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Optimal Topologies of Roof Trusses by STAAD Pro

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ABSTRACT: The purpose of this project is analysis and to determine the impacts of trusses shape in the design of plane truss for increasing structural efficiency with different configurations by using angle section. This study is need as sometimes there is difficulty or time consuming to choose the most successful or optimum truss shape designed roof truss. Three trusses (Pratt truss, Howe truss and Warren truss) which can be compared closely are chosen. The form and configuration of the truss rely upon the span of trusses and totally different hundreds. The height of truss was 20m from the ground and designed span of 10m, 12.5m and 15m with rise of 2m, 2.5m and 3m and analysis is done. It shows comparison of trusses between rise and span keeping angle and pitch of trusses constant for each truss. We considered self-weight, dead load and wind load before feeding our details on STAAD Pro V8i. The self-weight values were analysed using STAAD Pro as per IS 800:2007 whereas dead load, live load and wind load were calculated manually as per the code IS 800:2007 and IS 875-1987 (Part I, II, III).The overall designed load was distributed to the joints thus no moment was opposed by the members. The STAAD Pro method is employed for the calculation of the steel take-off in unit Kg wherever the truss with least value of steel take-off is taken into account as most economical. Three trusses were compared for every span with same rise. For same span, Warren truss pure mathematics looks to be the fore most suitable configuration with more savings of weight when put next to other trusses like Pratt truss or Howe truss. However, the results may vary in keeping with study and may be somewhat close which may facilitate more in future.

KEYWORDS: Optimization, Span, Rise, STAAD Pro, Trusses, Steel take-off

I. INTRODUCTION

Truss is an engineering structure that behaves as a single entity but in fact is a combination of beams and others members basically making a framework that can support engineering constructions like bridges, roof of a building or any other structure. They consist of two-force members but they are so assembled that when completed it forms a single object and clearly acts as one. There are various types of trusses namely Warren truss, Howe truss, K truss, Fink truss, Pratt truss, Gambrel truss etc.

Optimization in general refers to use of resources in such a way that it is most effective or best way to use such resources, in the same way optimization of trusses is the process by which we can find the way of using the trusses by which it will be most effective and we can use the trusses in most economical and effective way. Optimization in whole is the comparisons of all the available choices to find the best among them. Here by the help of analysis done with STAAD Pro we can compare different types of trusses under different measurements and finally find out which is the best trusses to use for different dimensions and availability.

Here we are concerned with the maximum strength on trusses by using minimum cost and this is achieved by the help of optimization of those trusses and that is the reason why we are doing optimising of trusses. By concerning about the minimum cost of trusses we cannot undermine the strength of the trusses that's why it is very important for us to find out the minimum cost of trusses without harming the strength of trusses.

Before steel became a common material for construction i.e. after the industrial revolution, trusses used to be made from wood or iron. Nowadays steel trusses are more common and are usually used along with concrete and wood

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are used very less. Since steel can be formed into several sections like Angles, C-sections, hollow sections and so on steel are way more convenient material. There are several of types of trusses with various span and rise which meets the required design however among them the most economical one that interests the Structure Engineers.

The support conditions and connection of members (bolting/welding) also have some effect to the structural behaviour of the truss. Although purlins are provided on truss joints but sometimes, they are provided on truss members because of maximum purlin spacing limitations or field constraints which helps to decrease the limitations somewhat and increases the efficiency of roof trusses.

