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Minimizing Weight by Optimizing Different Truss Parts Using Finite Element Analysis

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Abstract

This paper presents a study of minimizing weight by optimizing different truss parts using finite element analysis and comparing Warren trusses with other trusses. The aim of the optimization is to find a light design. Existing structural steel trusses were initially optimized for minimum weight and constrained with allowable stresses and deflections. Applicable Eurocode 3 design conditions are presented, which provide the constraints for the problem. Steel truss is a preferred solution in large-span roof structures due to its good attributes, such as being lightweight and durable. Existing structural steel trusses were initially optimized for minimum weight and constrained with allowable stresses and deflections. Constant spans of the trusses have been considered, and each truss has been subjected to the same types of load cases. The top chord member load has been kept constant in each truss at 2 kN/m. Two sets of load conditions are taken as the self-weight of the truss and the snow load, but the structure is calculated by the load combination. The structural steel trusses were optimized using the design optimization tool as a first-order optimization method in RFEM, and it was extended to compare the most suitable truss geometry for the minimum weight. Finally, it is concluded that the Warren truss has a higher stiffness-to-weight ratio than other trusses after optimization. The goal of this study was to analyze all trusses and ensure that the structural stress is less than the allowable stress and that the deflection is less than the allowable deflection. The span and height are constant in all cases because they have no impact on the weight increase; only the position of the rods and cross-section size affect the building's ability to withstand loads and weight increases. In this paper, a finite element analysis (FEA)-based optimization technique is proposed for the optimization of a light design that is constrained by allowable stresses and deflections. For this purpose, there have been studies on sizing optimization to minimize the mass of different steel truss roof system types both in the past and today. For this purpose, weight design and analysis of the optimum weight are carried out on ten different structural systems.

Keywords

Truss Structural Optimization, Geometry, Displacement, Weight

1. Introduction

As you know, structural optimization is an efficient method of solving the contradiction between architects and structural engineers. Structural optimization concerns achieving the best outcome of a given design while satisfying certain restrictions. Engineers have always tried to optimize the structural design for material savings and cost reduction. Optimization can be done with respect to the size, shape, and topology of the structure. Truss optimization has been approached using many different optimization techniques to optimize a realm of diverse truss structures, which encompass vast applications. A truss is a structure that consists of a stable and systematic arrangement of slender, interconnected members. Every truss member is aligned and connected at its joints. The arrangement of elements in a truss ensures that the members are both efficient and lightweight while carrying loads. The joints in trusses do not carry any moments because they are connected by frictionless pins. Therefore, truss members are only capable of carrying axial forces that are either compressive or tensile in nature. Trusses are highly used in modern construction. Trusses are more complex than rafters and are designed to support heavier loads over extensive spaces. They consist of a top chord, a bottom chord, and webbing, forming triangular shapes to hold the structure together. Because of this condition, trusses are commonly used in huge structures such as airports, riding arenas, or storage facilities. Steel trusses are most widely used in industrial buildings. These days, most of the trusses are made of steel; however, in some cases, timber and concrete trusses are also utilized. The sections used for steel trusses are generally angle sections, square hollow sections, pipe sections, T-sections, C-channel sections, etc. In any case of structural construction, the main objective is to reduce the cost of the project and fulfill structural requirements. Hence, it becomes necessary to optimize the structure to fulfill the economic requirement. The optimum design of a structure should satisfy various constraint limits, stress, and local stability conditions. The optimum shape of a truss depends not only upon its topology but also on the distribution of elemental cross-sectional areas. Some of the basic optimization techniques are mathematical programming, optimization criteria, approximation methods, and the fully stressed design method. In the past, many researchers have carried out research on the optimization of trusses. The steel truss element is independent of the second moment of area so, only the normal and shear forces are of main concern. Circular cross sections are best for bearing normal stress, although square and rectangular cross-sections are used in this study due to their wide use and ease of joining and are taken as per EN 1993 standard with material as per S355.

Andrew B. Templemen (1976) introduced the problem of finding member sizes that minimize the weight; it also explains its theoretical nature, being largely devoted to a proof of the dual method [1]. This paper aims to optimize and analyze different models of truss structures and compare Warren truss with other trusses. The goal of current steel trusses is mainly to minimize weight while considering permissible stresses and deflections. Mahdi Azizi *et al.* (2022) discussed that the optimization solutions provided by experts are only possible for minimal problems, and the use of computers is essential for the scientific problems we face daily [2]. Shahin Jalili and Yousef Hosseinzadeh (2015) used a cultural algorithm for truss structures to solve the problem of optimal design and achieve the minimum weight goal in stress and deflection constraints [3]. Musa Artar *et al.* (2023) were used for the purpose of determining the optimal weight structure for five previously studied steel truss roof systems with an optimization algorithm and a structural analysis (FEA) main program [4]. Jeffrey Smith *et al.* (2002), for building optimization, introduced a method of non-linearity for the design of truss structures, a general and complex building category [5]. Lahti, Olli Pekka (2017), has investigated the creation of light tubular roof trusses and to facilitate the implementation of geometry optimization in a design tool according to Eurocode 3 [6]. A. Kaveh and A. Zolghadr carried out a study on the optimization of trusses by topology optimization because many unnecessary members and nodes may exist in a structure, and topology optimization provides an opportunity to remove them. Topology optimization of structures reveals outstanding advantages when compared to sectional optimization [7]. Truss optimization has been approached using a wide variety of optimization techniques to optimize a realm of diverse truss structures, which encompass vast applications. These techniques involve cross-sectional and geometry optimization, as demonstrated by David Webb *et al.* (2017) [8]. Patrikar, A., and Pathak, K. K. (2016) presented a study of article optimization of the Fink Truss Fully Stressed Design (FSD) method using STAAD. Pro [9]. Himanshu Gaur *et al.* (2016) presented a paper in which shape optimization is performed on I-section flange beams. The performance of the beam is studied by changing any sectional dimension [10]. S. J. Salt *et al.* (2022) In the design of modern engineering components, many considerations need to be taken into account, including safety, cost, weight, and manufacturability [11]. Huan Li Teng Hai-Wen (2010) presented a fully stressed design of a statically indeterminate truss. His work and calculations can be used as a reference for engineering practice [12].

Atai Ahrari and Ali A. Atai (2013) carried out a study about the optimization problem because optimization is subjected to some constraints on nodal displacements, member stresses, critical buckling loads, natural frequencies, etc. The objective function is to minimize the structure weight, which supposedly estimates the overall cost [13]. Max Hultman (2010) presented a paper to develop a genetic algorithm that optimizes planar steel trusses with respect to minimum weight. His research on optimization refers to the three design categories: size, shape, and topology. The requirement is that the algorithm only proposes trusses that consist of elements taken from an available profile list and that it satisfies the relevant constraints given in Eurocode 3: Design of steel structures [14]. Arnoldas Norkus and Romanas Karkauskas (2004) presented a paper on optimization of the structure bar cross-sectional areas. The optimization mathematical model under stiffness and stability constraints consists of axial strength conditions expressed via areas of optimized bars, strength conditions versus buckling of bars, displacement limitation constraints, and constructive limitations for bar areas [15]. Alessandra Fiore *et al.* (2016) presented a paper on the weight minimization of planar steel trusses by adopting a differential evolution-based algorithm. Square, hollow sections are considered. Design optimization refers to size, shape, and topology. The design variables are represented by the geometrical dimensions of the cross sections of the different components of the truss, directly involving the size of the structure, and by some geometrical parameters affecting the outer shape of the truss [16]. Mercader Ardevol, Anna (2019) presented a thesis to develop a program able to solve steel frame optimization problems using a two-phase approach. The study of the optimization problem consists of minimizing the weight of a steel frame and ensuring that the solution found satisfies all the strength and stability criteria established in Eurocode 3 [17]. Mika Helminen (2017) presented a thesis to develop a sizing optimization method for a trussed steel portal frame that meets the strength and stability criteria presented in Eurocode 3 [18]. Timo Ketola March (2019) presented his thesis, which was to investigate and develop an algorithm-aided workflow for steel truss design. A process description is given for designing steel trusses according to Eurocode 3 [19]. In this study, a study of minimizing weight by optimizing different truss parts using finite element analysis and comparing Warren truss with other trusses was performed using RFEM 6. (SELECT series 06.0007) software. For this, 10 different trusses and the same snow load cases have been considered for constant span. Constant spans of the trusses have been considered, and each truss has been subjected to the same types of load cases, which have been kept constant throughout the analysis. So, by analyzing the 10 load combinations and the steel design, stress and displacement are calculated.

