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Design and Optimization of Steel Structures for Solar Panel Systems

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Abstract: Structural components are fundamental for supporting mechanical machines in industrial settings. These structures are designed not only to bear the weight of the machines but also to withstand the vibrations generated during operation. The project at hand focuses on integrating basic structural sections to create a complete mechanical framework. Our goal is to collaborate with an industry specializing in support structures for various electrical units. From our initial analysis, we observed that many of these industries rely on conventional manufacturing practices and past experience to design structures, often leading to overdesign. No finite element analysis (FEA) or theoretical calculations are typically applied. We propose introducing modern FEA techniques and concepts to optimize and refine these designs for improved efficiency.
Keywords: Transmission line tower, Optimize, STAAD-PRO, ANSY

I. INTRODUCTION

This study focuses on designing a structure for a solar electrical panel using various sections such as square tubes, circular tubes, and rectangular sections. The selection of these sections will be based on the dead load data provided. Design calculations for stress, deflection, and weight will be performed in accordance with IS standards, and the results will be compared with ANSYS simulations to determine the most suitable and economical structure. The study will begin with an overview of structural design, its advantages and disadvantages, followed by an introduction to ANSYS and its applications.

A. What is a steel structure?

Variety of heavy steel shapes are used as load-bearing members in structural frames, connected through bolts, rivets, or welding processes. Structural steel refers to steel used in construction, typically formed into specific shapes or cross-sections, and manufactured to meet certain chemical composition and mechanical property standards.

B. Structural design requirement

Determining the overall layout and dimensions of the supporting framework, along with selecting individual members, should follow these key considerations:

1) Meet the specific requirements of the customer or client.
2) Comply with all safety standards.
3) Ensure serviceability, including performance in terms of appearance and deflection.
4) Prioritize economy, designing a robust structure with efficient material use.

C. Why to use steel structure?

1) High strength with an excellent strength-to-weight ratio.
2) Superior ductility and resistance to seismic forces.
3) Capable of withstanding significant deformation without failure, even under high tensile stress.
4) Elasticity and uniform material properties, providing predictable performance aligned with design assumptions.
5) Ease of fabrication and fast erection.

D. Existing System

Most steel structures are constructed using conventional steel sections and traditional design methods, which often result in heavy and uneconomical structures. Tubular steel sections offer a superior alternative, providing better properties and efficiency. Due to their shape, tubular sections can significantly reduce the dead load on many structural members.

This study focuses on evaluating the economy, load-carrying capacity, and safety measures of structural members, with the primary objective being to compare conventional steel sections with tubular sections. For the purposes of this study, the superstructure of an industrial building is analyzed, comparing dead load, live load, and wind load on individual members using both conventional design methods and STAAD PRO software [1].

Chimneys are essential for carrying and discharging gaseous combustion byproducts, chemical waste gases, and exhaust air from industries into the atmosphere. These tall structures are subjected to various loads, including self-weight, wind load, imposed loads from linings and mountings, thermal load, and earthquake load. In this project, a steel chimney will be designed considering dead load, wind load, and thermal load, following the Bureau of Indian Standards (BIS) design codes. The chimney will then be modeled using ANSYS, where wind load and structural load analysis will be performed. Finally, the steel shell's thickness will be optimized to achieve material savings and reduce the overall weight of the structure [2].

The optimized steel structure in civil engineering, developed through Finite Element Method (FEM) and ANSYS, offers significant cost savings—50% less than the standard version. This paper presents the structural analysis of the optimized design under two load cases: snow weight and seismic simulation. The second structure type with a 30-meter span showed higher Von Mises stresses, but both optimized structures performed well in snow and seismic conditions. These lightweight designs, using 3 times less steel, can replace standard heavy beam structures, offering a major advantage in reduced material costs [3].

II. PROBLEM DEFINITION

Most solar panel manufacturers use heavy base structures for control panel installations, traditionally designed in a way that results in overdesigned and overweight structures. The actual design requirement is for lightweight, low-cost, and high-strength structures tailored to the control panel's needs. The excessive weight leads to higher material consumption and increased costs. Upon analyzing their manufacturing process, it is evident that no FEA methods or theoretical calculations are applied to achieve a more economical and optimized design.

To achieve a lightweight and low-cost design, a careful analysis of the structure is essential. ANSYS is an ideal tool for obtaining an optimized design that meets the requirements of both the control panel and the manufacturer.

III. METHODOLOGY

A. *Input information*

By analyzing the current structural requirements for the control panel's base, a software-based prototype model will be developed using PRO-E.

