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Optimization of steel truss configuration for structural efficiency using STAAD.Pro and ETABS

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ABSTRACT

The requirement of this study arises where sometimes it is difficult for taking too much time to choose an effective and economical truss shape or truss geometry during the design period. Now a day, our study about the steel structures, Industrial 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. 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.

Keywords: Truss Design, Steel Truss, Truss optimization, Truss Span.

I. INTRODUCTION

Structural optimization

Perform structural optimization analysis in the course of design using CAD-embedded STAAD.PRO Simulation to attain the satisfactory available power-to-weight, frequency, or stiffness performance in your designs, and reduce highly-priced prototypes, cast off rework and shop time and development costs.

Structural Optimization Overview

STAAD.PRO Simulation simplifies structural optimization with an aim-driven design technique to parametrically modify a layout so that it meets defined structural goals. You specify design dreams at the beginning of design to:

- Have STAAD.PRO software program warns you throughout the layout method if desires are violated.
- Use goals in a design examine in which STAAD.PRO Simulation mechanically adjustments allowable version dimensions to maximize or minimize adherence to the layout aim.

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Structural optimization makes use of more than one constraint to restrict the scope of the optimization process, ensuring that any layout study optimization meets the number one layout goal without violating the assisting design requirements [8].

The time period of most useful structure may be very indistinct. This is because a structure may be most desirable in special components. This one of a kind aspects are called goals, and might as an instance be the weight, feel or stiffness of the shape. A numerical assessment of a positive objective is viable through a goal feature, which determines the goodness of the structure in terms of weight, value or stiffness. Of course, the optimization needs to be accomplished inside some constraints; otherwise, it's a problem without a nicely described solution. Firstly, there are design constraints, like a constrained geometrical extension or restrained availability of various structural elements. Secondly, there are behavioral constraints at the structure that denotes the structural response under a sure load circumstance. Here may additionally, for example, limits on displacements, stresses, forces and dynamic reaction be looked after. Finally, there's one apparent call for that is valid for all structures, and it's far kinematical balance, in any other case they are mechanisms. This can be visible as a behavioral constraint. Structures that lie in the constraints are called viable answers to the optimization trouble. Optimization may be completed with appreciate to two or extra specific goal features. This is known as a multi-goal optimization (also referred to as multi-criterion or vector optimization). One example of this is Galante's (1996) try to discover a minimal weight of a truss using as few one-of-a-kind profiles as feasible. In multi-goal optimization, one fashionable goal characteristic may be prepared by using weighted elements of the concerned objective functions. Hence, by means of changing the weights, exclusive Optima are obtained. Other techniques for dealing with multi-goal optimization are also viable. When it comes to trusses, the optimization can be divided into 3 categories; sizing, shape and 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 (additionally called layered optimization). It is obvious although, that this technique doesn't constantly offer the excellent global answer, for the reason that issues aren't linearly separable. One of the strengths of a genetic algorithm is that a simultaneous optimization of all three parameters can be executed [9].

Truss optimization:

A truss is a structure of assembled bars, frequently arranged in a triangular shape. Theoretically, the bars in a truss are assumed to be related to each different with the aid of friction-loose joints. In actual-existence trusses even though, the joints are greater or much less stiff because of welding or screwing the bars collectively. Even with some stiffness inside the connections, a model with friction-free joints can correctly be used if the center of gravity axis of every bar meets within the point in which you positioned the joint in the model; see discern 1:

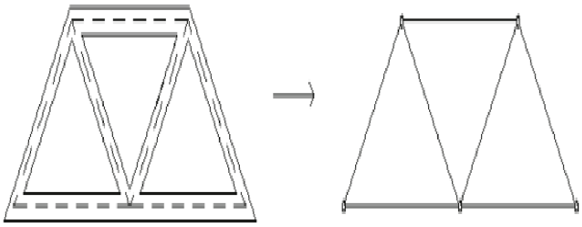

Fig 1: a truss structure with its corresponding theoretical model.