2. Design Check

In steel truss structure analysis, a negative member axial force indicates that the member or the joints at both ends of the member are in compression, while a positive member axial force indicates that the member or the joints at both ends of the member are in tension. A steel truss is a structure consisting of perfectly rectilinear bars connected in nodes by ideal cylindrical hinges and working to identify only the nodal load. Stress design is probably the most successful of the optimality criteria methods and is accountable for sparking discussion and generating the maximum interest in growing these sorts of methods. This approach is widely used in the design of steel truss structures. It is applicable to problems with only stress and a minimum gage limitation. So, when a structure no longer reaches its allowable stress, its area can be reduced to make it fully stressed. The convergence of DIF can be done through several iterations. In this study, an allowable stress of 355 MPa has been considered for analysis. To calculate the design internal forces in a bar, you can use the following formula:

$$N_{c,Rd} = A \times \frac{f_y}{\gamma_{M0}} \tag{1}$$

where $N_{c,Rd}$ is design axial force resistance, A is the cross-section area.

f_y is Yield strength and γ_{M0} is a partial factor. Therefore, in DIF Design component for N is $\eta_{,N}$ and $N_{c,Rd}$ Design compression force, so the utilization ratio of the member can be given as:

$$\eta_{,N} = \frac{N_{c,Ed}}{N_{c,Rd}} \tag{2}$$

where $\eta_{,N}$ is design component for N, $N_{c,Ed}$ is design axial force.

To design shear force resistance in a bar, you can use the following formula:

$$V_{pl,Rd} = A_v \times \frac{f_y}{\sqrt{3}} \Big/ \gamma_{M0} \tag{3}$$

where $V_{pl,Rd}$ is the design shear force resistance? A_v is cross-section shear area, f_y is Yield strength and γ_{M0} is a partial factor. Therefore, in DSF, the design component for V is $\eta_{,v}$ and $V_{pl,Ed}$ design compression force, so the utilization ratio of the member can be given as:

$$\eta_{,v} = \frac{V_{pl,Ed}}{V_{pl,Rd}} \tag{4}$$

Slender structures, like columns and towers, are characterized by their elongated shape and high length-to-width ratio because 90% of them are made from trusses. However, stability is a critical concern for these structures. Buckling, a collapse under compressive forces, poses a significant risk.

Flexural buckling about the principal y, z-axis acc. to EN 1993-1-1, 6.3.1.

To design the buckling resistance of a compression in a bar, you can use the following formula:

$$N_{b,Rd} = X_{y,z} \times A \times f_y / \gamma_{M0} \tag{5}$$

where $N_{b,Rd}$ is Design buckling resistance, A is cross-section area, f_y is Yield strength, γ_{M0} is Partial factor and $X_{y,z}$ Reduction factor for buckling. Therefore, in the design component for elastic critical force is $\eta_{N,cr}$ and $N_{c,Ed}$ in the design compression force, so utilization ratio of the member can be given as:

$$\eta_{N,cr} = \frac{N_{c,Ed}}{N_{b,Rd}} \tag{6}$$

Hence, by this formulation, area in each member is calculated and target stress is achieved in RFEM 6. (SELECT series 06.0007) software.

3. Modeling and Analysis of Trusses

The different types of trusses analyzed in this study are shown below in **Figures 1-10**. In this study, spans have been considered for all cases at 16 m, and height is

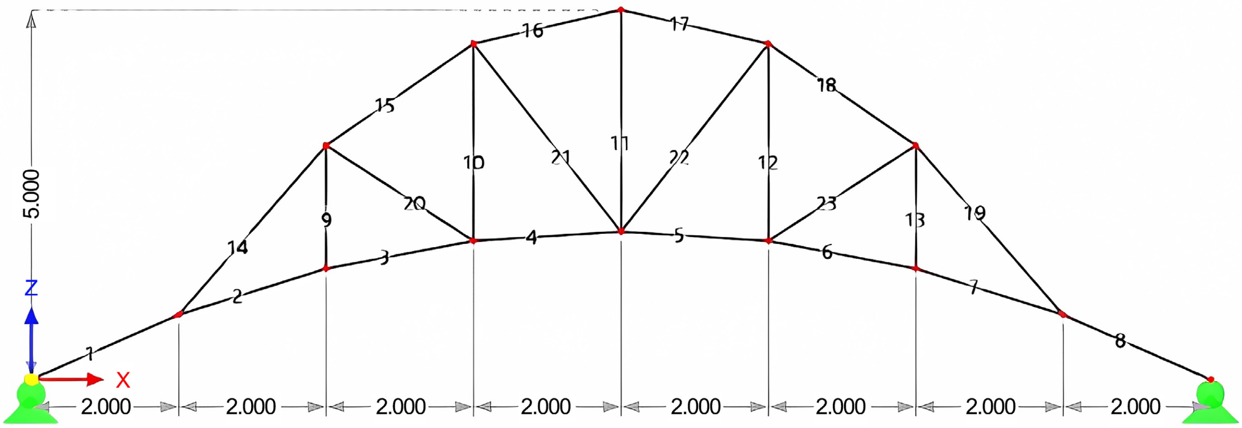


Figure 1. Configurations of Bowstring Truss a.

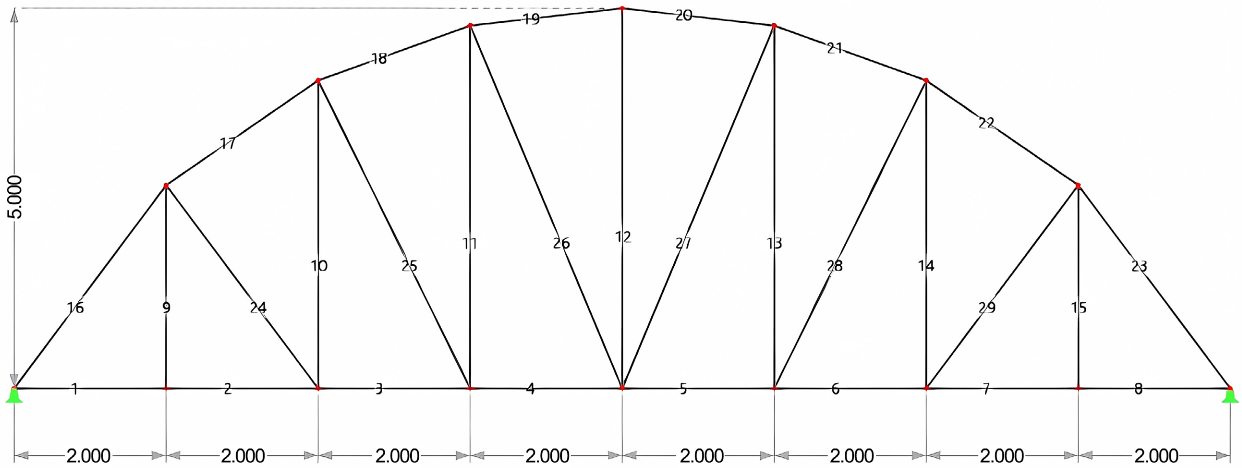


Figure 2. Configurations of Bowstring Truss b.