II. LITERATURE REVIEW

There are a lot of research has been done by engineers in quest of finding optimal way of using trusses .M. P. Saka (1991) ^[1] proposed a paper on optimization of structures and has done a lot of studies taking optimum criteria was employed. He then extended the study to find out the optimum slope to extend criteria for optimization. Andrew B. Temple man (1983) ^[2] proposed a paper on topic Optimization method in structure design stating the reason why only few research outputs in the field of structural optimization has been done to design practice and there has been a very little of it which satisfies the required needs of its users. S. Rajasekaran (1983) ^[3] has done research on Computer Aided Optimum Design of industrial Roof. In the study the design procedure on the optimal design of industrial roof was carried out. M.Ohsaki (1994) ^[4] presented a paper on how to find the optimal topologies keeping stress and displacement limitations under multiple static using genetic algorithms. The study shows that the using topology bits leads to connection to topology with small number of members. The proficiency of this approach is felt on examples of plain trusses and the effect of nodal cost on optimization also has been discussed. Er. Sanjeev Kumar et al. (2016) ^[9] studied about Optimization of Roof Truss Using STAAD PRO V8i. They studied how keeping the different spacing, span and pitch was helpful in finding out the optimal truss using angle sections. Their objective of the research was to govern the most effective truss among the 80 truss geometries and to compare the economic effect of various truss topologies used commonly in constructions. The study was done in various combination of spacing 3m and 4m with span of 10m, 20m, 30m and 40m in pitch 0.25, 0.2, 0.166, 0.142, and 0.125 in each span and spacing. The conclusion of the study was spacing of 3m, span 10m with pitch 1.25 was the most economical truss. 0.125 pitch was found to be the most economical truss among various spacing. Upendra Pathak et al. ^[5] studied on topic Optimization and rationalization of truss design. The different types of trusses such as A-type truss, Fink truss, Pratt truss, Howe truss, King post truss, Queen truss etc with sections such as Angle section, Tube section, Square hollow section, were used. The trusses were taken of span 16m for the analysing of different topologies and sections to get the desired optimum truss design. Effect of connections of members (bolts or welds), supports, location of purlins on truss in optimisation of truss was studied. A-type truss was found to have lesser weight as compared to other trusses. A notable decrease in weight of truss was seen while using a tube or square hollow section compared to angled section. Slope of optimal truss was around 24°. Vikas and Bhupinder Singh ^[6] performed a study for the purpose of effect of variation in geometrical parameters on the roof trusses in the design of plane truss by using angle section. Various nine truss geometry (Pratt roof truss, Howe roof truss, Warren roof truss, Fan roof truss, Pitched Pratt roof truss, Fink roof truss, Pitched Howe roof truss, K roof truss, and Diamond roof truss) with pinned support were chosen with total of five span (6m, 7m, 8m, 9m, and 10m) trusses with pitch 0.4, 0.8, 1.2, 1.6, 2, 2.4, 2.8 for each trusses were analysed and designed. Warren truss was found to be the most optimum and the lightest among the other trusses used in study which saves about 10% to 12% materials by its weights. Hajela, P., Lee, E., and Lin, C. Y. (1993) ^[10] had researched on topic Genetic algorithms in structural topology optimization. In his paper he described about use of stochastic search procedure which is the basis of genetic algorithms. This helps to develop optimal topologies of truss structures. Krish, U. (1989) ^[13] on his research "Optimal topologies of truss structures", Computer Methods in Applied Mechanics and Engineering compared various truss configurations with same pitch, span, spacing along the weight aspects. The most appropriate span was selected from study of its geometric shape, weight, economy and other criteria

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III. OBJECTIVES

The main objective of the study is to examine different trusses so as to find a way to use them optimally with the help of STAAD Pro V8i.

- 1) To extract the least steel take-off of the truss among three trusses.
- 2) To find the most economical trusses with the help of least self-weight.
- 3) To find the most effective truss geometry among the trusses in term steel take off.

Our project involves analysis and design of Truss using a very popular designing software STAAD Pro V8i. We have chosen STAAD Pro because of its following advantages:

- 1) Easy to use interface,
- 2) Accuracy of the solution,
- 3) Versatile nature of solving any type of problem,
- 4) Conformation with the Indian Standard Codes, for this we have considered dead loads, wind loads, and live loads. Different values and results were obtained at the end of project.

