Comparative Study on Optimization of Pratt, Howe and Warren Steel Truss

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Abstract— The purpose of this project is to design, analyse industrial roof truss and to determine the impacts of trusses geometry in the design of plane truss for increasing structural efficiency with different configurations by using channel, angle and beam shape section. This study is need as sometimes there is difficulty or time consuming to choose the most successful or optimum shape of designed roof truss. Two trusses (Pratt truss, Warren and Howe trusses) which can be compared closely are chosen. The form and configuration of the truss rely upon the span of trusses and total other different factors. The height of truss is kept 10m from the ground and designed span of 10m, 12m and 14 m with rise of 2m, 2.5m and 3m and analysis is done. It shows comparison of trusses between post optimisation values of steel take-off and span keeping height constant. We considered self-weight, dead load and wind load and other load combinations details on STAAD Pro V8i software. 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 KN wherever the truss with least value of steel take-off is taken into account as most economical as it gives a light weight structure with cutting the material cost of construction also member are optimised to desired sections thereby making the structure most efficient & economical in use. Pratt, Howe & warren trusses were compared for every span with same rise. For same span, Pratt truss geometry looks to be the fore most suitable configuration with more savings of weight when put next to other trusses.

Indexed Terms-- Truss design, Structural Efficiency, Models, Analyses, Truss Arrangement, Steel take-off, lesser weight, Truss optimization.

I. INTRODUCTION

A roof truss is a framed structure formed by adjoining various members in a particular pattern of triangles depending upon span, type of loading, slope and other requirements. Steel trusses are widely used in industrial buildings for many years. Every structure should have to fulfill the structural and economical requirements. Hence there is need of optimization of truss design to obtain minimum weight. All of the methods used for reducing the weight tend to reach an optimum design having a set of design constraints. The optimum design of a structure should satisfy various constraint limits such as displacement limits, stress and local stability conditions.

As it is well known that the optimum shape of a truss depends not only upon its topology, but also upon the distribution of element cross-sectional areas.

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 optimizing 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.

The support conditions and connection of members (bolting/welding) also have some effect to the structural behavior 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

A. Truss Structural Optimization

In truss structural optimization the most frequently optimized factor of a structure is its weight. The minimization of weight contributes not only to savings in material, but also in other aspects of the structure such as number of elements used, number of welds needed, outer surface area, etc.

The truss layouts are optimized for sizing, and a combination of sizing and shape with a minimal weight objective function. The minimal weight optimization is generally approached through optimizing either sizing (varying the cross sections of bars or bar groups), shape (varying the positions of nodes), topology (adding or removing elements between nodes), or one of their combinations.

Truss structural optimization implies the simultaneous optimization of sizing, shape, and topology.

Topological optimization depends on the structural stability of the construction. The most common objective function of truss structural optimization is the minimization of weight. The main objective is to minimize cost of structure by maintaining its structural integrity and safety and to find the optimum parameters for construction. To make the structure as light as possible i.e., to minimize weight or as stiff as possible one could make it more vulnerable to buckling or instability.

B. Topology and Geometry Optimization of Trusses

Optimization involves selection of optimum section size for all members using a procedure consisting of multiple cycles of analyses as well as iteration on section sizes until an overall structure least weight is obtained. Variable topology shape optimization is much more general than fixed topology shape optimization in that it leads modifications to the topology of structural elements. There are two broad classes of techniques which can be applied to optimize the shape and topology of a structural system early on in the design process:

1. Discrete optimization of the structural system.
2. Continuum optimization of the structural system

In the discrete optimization methods, the structure is generally modeled with discrete truss and/or beam/column elements, whereas in continuum methods, the structure is modeled as a continuum. The initial design of skeletal structures such as trusses and frames can be broken down into the selection of nodal (or joint) locations, and design of the connectivity structural elements. The former process is referred to as geometry optimization or configuration optimization, and the latter is called topology optimization.

Sizing optimization refers to locating the most excellent cross phase area of every member of the structure; shape optimization manner optimizing the outer shape of the shape; and topology optimization describes the search for the fine inner connectivity of the participants. One manner of optimizing those three parameters is to take them into attention one at a time, beginning with the topology optimization, a so called multi-degree optimization method.

C. General Geometry of Roof truss

For efficient structural performance, the ratio of span to truss depth should be chosen in the range 10 to 15. For an efficient layout of the truss members between the chords, the following is advisable:

1. The inclination of the diagonal members in relation to the chords should be between 35° and 55°.
2. Point loads should only be applied at nodes.
3. The orientation of the diagonal members should be such that the longest members are subject to tension (the shorter ones being subject to compression).
4. The pitch of a roof truss = (rise/span) should be 1/4 to 1/6 for proper drainage.
5. Spacing of a roof truss is kept 1/3 to 1/5 of the span. Roof truss usually require very light members.
6. A minimum angle section ISA 50 x 50 x 6 mm should be provided to avoid damage during transportation, erection, etc. Double angle section

are usually used for main rafter and ties.

7. Roof trusses usually require very light members. For smaller spans, tee sections are frequently used for chords, with angles used as internal members.