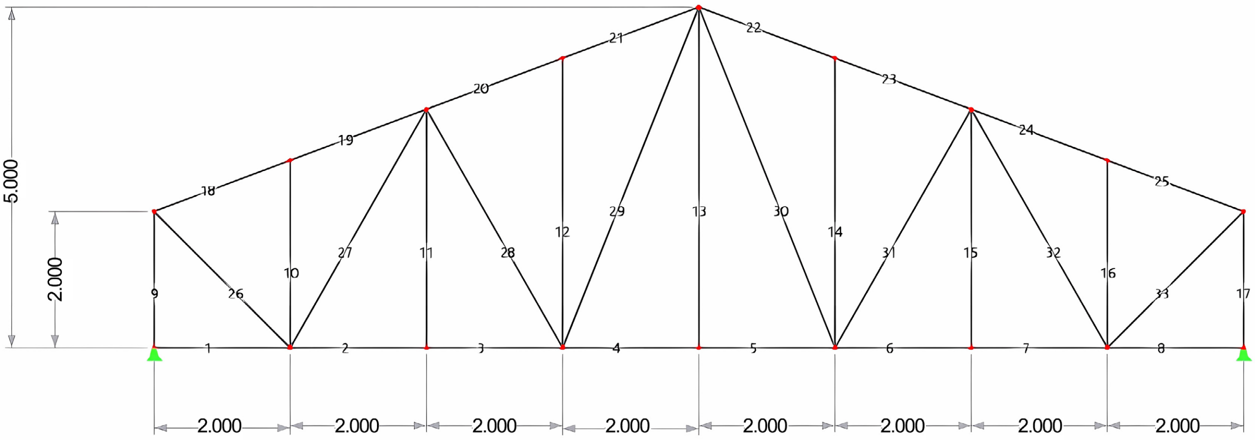


Figure 3. Configurations of Truss—Warren, Pitched a.

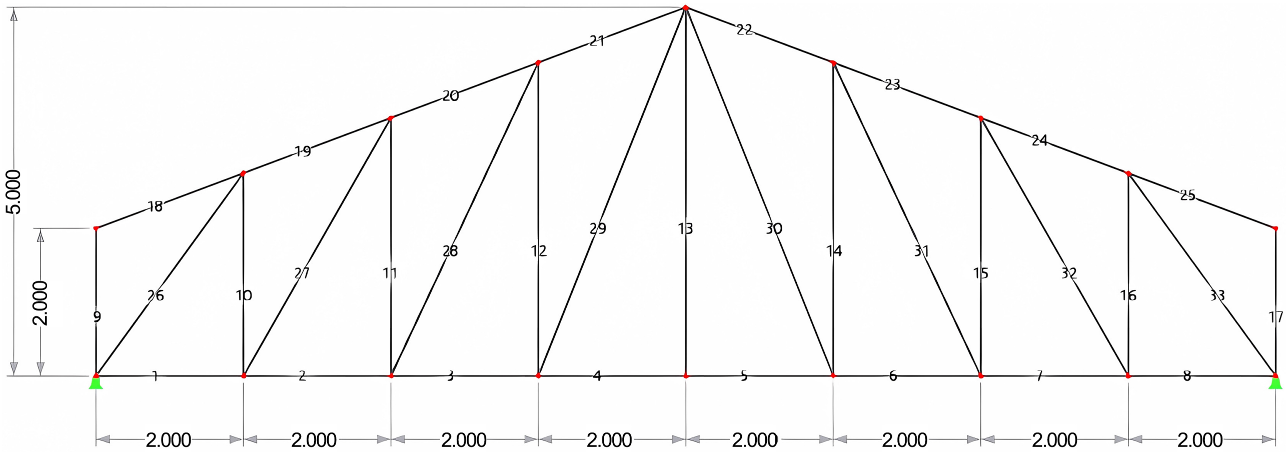


Figure 4. Configurations of Truss—Warren, Pitched b.

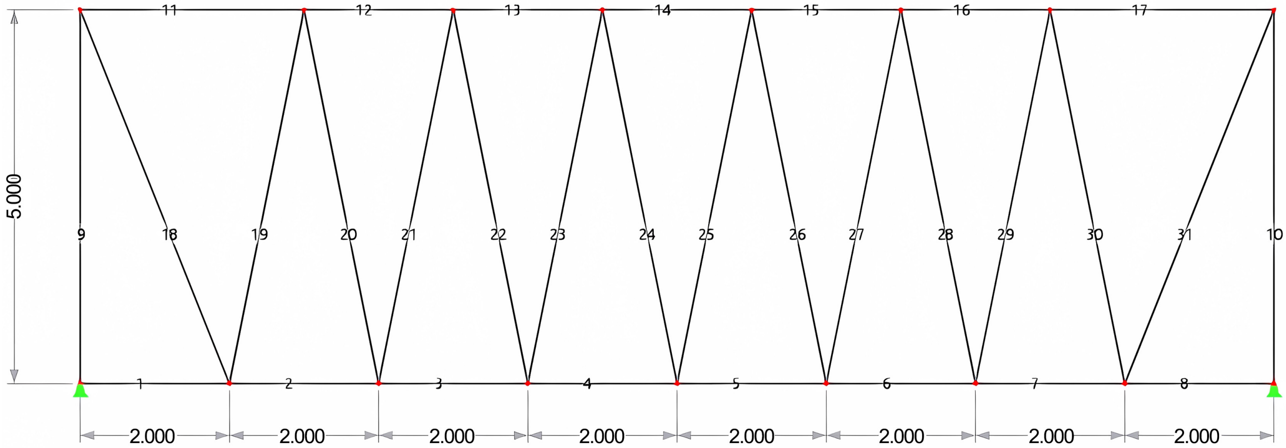


Figure 5. Configurations of Truss—Flat a.

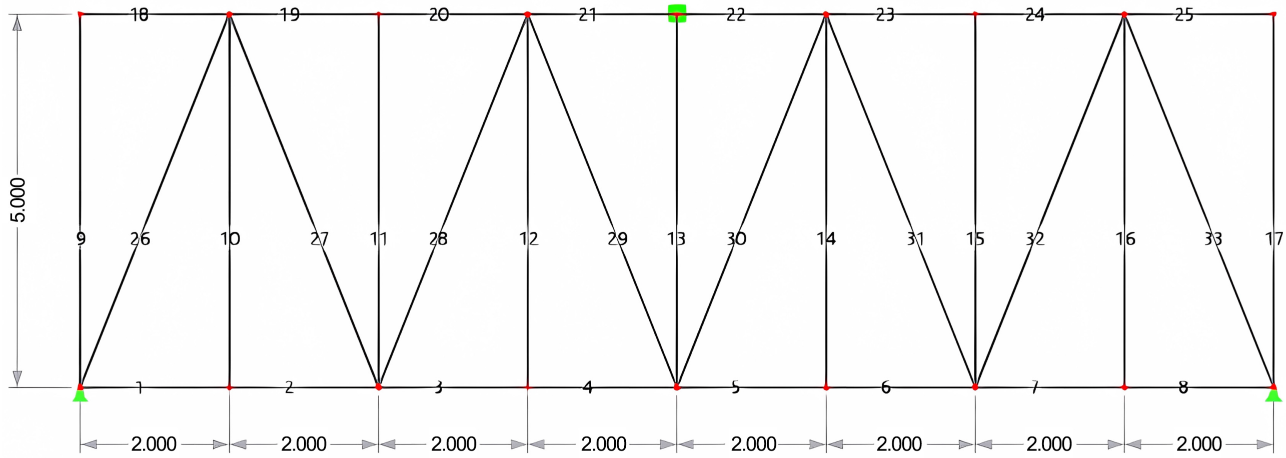


Figure 6. Configurations of Truss—Flat b.

kept constant at 3 m for all cases. Modeling of the trusses has been carried out using RFEM 6. (SELECT series 06.0007) software.

Properties and geometrical parameters for all trusses used are given in **Table 1** and Table 2, respectively.