IV. METHODOLOGY

To accomplish the task various types of trusses were selected. The span and height were assumed and A.C.C steel is was considered for calculation. Their Load calculation, analysis and design were calculated. A truss system may be subjected to dead loads, live loads, and wind load. For roof truss system, the dead loads consist of cladding, insulation, self-weight of trusses and purlins, services etc. Dead load (Includes roof sheet, purlin and other finishes) has been calculated as per Indian standard IS 875 (Part-I). For live load, IS 875 (Part-II) was considered. And wind load was calculated according to IS 875 (Part-III) in separate worksheet. The total load (Live load, Dead load, and Wind load) was applied vertically at each joint of each trusses and the steel take-off was calculated with the help of STAAD Pro Vi8. Load combination was generated according to IS 800:2007 for steel design.

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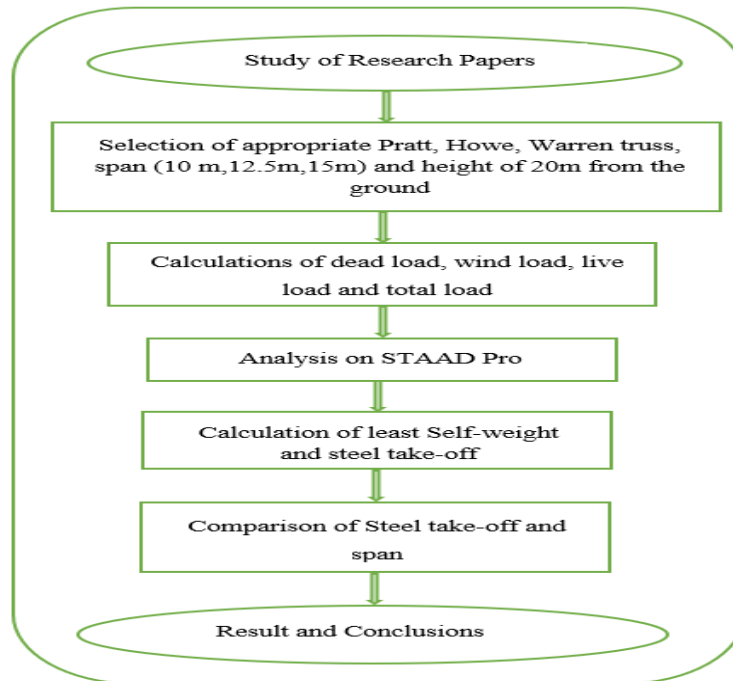


Fig.1 Methodology Chart

V. STEEL TAKE OFF FOR VARIOUS TRUSSES

The steel take-off for various trusses with different loading condition along with their figure and graph are cited below.

PRATT TRUSS

Pratt roof Truss with their tables showing span and steel take-off, figures and graph plotted between span and steel take-off are below.

Span(m)	Top Chord (ISA)	Middle Chord(ISA)	Bottom Chord(ISA)	Steel take-off (kg)
10	70 x 70 x 5	50 x 50 x 3	35 x 35 x 5	128.826
12.5	80 x 80 x 6	60 x 60 x 5	45 x 45 x 4	243.417
15	125 x 95 x 6	65 x 65 x 5	65 x 45 x 6	382.466