As long because the load is applied in some of the nodes, the bars will most effectively be subjected to compressive or tensile everyday forces. This is one part of the rationale for why trusses are so mild compared to their load capability; bar effect is extra green than beam effect. The other part is that the triangle is the only solid shape that extends in two dimensions. Due to their performance, trusses are appropriate in long span structures with high demands in stiffness and power. Typical scopes of makes use of our bridges, long-span roof structures, and transmission towers. Some well-known examples of truss structures are the Eiffel tower in Paris, the Harbor Bridge in Sydney and the Oresund Bridge (a cable-stayed truss bridge) among Copenhagen and Malmoe [9].

Graphic statics

Graphical techniques have been used for centuries to investigate and design a ramification of systems. In this section, we supply a short historic evaluation of such techniques and introduce the methodology and notation used throughout this work.

A history of graphical methods

The foundation of Graphic Statics may be traced lower back to the writings of Simon Stevin (1586), wherein a parallelogram rule the use of pressure vectors and polygons turned into first used to analyze forces in a structure. Later, Pierre Varignon (1687, 1725) validated the law of force polygon and brought the use of funicular polygons, however graphical (equilibrium) analysis the use of vectorized diagrams changed into no longer formalized until Culmann wrote his Die graphic Statik (Culmann 1864; Block et al. 2006). It turned into Maxwell, but, who first delivered the perception of structural reciprocity to remedy structural frames (Maxwell 1864, 1870). In those papers, Maxwell describes how one should locate forces in structural frames: a reciprocal diagram can be generated through drawing traces perpendicular to the lines of action of the structural participants, such that everyone member connected at an unmarried node create a polygon. The ensuing diagrams were taken into consideration reciprocal, as Maxwell described, “two figures are reciprocal while the properties of the first relative to the second one are the same as the ones of the second relative to the first”. The resulting lengths of the lines in the new diagram are proportional to the forces within the authentic member diagram. This idea is described in extra detail in Section three. Also, in this work, Professor Rankine was acknowledged for being the primary one to apply the most preferred announcement of graphical techniques at the time. Luigi Cremona (1890) further refined the approach via introducing an exclusive node to polygon mapping approach, in which the strains within the force diagram had been parallel to the traces of movement of the structural participants. These diagrams have been less complicated to study than the ones of Maxwell, which were rotated 90◦. The Graphic Statics approach delivered through Cremona have become so famous that these days; the graphical technique of fixing structural trusses is frequently referred to as the Cremona technique [10].

II. LITERATURE REVIEW

Chotiga Choensiridamrong et.al in (2014)[2] presented two approaches to determine the optimal plane trusses using the particle swarm optimization. The two-stage optimization and the simultaneous topology-sizing optimization of plane trusses are investigated and compared. The matrix representation of both topology and element size is introduced and integrated into the standard particle swarm algorithm to enable higher flexibility and computational efficiency. The truss weight is to be minimized subject to stability, stress and deformation constraints. The results show that the simultaneous optimization provided much better solutions with higher expense of computational time.

HK Dhameliya et.al in (2014) [3] attempted to compare various truss configurations with same span, pitch, the spacing of truss regarding the weight aspects. All the trusses have been analyzed and designed by Staad Pro, software for the span 20 m which are the most common spans used in practices. From the parametric study, the most appropriate span will be formulated considering geometric shape, weight, economy and other criteria.

Jian-Ping Li et.al in (2014) [5] applied the species conserving genetic algorithm (SCGA) to search multiple solutions of truss topology optimization problems in a single run. A real-vector is used to represent the corresponding cross-sectional areas and a member is thought to be existent if its area is bigger than a critical area. A finite element analysis model has been developed to deal with more practical considerations in modeling, such as existences of members, kinematic stability analysis and the computation of stresses and displacements. Cross-sectional areas and node connections are taken as decision variables and optimized simultaneously to minimize the total weight of trusses. Numerical results demonstrate that some truss topology optimization examples have many global and local solutions and different topologies can be found by using the proposed algorithm in a single run and some trusses have a smaller weight than the solutions in the literature.