The loading conditions taken in this study are given in Table 3. Total numbers

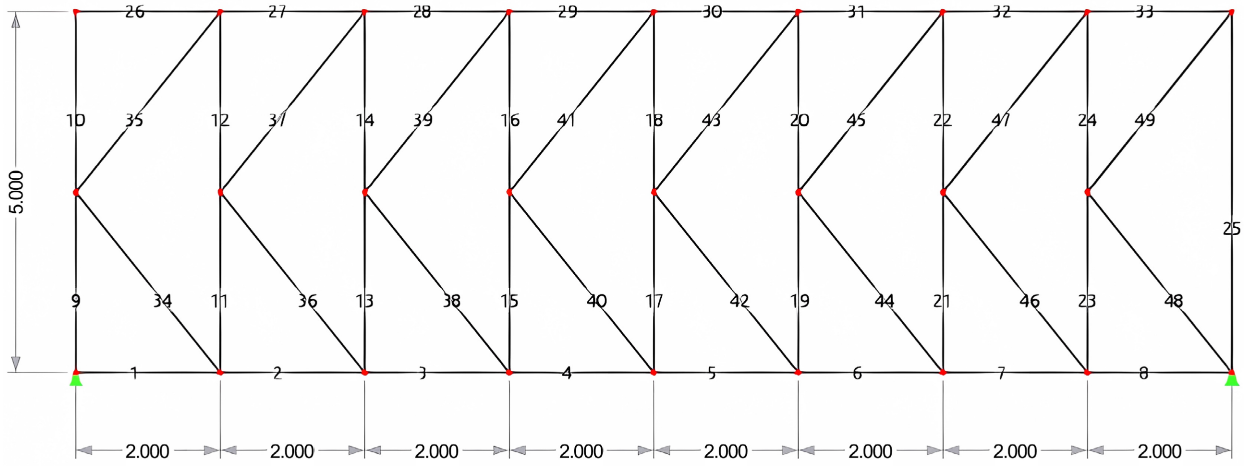


Figure 7. Configurations of K-type web Truss a.

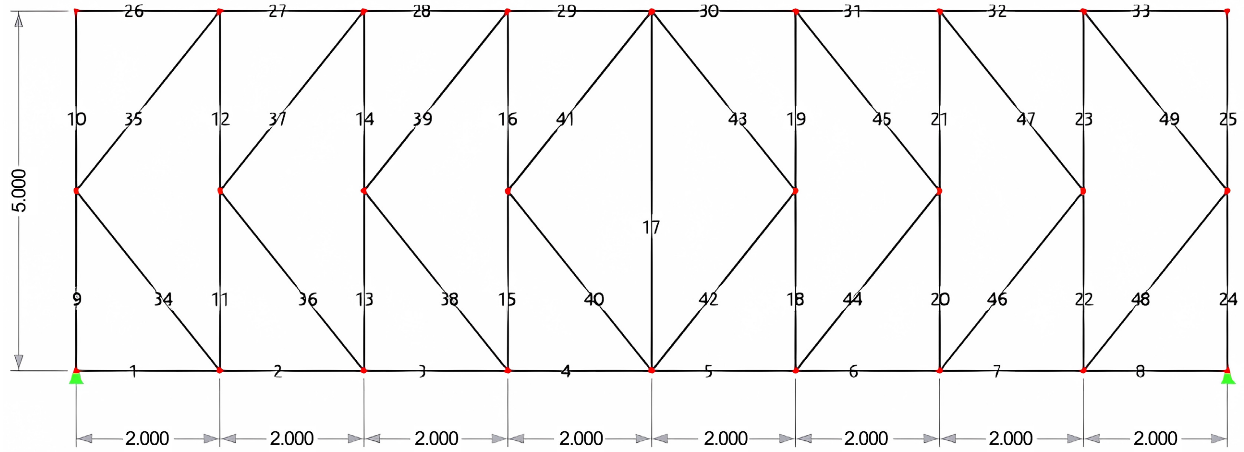


Figure 8. Configurations of K-type web Truss b.

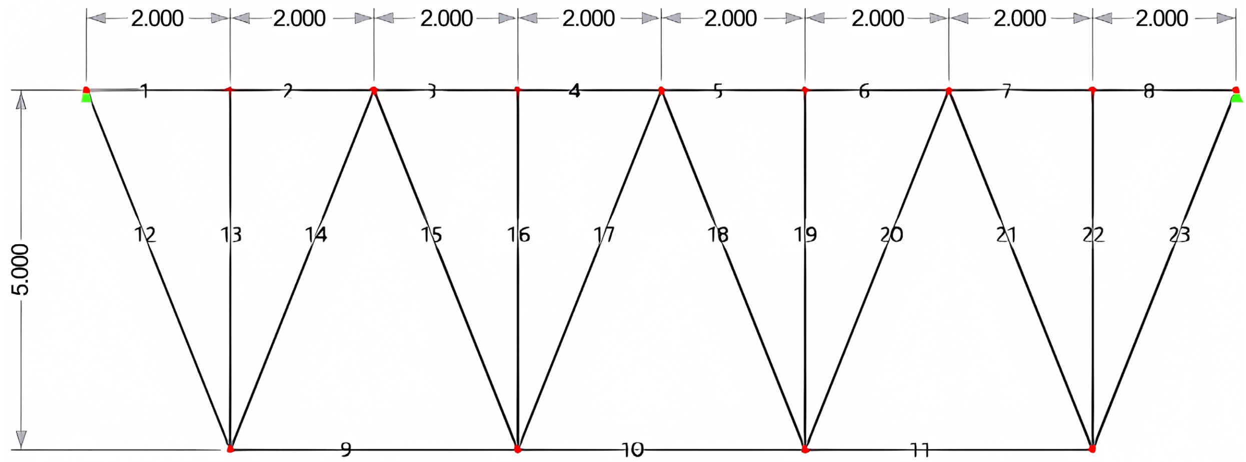


Figure 9. Configurations KT-type of Truss a.

of 2 loads are taken: self-weight and snow load of 2 kN/m. In any situation, the snow load is maintained at 2 kN/m. The loads are shown in **Figures 11-13**.

The steel truss material was defined as linear isotropic truss material. The inputs for the isotropic material are elastic modulus and Poisson ratio. The boundary conditions were set such that the truss is simply supported. This means that the left node is fixed in space, and the right node is set as a pinned support.