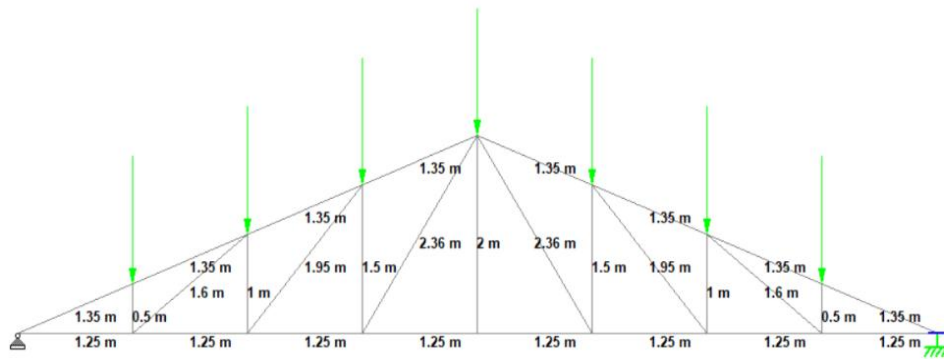
Table.1 SteelTake-Of for PRATT Truss

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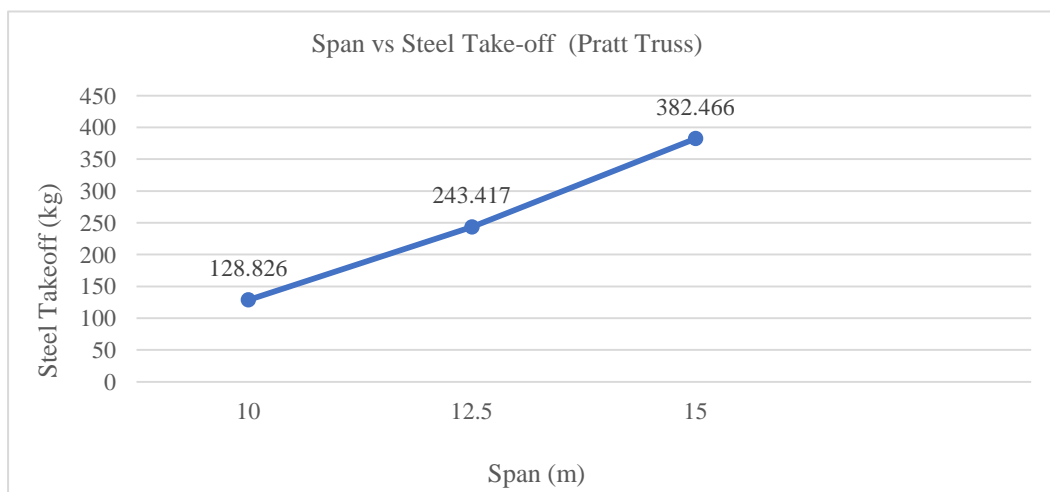
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(a)



(b)

Fig. 2. Pratt Truss (a) For 10m (b) Span vs Steel take-off

Fig 2.(a) shows the load application in pratt truss of 10m length. The total load comprising live, dead and wind load is applied throughout the truss. Similarly keeping the pitch and angle same for 12.5m and 15m length pratt truss, same loads were applied.

Fig 2.(b) represents the comparison between span and steel take-off in a chart. The value of steel-takeoff increases with increase in span length in linear manner.

HOWE TRUSS

Howe roof Truss with their tables showing span and steel take-off, figures and graph plotted between span and steel take-off are below.