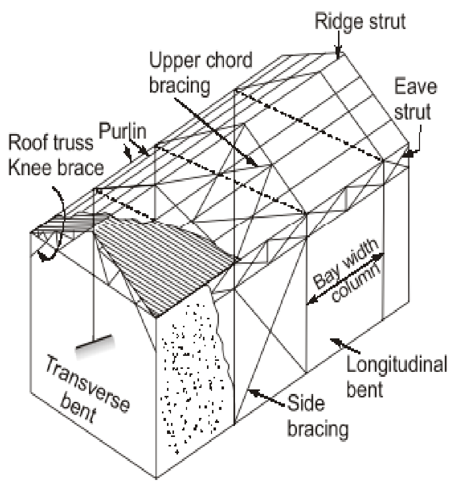


Fig 1. Structural Frame of an Industrial shed

D. Need of Study

Long span structures are needed to resist lateral forces over the span length without vertical members at the mid spans, for such structures truss arrangement is more beneficial to distribute tension and compression of each members. Benefits of truss structures are as follows:

1. To provide lateral stiffness to the structure.
2. To minimize structure weight and support divisions.
3. Fast assembling and arrangement at the site

II. LITERATURE REVIEW

- Yamank Sahu, Deepak Kumar, Bandewar Sachin Jat,Structure Optimization Valuation for Steel Trusses using STADD Pro Tool, International Journal for Scientific Research & Development, Vol. 9, Issue 11, 2022.

In this study the requirement to choose an effective and economical truss shape or truss geometry during the design period is discussed. The study about the steel structures, steel trusses make one of the major structural systems, which require for accurate and reasonable design. The shape and configuration mainly depend upon the span of trusses and a variety of loads. We have proposed to optimize the steel truss pattern for increase structural efficiency. Long span structures are needed to resist lateral forces over the span length without vertical members at the mid spans, for such structures truss arrangement is more beneficial to distribute tension and compression of each members. We have tested the considered models using Staad.Pro .The designed steel truss structures are analyzed for increasing structural efficiency. The present investigation will encourage the utilization of steel truss arrangement for long span structures which may be cost effective, easy and fast in assembling. And concluded that in truss arrangement Howe type truss is comparatively best suitable whereas in terms of sections beam section is more resistible and economical.

- Shilpa Chauhan, Rohit Sharma, Abhishek Gupta, Optimization of steel truss configuration for structural efficiency using STAAD.Pro and ETABS, International Journal for Scientific Research & Development, Vol. 6, Issue 9, September 2017.

In this study they have proposed to optimize the steel truss pattern for increase structural efficiency. We have tested the considered models using Staad.Pro and ETABS. We have designed steel truss of different spans i.e. 7m, 10m, 12m, 15m and 18m. The designed steel truss structures are analyzed for increasing structural efficiency with different configurations. Our proposed work shows that more strength beam and strength angle is required if we design the same structure with same material in ETABS as compared to Staad.Pro which demonstrates that it requires less strength. By analyzing the graphs, we could also conclude that as the span of structure increases the strength beam and strength angle condition is increasing considerably in ETABS as compared to Staad.Pro. In this study, main focus is to analyze the steel truss configurations for comparison among STAAD. Pro & ETABS by taking into consideration the strength parameters. The analysis results shall compare to acquire optimum and perfect truss design.

- Vikas Khandelwal, Abinash Gajurel, Hemant Sah, Roshan Giree, Sarupya Dhakal ,Optimal Topologies of Roof Trusses by STAAD Pro, Vol. 9, Issue 1, January 2020.

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.

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 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.

- Upendra Pathak, Dr. Vivek Gargm ,Optimization and rationalization of truss design, International Research Journal of Engineering and Technology, Volume: 02 Issue: 05 Aug-2015.

In present work, roof truss of span 16m has been analyzed for different geometries and sections to get the desired optimum truss design. The design is further optimized for varying slopes of truss. In design of steel trusses different types of geometries (A-type truss, Fink truss, Pratt truss, Howe truss, King post truss, Queen post truss etc.) and sections (Angle section, Tube section, Square hollow section etc.) are widely used. The various truss analyses are performed by using structural analysis software i.e. STAAD Pro. The analysis results are compared to obtain optimum and accurate truss design. The results indicate that A-type truss has lesser weight compared to other truss geometries. The truss consists of tube/square hollow section is having much lesser weight compared to angle section. The optimum truss slope is found nearly 24º. The truss with rigid connection between members is found heavier than the truss with pin connection. Similarly truss supported on fixed base/purlins resting on truss members causes bending moment in top chord of the truss members which in turn modify the sectional requirement of the members.

- Avanti Patrikar, K. K. Pathak, Fully Stressed Design of Fink Truss Using STAAD.Pro Software, Open Journal of Civil Engineering, Volume 6, 631- 642, September 21, 2016

They presented 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. Results of the study will be helpful in the designing of a truss that must fulfill the requirement of economy as well as strength.

- Shivam Goel, K.K.Pathak, Topology Optimization of Warren Trusses, International Journal of Engineering Research. Volume No.5, Issue Special 1 pp: 95-98

In this study they have considered 9 Warren truss each with a distinct span and height and each truss was subjected to 9 loading conditions and 81 cases were formulated. Each case was optimized to get a target stress of 100 MPa in each member and the steel take off was calculated. This steel take off was compared with other span and height combinations of the Warren truss for the same loading condition and the mass used of the steel was compared. In this way optimization results in the efficient utilization of material and hence reducing the cost of the structure. They examined the steel take-off of various truss structures obtained through repeated iterations and having a constant stress of 100MPa in each member. They noticed that the weight of the structure does not always increase with the increase in span or height.

