



Determination Of Axial Forces In The Members Of A Trusses

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Abstract: This study determination of the accuracy of axial forces calculations in truss members using analytical and numerical methods. The Method of Joints and Method of Sections are employed analytically, while the Finite Element Method is utilized numerically. A comparative analysis of a steel/aluminum truss case study reveals excellent agreement between the two approaches, validating the reliability of axial force calculations. The findings underscore the importance of rigorous verification procedures to ensure truss structural integrity and inform design optimization. In this project we analyzed the axial forces in member of the trusses by analytical and numerical methods. Improve the trusses design accuracy and the validate of axial forces.

KEYWORDS: Truss Structures, Axial Forces, Analytical Method, Numerical Methods Method of joints.

1.INTRODUCTION

Trusses are structural frameworks composed of interconnected straight members that form a rigid structure, typically used in bridges, roofs, and other civil engineering applications. The primary function of a truss is to transfer loads efficiently from one point to another, distributing the applied forces through its various members. Each member of a truss can either be in tension (pulled apart) or compression (pushed together) depending on the direction and nature of the external loads applied to the structure. Determining the axial forces in the members of a truss is essential for the design and analysis of these structures. The axial force in each member is a critical parameter in ensuring the truss's stability and strength. Accurate calculation of these forces helps engineers decide the material and cross-sectional dimensions of each member, ensuring that the truss can safely withstand the applied loads without failure. Methods such as the method of joints, the method of sections, and matrix analysis are commonly employed to analyze trusses and determine the axial forces.

2.LITERATURE REVIEW

Yao Cui et al. [1]: In this research he explained about coupling beam for coupling shear wall structures. In this he used bending type frictional steel truss coupling beam (BFTCB) it concentrates about the deformation and energy dissipation. In this model it consists of trilinear backbone curve and about unloading. He analyzed the hysteretic curve characteristics from previous tests, these curves are generated by FE method.

Krishanu Roy et al. [2]: He study of variations in the number and locations. In this research he introduced to simulate different boundary conditions. According to parametric study he explored the effects of span height ratio and variability. In this study lateral support locations on truss strength and failure modes. According to the American iron and steel institute (AISI 2016). In this test to design strength ratio is 0.86.

Joonas Tulonen et al. [3]: He researched the novel strain-based model is verified against the selected data base and proves to be accurate tool for analysis. He studied about the predict of failure loads by analysis of the calculations results. He studied it is found that by adjusting the shear panel. He researched the softening factor of concrete under shear of the plasticity. In this paper he focused on combined effects of bending and torsion on solids rectangular concrete beam.

Jozef Backo et al. [4]: In this method he researched the static analysis of the truss was investigated and the analytical and computational method of the roof structure. He studied the beginning of analytical method is used for determination of value of external supports in this method axial force and principles stresses in the truss element are calculated. By according to the truss computational method is modeled by the finite element method.

Yauns et al. [5]: He studied about the fixed nodal position method (FNPM) this method developed for design of geometric configuration. And internal forces are distributed for a class of truss structure. He researched according to the (FNPM) first assigned nodal coordination for a truss structure and also he determined that the internal forces are distributed on the structure. He studied highlight of the (FNPM) is that the prescribed the nodal coordinate process this adaption algorithm was produced the viable engineering solutions. This research is used for finding of complicated truss structure.

Marco Domanes chi et al. [6] : The paper highlights the significance of optimization algorithms, especially population-based metaheuristic algorithms, in addressing complex civil engineering design problems. These algorithms have been effective in optimizing steel trusses, which are a common focus in structural optimization literature. The literature indicates three main categories of optimization problems in steel trusses: size, shape, and topology optimization. Recent trends emphasize novel optimization methods that incorporate uncertainty estimation and advanced structural analyses, as well as multi-objective optimization that considers sustainability and regulatory.

J. J. Salinas et al. [7] The paper discusses the introduction of multi-laminated nailed joints in the Canada Plan Service (CPS), aimed at creating robust hand-nailed roof trusses suitable for farm construction. This innovation is significant for enhancing the structural integrity of timber trusses. The traditional design approach for these trusses involved assuming pinned connections at member ends. However, the paper highlights that this method did not accurately predict failure locations during load tests, indicating a need for

a more refined analysis that considers joint stiffness and secondary stresses. The authors conducted load tests on two families of multi-laminated trusses. The results showed unexpected failure locations, which were not aligned with traditional analysis predictions. This discrepancy pointed to the inadequacy of the conventional methods in capturing the complexities of joint behavior under load.