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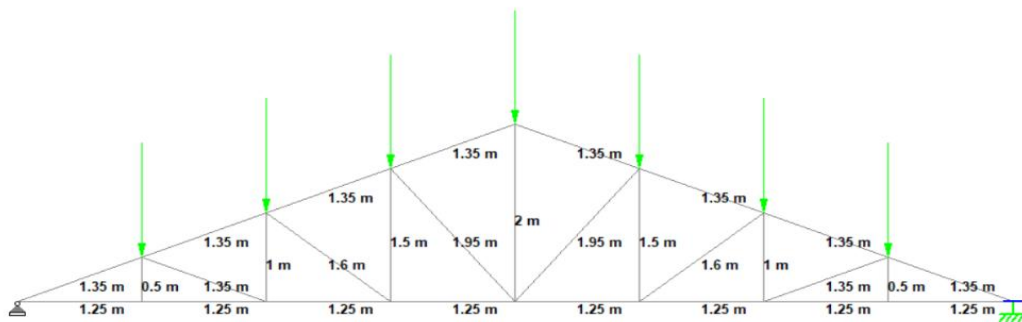
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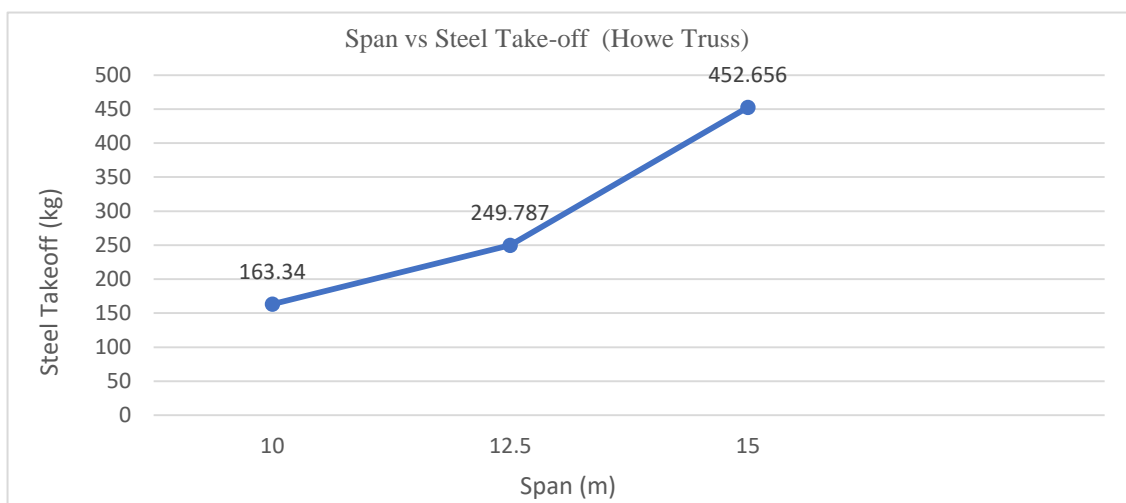
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Span(m)	Top Chord (ISA)	Middle Chord (ISA)	Bottom Chord (ISA)	Steel take-off (kg)
10	70 x 70 x 5	60 x 60 x 5	35 x 35 x 5	163.340
12.5	80 x 80 x 6	70 x 70 x 5	45 x 45 x 4	249.787
15	125 x 95 x 6	90 x 90 x 6	75 x 50 x 5	452.656

Table.2 SteelTake-Off for HOWE Truss



(a)



(b)

Fig. 3. Howe Truss (a) For 10m (b) Span vs Steel take-off

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Fig 3.(a) shows the load application in howe truss of 10m length for 2m rise. The total load comprising live, dead and wind load is applied throughout the truss. Similarly, keeping the pitch and angle same for 12.5m and 15m length howe truss, same loads were applied.

Fig 3.(b) represents the comparison between span and steel take-off in a chart. The value of steel-takeoff increases with increase in span length.

WARREN TRUSS

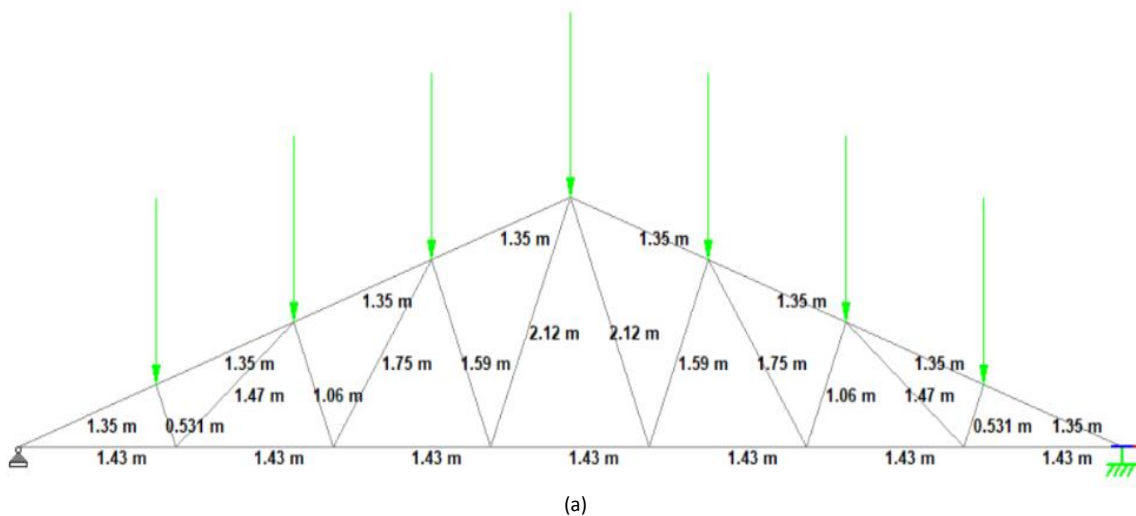
Warren roof Truss with their tables showing span and steel take-off, figures and graph plotted between span and steel take-off are below.