- S. Rajasekaran, Computer Aided Optimal Design of Industrial Roof, ASCE Journal of Structural Engineering. Volume 10, No 2, July 1983: pp. 41-50.

Rajasekaran has carried out research on optimal design of industrial roof system by using computer aided technique. He investigated on finding optimal spacing of roof truss of a given span and length to get optimum weight.

- Er. Sanjeev Kumar, Brahmjeet Singh, Er. Bhupinder Singh, Optimization of Roof Truss Using STAAD PRO V8i, International Journal of Recent Research Aspects ISSN: 2349-7688, Vol. 3, Issue 1, March 2016, pp. 86-90

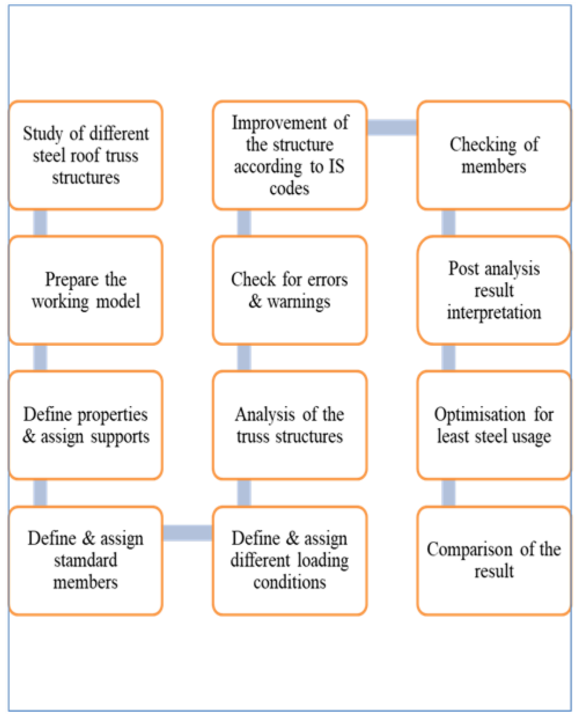
They studied the effect of different spacing, span, and pitches, in order to find out the most economical truss by using angle section. In present work, "HOWE ROOF TRUSS" of span varying from 10m to 40m has been analyzed for different geometries to get the desired optimum truss design. The various truss analyses are performed by using structural analysis software i.e. STAAD Pro. The analysis results are compared to obtain optimum and accurate truss design. In investigating the effectiveness of various truss geometries, a total of 80 truss geometries are analyzed. This study includes the determination of dead load, live load and wind load as per Indian Standard Codes IS 800:2007 and IS 875(Part 3)-1987. The Howe truss is analyzed by taking different pacing's at different spans and pitches. The loads at each panel and node are calculated manually and then the loads are entered into Staad pro software for analysis and designing. The Staad pro software output method is used for determining the steel takeoff (weight).The truss with a least value of steel takeoff is considered as most economical truss.

III. OBJECTIVES

1. To find out the least steel take-off from Pratt, Howe and Warren steel trusses.
2. To observe utilization ratio after member optimization of trusses.
3. To compare results of Pratt, Howe and Warren truss.
4. To find out the most economical truss in terms of steel usage using optimization.

IV. METHODOLOGY

A. Work flow chart of truss design and analysis procedure:



B. Parameters for truss design

Sr.No.	Particulars	Data
1.	Type of Truss Models used for analyses	Pratt truss, Howe truss & Warren truss
2.	Span of truss	10 m , 12 m , 14m
3.	Height of truss	10 m
4.	Sections	Angle, Channel ,S shape ,I shape W shape, M shape
5.	Top chord member	ISA 100 x 100 x 12
6.	Bottom chord member	ISMB200
7.	Web or diagonal member	ISA 60 x 60 x 10
8.	Material	Steel
9.	Support condition	Fixed support
10.	Grade of steel	Fe 415
11.	Poisson's ratio	0.3

12.	Modulus of elasticity	205 GPa
13.	Density	7833.409 kg/m^3

Table 1. Parameters for truss design

C. Experimental work overview

In the present work with the end goal to find out least steel take-off after steel optimization and observe utilization ratio after member optimization using software named Staad Pro V8i, through a comparative study is carried out between Pratt, Howe and Warren trusses. Angle, Channel, Beam shape steel sections are considered and height of truss is kept constant for all the three models of span 10 m, 12 m, & 14m. For this study different properties, fix end supports, standard member size and different loading conditions are define, assigned and then analysis of truss structure is performed also check for errors and warning are considered. Improvement of the truss structure according to IS code provisions is also followed using Staad Pro V8i software. The results of Pre and Post optimization of steel take-off and member weight among different truss structures are further compared with other models for optimum design and to achieve our objective of finding out a light weight steel structure thereby achieving most economical and effective truss geometry in terms of steel usage using optimization.