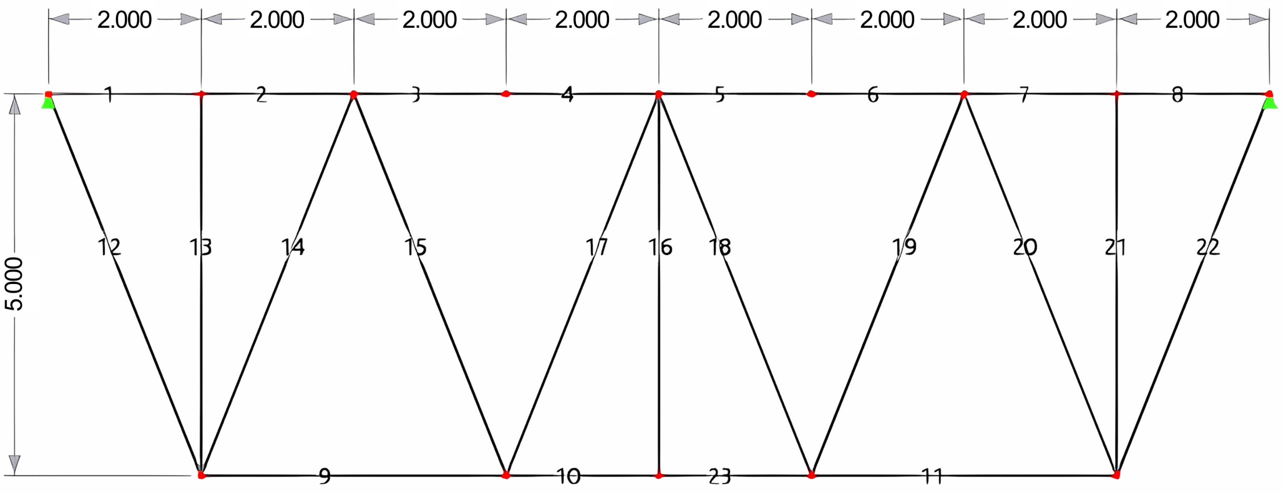
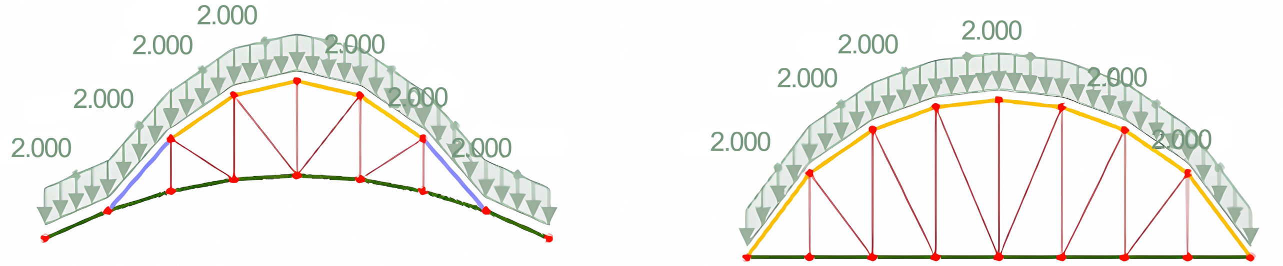
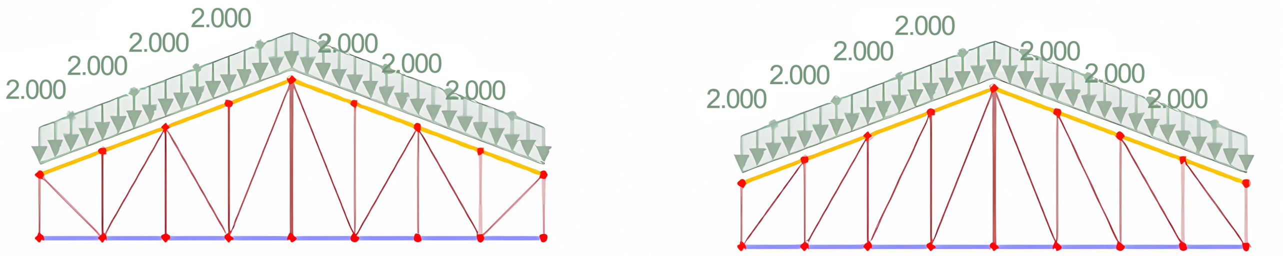


Figure 10. Configurations KT-type of Truss b.



Configurations of Bowstring Truss a.

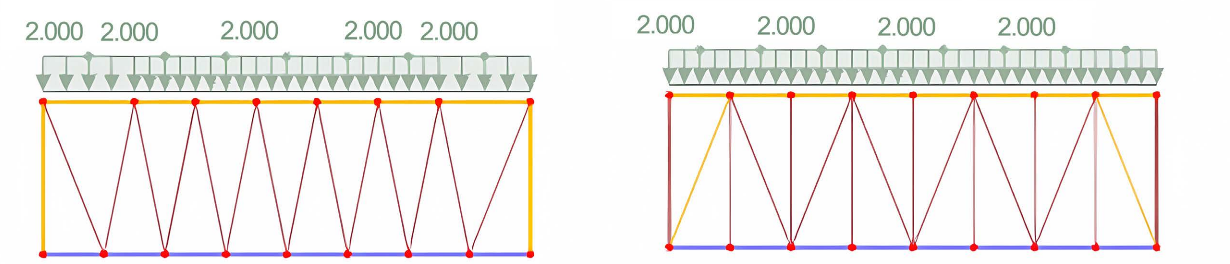
Configurations of Bowstring Truss b



Configurations of Truss - Warren, Pitched a

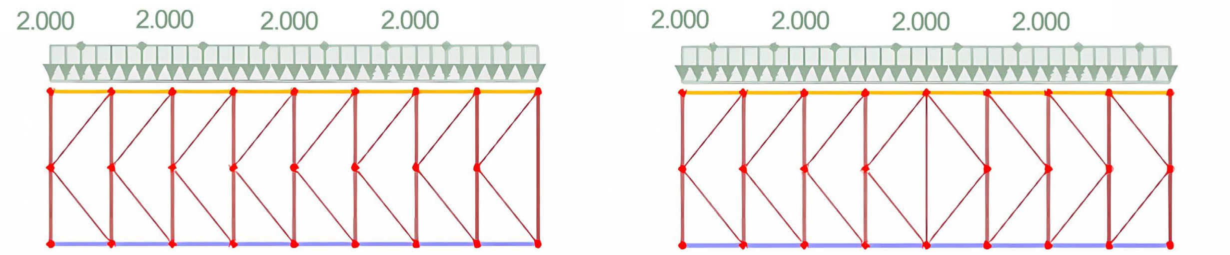
Configurations of Truss - Warren, Pitched b

Figure 11. Diagram showing line load position.



Configurations of Truss - Flat a

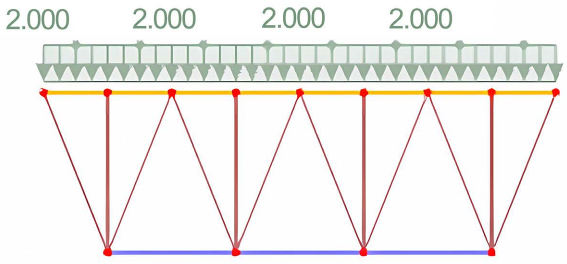
Configurations of Truss - Flat b



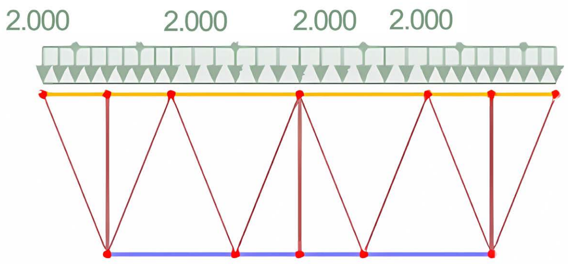
Configurations of K-type web Truss a

Configurations of K-type web Truss b

Figure 12. Diagram showing line load position.



Configurations KT-type of Truss a



Configurations KT-type of Truss b

Figure 13. Diagram showing line load position.

Table 1. Properties of all trusses.

Type of truss	Parameters	Value
Bowstring Truss a	Members	23
Bowstring Truss b	Members	29
Warren, Pitched a	Members	33
Warren, Pitched b	Members	33
Truss—Flat a	Members	31
Truss—Flat b	Members	33
K-type web Truss a	Members	49
K-type web Truss b	Members	49
KT-type of Truss a	Members	23
KT-type of Truss b	Members	22
All of truss	Material	S355
All of truss	Poisons Ratio	0.30
All of truss	Density	7850 kg/m^3
All of truss	Modulus of Elasticity	210 GPa
All of truss	Supports	1st location Pinned support 2nd location Roller support

Table 2. Geometrical parameters of all trusses.

All cases	Span (m)	Height (m)
All truss	16	5

Table 3. Loads cases and load combinations.

Types of trusses	Pre-Optimization-Self-Weight (kg)	Snow Load (kN/m)	Load Combination
Bowstring Truss a	962.1	2	1.15*G + 1.5*S
Bowstring Truss b	957.2	2	1.15*G + 1.5*S
Warren, Pitched a	987.4	2	1.15*G + 1.5*S
Warren, Pitched b	1007.6	2	1.15*G + 1.5*S
Truss—Flat a	1192.5	2	1.15*G + 1.5*S
Truss—Flat b	1247.3	2	1.15*G + 1.5*S
K-type web Truss a	1246.6	2	1.15*G + 1.5*S
K-type web Truss b	1246.6	2	1.15*G + 1.5*S
KT-type of Truss a	1077.1	2	1.15*G + 1.5*S
KT-type of Truss b	1036.3	2	1.15*G + 1.5*S

4. Results and Discussion

The outcomes of applying the analysis methodologies outlined in the prior sections will be discussed in the upcoming section. The results of various tests are shown together with the optimization of each candidate member. The findings from this research will assist in selecting the optimal truss for real-time loadings. The outcomes from the 2D FEM consist of nodal displacements and axial and shear forces in every member. There was minimal variation in stress distribution across the model. Some of the members are under compression, and some are under tension. The only variation was the level of pressure in every truss.