Pei-Ling Chen et.al in (2014) [1] proposed a theoretical basis for k-truss and uses it to design an algorithm based on graph-parallel abstractions. Their experiment results show that their method in the graph-parallel abstraction significantly out performs the methods based on Map Reduce in terms of running time and disk usage.

Seung kook Yun et.al in (2014) [7] presented a decentralized algorithm for the coordinated assembly of 3-D objects that consist of multiple types of parts, using a networked team of robots. They described the algorithm and analyze its convergence and adaptation properties. They partitioned construction in two tasks: tool delivery and assembly. Each task is performed by a networked team of specialized robots. They analyzed the performance of the algorithms using the balls into bins problem and show their adaptation to the failure of robots, dynamic constraints, multiple types of elements, and reconfiguration. They instantiated the algorithm to building truss-like objects using rods and connectors. They implemented the algorithm in simulation and show results to construct 2-D and 3-D parts. Finally, they described ahardware implementation of the algorithms, where mobile manipulators assemble smart parts with IR beacons.

Michael Fenton et.al in (2016) [4] applied grammatical evolution. It can represent a variable number of nodes and their locations on a continuum. A novel method of connecting evolved nodes using a Delaunay triangulation algorithm shows that fully triangulated, kinematically stable structures can be generated. Discrete beam-truss structures can be optimized without the need for any information about the desired form of the solution other

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than the design envelope. Their technique is compared to existing discrete optimization techniques, and notable savings in structure self-weight are demonstrated. In particular, their new method can produce results superior to those reported in the literature in cases in which the problem is ill-defined and the structure of the solution is not known a priori.

Mingli Wu et.al in (2016) [6] focused on the electromagnetic shielding performance of the steel truss bridge in electrified railway. The background of the study is based on the AC and DC railway systems which are running in parallel in the project of Dashengguan Bridge. The multi-conductors model including the steel truss bridge as well as the of the conductors of traction supply systems are constructed by the Q3D software. After that, the electrostatic voltage, induction electromotive force with and without the influence of steel truss bridge has been computed. By comparing the result fewer than two distinct conditions, the electromagnetic shielding performance of the steel truss bridge can be evaluated.

III. PROBLEM FORMULATION

In buildings, trusses allow engineers to create large open spaces with fewer materials. Using fewer materials also allows contractors to build cheaply. Spaces in trusses allow pipes and wires to easily pass through the ceiling. Despite being specific in design, there are many different types of trusses that engineers can use. This allows them to still be creative and to include structures such as vaulted ceilings. In both buildings and bridges, trusses are popular because they are incredibly strong. In fact, wood trusses are often used with concrete, a material considered much stronger than lumber. We propose to design a new structure to maximize, minimize or stabilize the load capacity according to structural strength.

