans, the overall comparison of steel mass is obviously less, but even with in the span there is some variation. As observed from the study the optimal mass for the load case 8 (i.e. 125/150/100) is 748.964 Kg and the same for the case 15 150/125/175 is 1010.315 kg , so there is significant variation in the steel mass.

2. For 10 m span Howe Truss having a rise of 2 m, it is seen that variation is more than 8m span in the steel mass.

3. For 12 m span Howe Truss having a rise of 2 m, it is seen that variation is more than 8m & 10m span in the steel mass.

Since it is the biggest span in comparison to the other two, the overall steel mass will be more.

It is concluded that weight always increase with increase in the span or height. Hence, it is necessary for design engineer to optimize the structure to have the best height and span combination to save the material and make the structure economical. The following conclusions can be drawn out of the above graph in Figure 9:

1. The pattern of variation of graph for the deflection per unit of mass is same for all the three spans.

2. As the span increases the deflection per unit of also increases and the increment is rapidly growing with span.

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