Sirichai et al. [8] Bamboo is increasingly recognized as a viable alternative to traditional materials like steel in construction. It is noted for its high mechanical resistance and rapid growth, making it an economical choice for building structures, including houses and greenhouses. The study focuses on the physical and mechanical properties of sweet bamboo culms (*Dendrocalamus asper* Backer) from Thailand, specifically using 3-year-old bamboo for structural analysis. This age is chosen to ensure optimal strength and flexibility for construction purpose. The paper presents an analysis of various truss shapes designed for a greenhouse structure. The analysis involved calculating cross-section areas, self-weight, and displacement values under standard loads (Dead Load, Live Load, and Wind Load) to determine the most effective design.

Zigang Shen et al. [9] Long-span steel trusses are essential in factory buildings due to their ability to support large loads over considerable distances. However, they are susceptible to issues such as transverse cracks and oblique deformations, especially under dynamic loads, which can compromise their functionality and safety. The study introduces a variable axial force cable system as a method to reinforce these trusses. This approach aims to enhance the load-bearing capacity and stability of the trusses, addressing the common problems associated with fatigue and stress distribution. The research employs the finite element method to model the forces acting on the trusses. This method is widely recognized for its effectiveness in analyzing structural behavior under various loading conditions. The paper discusses the reinforcement effects under different scenarios, focusing on stiffness, bearing capacity, and stability.

Y. Xiao et al. [10] The paper discusses glue-laminated bamboo, or glulam, as a structural material that offers advantages over conventional materials like steel and timber. This innovative material is produced by hot-pressing bamboo strips with phenol formaldehyde resin, resulting in a more uniform and reliable structural element compared to traditional bamboo forms, which often suffer from issues like non-uniformity and unreliable bearing strength. The literature highlights that glulam exhibits mechanical properties similar to typical glulam materials, with a density of 880 kg/m^3 , which is heavier than most timber materials. This information is crucial for understanding the performance characteristics of glulam in structural applications. The research group has made significant progress in applying glulam in real-world structures, such as disaster relief shelters and residential houses.

3.METHODOLOGY

This methodology discussed about the process about our mini project work and what are the methods are use in our mini project. This study aims to rigorously assess the accuracy of axial force calculations in truss members through both analytical and numerical methods, specifically employing the Method of Joints and the Method of Sections for the analytical approach, alongside the Finite Element Method (FEM) for the numerical analysis. The methodology is structured to facilitate a comprehensive understanding of the axial forces at play in truss systems, which is crucial for ensuring the structural integrity and optimizing the design of these frameworks.

3.1. Numerical Method

Finite Element Method (FEM): The FEM provides a sophisticated approach to analyze the truss by discretizing the structure into smaller, manageable elements. Each element is modeled to capture the behavior of the truss under applied loads, allowing for a detailed investigation of stress distribution and deformation. This method not only enhances the accuracy of axial force calculations but also enables the examination of complex geometries and loading scenarios.

3.2. Analysis Techniques

Once the data is collected through both analytical and numerical methods, a thorough comparative analysis is conducted. The results from the Method of Joints and Method of Sections are systematically compared to those obtained from the FEM. Key performance indicators, such as the magnitude of axial forces, are evaluated to determine the level of agreement between the two methodologies. Statistical tools, including percentage deviation and correlation coefficients, are employed to quantify the accuracy and reliability of the results. Additionally, the study emphasizes the importance of rigorous verification procedures. This involves cross-referencing the calculated axial forces against established design codes and standards, ensuring that the derived values not only meet theoretical expectations but also align with practical applications. The findings from this comparative analysis not only serve to validate the axial force calculations but also highlight the critical role of accurate design in maintaining the structural integrity of trusses.

3.3. Welding and Assembly

- Prepare joints by cleaning surfaces for better weld adhesion.
- Arrange members in position using jigs and fixtures to maintain alignment.
- Tack-weld the joints first to hold the structure together.
- Perform full welding using TIG, MIG, or arc welding as per material suitability.
- Check for proper penetration and avoid over-welding, which may weaken the structure.

4.FABRICATION:

This chapter discuss about Fabrication and step by step procedure for the fabrication of truss member.

INTRODUTION OF FABRICATION

In truss fabrication, understanding the axial forces in truss members is crucial to ensuring structural stability, safety, and material efficiency. The axial force in a truss member is determined based on the principles of static equilibrium, assuming that the joints are pin connections and the loads are applied only at the joints.

