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Indeterminate Structures At Variance With Determinate Structures

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Abstract

A Structure is made up of different components and the ways these components are assembled determine whether the structure is determinate or indeterminate in nature. To analyze a structure properly, certain idealizations must be made as to how the members are supported and connected together. Determinate Structures are easy to analyze as compared to indeterminate structures where we need to first determine the indeterminacy of the Structures and then use compatibility equations and different methods to solve them. In this paper I have briefly defined determinate and indeterminate structures followed by their respective advantages and then concluded with applications and hence explained the reasons that prompt us to go for indeterminate structures rather than determinate Structures.

Key Words: Structure, structural analysis, determinate, indeterminate, stiffness, fabrication error.

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INTRODUCTION

Before beginning to analyze a structure, it is important to know what kind of structure it is. Different types of structures may need to be analyzed using different methods. For example, structures that are determinate may be completely analyzed using only static equilibrium, whereas indeterminate structures require the use of both static equilibrium and compatibility relationships to find the internal forces. In addition, real structures must be stable. This means that the structure can recover static equilibrium after a disturbance. There is no point analyzing a structure that is not stable. Any structure is designed for the stress resultants of bending moment, shear force, deflection, torsional stresses, and axial stresses. If these moments, shears and stresses are evaluated at various critical sections, then based on these, the proportioning can be done. Evaluation of these stresses, moments and forces and plotting them for that structural component is known as analysis. Determination of dimensions for these components of these stresses and proportioning is known as design. So, we can say that analysis of any structure is very important for its design criteria.

STRUCTURE AND ITS ANALYSIS

A structure is defined as a system of interconnected members assembled in a stable configuration and used to support a load or combination of loads under the equilibrium of various external forces and internal reactions. Or simply we can say that it is an assemblage of load bearing elements in construction. A structure must be strong enough to support its own weight and whatever load is put on it.
Structural analysis deals with determining the internal forces such as Shear forces and Bending moments, and internal stresses such as compressive stresses or tensile stresses, bending stresses and torsional stresses that are developed inside the structures because of the applied external forces. It also means prediction of the response of structure subjected to specified loads and studying the behavior of structures using the knowledge of solid mechanics.

CLASSIFICATION OF STRUCTURE

There are several types of civil engineering structures, including buildings, bridges, towers, arches, and cables. Members or components that make up a structure can have different forms or shapes depending on their functional requirements. Structures can be classified on various basis like functions performed, load transfer mechanism, analysis, etc.
On the basis of analysis we have:

- Determinate structures.
- Indeterminate structures.

Determinate structures are analysed just by the use of basic equilibrium equations. By this analysis, the unknown reactions are found for the further determination of stresses. Redundant or indeterminate structures are not capable of being analysed by mere use of basic equilibrium equations. Along with the basic equilibrium equations, some extra conditions are required to be used like compatibility conditions of deformations etc. to get the unknown reactions for drawing bending moment and shear force diagrams.

Determinate structures:

A statically determinate structure is the one in which reactions and internal forces can be determined solely from free-body diagrams and equations of equilibrium, independent of the material from which the structure has been fabricated. For example simply supported beams, cantilever beams, three hinged arches etc.

Distinctive features:

- All the support reactions and internal member forces can be determined using only static equilibrium equations.
- Total number of reactions and forces to be calculated is equal to or less than the number of equations of static equilibrium available.
- Number of unknowns ≤ Number of equilibrium equations.
- These are easy to analyze i.e. calculation of forces and reactions is way more convenient
- They prevent stresses developed due to fabrication error
- They prevent stresses due to thermal changes
- They prevent stresses due to settlement changes

Indeterminate structures:

In statics and structural mechanics, a structure is statically indeterminate when the static equilibrium equations - force and moment equilibrium conditions - are insufficient for determining the internal forces and reactions on that structure. For example, both ends fixed beam, continuous beam, two hinged arches, etc.

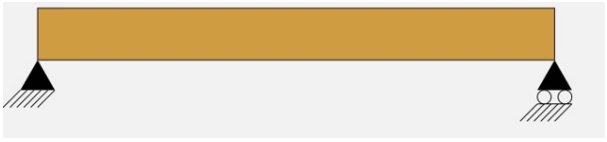
Distinctive features:

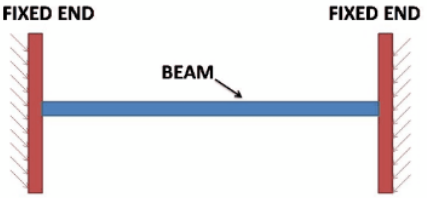
- Number of independent static equilibrium equations is not sufficient for solving all the external and internal forces.
- Consists of more members and/or more supports reactions, where these members or reactions are called redundant.
- Number of unknowns > Number of equilibrium equations.
- Indeterminate structures have less bending moment.

- They have more stiffness and hence undergo less deformation.
- Statically indeterminate structures have ability to redistribute the loads.

APPLICATIONS

In today's real world "ALMOST ALL STRUCTURES ARE STATICALLY INDETERMINATE" that is what keeps us safe in the event of failure in any of the thousands of components in a structure.
What happens if one support fails in a simply supported beam and fixed beam?





Simply supported beam being a determinate structure will collapse completely but on the other hand fixed beam being an indeterminate structure may just survive as both the end supports are rigid. That is the basic logic behind imparting indeterminacy (additional supports or members) to structures to ensure stability on load application.

THE REASONS WE PREFER INDETERMINATE STRUCTURES ARE:
Indeterminate structures always have less bending moment.
In case of simply supported beam the bending moment is twice the bending moment of fixed beam. Also tensile and compressive stresses increase proportionally with bending moment so we can say that simply supported beam being determinate will undergo more tensile and compressive stresses than the indeterminate fixed beam.

On providing redundant supports or members to a structure, the stiffness increases. More stiffness implies less deformation and deflection. In case of simply supported beam the deflection is 4 times as compared to that of indeterminate fixed beam. So we can say, indeterminacy ensures less deformation.

Statically indeterminate structures have ability to redistribute the loads. The failure of one support in a determinate structure leads to the collapse of whole structure. On the other hand, indeterminate structures are capable of some degree of redistribution of the loads which means if other members can carry the additional load ,the structure will not fail i.e.; The failure of one support doesn't necessarily lead to collapse of whole structure.

CONCLUSION

- Structures are classified on different basis and on the basis of analysis we have determinate and indeterminate structures.
- Structures for which unknown forces can be found by equilibrium conditions are called determinate structure and structures for which unknown forces and reactions cannot be found out by equilibrium conditions are called indeterminate structures.
- Determinate Structures are independent of temperature, fabrication and settlement changes but when it comes to loading indeterminate structures are much more stable.
- Indeterminate structures have less bending moment and deflection which make them more stable and stiff.
- Indeterminate structures are difficult to analyze. However, some powerful software do all the analysis and calculations for the designers these days e.g. C-beam is a continuous beam software package that allows the user to solve statically indeterminate structures.

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