V. STRUCTURAL MODELLING AND ANALYSIS OF TRUSS

A. Modelling of truss

Cases & parameters Pratt, Howe & Warren truss assigned in present study are as follows:

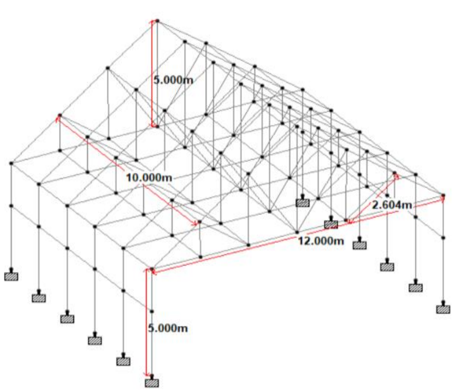


Fig 2.Pratt truss model of span 10 m

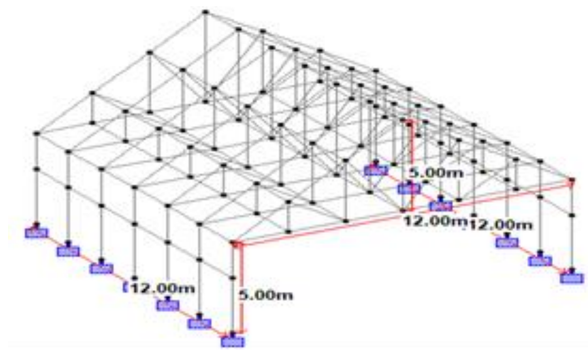


Fig 3.Pratt truss model of span 12 m

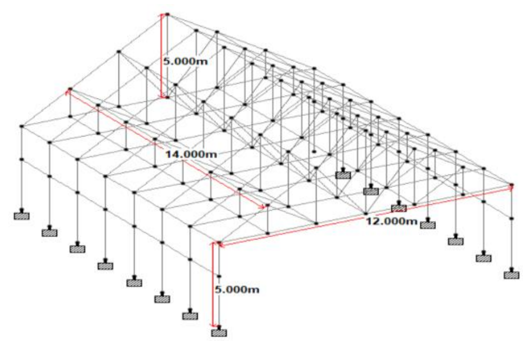


Fig 4. Pratt truss model of span 14 m

In the same way structures are modelled for 10m, 12m, 14m span for Howe & Warren truss keeping 10 m height from ground constant in each case.

Span (m)	Top Chord (ISA)	Middle Chord (ISA)	Bottom Chord (ISMB)	Total Nodes	Total Beams
10	100 x 100 x 8	60 x 60 x 10	200	96	220
12	100 x 100 x 12	90 x 90 x 12	250	112	259
14	110 x 110 x 10	90 x 90 x 12	350	128	298

Table 2. Parameters for Pratt truss

Span (m)	Top Chord (ISA)	Middle Chord (ISA)	Bottom Chord (ISMB)	Total Nodes	Total Beams
10	100 x 100 x 10	80 x 80 x 10	250	96	220
12	100 x 100 x 10	90 x 90 x 10	250	140	339
14	100 x 100 x 10	90 x 90 x 10	300	160	390

Table 3. Parameters of Howe truss

Span (m)	Top Chord (ISA)	Middle Chord (ISA)	Bottom Chord (ISMB)	Total Nodes	Total Beams
10	100 x 100 x 10	90 x 90 x 10	350	108	254
12	100 x 100 x 8	90 x 90 x 12	300	126	299
14	110 x 110 x 10	90 x 90 x 12	300	144	344

Table 4.Parametrs for Warren truss

Steps followed in this study are as follows:

Step-1: Modelling of the structure in Staad.pro

Step-2: Assigning Sectional properties and standard members as per Steel Table.

Step-3: Assigning Support Condition

Step-4: Assigning load conditions:

Step-5: Analysis of structure:

Step-6: Check for errors & warnings by assigning each command to the section and then performing analysis using run analysis command.

Step-7: Improvement of the structure according to IS codes in found with errors.

Step -8: Checking for failure of members if fails then changing section properties and check for utility ratio criteria which must be less than 1 for all cases.

Step -9: Post analysis result interpretation.

Step-10: Select check code command and select optimized command to find out least steel take-off using optimization.

Step-11: Comparison of Results.