IV. RESEARCH METHODOLOGY

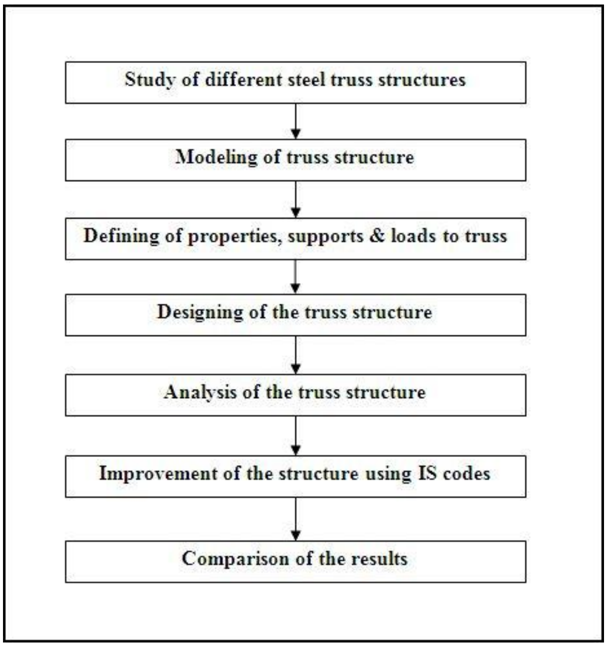

Fig 2: Research Methodology

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V. EXPERIMENTAL RESULTS

We have proposed to optimize the steel truss configuration for increasing structural efficiency. We have tested the designed models using ETABS Integrated Building Design Software and Staad.Pro structural analysis and design Program. ETABS has been developed specifically for multi-story commercial and residential building structures, such as office towers, apartments, and hospitals. The SAFE System provides an efficient and powerful program for the analysis and design of concrete slabs and foundations, with or without post-tensioning. STAAD.Pro is a general purpose structural analysis and design program with applications primarily in the building industry - commercial buildings, bridges and highway structures, industrial structures, chemical plant structures, dams, retaining walls, turbine foundations, culverts and other embedded structures, etc. We have designed steel truss of different sizes i.e. 7m, 10m, 12m, 15m, and 18m. The designed steel truss structures are analyzed for increasing structural efficiency with different-different configurations.