A design check was carried out for the target stress, which is under the allowable stress of 355 MPa, and the cross-sectional areas of the members were noted down. Since the density of steel was known, *i.e.*, 7850 kg/m^3, steel takeoff was calculated for the overall truss structure. A cross-section has been used for analysis in this study, and thicknesses of 5 and 8 mm are considered. Prior to optimization, Table 4 presented the mass of the truss and the properties of the cross section.

Table 4. Pre-optimization cross-section properties.

Types of Trusses	**Pre-Optimization Cross-Section Properties**														
	Top Chord					Bottom Chord					Diagonal & Vertical Rods				
	Depth	Width	Thickness	Area of Cross Section (m^2)	Mass (kg/m)	Depth	Width	Thickness	Area of Cross Section (m^2)	Mass (kg/m)	Depth	Width	Thickness	Area of Cross Section (m^2)	Mass (kg/m)
Bowstring Truss a	100	100	5	0.00184	14.4	150	100	8	0.00352	27.6	60	60	5	0.00104	8.2
Bowstring Truss b	100	100	5	0.00184	14.4	150	100	8	0.00352	27.6	60	60	5	0.00104	8.2
Warren, Pitched a	100	100	5	0.00184	14.4	150	100	8	0.00352	27.6	60	60	5	0.00104	8.2
Warren, Pitched b	100	100	5	0.00184	14.4	150	100	8	0.00352	27.6	60	60	5	0.00104	8.2
Truss—Flat a	100	100	5	0.00184	14.4	150	100	8	0.00352	27.6	60	60	5	0.00104	8.2
Truss—Flat b	100	100	5	0.00184	14.4	150	100	8	0.00352	27.6	60	60	5	0.00104	8.2
K-type web Truss a	100	100	5	0.00184	14.4	150	100	8	0.00352	27.6	60	60	5	0.00104	8.2
K-type web Truss b	100	100	5	0.00184	14.4	150	100	8	0.00352	27.6	60	60	5	0.00104	8.2
KT-type of Truss a	100	100	5	0.00184	14.4	150	100	8	0.00352	27.6	60	60	5	0.00104	8.2
KT-type of Truss b	100	100	5	0.00184	14.4	150	100	8	0.00352	27.6	60	60	5	0.00104	8.2

Structure optimization is shown in the table below, *i.e.*, post-optimization cross-section properties. It has been verified that optimized trusses adhere to the specified design limitations; now it is required to analyze that not all members need to have the same cross-sections as they are not all required to bear heavy loads. Hence, the optimization feature in 2D RFEM was utilized to determine the most efficient cross-sectional areas. Each individual truss component contributes to the overall weight of the truss. Table 5 shows the Post-optimization Cross-Section properties of all trusses.

Table 5. Post-optimization cross-section properties.

Types of Trusses	Post-Optimization Cross-Section Properties														
	Top Chord					Bottom Chord					Diagonal & Vertical Rods				
	Depth	Width	Thickness	Area of Cross Section(m^2)	Mass (kg/m)	Depth	Width	Thickness	Area of Cross Section(m^2)	Mass (kg/m)	Depth	Width	Thickness	Area of Cross Section(m^2)	Mass (kg/m)
Bowstring Truss a	80	80	5	0.00144	11.3	250	150	5	0.00384	30.1	70	70	4	0.00101	7.9
Bowstring Truss b	80	80	5	0.00144	11.3	250	150	5	0.00384	30.1	70	70	4	0.00101	7.9
Warren, Pitched a	80	80	5	0.00144	11.3	150	100	4	0.00189	14.8	70	70	4	0.00101	7.9
Warren, Pitched b	80	80	5	0.00144	11.3	150	100	4	0.00189	14.8	70	70	4	0.00101	7.9
Truss—Flat a	80	80	5	0.00144	11.3	150	100	4	0.00189	14.8	70	70	4	0.00101	7.9
Truss—Flat b	80	80	5	0.00144	11.3	150	100	4	0.00189	14.8	70	70	4	0.00101	7.9
K-type web Truss a	80	80	5	0.00144	11.3	150	100	4	0.00189	14.8	70	70	4	0.00101	7.9
K-type web Truss b	80	80	5	0.00144	11.3	150	100	4	0.00189	14.8	70	70	4	0.00101	7.9
KT-type of Truss a	80	80	5	0.00144	11.3	150	100	4	0.00189	14.8	70	70	4	0.00101	7.9
KT-type of Truss b	80	80	5	0.00144	11.3	150	100	4	0.00189	14.8	70	70	4	0.00101	7.9

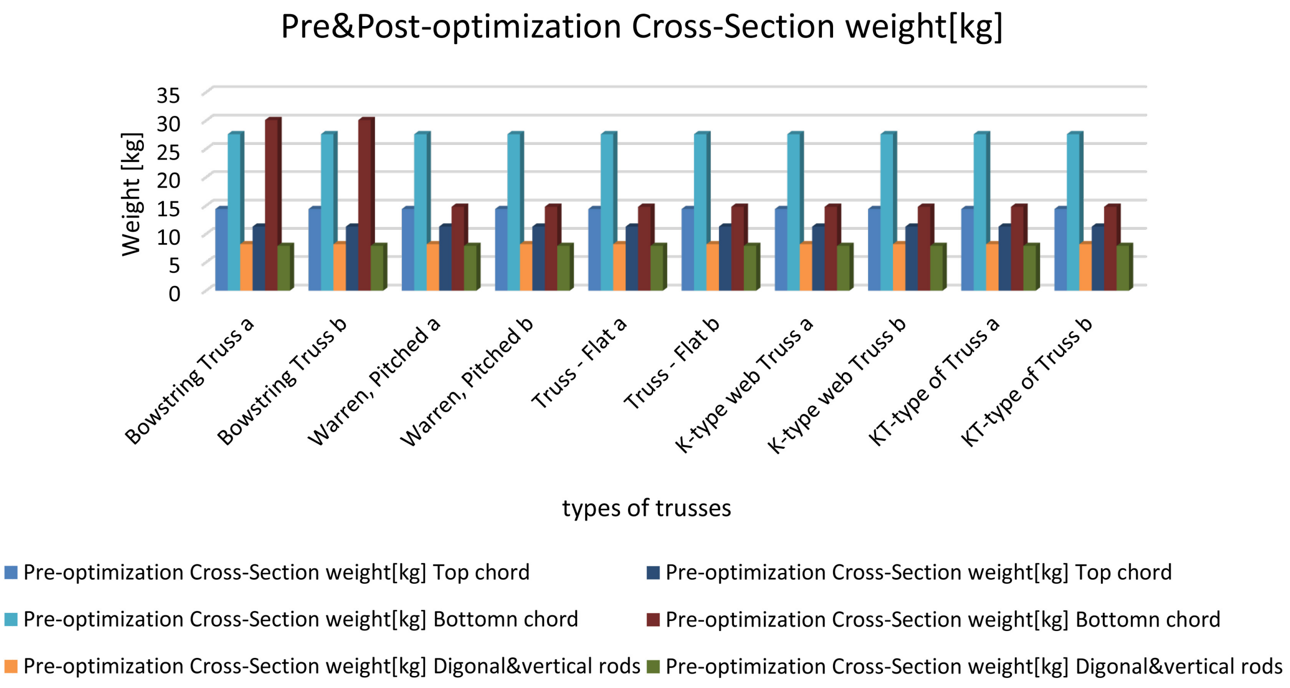


Figure 14. Cross-section weight and types of trusses graph.

Figure 14 demonstrates the optimization process in both its pre- and post-stages. The structural weight has decreased in proportion to the cross-sectional areas of individual members. There has been a significant decrease in optimizing the truss, which involves considering the weight of the truss and the area of its cross-sections.