Span(m)	Top Chord (ISA)	Middle Chord (ISA)	Bottom Chord (ISA)	Steel take-off (kg)
10	70 x 70 x 5	50 x 50 x 3	35 x 35 x 5	122.436
12.5	80 x 80 x 6	60 x 60 x 5	50 x 50 x 3	222.658
15	125 x 95 x 6	70 x 70 x 5	65 x 45 x 6	372.216

Table.3 Steel Take-Off for Warren Truss

Fig 4.(a) below shows the load application in warren truss of 10m length. The total load comprising live, dead and wind load is applied throughout the truss. Similarly, keeping the pitch and angle same for 12.5m and 15m length warren truss, same loads were applied.

Fig 4.(b) represents the comparison between span and steel take-off for warren truss in a chart. The value of steel-takeoff increases with increase in span length in slightly straight manner.

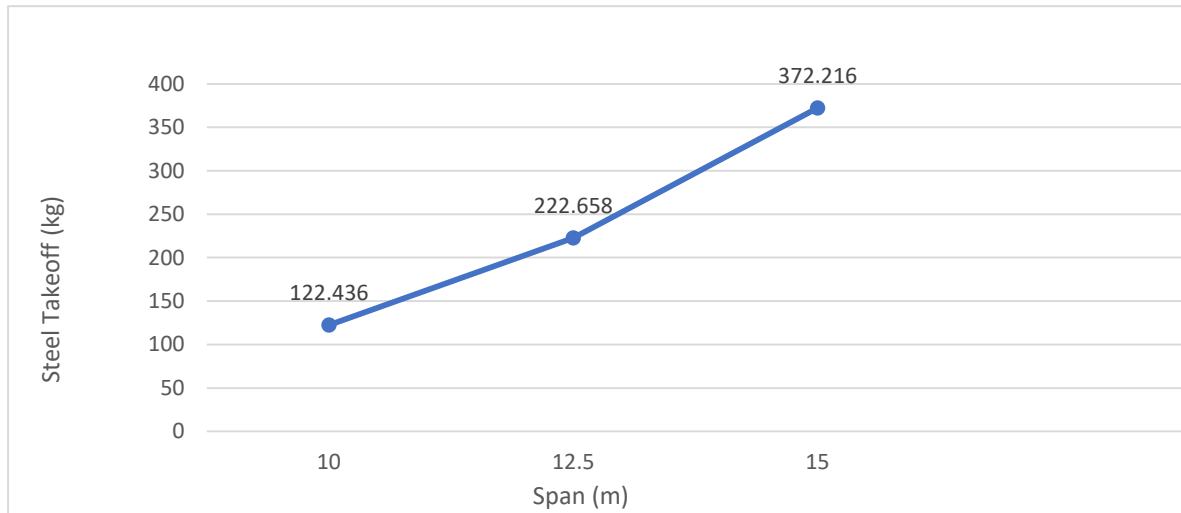


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(b)

Fig. 4. Warren Truss (a) For 10m (b) Span vs Steel take-off

VI. SUMMARY FOR TRUSSES

From the study and result, the summary comparison between the trusses can be done from which the lightest weight for each span of 10m, 12.5m and 15m can be obtained. Fig. 5, bar-chart graph of span and steel take-off shows the comparison among the Pratt, Howe and Warren truss with different length.