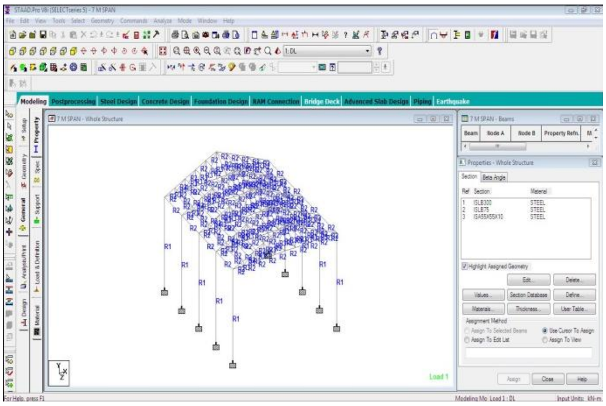

Fig 3: Properties of 7m Truss Structure

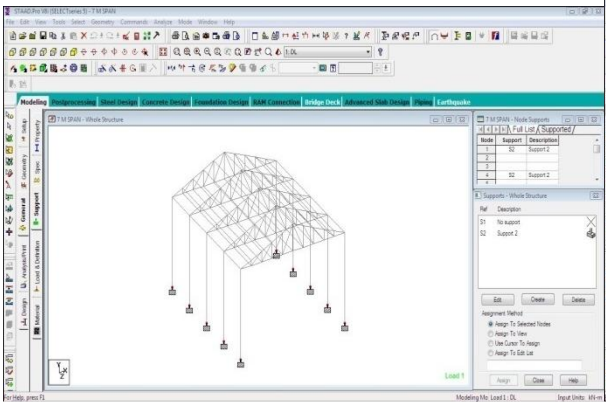

Fig 4: Supports of 7m Truss Structure

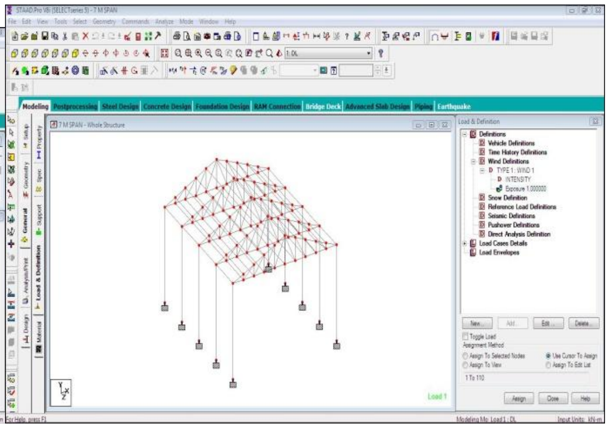

Fig 5: Load Definitions of 7m Truss Structure

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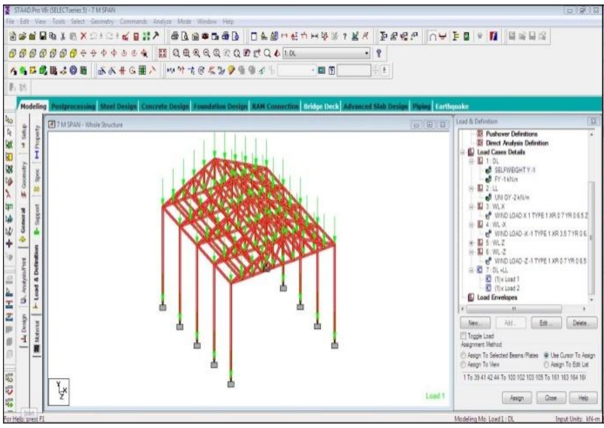
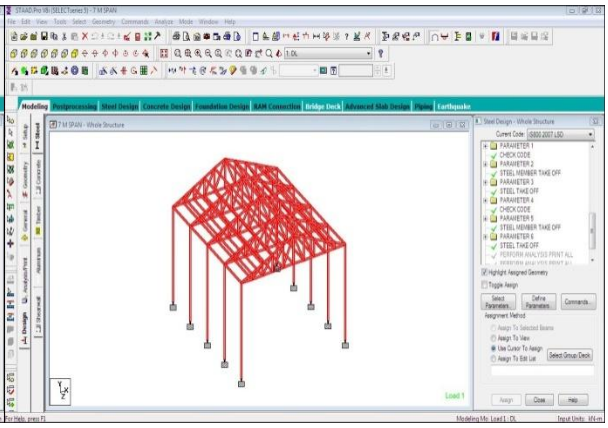

Fig 6: Load Case Details of 7m Truss Structure   Fig 7: IS Code of 7m Truss Structure

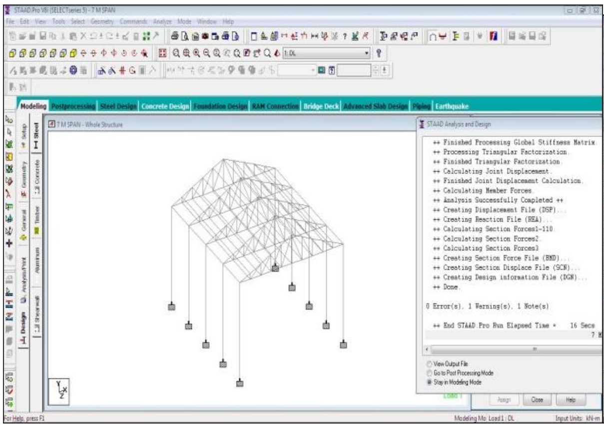
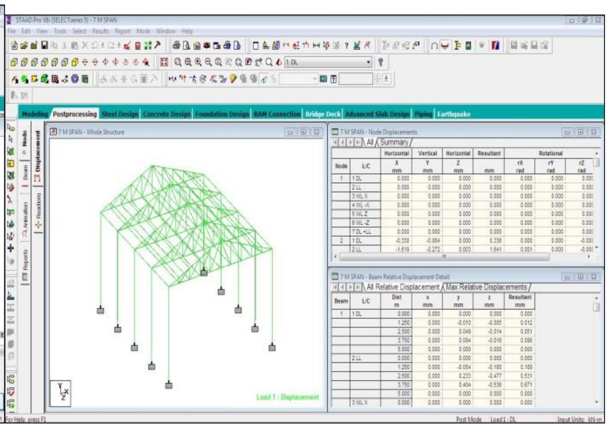

Fig 8: Analysis of 7m Truss Structure   Fig 9: Displacement of 7m Truss Structure