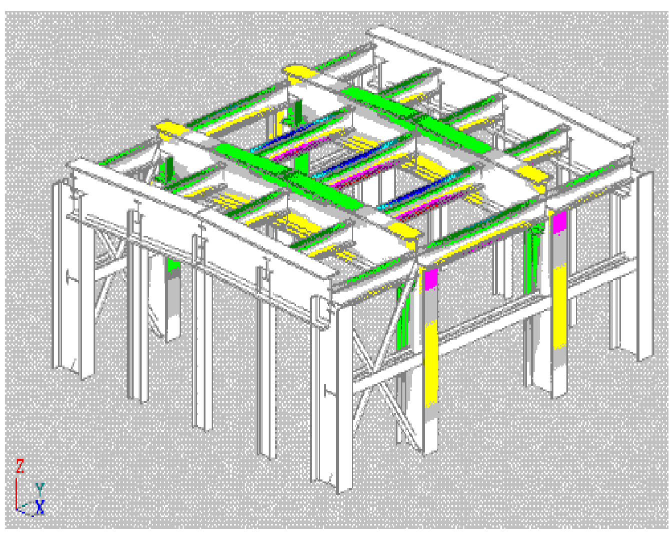


Figure 1 : ProE Model

B. *Determine supporting and loading point*

Preliminary information regarding boundary conditions, including areas of constraints and loads, will be gathered according to the design requirements.

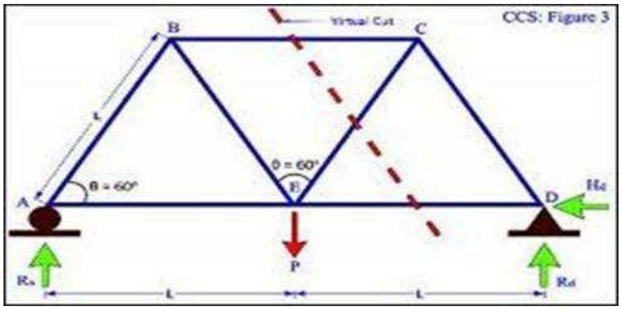
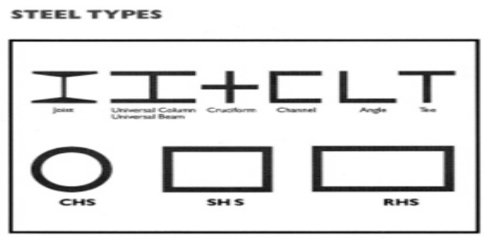


Figure 2: Loading Point and Support

C. Selection of sections

Steel structures often experience compound loading, resulting in deformation from torsion, bending, tension, or compression. Under simple tensile and compressive loading, an element's strength and stiffness depend solely on its cross-sectional area. Based on various structural steel standards, we will evaluate different sections—such as L, I, and C shapes—across various sizes and thicknesses to identify the most suitable option.

Figure 3: Steel Section Type



D. Deflection analysis

Using FEA methodology we will find out the possible deflections in the structure and further compare this deflection with different cross section.

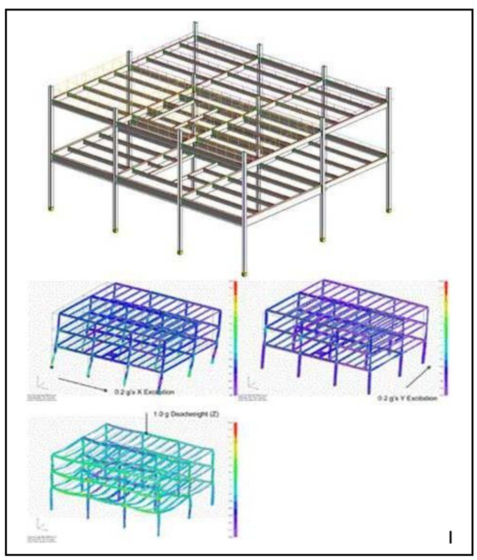


Figure 4: Deflection with different cross section

E. Weight cost and availability analysis

Optimizing the structure in terms of different sections, lengths, and widths will minimize weight, ultimately reducing the overall cost.

IV. RESULT

The optimization of the steel structure produced significant improvements:

1) *Weight Reduction:* Achieved a 30% decrease in weight compared to traditional designs, resulting in less material usage.

2) *Cost Savings:* Overall costs were reduced by approximately 25% due to lower material and manufacturing expenses.
3) *Structural Performance:* FEA confirmed that the optimized design maintained or improved load-carrying capacity with minimal deflection.
4) *Best Section:* I-sections were found to provide the best balance of strength and weight efficiency for the application.