A truss is a structural framework composed of straight members connected at joints, typically designed to carry loads efficiently. Trusses are widely used in bridges, roofs, towers, and various structural applications due to their ability to transfer loads primarily through axial forces (tension or compression), minimizing bending moment.

MAJOR COMPONENTS:

- 3.1.1. Steel Bars
- 3.1.2. Roller supports
- 3.1.3. Hinged Supports
- 3.1.4. Weight Hanger
- 3.1.5. Weight Measurements

3.1.1. Steel Bars:

Steel bars are long, solid pieces of steel that come in various shapes, sizes, and grades. They are essential components in construction, manufacturing, and other industries due to their strength, versatility, and durability. The steel bar is used in trusses as shown in figure-1



Fig-1: Steel Bars

Roller Bearings

Roller bearings are a type of mechanical component used to reduce friction between moving parts, enabling smoother and more efficient motion. They consist of rolling elements (like cylinders or rollers) that help support radial or axial loads. Roller bearings are often used in machinery, vehicles, and other applications that require the smooth rotation of parts. To ensure long-lasting performance, roller bearings need to be properly maintained, which includes regular inspection for wear and tear and proper lubrication. Common lubricants for roller bearings include grease or oil, depending on the specific application and environmental conditions. Roller bearings are



Fig-2: Roller Bearing

Hinged Supports:

Hinged supports are mechanical devices used to provide support to structures or components while allowing rotational movement around a fixed axis. They are widely used in engineering, construction, and mechanical applications to support beams, columns, machinery parts, and other structures.

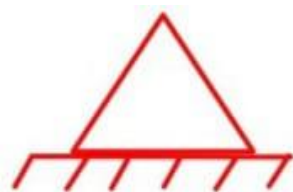


Fig-3 Hinged Support

Weight hangers are devices or systems designed to hold and support weights, typically for use in weight measurement, testing, or calibration processes. They are commonly found in various industries, including laboratories, manufacturing, and fitness.



Fig 4 Weight Hangers

Weight measurement: refers to the process of determining the mass or weight of an object. It plays a crucial role in various fields such as science, industry, commerce, and everyday life. Weight is the force exerted on an object due to gravity and is commonly measured in units such as grams (g), kilograms (kg), or pounds (lbs.), depending on the system of measurement used.



Fig- 5 Weight measurement

PROBLEM STATEMENT:

A truss is a structural framework composed of interconnected members, typically arranged in triangular units, to support loads. The problem involves determining the axial forces (tension or compression) in the individual members of a truss based on the applied loads and boundary conditions. The solution will provide the axial force in each truss member, indicating whether the member is in tension or compression, and the magnitude of the force. This will allow the designer or engineer to assess the performance of the truss under the applied loads and make necessary design decisions.



Truss without load



Truss with load

5.DESIGN & MODELING

1.Start in the Part Design Workbench:

Ensure the user is in the Part Design Workbench. If needed, select it from the Workbench dropdown list.

2. Create a New Document:

Create a new document if one isn't already open. It's advisable to save the work with a chosen name.

3. Create a New Body:

Click "Create new body" to initiate and activate a body, which is essential for beginning in Part Design. If a sketch is created without an existing body, the software automatically creates and activates one.

4. Sketching:

Start a new sketch by clicking "create a new sketch" under the new body element.

Choose a plane for the sketch, preferably one of the predefined planes like XY, XZ, or YZ.

Utilize the sketcher environment tools for creating sketch elements, dimensioning, and applying constraints.

5. Part Design Features:

Use tools to create 3D features from the 2D sketches.

The specific tools and steps will vary based on the design requirements.

6. Saving Work:

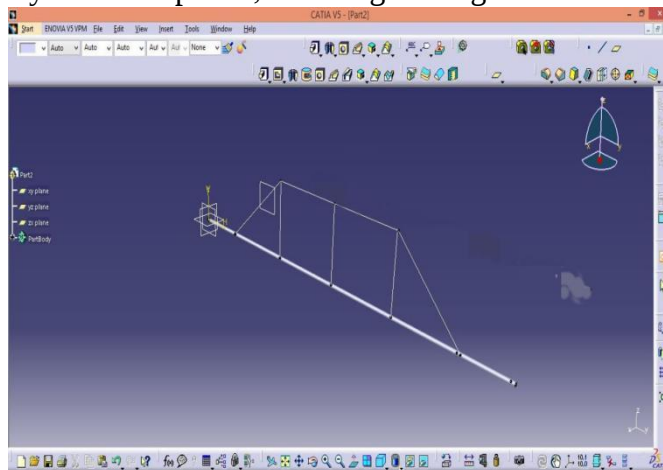
Save the work frequently to prevent data loss.