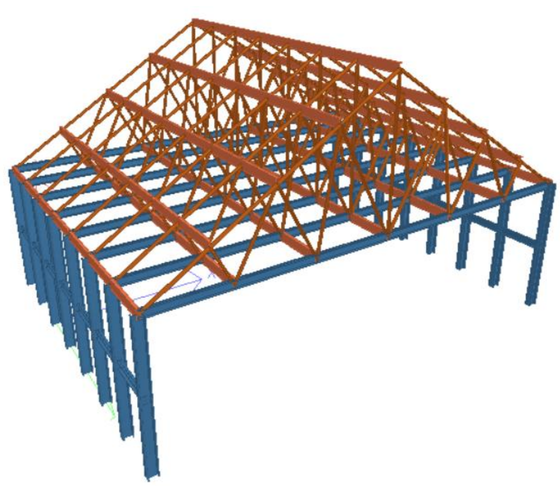


Fig 5. Modelling of truss in staad.pro

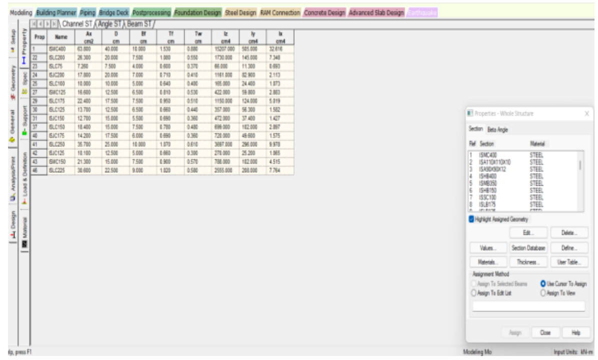


Fig 6.Section Properties of 14 m Pratt Truss

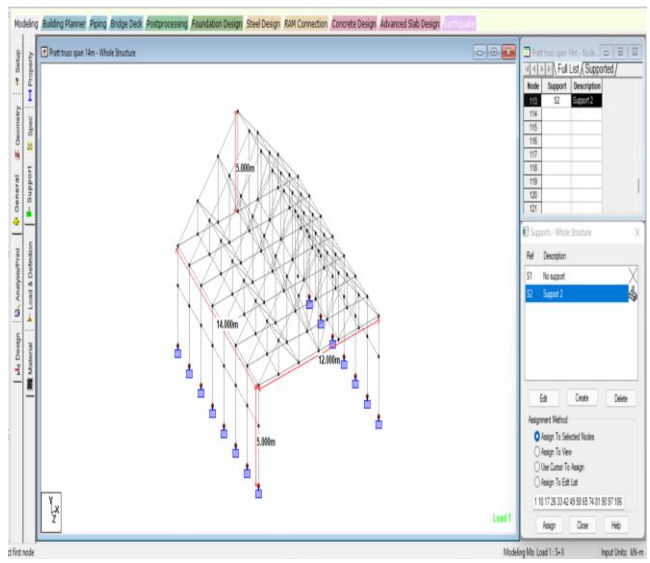


Fig 7. Fixed end support for 14m Pratt truss

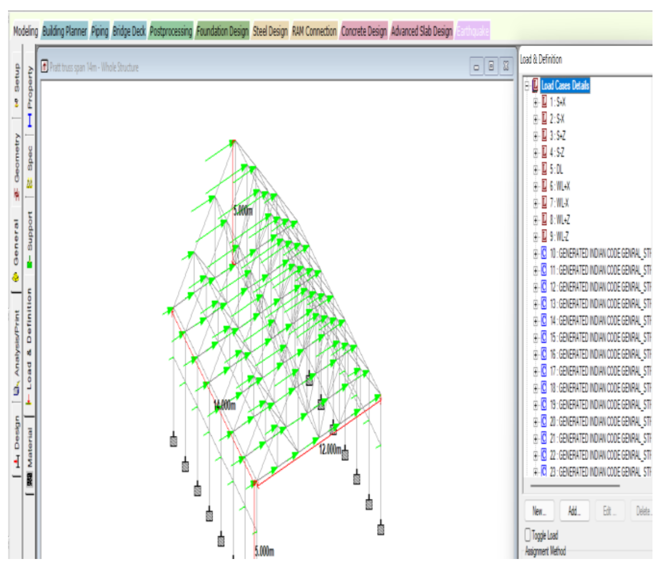


Fig 8. Load Cases details of 14 m Pratt Truss

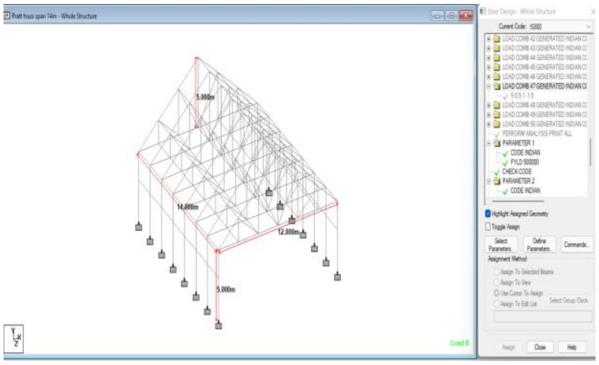


Fig 9.IS Code 800 details of 14 m Pratt Truss

In the same way structures are designed for 10m, 12m, 14m span for Howe & Warren truss keeping in each case by defining & assigning section properties, support condition and load case details using IS Code provisions.

B. Analysis of truss structure using STAAD.Pro V8i software

The various types of trusses have been considered and they are analyzed using a computer software called Staad pro.

STAAD Pro V8i is used to calculate optimum cross-sectional area for each and every truss member in reducing weight of truss and thereby reducing loads at joints causing reduction in stress level. Its identified there is big drop in weight of truss and area of cross section making the truss optimized.

Steps involved in optimization of truss:

1. After modelling of structure and assigning load case details several parameters are defined to the structure such as check code, take-off, Selection of IS code to INDIAN and improvement of the structure according to IS code.
2. Select – Selects least weight section size based on specifications of the desired code.
3. Select Optimized – selects optimum section size for all members using a procedure consisting of multiple cycles of analyses as well as iteration on section sizes until an overall structural least weight is obtained.
4. After assigning design parameters click on select, select all and select optimize will perform member optimization for the member section given by us.
5. Take off taken after optimization will give member steel weights of all sections used in the structure.
6. 6.Again click on select all, select optimize and take off taken after optimization will give us the steel take off for all the sections hereby performing double analysis is done by select optimize giving us optimum section size for all members.
7. Hence total least steel take-off among different truss geometry can be easily found and compared to obtain most economical truss in terms of steel usage using optimization.