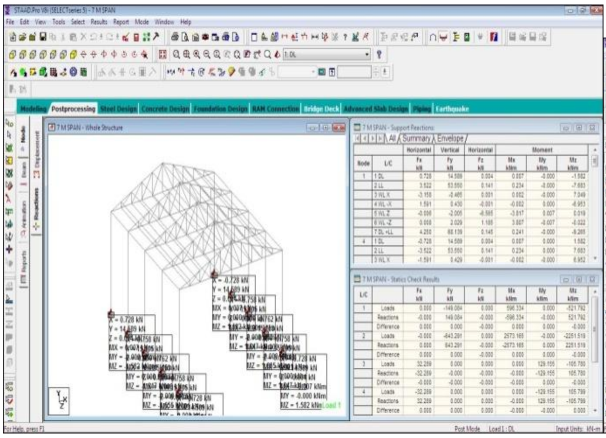
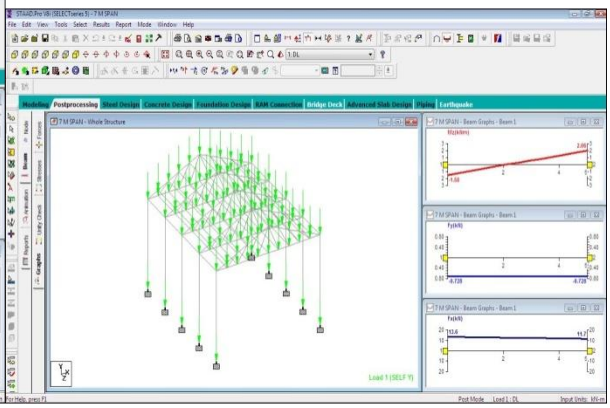

Fig 10: Reactions of 7m Truss Structure   Fig 11: Forces and Moment of 7m Truss Structure

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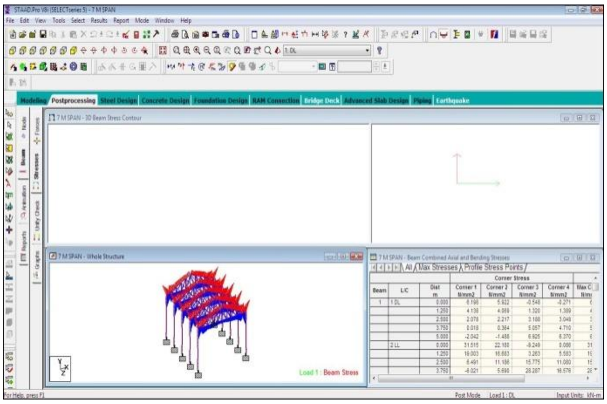


Fig 12: Stresses of 7m Truss Structure

In the same way structures are designed for 10m, 12m, 15m, and 18m and analyzed for truss structure optimization. Then the truss structures designed using Staad.Pro are imported to the ETABS and analyzed for structure failure.

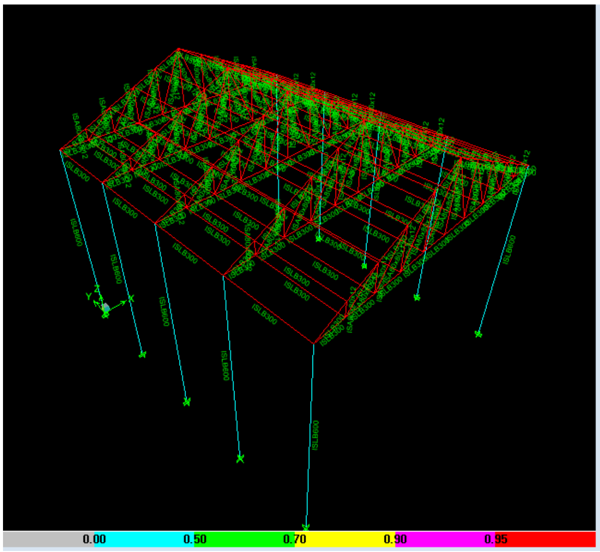
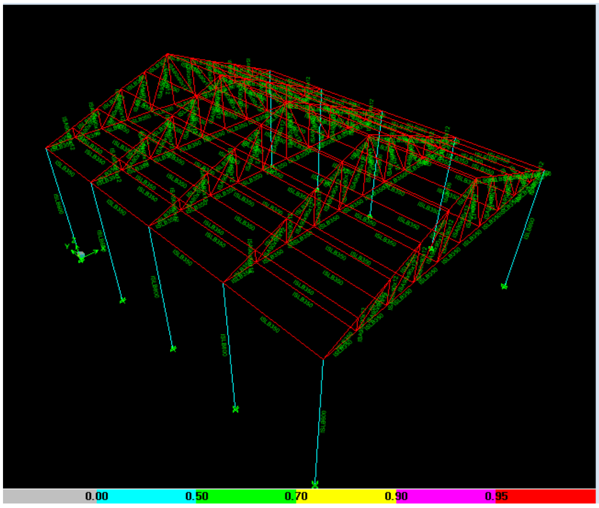