7.The software that is used is CATIAV5

Figure 4.1 says that the it is the design of the structural frame which is designed in CATIAV5.The image displays a wireframe model in CATIA V5, a 3D CAD software.This appears to be a preliminary design or sketch, possibly of a bridge or structural element, using lines to define its shape and form. Key features include:

Wireframe Model:

The structure is represented by lines and points, outlining the edges and vertices.

**Reference Planes:**

The "xy plane," "yz plane," and "zx plane" indicate the 3D space orientation.

Points and Lines:

The model is constructed from connected points and lines, defining the structure.

Fig 6 Design of the structural frame.

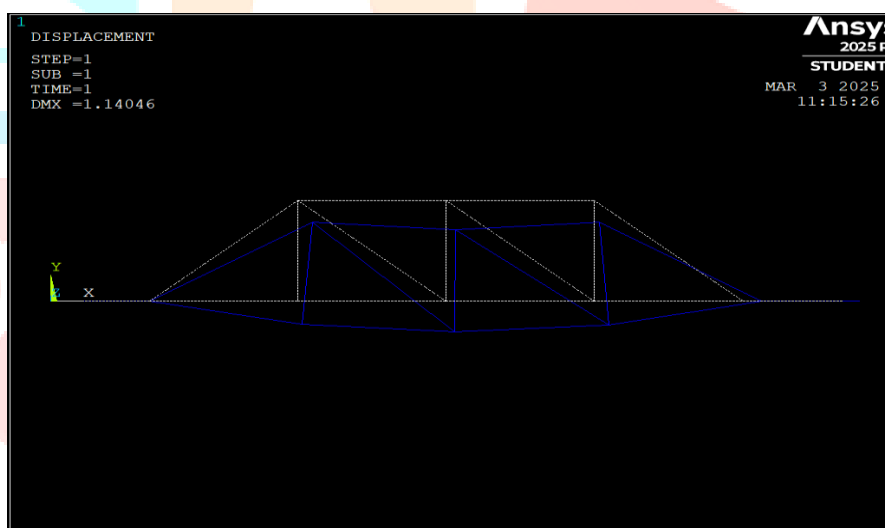
6.ANALYSIS

Fig 7

The figure describes about the deformation in the structural frame. In ANSYS, the deformation of a structural frame is computed by applying loads and boundary conditions to the model, meshing the geometry, solving for displacement and stress responses, and then visualizing the results using various post-processing tools. This helps engineers understand how the frame will deform and whether it can withstand the applied loads safely.

1. The figure itself shows the stress distribution in the truss.
2. In the result itself shows variations in the structural frames by indicating with the colours.
3. The red colour indicates that stress is more at that point.
4. The blue colour indicates as zero stress at that point.
5. The green colour indicates that the stress is safe.

7.RESULTS

When applying the methods above, you will end up with the axial forces for each of the members in the truss. The results will tell you if the member is in tension or compression based on the sign of the axial force:

Positive Axial Force: The member is in tension.

Negative Axial Force: The member is in compression

When you perform a structural analysis on a frame in ANSYS, the software provides a variety of results that describe the behavior of the frame under the applied loads. These results give engineers critical insights into the performance of the structure, including displacement, stress distribution, reaction forces, and safety factors.

These results give engineers critical insight into the frame's performance under various loading conditions, helping to optimize the design, identify potential failure points, and ensure that the structure meets the required safety and performance standards.