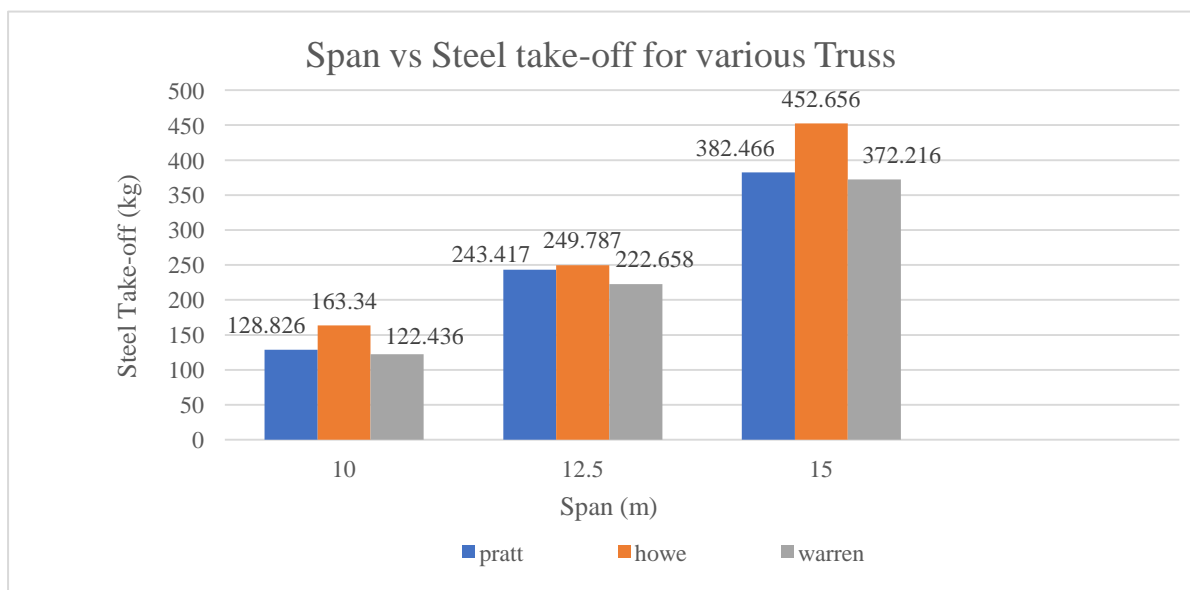


Fig. 5. Span vs Steel take-off for Various Truss

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As from above chart we can summarize that the value of steel take-off in trusses keeps increasing for increasing in span. Also, the differences between trusses on the basis of structure deflection can be seen. The steel take-off value for Howe truss is highest for each span while lowest values are for Warren truss. The weight of warren truss is lightest compared to two other trusses so we can say that warren truss is best among all three and is economical as the least steel take-off of the truss among three trusses. Warren truss meets the required design among them and is the most economical one that interests the Structure Engineers.

VII. CONCLUSION

Based on the study performed on roof truss of varied span following results are obtained.

- The steel take-off for Warren truss at 10m, 12.5m and 15m are often seen lowest compared to Pratt and Howe trusses. Then the value of Pratt truss is often seen slightly below Howe at 10m and 15m span.
- Warren truss is the lightest and most economical among three trusses and it can be used for cost cutting as it saves about 3% - 9 % of material's weight than Pratt truss and 12% to 33% depending upon to span length.
- The calculation of self-weight of various members in the trusses, shape and size are vital components because the forces also be totally different within the same trusses.
- This analysis might not be operating and the distribution of loads could also be somewhat totally different in case of daily construction at field/site.
- It can be concluded from steel take-off v/s span chart of various trusses that their value varies linearly with none outlined pattern. So, an engineer's expertise comes handy and had to select optimum structure for stability.

VIII. FUTURE SCOPE

In future different things along with the steel take off can be considered because this work has been completed in STAAD Pro and challenges will be different when we move into its applications and clearly this will give us the idea to a large extent. By combining these studies with the requirements, we can find out even better ways to use the trusses in our engineering structures in future and could be a huge turning point in civil engineering.

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