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Exploring Structural Analysis of Building Conventionally

Rutvij Patel
Pooja Construction

***Abstract:** Two methodologies are used to analyze the complete structure throughout the structural analysis procedure - Conventional Method and Software Base Method. A description of traditional techniques is included in this text. A structural engineer must be proficient in conventional methods of analysis. This article includes references to sub methods, total methods, conventional method processes, and examples. The accuracy of the analysis is crucial, failing which the structure will not be able to support the weight. This article covers a wide range of subjects, such as analysis techniques, definitions, and load calculations in analysis. The accuracy of the traditional analysis method is also discussed.*
***Keywords:** Structural Analysis, Material Science, Analytical Methods, Limitations, Classification.*

I. INTRODUCTION

A subfield of solid mechanics called structural analysis makes use of condensed models of solids like bars, beams, and shells to aid in engineering decision-making. Determining the impact of loads on the physical structures and its constituent parts is its primary goal. The models employed in structural analysis are frequently differential equations in a single spatial variable, in contrast to the theory of elasticity. Any structure that has to support weights, such as ships, airplanes, bridges, and buildings, is subject to this kind of examination. Structural analysis computes a structure's deformations, internal forces, stresses, support responses, velocity, accelerations, and stability using concepts from applied mechanics, materials science, and applied mathematics. The analysis's findings confirm a structure's suitability for usage, frequently avoiding the need for experimental testing. Particular.

II. WHAT IS STRUCTURE AND ITS LOAD

A. Structure

A structure is defined as a body or a system of connected pieces in structural analysis that is utilized to sustain a load. In other engineering disciplines, ship and aircraft frames, tanks, pressure vessels, mechanical systems, and electrical supporting structures are crucial examples.

Notable examples in civil engineering include buildings, bridges, and towers. Other engineering specialties work on a wide range of non-building structures. When designing a structure, an engineer must take economic, environmental, and safety limitations into mind.

The combination of structural components and their materials is known as a structural system. It is crucial for a structural engineer to be able to identify the different components of a structure and categorize it according to its shape or function. In addition to connecting rods, trusses, beams, and columns, other structural components that direct the systemic forces through the materials include cables, arches, cavities, and channels; they can even be angles, surface structures, or frames.

B. Loads

The loads a structure must support must be identified once the dimensional requirements have been established. Therefore, defining the loads acting on the structure is the first step in structural design. Building regulations generally specify the design loading for a structure. Engineers must adhere to the criteria of both basic building regulations and design codes for the structure to continue to be dependable.

In the design process, structural engineers must deal with two different kinds of loads. The weights of the different structural parts and any things that are fixedly fastened to the structure make up the first category of loads, known as dead loads. The floor slab, roofing, walls, windows, plumbing, electrical fittings, and other various attachments are a few examples of what this includes. Live loads are the second kind of loads, and they differ in size and position.

Live loads come in various forms, including those from buildings, railroad and highway bridges, impact loads, wind, snow, earthquakes, and other natural loads.

III. ANALYTICAL METHODS

A structural engineer must ascertain details like structural loads, geometry, support conditions, and material characteristics to conduct an appropriate analysis. Such a study usually yields displacements, stresses, and support responses. After that, this data is contrasted with standards that denote the circumstances of failure. Stability, non-linear behavior, and dynamic responsiveness may all be examined in advanced structural analysis.

The elasticity theory technique, which is essentially a specific instance of the broader area of continuum mechanics, the finite element approach, and the mechanics of materials approach—also known as strength of materials—are the three methods used in the study. The first two utilize analytical formulas that can usually be solved by hand. They apply primarily simple linear elastic models and result in closed-form solutions.

The finite element approach is a numerical technique for resolving differential equations produced by mechanics theories like strength of materials and elasticity theory. The finite-element approach, on the other hand, is more suitable for structures of any size and complexity and is dependent mainly on computer processing capacity.

The concept relies on three essential relations, namely equilibrium, constitutive, and compatibility, irrespective of the technique used. When any of these relations are only partially met, that is, merely an approximation of reality, the solutions are approximate.

A. Limitations

Every technique has some notable drawbacks. Material mechanics is restricted to fundamental structural components with relatively straightforward loading scenarios. Nonetheless, the permitted loading conditions and structural components are enough to address many practical engineering issues. In principle, structural components with any shape may be solved under any loading situation thanks to the theory of elasticity.