Fig 13: Steel Design for 7m Truss Structure using ETABS



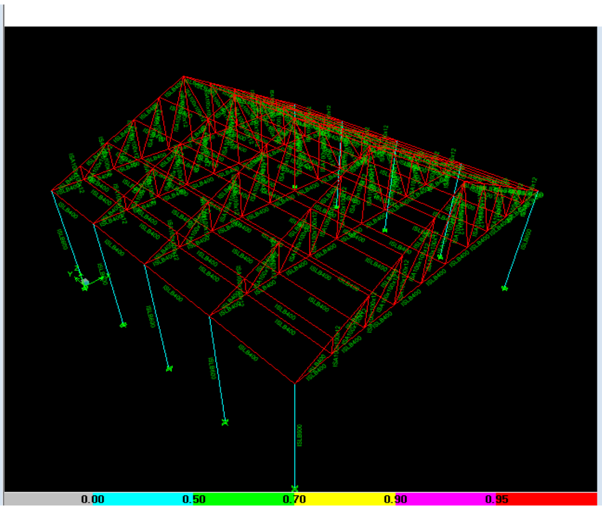


Fig 14: Steel Design for 10m Truss Structure using ETABS Fig 15: Steel Design for 12m Truss Structure using ETABS

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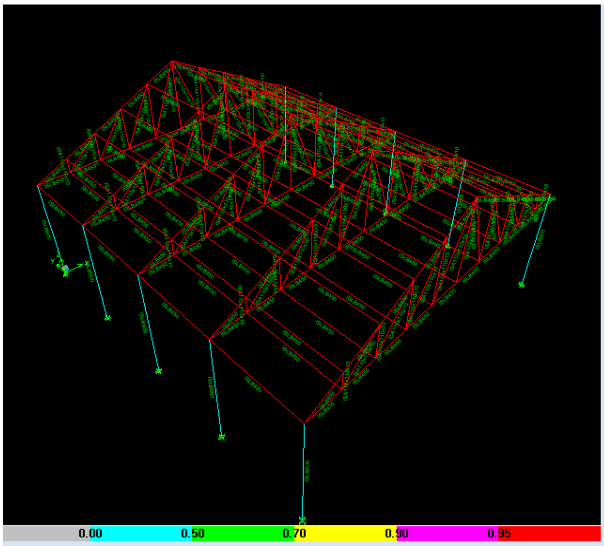

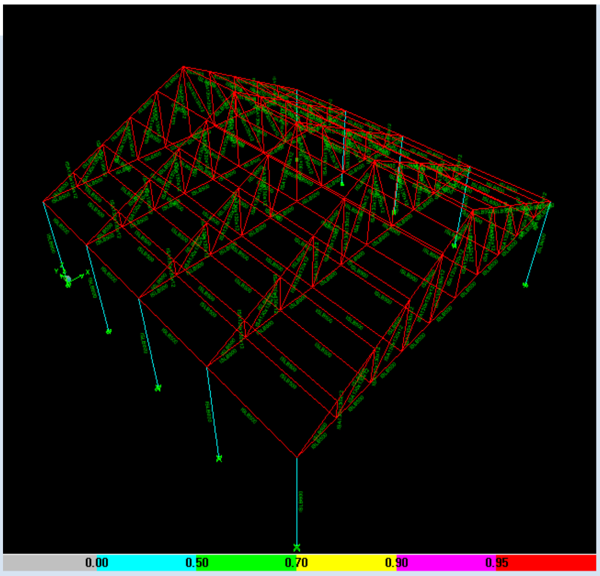

Fig 16: Steel Design for 15m Truss Structure using ETABS Fig 17: Steel Design for 18m Truss Structure using ETABS