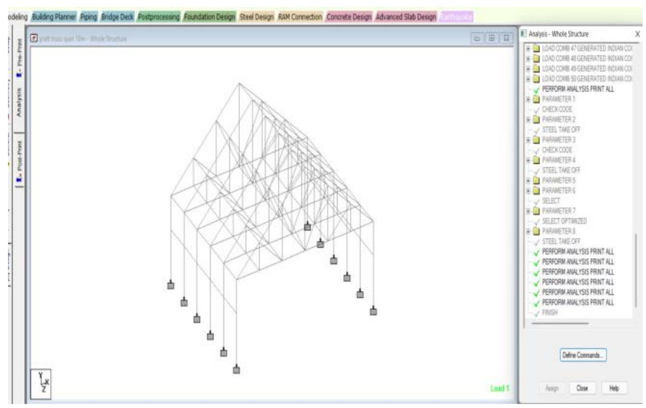


Fig 10. Analysis of 10 m Pratt Truss

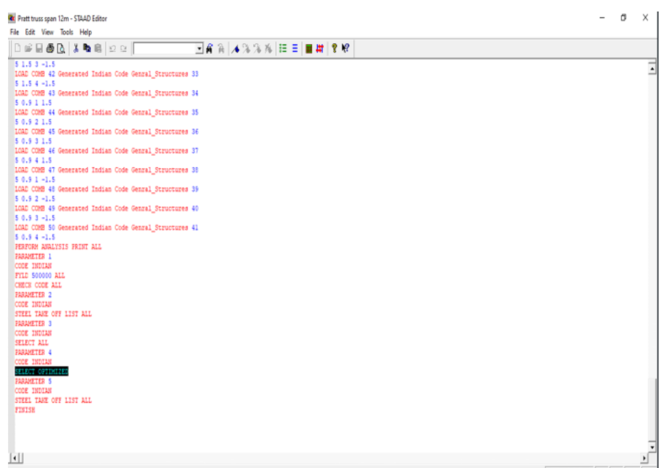
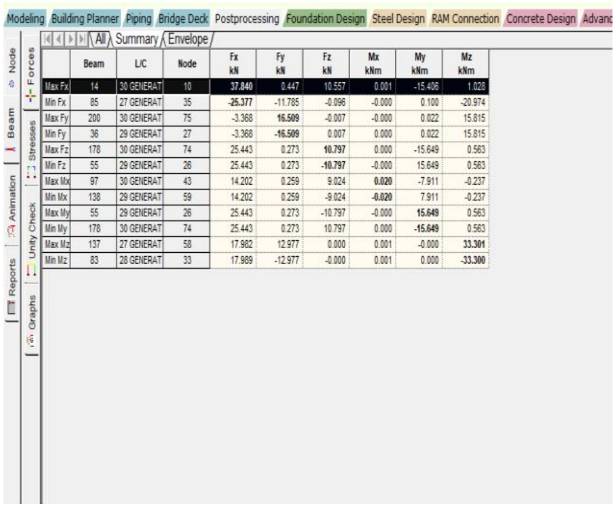


Fig 11. Steel optimization of 10 m Pratt truss



	Beam	L/C	Node	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
Max Fx	14	30 GENERAT	10	37.840	0.447	10.557	0.001	-15.406	1.028
Min Fx	85	27 GENERAT	35	-25.377	-11.785	-0.096	-0.000	0.100	-20.974
Max Fy	200	30 GENERAT	75	-3.368	16.509	-0.007	-0.000	0.022	15.815
Min Fy	36	29 GENERAT	27	-3.368	-16.509	0.007	0.000	0.022	15.815
Max Fz	178	30 GENERAT	74	25.443	0.273	10.797	0.000	-15.649	0.563
Min Fz	55	29 GENERAT	26	25.443	0.273	-10.797	-0.000	15.649	0.563
Max Mx	97	30 GENERAT	43	14.202	0.259	9.024	0.020	-7.911	-0.237
Min Mx	138	29 GENERAT	59	14.202	0.259	-9.024	-0.020	7.911	-0.237
Max My	55	29 GENERAT	26	25.443	0.273	-10.797	-0.000	15.649	0.563
Min My	178	30 GENERAT	74	25.443	0.273	10.797	0.000	-15.649	0.563
Max Mz	137	27 GENERAT	58	17.982	12.977	0.000	0.001	-0.000	33.301
Min Mz	83	28 GENERAT	33	17.989	-12.977	-0.000	0.001	0.000	-33.300

Fig 12. Beam force details for 10 m Pratt truss

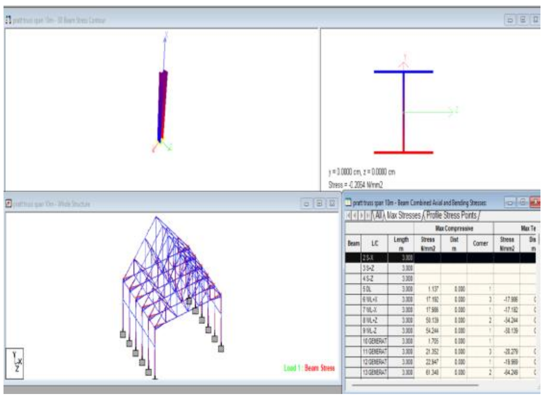


Fig 13 Beam combined axial & bending stresses details for 10 m Pratt truss

VI. RESULTS & COMPARISON

A. Structural Analysis for Pre and Post Optimization of Truss Members

The pre & post optimization results in terms of steel take-off for case I Pratt truss members in KN are as follows & the same procedure is done for all the other cases of different spans.