However, analytical solutions are only applicable in mildly complicated situations. A system of partial differential equations must also be solved to solve elasticity issues, which is a significantly more mathematically difficult task than solving mechanics of materials problems, which only call for the solution of one ordinary differential equation at most. The finite element approach may be both the most practical and the most restricted. This approach itself depends on solving equations based on other structural theories (like the other two covered here). With the caveat that there will always be some numerical error, it does, however, typically make it possible to solve these equations, even with highly complicated geometry and loading circumstances. A thorough grasp of this method's limits is necessary for its practical and dependable application.

B. Methods

1) Strength of Material Method (Traditional Approach)

The mechanics of materials technique, the most straightforward of the three approaches provided, may be used for essential structural elements subject to loadings, such as circular shafts subject to torsion, prismatic beams in a condition of pure bending, and axially loaded bars. The superposition concept can be used to superimpose the solutions under certain circumstances to analyze a member enduring combined loading. Unique case solutions for typical constructions like thin-walled pressure vessels are available.

The method of sections and joints for truss analysis, the moment distribution technique for small rigid frames, and the portal frame and cantilever method for big rigid frames are all products of using this methodology in combination with statics for studying whole systems. These techniques were created in the second part of the nineteenth century, except for moment distribution, which was used in the 1930s. They remain in use for small-scale constructions and large-scale building preparatory designs.

Euler-Bernoulli beam theory and linear isotropic infinitesimal elasticity serve as the foundation for the answers. Stated differently, these presumptions include, but are not limited to, the following:

- The materials in question are elastic.
- Stress and strain are linearly related.
- The material (but not the structure) behaves the same regardless of the direction of the applied load.
- All deformations are small.
- Beams are long concerning their depth.

The farther an engineering model deviates from reality, the less helpful (and riskier) the outcome becomes, as with any oversimplifying assumption.

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1) Example

The method of joints and sections are the two widely utilized techniques for determining the truss element forces. An example that is solved utilizing both techniques is shown below in Fig 1. The problem that needs to have the truss element forces determined is shown in the first diagram below. The loading diagram, the second diagram, shows the joint response forces.

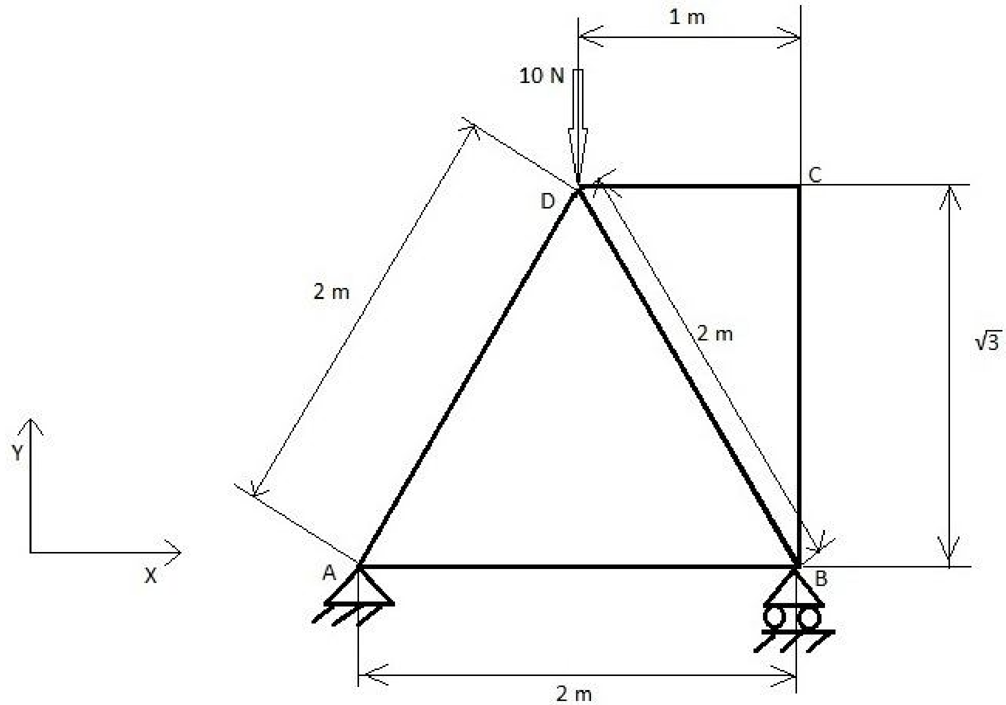

Fig 1. Example Diagram.

There will be two reaction forces at point A because of the pin joint. Both points are oriented in the same direction (x, y). There is only one response force in the y direction at point B due to the roller joint in Fig 2. Assuming that each of these forces is moving positively (the value will be harmful if they are not).