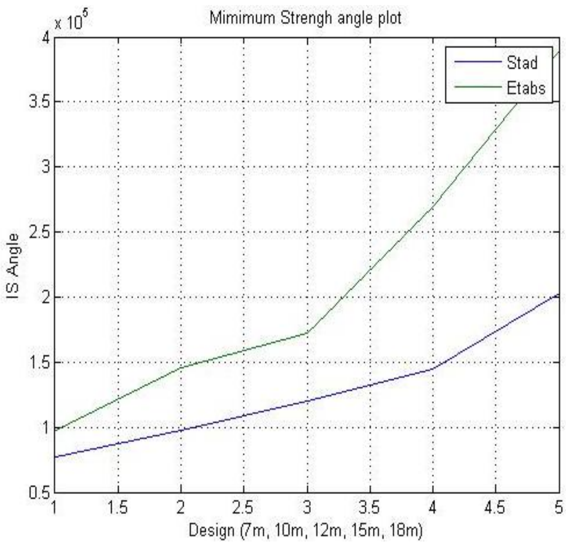

Fig 18: Comparison of Minimum Strength Angle for Truss Structure using Staad.Pro and ETABS

The Comparison of Minimum Strength Angle for Truss Structure using Staad.Pro and ETABS is shown in figure 13. The Comparison shows that more strength angle is required if we design the same structure with the same material in ETABS as compared to Staad.Pro which demonstrates that it requires less strength angle. By analyzing the graph we could also conclude that as the span of the structure increases the strength angle requirement is increasing drastically in ETABS as compared to Staad.Pro.

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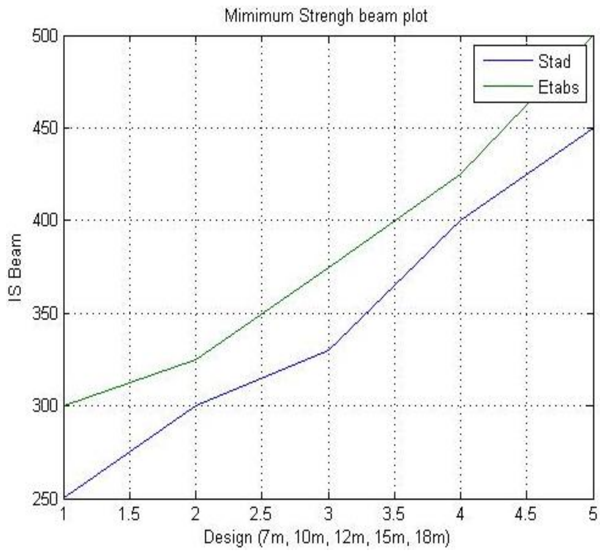

Fig 19: Comparison of Minimum Strength Beam for Truss Structure using Staad.Pro and ETABS

The Comparison of Minimum Strength Beam for Truss Structure using Staad.Pro and ETABS is shown in figure 14. The Comparison shows that more strength beam is required if we design the same structure with the same material in ETABS as compared to Staad.Pro which demonstrates that it requires less strength angle. By analyzing the graph, we could also conclude that as the span of the structure increases the strength beam requirement is increasing drastically in ETABS as compared to Staad.Pro.

VI. CONCLUSION

Structural topology optimization is a powerful and well-established technique to determine the optimal geometry to design efficient structures. There are several methods that have been used for structural optimization, and their utilization depends on the specific project or application considered. These methods include topology optimization, shape optimization, size optimization, and form finding, amongst others. We propose to design a new structure to maximize, minimize or stabilize the load capacity according to structural strength. Our proposed work shows that more strength beam and strength angle is required if we design the same structure with the same material in ETABS as compared to Staad.Pro which demonstrates that it requires less strength angle. By analyzing the graphs, we could also conclude that as the span of the structure increases the strength beam and strength angle requirement is increasing to a great extent in ETABS as compared to Staad.Pro.

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