STEEL TAKE-OFF

	PROFILE	LENGTH (METE)	WEIGHT (KN)
ST	ISHB350	60.00	39.593
ST	ISMB200	92.00	21.768
ST	ISA100X100X8	93.72	11.088
ST	ISA60X60X10	167.80	14.180
ST	ISMC250	120.00	35.952
		TOTAL =	122.579

Fig 14 Steel take-off for Pratt 10 m truss Pre – optimization

STEEL TAKE-OFF

	PROFILE	LENGTH (METE)	WEIGHT (KN)
ST	ISSC120	24.00	6.158
ST	ISLB125	24.00	2.784
ST	ISLB75	48.00	2.843
ST	ISA75x75x5	124.97	6.979
ST	ISA150x150x10	30.00	6.729
ST	ISA50x50x3	16.64	0.377
ST	ISA100x100x6	39.95	3.590
ST	ISA110x110x8	46.64	6.126
ST	ISJC175	8.00	0.873
ST	ISLC75	72.00	4.016
ST	ISJC100	8.00	0.455
ST	ISJC125	8.00	0.621
ST	ISWB150	8.00	1.334
ST	ISJB225	16.00	2.003
ST	ISJB200	12.00	1.162
ST	ISJC150	12.00	1.171
ST	ISLC100	12.00	0.922
ST	ISWB175	12.00	2.590
ST	ISLB175	8.00	1.309
ST	ISA50x50x4	3.33	0.099
		TOTAL =	52.141

Fig 15. Steel take-off for Pratt 10 m truss Pre – optimization

A. Discussion and comparison on results of optimized Pratt, Howe & Warren steel truss.

It is confirmed that optimized trusses are within the limits of design constraints, to analyze cross-sections of all the members may not be same. Therefore, optimization tool in Staad.Pro V8i is used to calculate optimum cross-sectional areas for each and every truss member in reducing weight of truss and their by reducing loads at joints causing reduction in stress levels.

It is identified that there is a big drop in weight of the truss and area of cross-sections making the truss optimized. The following table 5 & 6 show reduction in structural weight in proportion with cross-sectional areas of individual members for pre & post optimization.

- Weight reduction in trusses:

Sr. No.	Truss Geometry	Span (meter)	Pre-Optimization members & their weights (kN)			Total weight (kN)
			Top chord (ISA)	Web (ISA)	Bottom chord (ISMB)	
1.	Pratt	10 m	100x100x8	60x60x10	200	122.57
			11.08	14.18	21.76	
		12m	100x100x12	90x90x12	250	149.49
			18.98	30.38	43.142	
		14 m	110x110x10	90x90x12	350	261.79
			26.73	28.522	63.53	
2.	Howe	10 m	100x100x10	80x80x10	250	142.41
			13.75	19.47	33.641	
		12 m	100x100x10	90x90x10	250	255.32
			20.54	49.38	49.73	
		14 m	100x100x10	90x90x10	300	286.89
			22.14	47.99	70.34	
3.	Warren	10 m	100x100x10	90x90x10	350	230.79
			19.04	33.06	65.58	
		12 m	110x110x8	90x90x12	300	258.74
			19.89	45.57	67.64	
		14 m	110x100x10	90x90x12	300	302.98
			28.05	52.08	77.56	

Table 5. Pre-Optimization members & their weights

Sr. No.	Truss Geometry	Span (meter)	Post-Optimization members & their weights (kN)			Total weight (kN)
			Top chord (ISA)	Web (ISA)	Bottom chord (ISMB)	
1.	Pratt	10 m	150x150x10	75x75x5	120	52.14
			6.72	6.97	6.15	
		12m	100x100x6	70x70x6	150	73.64
			7.47	0.49	15.19	
		14 m	150x150x10	90x90x6	200	93.04
			8.97	1.04	13.13	
2.	Howe	10 m	100x100x6	60x60x4	150	64.12
			6.40	0.72	6.36	
		12 m	100x100x6	90x90x6	200	174.38
			5.66	3.14	24.08	
		14 m	100x100x7	90x90x6	200	148.08
			1.73	1.79	17.51	
3.	Warren	10 m	100x100x8	50x50x4	225	131.80
			5.11	0.60	15.18	
		12 m	100x100x8	50x50x4	200	149.42
			4.15	0.70	28.46	
		14 m	110x110x8	50x50x4	200	170.65
			5.08	0.80	30.65	

Table 6. Pre-Optimization members & their weights

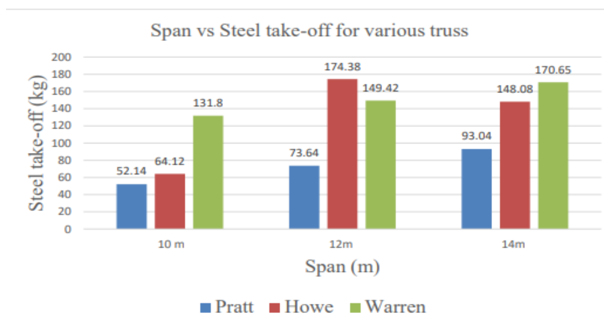
The following table 7 shows comparison between steel take-off values for pre & post optimization for Pratt, Howe & Warren trusses from which the lightest weight for each span of 10 m, 12 m, 14 m can be obtained.