The ultimate goal of using optimization in the construction of a truss is to achieve a lower-weight structure with higher strength. Strength can be quantified by calculating the utilization ratio of safety for each truss member. When the utilization ratio reaches a value greater than or equal to one, the structure will fail. Another way to define it is as being equivalent to the safety factor. This factor is utilized for comparing various trusses and members with each other. Calculating the utilization ratio for each member in every truss model is how it is accomplished.

Tables were created to analyze steel usage and maximum displacement in all situations, followed by the creation of graphs and tables displayed in **Figure 15**, **Figure 16** and **Table 6**, **Table 7**.

Table 6. Weight optimization of truss structures.

Types of Trusses	Pre-Optimization-Self-Weight [kg]	Post-Optimization-Self-Weight [kg]
Bowstring Truss a	962.1	811.1
Bowstring Truss b	957.2	985.2
Warren, Pitched a	987.4	753.5
Warren, Pitched b	1007.6	766.3
Truss—Flat a	1192.5	902.6
Truss—Flat b	1247.3	938.9
K-type web Truss a	1246.6	915.4
K-type web Truss b	1246.6	915.4
KT-type of Truss a	1077.1	684.6
KT-type of Truss b	1036.3	658.8

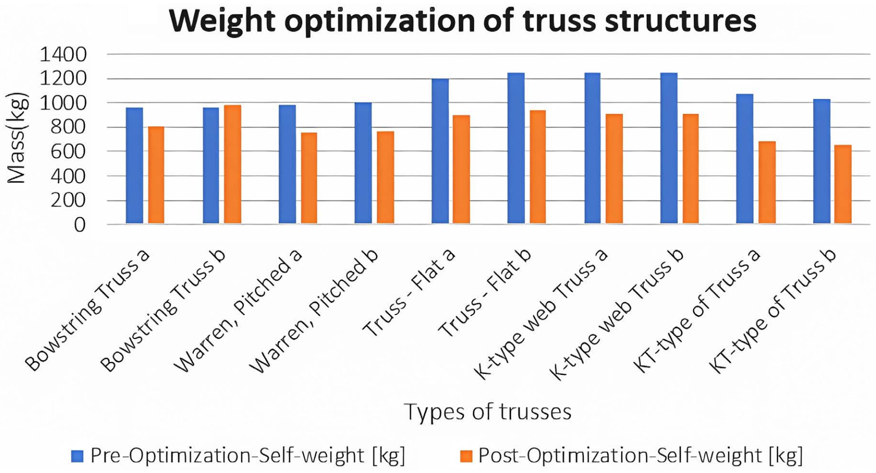


Figure 15. Mass and types of trusses graph.

In **Table 8** and **Figure 17**, the pre- and post-optimum ultimate design situations, along with their respective results, are shown for all trusses.

Table 7. Displacement among different trusses in mm.

	Max-Displacements [mm]					
Types of Trusses	Pre-Optimization			Post-Optimization		
	U_x	U_z	$U_{\_tot}$	U_x	U_z	$U_{\_tot}$
Bowstring Truss a	0.1	0.6	0.61	0.9	1.7	1.92
Bowstring Truss b	2.2	1.2	2.51	1.6	1.7	2.33
Warren, Pitched a	2.5	1.4	2.87	1.9	2	2.76
Warren, Pitched b	2.2	1.4	2.61	1.9	2.3	2.98
Truss—Flat a	2.5	1.2	2.77	2.2	4.5	5.01
Truss—Flat b	2.5	1.5	2.92	1.9	2.4	3.06
K-type web Truss a	0.5	0.8	0.94	0.7	2	2.12
K-type web Truss b	0.5	0.8	0.94	0.5	2	2.06
KT-type of Truss a	2.6	1.5	3.00	2	3.3	3.86
KT-type of Truss b	2.5	1.5	2.92	2	8.6	8.83

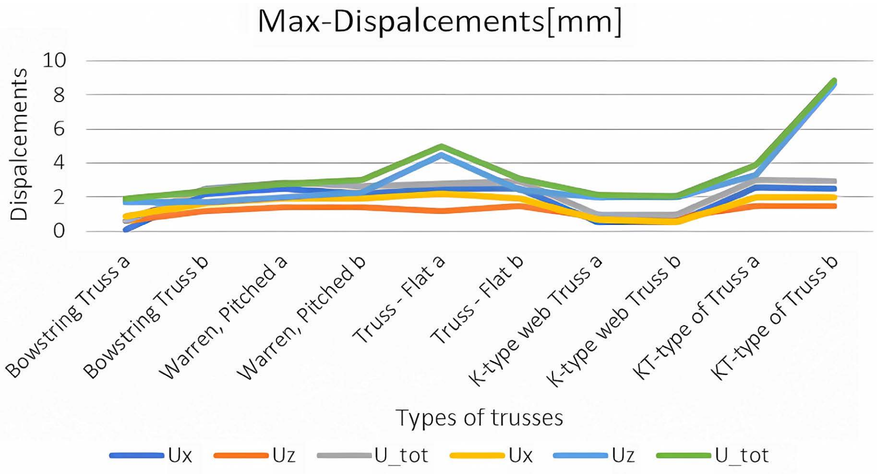


Figure 16. Displacement graph among different trusses.

Table 8. Ultimate design situation among different trusses.

	Ultimate Design Situation	
Types of Trusses	Pre-Optimization Design Check Ratio	Post-Optimization Design Check Ratio
Bowstring Truss a	1.91	0.74
Bowstring Truss b	0.16	0.25
Warren, Pitched a	0.53	0.85
Warren, Pitched b	0.52	0.37
Truss—Flat a	0.86	0.64
Truss—Flat b	0.45	0.40
K-type web Truss a	0.49	0.69
K-type web Truss b	0.35	0.56
KT-type of Truss a	0.69	0.47
KT-type of Truss b	0.72	0.50

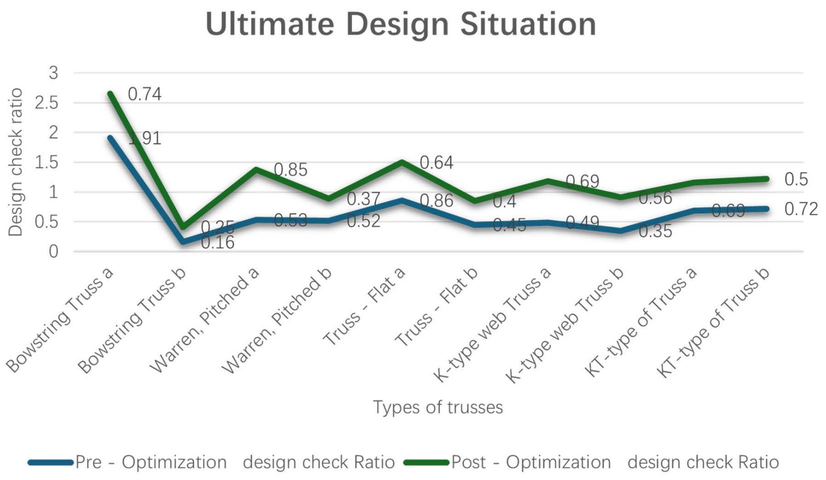


Figure 17. Ultimate design situation graph among different trusses.