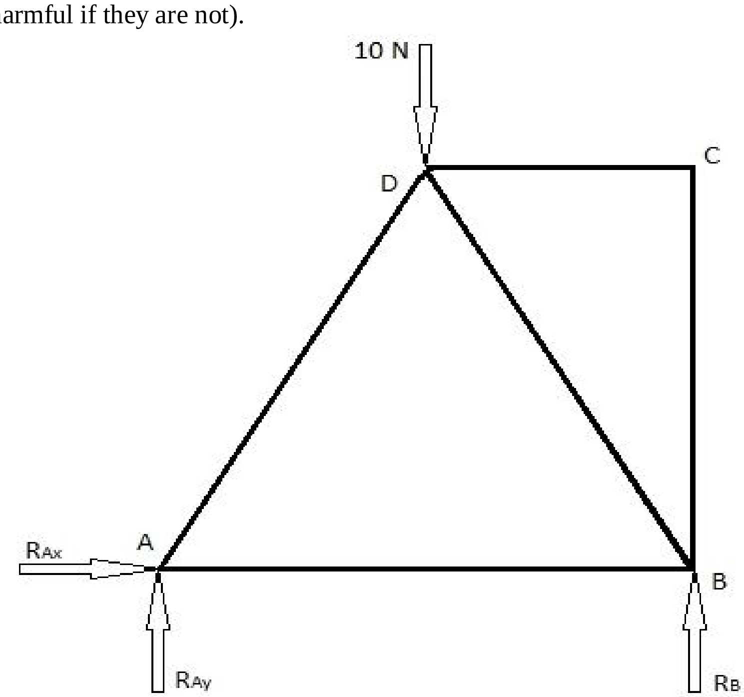

Fig 2. Reaction Force Diagram.

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The total of moments about each location and the sum of forces in any direction is zero because the system is in static equilibrium. As a result, it is possible to compute the response force’s size and direction in Fig 3.

$$\sum M_A = 0 = -10 * 1 + 2 * R_B \Rightarrow R_B = 5$$
$$\sum F_y = 0 = R_{Ay} + R_B - 10 \Rightarrow R_{Ay} = 5$$
$$\sum F_x = 0 = R_{Ax}$$

Fig 3. Computed Moment and Sum Forces.

a) Methods of Joints

This approach uses force balancing at each truss structure joint in the x and y dimensions in Fig 4.

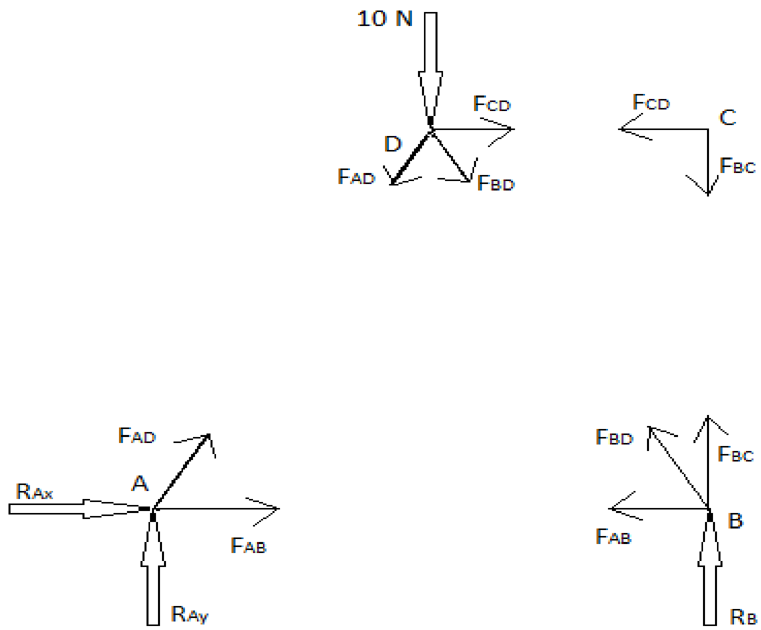

Fig 4. Force Balancing Diagram.

At A in Fig 5,

$$\sum F_y = 0 = R_{Ay} + F_{AD}\sin(60) = 5 + F_{AD}\frac{\sqrt{3}}{2} \Rightarrow F_{AD} = -\frac{10}{\sqrt{3}}$$
$$\sum F_x = 0 = R_{Ax} + F_{AD}\cos(60) + F_{AB} = 0 - \frac{10}{\sqrt{3}}\frac{1}{2} + F_{AB} \Rightarrow F_{AB} = \frac{5}{\sqrt{3}}$$

Fig 5. Calculation at A.

