# STATIC/MODAL ANALYSIS OF CANTILEVER BEAM

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**ABSTRACT**

*Finite Element Analysis (FEA) is a numerical technique (Numerical analysis, means the study of algorithms that use numerical approximation, for the problems of mathematical analysis, as distinguished from discrete mathematics) for finding approximate solutions to boundary value problems. It uses methods of variations (the calculus of variations, means maximizing or minimizing functional) to minimize an error function and produce a stable solution The main purpose of this project is to analyze a simple cantilever beam and how to improve the strength with different cross section(C section is analyze). Not only geometry but materials (Steel and Composite) will be also studied to get optimum beam design. The analysis will be performed using FEA (ANSYS) and hand calculation to ensure solution convergence for the structure. To validate FEA results a cantilever will be tested for static deflection and can be compared with FEA for simple beam plate. Modal analysis will be carried out to find the natural frequency of beam to ensure that there is no resonance and static analysis to calculate static deflection and FOS (strength).*

**Keywords:** *Cantilever Beam, Vibration, Ansys, Types of Cantilever.*

## 1. INTRODUCTION

A cantilever is a rigid structural element, such as a beam or a plate, anchored at only one end to a (usually vertical) support from which it is protruding. Cantilevers can also be constructed with trusses or slabs. When subjected to a structural load, the cantilever carries the load to the support where it is forced against by a moment and shear stress. Cantilever construction allows for overhanging structures without external bracing, in contrast to constructions supported at both ends with loads applied between the supports, such as a simply supported beam found in a post and lintel system.

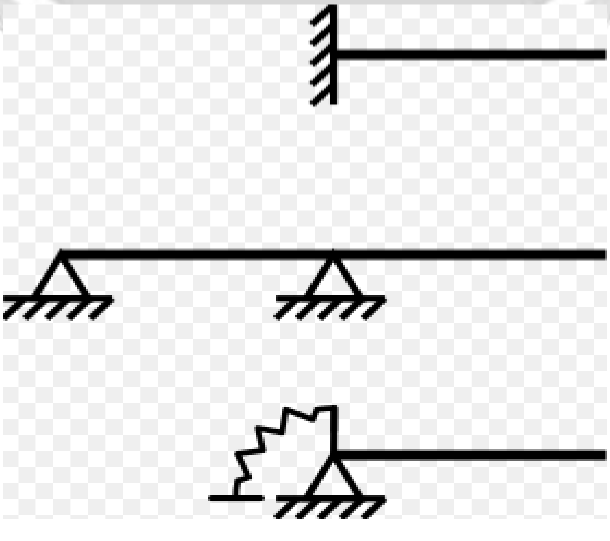

**Fig.1: Three Types of Cantilever**

The top example has a full moment connection (like a horizontal flagpole bolted to the side of a building). The middle example is created by an extension of a simple supported beam (such as the way a diving board is anchored and extends over the edge of a swimming pool). The bottom example is created by adding a Robin boundary condition to the beam element, which essentially adds an elastic spring to the end board. The middle and bottom example may be considered structurally equivalent, depending on the effective stiffness of the spring and beam element

### 1.1 vibration Basics

Vibration is the motion of a particle or a body or system of connected bodies displaced from a position of equilibrium. Most vibrations are undesirable in machines and structures because they produce increased stresses, energy losses, because added wear, increase bearing loads, induce fatigue, create passenger discomfort in vehicles, and absorb energy from the system. Rotating machine parts need careful balancing in order to prevent damage from vibrations. Vibration occurs when a system is displaced from a position of stable equilibrium. The system tends to return to this equilibrium position under the action of restoring forces (such as the elastic forces, as for a mass attached to a spring, or gravitational forces, as for a simple pendulum). The system keeps moving back and forth across its position of equilibrium. A system is a combination of elements intended to act together to accomplish an objective. For example, an automobile is a system whose elements are the wheels, suspension, car body, and so forth. A static element is one whose output at any given time depends only on the input at that time while a dynamic element is one whose present output depends on past dynamic. In the same way we also speak of static and dynamic systems. A static system contains all elements while a dynamic system contains at least one dynamic element.