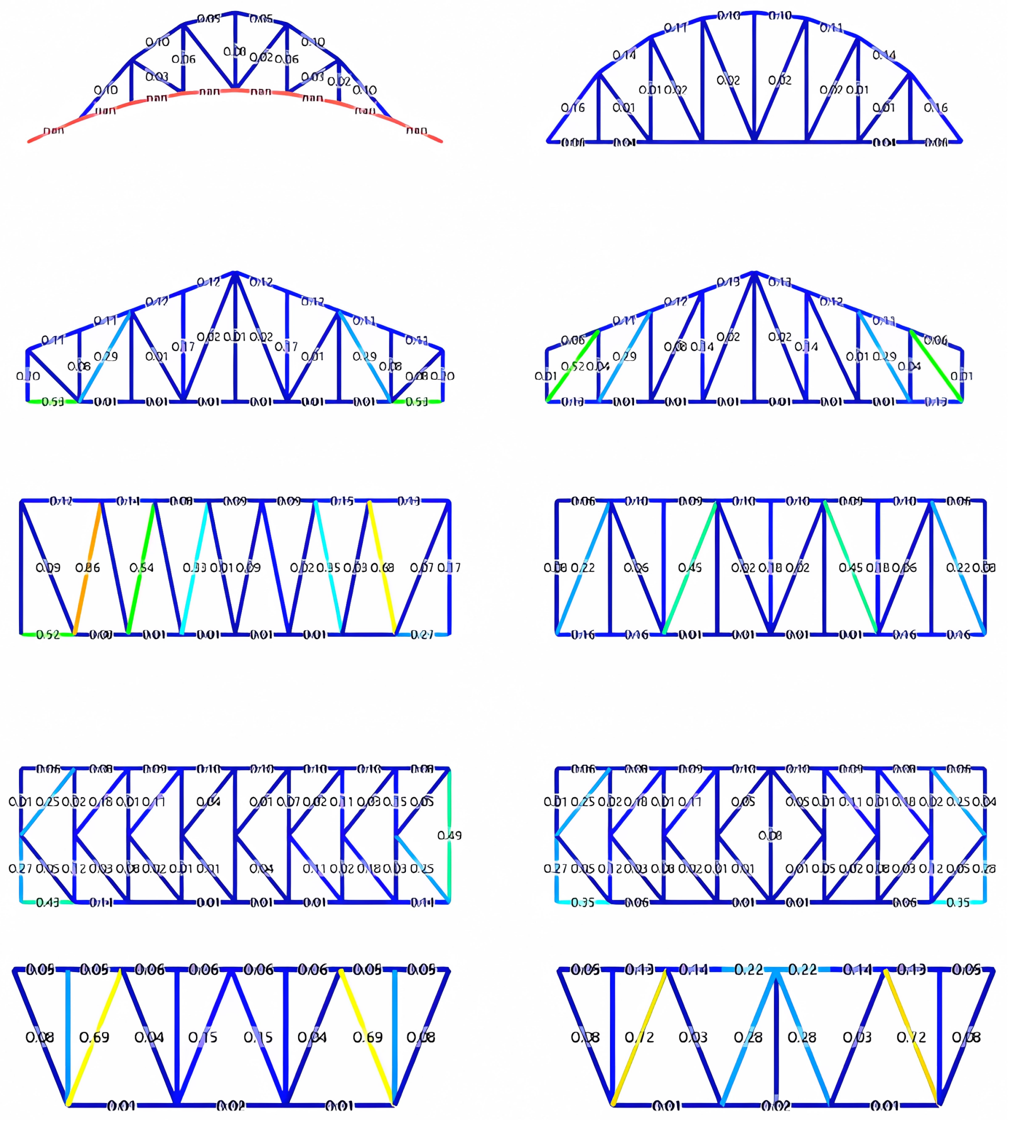


Figure 18. Pre-optimum ultimate design situation models and results obtained for all trusses.

Figure 18 and **Figure 19** illustrate the pre- and post-optimum ultimate design situations, along with the corresponding results, for all trusses.

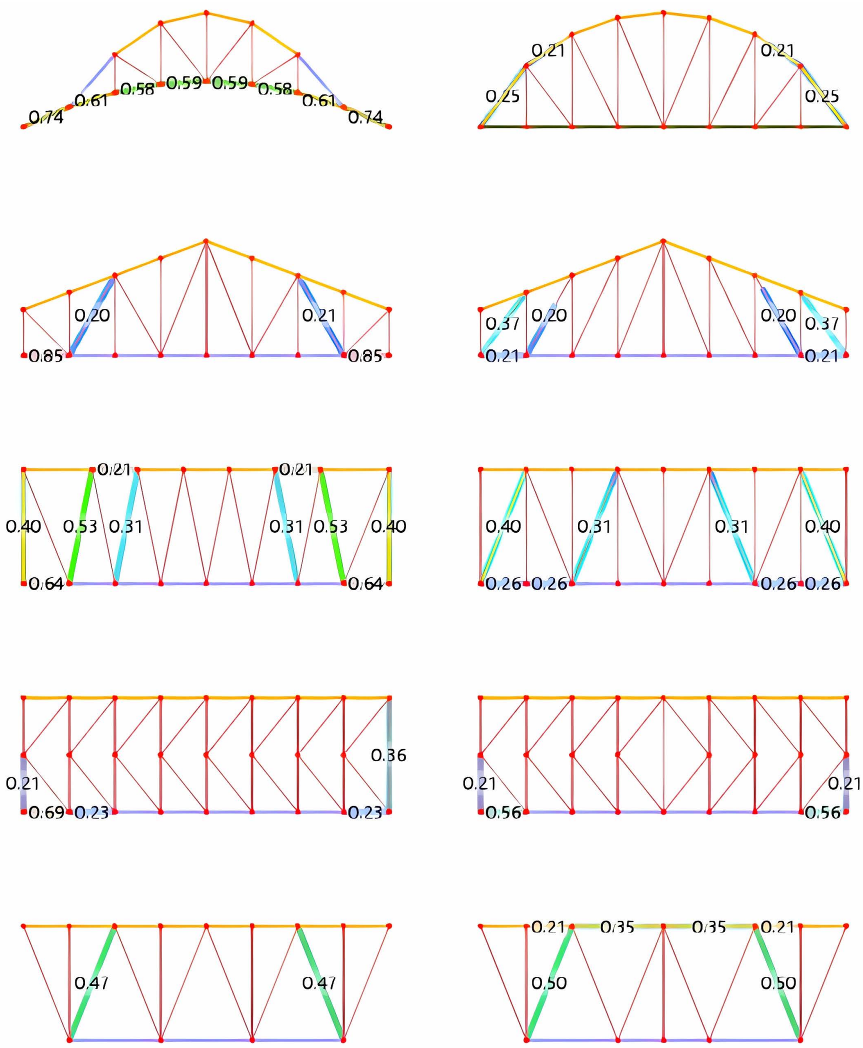


Figure 19. Post-optimum ultimate design situation models and results obtained for all trusses.

5. Conclusions

Following optimization, the Warren and KT trusses have a lower weight than other trusses under similar loading conditions. Although the designs of the two trusses are identical, Warren's has more vertical rods. Dividing the vertical elements into smaller parts is the concept behind the Warren Truss. The compression of the vertical members is the reason behind this. A member's ability to withstand buckling due to compression increases with its length. Best strength-to-weight ratios are associated with Warren trusses. They are advantageous for large structures such as roofs and bridges due to their capacity to support substantial loads and effectively dissipate stresses. Additional benefits of Warren trusses include their ability to span large areas without the need for several piers or columns of support. In this study, the stressed design of trusses has been carried out using RFEM 6. (SELECT series 06.0007) software for different trusses with constant spans of 16 m, a rise of 5 m, and two different load cases. Finite Element Analysis (FEA): RFEM software is used to perform detailed structural analysis and simulation. This involves dividing the structure into finite elements and analyzing its behavior under various loading conditions. RFEM software provides valuable insights into stress distribution, deformation, and failure modes, allowing engineers to optimize the design for performance and reliability; for example, consider the design optimization of a structural component, such as a beam, to minimize weight while ensuring sufficient strength and stiffness.

- It is recognized that the nodal displacements at crucial nodes are generally similar and within bounds.
- It is recognized that the safety design ratio is approximately the same in all trusses and has also met the design limitation.
- It shows the real resistance of loads for the Warren truss due to its geometrical structure, which is far better than other trusses.
- When different load cases are applied to a 16-meter span Warren Truss with a 5-meter rise, the total steel quantity of the truss remains relatively consistent.
- The results indicate that weight may not always increase with length or height, which is why I have kept all trusses at a constant span or rise.
- It can be inferred from the displacement graph that there is minimal change in displacement for various load scenarios within the same span.
- Due to the reduction in weight, construction costs can be reduced significantly by saving materials.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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