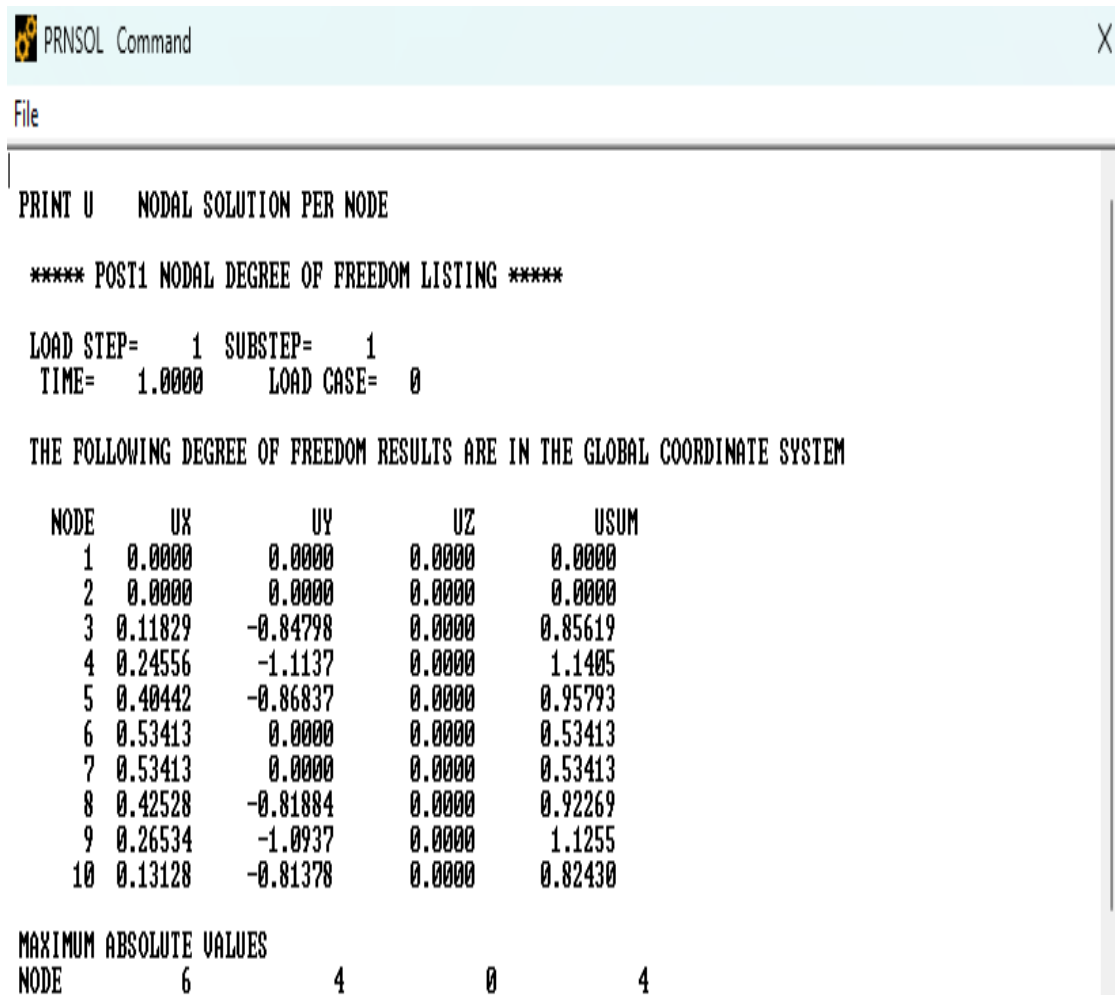
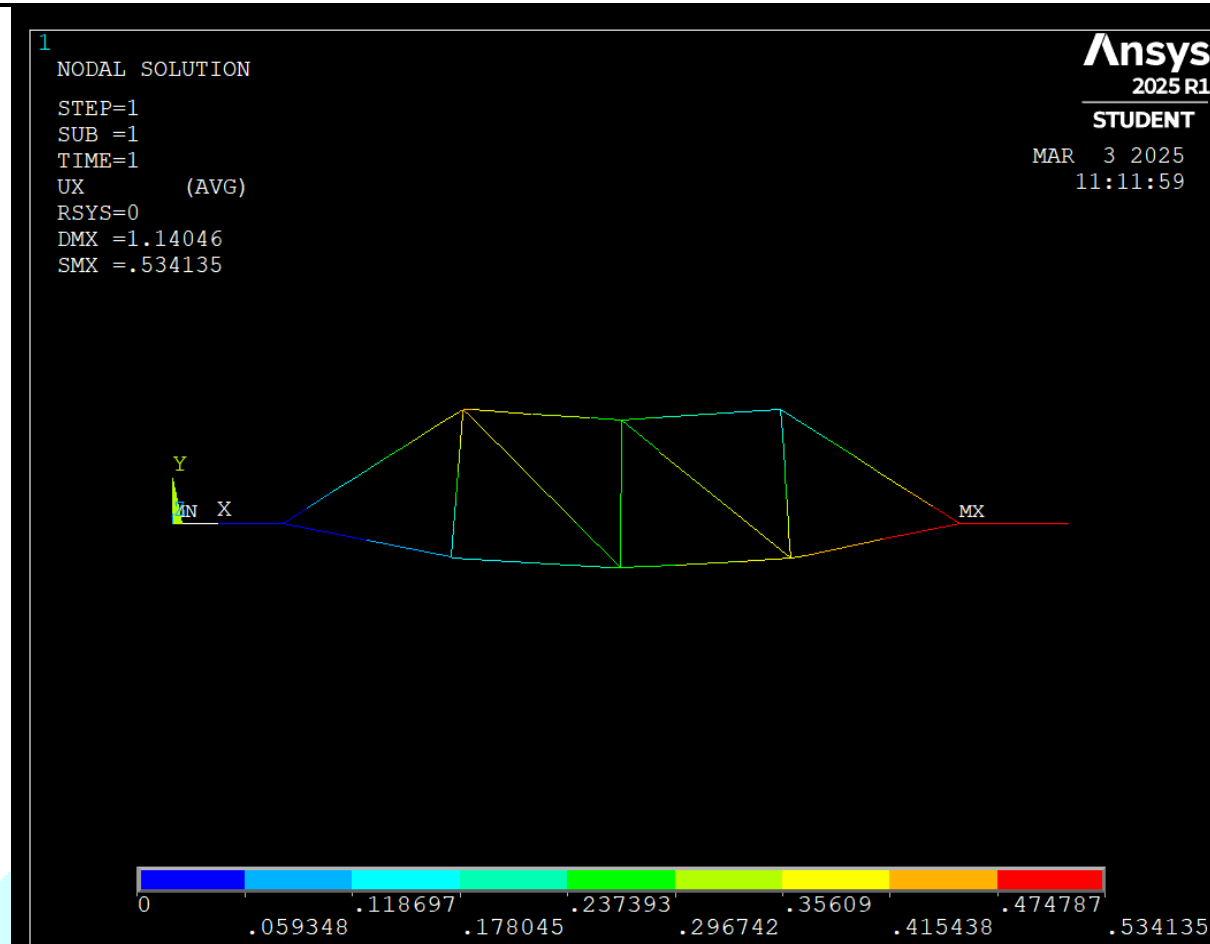