A physical system undergoing a time-varying interchange or dissipation of energy among or within its elementary storage or dissipative devices is said to be in a dynamic system. All of the elements in general are called passive, i.e., they are incapable of generating net energy. A dynamic system composed of a finite number of storage elements is said to be lumped & discrete, while a system containing elements, which are dense in physical space, is called continuous system. The analytical description of the dynamics of the discrete case is a set of ordinary differential equations, while for the continuous case it is a set of partial differential equations. The analytical formation of a dynamic system depends upon the kinematic or geometric constraints and the physical laws governing the behavior of the system.

### 1.2 Ansys 16.0

Ansys Mechanical software is a comprehensive FEA analysis (finite element) tool for structural analysis, including linear, nonlinear and dynamic studies. The engineering simulation product provides a complete set of elements behavior, material models and equation solvers for a wide range of mechanical design problems. In addition, ANSYS Mechanical offers thermal analysis and coupled-physics capabilities involving acoustic, piezoelectric, thermal–structural and thermo-electric analysis.

With a solid foundation of element and material technology, ANSYS structural analysis software offers various advanced modeling methods for different kinds of applications.

## 2. LITERATURE SURVEY

As our primary objective is to study the dynamic behavior of cantilever beam to evaluate strength of beam by changing composite material and modifying geometry of beam, a literature survey is carried out to understand current trends in this field. Many papers related to vibration analysis in FEA & validate FEA results with analytical calculations or experimental testing is reviewed. Before proceeding to actual work it was essential to understand what are different types methods possible to carry out with existing software's, when to use those and what are the overall capabilities of such software's. As the software available for vibration and static analysis is ANSYS which we were not able to use at the beginning, the most basic and immediate need was to learn the software and be able to setup at least simple vibration studies with it. Thus the literature survey included help files of these software's as well which turned out to be very fruitful. Almost entire software learning was done using the help files and tutorials. Few papers were found in which similar studies were carried out using ANSYS. In this project, will discuss the outcomes and the setup of such problems in software and hence provided the evidence that such works can be carried out. Some papers elaborating the cantilever section effect on natural frequency. Surveying help files of software's also helped in understanding the working of software's and effect of many options available in the software on results obtained.

## 3. CANTILEVER BEAM SYSTEM

| Parameters | Value |
|---|---|
| Length(m) | 0.4 |
| Breadth(m) | 0.02 |
| Thickness(m) | 0.003 |

**Table-1: Basic Parameter**

| Parameter | Structural Steel | Glass Epoxy |
|---|---|---|
| Young's Modulus(Mpa) | $210X10^3$ | $53.7X10^3$ |
| Poisson's Ratio | 0.3 | 0.238 |
| Density($Kg/M^3$) | 7850 | 2232 |
| Tensile Strength(Mpa) | 460 | 260.4 |

**Table-2: Material Properties of Beam**

### 3.1 Mathematical Calculation:

For a simple elastic beam with uniform cross-sectional area, the known natural frequency can be calculated by using Euler Bernoulli's beam theory

First natural Frequency is,

$$\omega_1 = (1.875)^2 \sqrt{\frac{EI}{\rho A l^4}}$$

Second natural Frequency is,

$$\omega_2 = (4.694)^2 \sqrt{\frac{EI}{\rho A l^4}}$$

$$\omega_n = 2\pi F$$

Where,

$\omega_1$ & $\omega_2$ = 1st & 2nd natural frequency (Rad/sec)

F= Natural frequency of beam (Hz)

L = Length of beam

A= Area of cross-section of beam

ρ= Density of material of beam

E= Young's modulus of material of beam

I= Moment of inertia.