At D in Fig 6,

$$\sum F_y = 0 = -10 - F_{AD}\sin(60) - F_{BD}\sin(60) = -10 - \left(-\frac{10}{\sqrt{3}}\right)\frac{\sqrt{3}}{2} - F_{BD}\frac{\sqrt{3}}{2} \Rightarrow F_{BD} = -\frac{10}{\sqrt{3}}$$
$$\sum F_x = 0 = -F_{AD}\cos(60) + F_{BD}\cos(60) + F_{CD} = -\frac{10}{\sqrt{3}}\frac{1}{2} + \frac{10}{\sqrt{3}}\frac{1}{2} + F_{CD} \Rightarrow F_{CD} = 0$$

Fig 6. Calculation at D

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At C in Fig 7,

$$\sum F_y = 0 = -F_{BC} \Rightarrow F_{BC} = 0$$

$$\sum F_x = -F_{CD} = -0 = 0$$

Fig 7. Calculation at C.

Even if the forces in every truss member have been identified, it is a good idea to finish the remaining force balances to confirm the findings.

At B in Fig 8,

$$\sum F_y = R_B + F_{BD}\sin(60) + F_{BC} = 5 + \left(-\frac{10}{\sqrt{3}}\right)\frac{\sqrt{3}}{2} + 0 = 0$$

$$\sum F_x = -F_{AB} - F_{BD}\cos(60) = \frac{5}{\sqrt{3}} - \frac{10}{\sqrt{3}}\frac{1}{2} = 0$$

Fig 8. Calculation at B

b) Methods of Sections

When determining the truss element forces of a small number of members, this approach can be applied. Using this procedure, the member whose force must be determined is sliced through by a single straight line in Fig 9a and Fig 10a. This approach is limited, though, as the cutting line can only go through a maximum of three truss construction components. This limitation results from the fact that this approach finds a maximum of three unknown truss element forces via which this cut is done using the force balances in the x and y direction and the moment balance. In the example above, find the forces FAB, FBD, and FCD in Fig 9b and Fig 10b.

- *Ignore the Right Side*

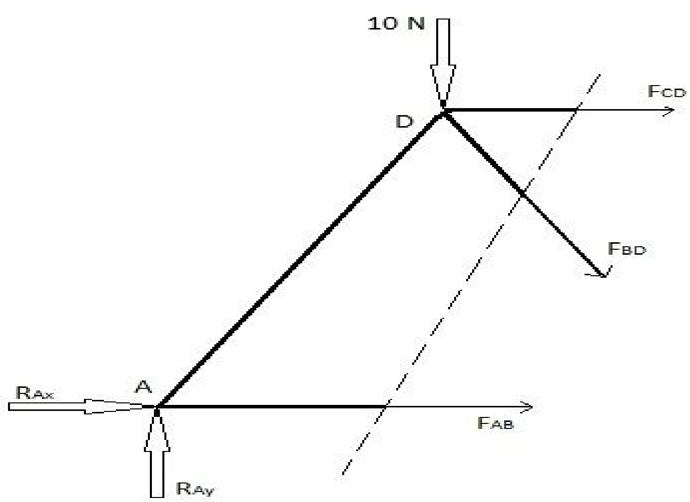

Fig 9a. Ignored Right Side Diagram

$$\sum M_D = 0 = -5*1 + \sqrt{3}*F_{AB} \Rightarrow F_{AB} = \frac{5}{\sqrt{3}}$$

$$\sum F_y = 0 = R_{Ay} - F_{BD}\sin(60) - 10 = 5 - F_{BD}\frac{\sqrt{3}}{2} - 10 \Rightarrow F_{BD} = -\frac{10}{\sqrt{3}}$$

$$\sum F_x = 0 = F_{AB} + F_{BD}\cos(60) + F_{CD} = \frac{5}{\sqrt{3}} - \frac{10}{\sqrt{3}}\frac{1}{2} + F_{CD} \Rightarrow F_{CD} = 0$$

Fig 10a. Calculation of FAB, FBD and FCD.