Fig Results of the designed structural frame



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DISCUSSION

- **Compression vs. Tension:** The results show which members are carrying tensile forces and which are carrying compressive forces. Tension forces typically elongate a member, whereas compressive forces tend to shorten it. This distinction is important for designing the members to withstand these forces.
- **Force Distribution:** The axial forces in the truss members will vary depending on the placement of the load and the geometry of the truss. Generally, the truss members near the load will have higher axial forces, especially if they are positioned closer to the load application point.
- **Structural Behavior:** A truss system is efficient because it transfers loads through its triangular configuration, with forces being carried mainly by the axial forces in the members. Understanding whether a member is in tension or compression helps engineers optimize the design of the truss, choosing materials and cross-sectional areas that are suitable for the calculated forces.
- **Impact on Design:** If members experience excessive compressive forces, they may buckle, which could compromise the structural integrity of the truss. Members in tension are typically less vulnerable to failure, but the material needs to be designed to handle the tensile forces without stretching beyond acceptable limits.

8.CONCLUSION:

The determination of axial forces in the members of a truss is a fundamental aspect of structural analysis and design. By applying methods like the Method of Joints or the Method of Sections, we can efficiently calculate the internal forces acting on each truss member. These methods involve solving equilibrium equations at various joints or sections to obtain the axial forces, which can indicate whether the members are in tension or compression.

The results from these analyses provide essential insights into the behavior of the truss structure under loading conditions. Knowing the axial forces allows engineers to ensure that the members are designed with appropriate materials, sizes, and cross-sectional areas to withstand the forces without failure. Members experiencing tension are generally more stable, while those under compression require careful consideration of potential buckling risks.

In conclusion, the accurate determination of axial forces in trusses is crucial for the safe and cost-effective design of structures. It ensures that all members perform their intended function, contributing to the overall stability and efficiency of the structure. Proper understanding and application of these methods not only improve safety but also optimize the material usage and cost in truss design.

In conclusion, the accurate determination of axial forces is an integral part of truss design. The results not only help engineers design safe and efficient structures but also optimize the material usage to minimize costs while maintaining structural safety and integrity. The axial force analysis also assists in identifying critical members that need reinforcement or specific material properties, ensuring the truss functions as intended under various loading conditions.

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