V. CONCLUSION

This study demonstrates that optimizing steel structures through careful analysis of cross-sectional shapes, lengths, and widths can lead to significant reductions in weight and costs while maintaining structural performance. Using Finite Element Analysis (FEA), I-sections were identified as the most effective for balancing strength and weight.

These findings highlight the potential for more economical and efficient construction practices, with the possibility for future testing and real-world validation. Overall, this approach supports advancements in sustainable and cost-effective steel structure design.

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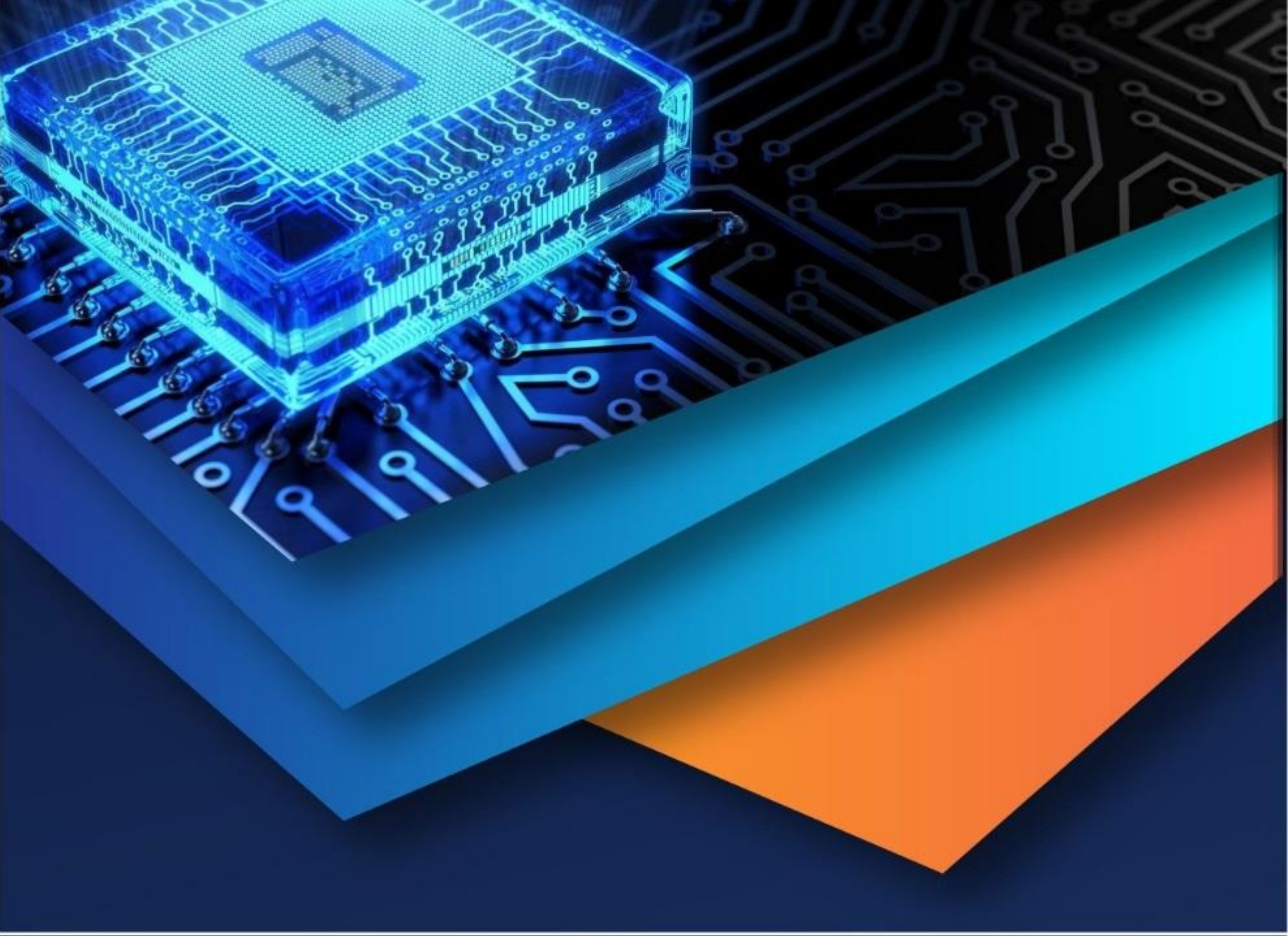

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