- *Ignore the Left Side*

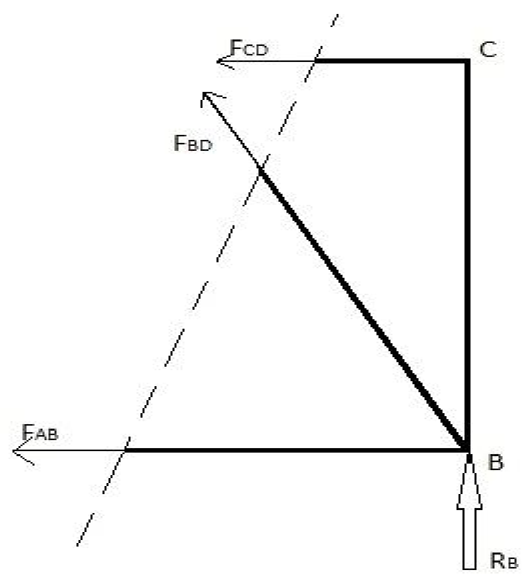

Fig 9b. Ignored Left Side Diagram

$$\sum M_B = 0 = \sqrt{3}*F_{CD} \Rightarrow F_{CD} = 0$$

$$\sum F_y = 0 = F_{BD}\sin(60) + R_B = F_{BD}\frac{\sqrt{3}}{2} + 5 \Rightarrow F_{BD} = -\frac{10}{\sqrt{3}}$$

$$\sum F_x = 0 = -F_{AB} - F_{BD}\cos(60) - F_{CD} = -F_{AB} - \left(-\frac{10}{\sqrt{3}}\right)\frac{1}{2} - 0 \Rightarrow F_{AB} = \frac{5}{\sqrt{3}}$$

Fig 10b. Calculation of FAB, FBD and FCD.

Using the above procedure, with a section traveling through the remaining members, one may find the forces of the truss elements in the remaining members.

2) Elasticity Method

In general, elasticity techniques may be used to any shaped elastic solid. It is possible to simulate individual members, such as plates, shells, columns, beams, and shafts. The linear elasticity equations provide the solutions. There are fifteen partial differential equations in the set of equations of elasticity. Only very basic geometries may provide analytical solutions due to the nature of the mathematics involved. A numerical solution technique, such the finite element method, is required for complicated geometry.

3) Methods of Using Numerical Approximation

It is customary to base structural analysis on approximations of differential equation solutions. Usually, numerical approximation techniques are used for this. The Finite Element Method is the most widely used numerical approximation in structural analysis.

The finite element technique approximates a structure as an assemblage of parts or components with different types of connections between them, each with a stiffness assigned to it. Since a continuous system, like a plate or shell, has a finite number of components linked at a finite number of nodes, it may be modeled as a discrete system in which the total stiffness is the sum of the stiffnesses of the individual parts. The stiffness (or flexibility) relation of an element determines how that element behaves. The system's stiffness or flexibility relation is obtained by assembling several stiffnesses into a master stiffness matrix that depicts the complete structure. For essential one-dimensional bar elements, we may use the mechanics of materials technique to determine the stiffness (or flexibility) of a given element; for more sophisticated two- and three-dimensional components, we can utilize the elasticity approach. The most effective way to progress analytically and computationally is to solve partial differential equations using matrix algebra.

Early matrix methods were used to model articulated frameworks with truss, beam, and column elements. Later, more sophisticated matrix methods—known as "finite element analysis"—model an entire structure with one-, two-, and three-dimensional elements. They can be applied to articulated and continuous systems, including plates, shells, articulated systems, and pressure vessels. Matrix finite-element analysis, which may be further divided into two primary approaches: the displacement or stiffness technique and the force or flexibility method, is commonly used in commercial computer software for structural analysis. Due to its simplicity in formulation for sophisticated applications and ease of execution, the stiffness approach is the most often used. Currently, finite-element technology is innovative enough to handle almost any system, given enough processing power. It may be used for both linear and non-linear analysis, solid-fluid interactions, anisotropic, orthotropic, and isotropic materials, as well as static, dynamic, and environmental external influences. However, since a lot depends on the model and the accuracy of the data input, this does not guarantee that the computed answer will always be trustworthy.

IV. CONCLUSION

The conventional approach includes sub methods in addition to its three main ways for analysis. These techniques are a little difficult to learn and a little sophisticated. To minimize the likelihood of errors, these techniques must be fully learned. Errors prevent precise load estimates and a perfect study of the structure from being produced. The structure is altered somewhat because of mistakes. Due to lack of accuracy, less material is used and the strength of the structure is compromised. Sometimes more material is used than necessary due to inaccurate measurements, which raises the structure's cost. This paper explains the procedure in full and the precautions to take to prevent all these issues.

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