**3.2 Modal Analysis:**

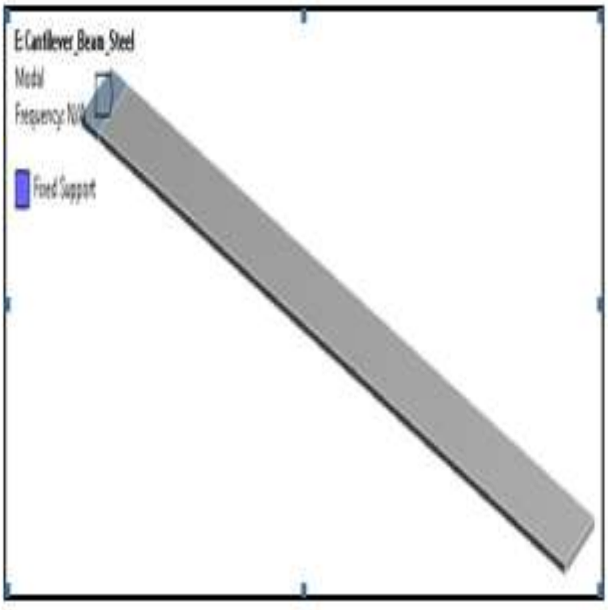


**Fig- 2: Cantilever Beam of Steel**

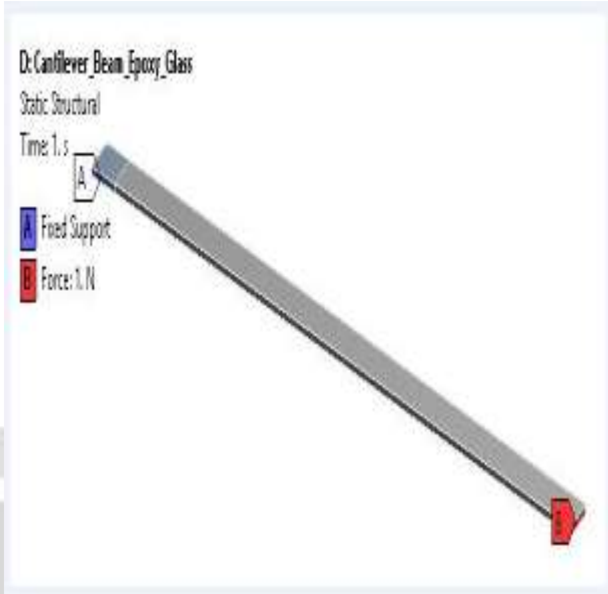


**Fig.3: Cantilever Beam Of Epoxy Glass**

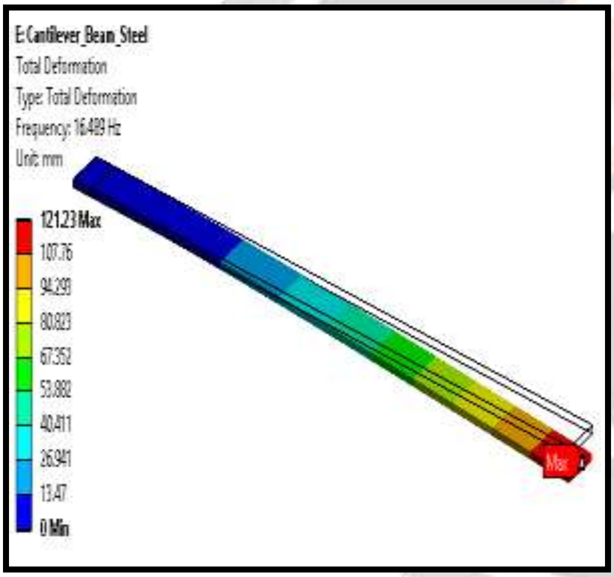


**Fig- 4: Mode-1 Steel**

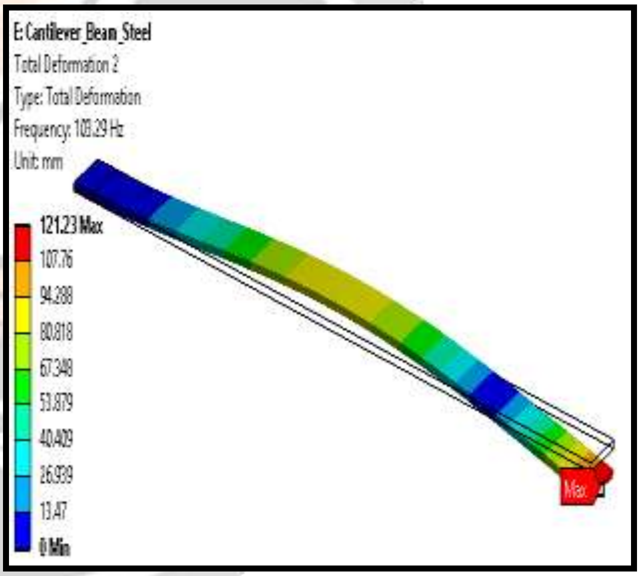


**Fig- 5: Mode-2 Steel**

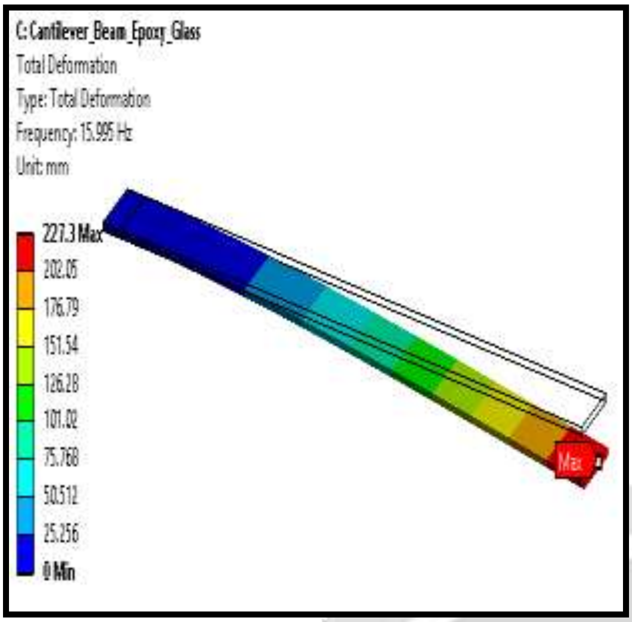


Fig- 6: Mode-1 Glass Epoxy

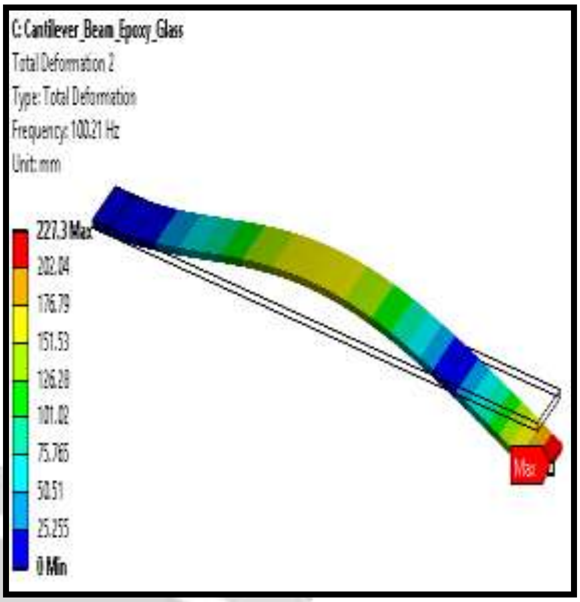


Fig- 7: Mode-2 Glass Epoxy

## 4. Modal Results

| Mode No | Analytical Frequency (Hz) | FEA Frequency (Hz) | % Change of FEA Vs Analytical |
|---|---|---|---|
| 1 | 15.67 | 16.49 | 5.21% |
| 2 | 98.22 | 103.29 | 5.16% |

**Table-3: Natural Frequency of Steel Beam**

| Mode No | Analytical Frequency (Hz) | FEA Frequency (Hz) | % Change of FEA Vs Analytical |
|---|---|---|---|
| 1 | 14.87 | 16.00 | 7.60% |
| 2 | 93.17 | 100.21 | 7.56% |

**Table-4: Natural Frequency of Epoxy Beam**

| Mode No. | Modal Analysis Frequency(Hz) | |
|---|---|---|
| | Mild Steel | Epoxy Resin |
| 1 | 16.49 | 16.00 |
| 2 | 103.29 | 100.21 |

**Table-5: Comparison of Frequency**

## 4. CONCLUSION

In the paper we studied the Frequency analysis of Cantilever beam of steel and Epoxy glass. In the FEA analysis & Analytical analysis I get frequency of both beams. So I observe that the Analytical frequency and FEA frequency of beam are change but 10% variation reasonably accepted and considered as a good results, The modal analysis frequency of Epoxy beam less than mild steel beam.

## 5. ACKNOWLEDGMENT

I would like to be thankful to Prof. Dr. S. N. Shelke (M. E. coordinator and Project Guide, R. H. SAPAT COE, Nashik), Prof. K.V. Chandratre (HOD, Mechanical department R. H. SAPAT COE ) and Dr .P.C. Kulkarni ( Principal, R. H. SAPAT COE),all my teachers and my friends for their guidance.

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## BIOGRAPHIES

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