Sr.No.	Truss geometry	Span (Meter)	Pre-optimization values of steel take-off (kN)	Post-optimization values of steel take-off (kN)
1.	Pratt	10 m	122.57	52.14
		12 m	149.49	73.64
		13 m	261.79	93.04
2.	Howe	10 m	142.41	64.12
		12 m	255.32	174.38
		14 m	286.89	148.08
3.	Warren	10 m	230.79	131.80
		12 m	258.74	149.42
		14 m	302.98	170.65

Table 7. Comparison between steel take-off values

B. Comparison between Pratt, Howe & Warren truss

Bar-chart graph 1 of span and steel take-off shows the comparison among the Pratt, Howe & warren truss with different length.

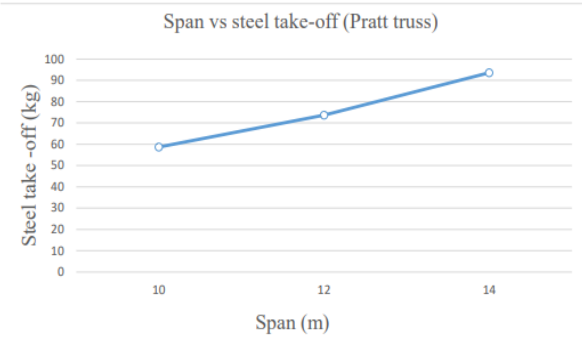


Bar-chart graph 1. Span vs. steel take-off for various truss

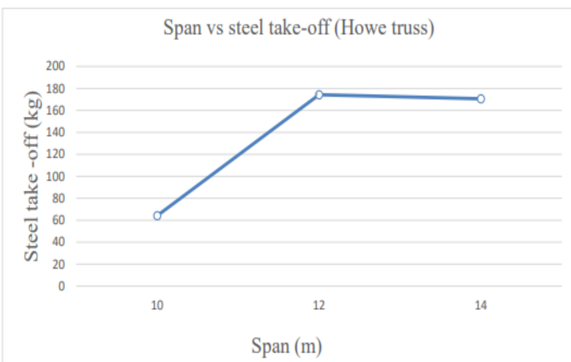
As from above graph we can summarize that the value of steel take-off in trusses keeps increasing for increasing in span.

The steel take-off value for Warren truss is highest for each span while lowest values are for Pratt truss. The weight of Pratt truss is lightest compared to other truss so we can say that Pratt truss is best among all three trusses and is economical as the least steel take-off of the truss among three trusses. Pratt truss meets the required design among them and is the most economical one truss geometry from our research work.

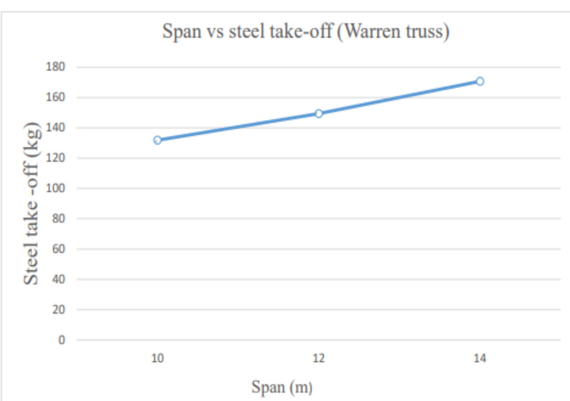
The following graphs are plotted between span & steel takeoff for Pratt, Howe and Warren truss.



Graph 1.Span vs. steel take-off for Pratt truss



Graph 2.Span vs. steel take-off for Howe truss



Graph 3.Span vs. steel take-off for Warren truss

Graph 1. Represents the comparison between span and steel take-off in a chart for Pratt truss. The value of steel-takeoff increases with increase in span length in linear manner.

Graph 2. Represents the comparison between span and steel take-off in a chart for Howe truss. The value of steel-takeoff increases with increase in span length in linear manner and the post optimization attains a constant range.

Graph 3. Represents the comparison between span and steel take-off in a chart for warren truss. The value of steel takeoff increases with increase in span length in slightly straight manner.

CONCLUSION

Structural topology optimization is a powerful and well-established technique to determine the optimal geometry to design efficient structures. In this paper the parametric study of Pratt, Howe & Warren truss of span 10 m, 12 m, and 14 m for constant height is done. Steel take-off are calculated for pre and post optimization of trusses using Staad.pro V8i software.
Following conclusions can be made after comparison of Pratt, Howe & Warren truss:-

- The average steel take-off values for Pratt, Howe & Warren truss at 10 m, 12 m and 14 m span is 72.94% ,128.86 % & 150.62 % .Pratt truss values are often seen lowest compared to other truss with a percentage reduction in steel weight by 40.98 % ,56.46 % and 57.107 % post optimization .
- The least steel take-off of 52.14 KN, 73.64 KN & 93.04 KN for 10 m, and 12 m & 14 m span of Pratt truss after comparison is obtained.
- The percentage reduction in weight of member after comparison of pre & post optimization results of member take-off are observed as 25.60%,20.60% & 22.21% with utilization ratio less than 1 for all the cases.
- It is observed from the steel take-off v/s span chart of various trusses that the value of steel take –off keeps on increasing with increase in span hence it's very important to select optimum structure for stability.
- From all the comparisons between trusses Pratt truss is the lightest and most economical truss in terms of steel usage as it has least steel takeoff and saves material weight than Warren & Howe

truss thereby saving a large amount material cost of construction.

VII. FUTURE SCOPE

1. 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.
2. 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.
3. In the present study long span truss arrangement is considered whereas in future long span truss with unsymmetrical divisions can be consider.
4. The effect of seismic analysis can be include in future as in this study wind pressure is considered.

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